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Climate Change Adaptation Strategies

03-04 December 2009

Editors
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AVR Kesava Rao
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Editors' Preface

Climate change is real. Technologies in tune with climate change are yet to be developed for sustenance of agriculture production. National Action Plan on Climate Change (NAPCC) has been formulated by the Government of India in 2008. One of the eight identified Missions is 'Establishing a Strategic Knowledge Platform for Climate Change'. Taking the lead, the Kerala Agricultural University has established the Centre for Climate Change Research (CCCR) in December 2007 to address the climate related issues. The CCCR has already taken up detailed agroclimatic characterization and climate change analysis along with bringing awareness among various stakeholders on climate change adaptation and mitigation strategies.

To review and identify gaps in our knowledge in climate change adaptation strategies, the Kerala Agricultural University took initiatives to organize a National Seminar on "Climate Change Adaptation Strategies in Agriculture and Allied Sectors" during 3-4 December 2009 at its main campus, Vellanikkara, Thrissur, India.

Several distinguished scientists from various research institutes in India have participated in the seminar and presented research papers. Participation of eminent international scientists Prof. Peter Davis, University of Western Australia, Perth and Dr. Senthold Asseng, CSIRO has also made the national seminar as international.

There are fourteen invited presentations by distinguished scientists and 42 contributed research papers by eminent scientists and policy makers. These were scheduled in six technical sessions viz., Climate change adaptation in relation to natural resources management, Agriculture, Horticulture, Forestry, Fisheries and Animal Sciences.

The seminar could provide a common platform for teachers, scientists and policy makers to interact in relation to climate change adaptation strategies. It is hoped that the outcomes of the seminar lead for formulating multi-disciplinary and multi-institutional research projects and bring out enhanced awareness on climate change adaptation.

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03-04 December 2009

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SESSION II
Weather variability

National Seminar on Climate Change Adaptation Strategies
in Agriculture and Allied Sectors, held at KAU during 03-04 December 2009

Climate change impact on the inter-relation between tropical cyclones over north western Pacific Ocean and Indian summer monsoon

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Abstract

The present study has designed to examine the relationship between Tropical Cyclone (TC) activity over NW Pacific and monsoon rainfall over India. In this study relation between the tropical cyclone track data from Joint Typhoon Warning Centre over NW Pacific and significant features of monsoon circulations over Indian region have been looked into. It has been observed that the TC activity over NW Pacific is inversely and significantly correlated with monsoon rainfall over India. The characteristic of SST over Northern Indian Ocean and NW Pacific Ocean is analyzed during the occurrence of TC over NW Pacific. As a result of the warm SSTs gives result a large number of TCs over the West Pacific during summer. Spatial dependence of the relationship revealed that TCs forming over NW Pacific and moving northwards have an adverse effect on Indian monsoon rainfall. The extended TC activity can cause anomalous circulation anomalies like large-scale subsidence over the Indian region, which may weaken the Indian monsoon circulation and rainfall activity. It was observed that TCs forming over the South China Sea and moving westwards may have a positive impact on monsoon rainfall over India. The westward propagating TCs of the West Pacific can act as precursors of low pressure disturbances in Bay of Bengal and cause good rainfall over different parts of India. It also revealed that in most of the occasions during the onset and stabilization period of the south west monsoon, generally no typhoon formation takes place in the Pacific region. There were cases when typhoon is developed

and move to Bay of Bengal and intensify the monsoon depression. It happened only in the last week of June or fist week of July. In the recent years it noticed that, soon after the monsoon onset or very close to the monsoon onset period, typhoon used to develop in the Pacific and intensify. It was noticed that the monsoon activity has been subdueded in such cases. This can be taken as one of the effects of the global warming and related climate change.

Introduction

The sea and swell condition over Indian Sea is related to the strength of monsoon as it changes through active and break cycles. Research of the recent few decades have shown that one of the parameters influencing Indian monsoon is the tropical cyclone (typhoon) of the western North Pacific Ocean – Kanamitsu and Krishnamurti (1978), Joseph (1990) & Rajeevan (1993). Raman (1955) had shown that during the break monsoon periods typhoons have preferred northward motion. One of the major contributors for the severe monsoon drought in India of 2002 was the excessively large typhoon activity in west Pacific (Gadgil et al, 2003). It is believed that when typhoons are active, the increased convection in the western north Pacific ocean suppresses the convective activity (and hence rainfall) over India presumably due to the Walker type of circulations set up and the large scale east-west shifts of atmospheric circulation features (Kanamitsu and Krishnamurti, 1978). Conversely when the Indian monsoon is active, available studies show that typhoon activity is suppressed (Joseph, 1990). Thus there is a see-saw in the interannual time scale in convection between India and the Indian seas on one side and western Pacific Ocean on the other side. Both these areas are strongly controlled by intra-seasonal oscillations during the monsoon season – Sikka and Gadgil (1980) and Joseph (1990). Remnants of westward moving typhoons are found to trigger monsoon depressions in the Bay of Bengal (Saha et al, 1981 and Ramanna, 1969). Thus there is a need to study monsoon – west Pacific typhoon interaction on inter-annual and intra-seasonal time scales and their effect on condition of sea and swell. Therefore this study will deal on the relationship between the strength of the low level wind field of monsoon (low level jet) and the active – break cycle of the monsoon on one hand and the typhoon activity over Western Pacific on the other hand. A recent study by Joseph and Sijikumar (2004) has shown that during break monsoon spells, the Low Level Jet-stream of the Asian summer monsoon (Findlater, 1969) by-passes India and flows along latitudes south of Sri Lanka but north of the equator, transports large quantities of moisture generated over the south Indian ocean to the west Pacific ocean, to feed the typhoons there, depriving India of this moisture source.

Materials and methods

Typhoon data, Monsoon rainfall data, Daily means of all India rainfall of the monsoon season, wind, temperature and other data of the global atmosphere from National Centers for Environmental prediction / National Center for Atmospheric Research (NCEP/NCAR) re-analysis data, Weather Satellite data and as a proxy for deep convection, Outgoing Long wave Radiation (OLR) data from National Oceanic and Atmospheric Administration (NOAA) for the period 1975 to 2000 formed the material for this study.

Results and discussion

The relationship between the West Pacific Typhoon and Monsoon Onset over Kerala (MOK) indicated that the Cyclogenesis generally was not seen close to the dates of MOK, though there were few exceptional cases observed (1976, 1985,1990,1994,1995 and 2000). During the period 20 - 40days after MOK, Cyclones became active in the West Pacific region with exceptions in 1975 (no cyclogenic activity occurred for the first 40 days after MOK), 1996 (no cyclogenic activity occurred for the first 30 days after MOK) and 1998 (no cyclogenic activity occurred for the first 34 days after MOK). It is also observed that out of 26 years studied, in 18 years west Pacific region was devoid of any kind of cyclogenic activity for the first 5 days. For two years (1994 & 1999), on the 5th day, a depression was found to develop. During 1983, 1984, 1988, 1992 and 1998, no cyclogenic activity was observed for 80 days prior to MOK. At the onset of the Northern Hemispheric summer monsoon, there was a rapid transition of cloudiness and rainfall from the South Pacific/Australian/ Indonesian area to South Asia (Meehl, 1987). Thus the date of MOK might be related to the CDCS of the Southern Hemisphere. Seven out of 10 cases, CDCS occurred in April or early May, otherwise in most of the years, CDCS occurred in May only. At the time of MOK, there was increased convection in a band about 5-10 degrees wide meridionally, extending from South Arabian

Sea to South China and convection is suppressed all around, particularly in the West Pacific Ocean.

At pentad -8, there was deep convection around the equator east of about 70°E and extending into the West Pacific Ocean. From pentad -7 to -1, one can notice that the convection in the western Pacific was decreasing considerably and steadily. It was also seen that during the same period, the convection over the Indian Ocean increased and moved slightly northwards. At pentad -1, a region of intense convection was found over the Arabian Sea. The situation remained more or less the same till pentad -3. At pentad -2, an elongated narrowband of convection forms close to the equator in the Indian Ocean. This band grew rapidly in area and intensity and moveed north steadily resulting in MOK at pentad 0. Intense convection over the South East Arabian Sea was observed at pentad 0.During pentads +1 to +8, convection slowly moved North & North West and by pentad +8, monsoon rains were fully established over India. Superposed epoch analysis of OLR data shows that MOK is a significant stage in the evolution of the OLR field in the tropics.

From an analysis of the data of tropical cyclones of the Southern Hemisphere and that of the OLR of the tropical belt, it appeared that delays in MOK were associated with delays in the seasonal transition of the equatorial convective cloud mass (ECCM) westward and northward during April to June.

Whenever a strong anticyclone flow developed in the extra tropic region along with Tropical depression/Typhoon of the North Pacific Ocean, the wind strength in the tropical region of the Pacific Ocean also strengthened. A corresponding low-level wind in the Bay of Bengal was also observed. It was also noticed that during this period, when no anticyclonic flow noticed in the extra tropics, the wind strength in the tropical region was light. The strength of the wind in the Bay of Bengal and Arabian Sea during such a condition was directly proportional to the wind strength experienced in the Pacific region.

Conclusions

Whenever a strong anti cyclonic flow developed in the extra tropic region along with Tropical depression/Typhoon of the North Pacific Ocean, the wind strength in the tropical region of the Pacific Ocean also strengthened. A corresponding low-level wind in the Bay of Bengal was also observed. It was also noticed that during this period, when no anti cyclonic flow noticed in the extra tropics, the wind strength in the tropical region was light. The strength of the wind in the Bay of Bengal and Arabian Sea during such a condition was directly proportional to the wind strength experienced in the Pacific region. This information is very valuable in understanding of the development of roughness in the sea conditions (Sea and Swell) in the Bay of Bengal and Arabian Sea. From an analysis of the data of tropical cyclones of the Southern Hemisphere and that of the OLR of the tropical belt, it appeared that delays in the date of onset were associated with delays in the seasonal transition of the equatorial convective cloud mass (ECCM) westward and northward during April to June. In majority of the cases during the onset and stabilization period of the south west monsoon, generally no typhoon formation took place in the Pacific region. There were cases when typhoon was developed, it moved to Bay of Bengal and intensified the monsoon depression. This happened only in the last week of June or fist week of July. In the recent years it was noticed that, soon after the monsoon onset or very close to the monsoon onset period, typhoon used to develop in the Pacific and intensified. It was noticed that the monsoon activity has been subdued in such cases.

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Variability of rainfall over Peninsular India, before and after 1976

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Abstract

To understand the variability in rainfall over the different subdivisions over peninsular India with a focus over Kerala, sub-divisional rainfall from IITM for the period 1951-2005 formed the material for the study. Southwest monsoon (SWM) and Northeast monsoon (NEM) rainfall over peninsular India experienced more number of WET / DRY years. Coastal Andhra Pradesh, coastal Karnataka and Rayalaseema had more WET years after 1976 during SWM. Rayalaseema had 8 Wet years after 1976 in comparison to 2 Wet years during 1951-1975. All other subdivisions experienced more DRY years after 1976. An increase in the mean rainfall and Standard Deviation (SD) is observed over these subdivisions except Coastal Karnataka, where the mean and SD decreased by about 211 mm.

The number of WET years decreased over coastal Andhra Pradesh and coastal Karnataka while in all other subdivisions the number of WET years increased. It is noticeable that Tamil Nadu experienced 6 WET years after 1976, compared to 1 WET year during the period 1951-75. The number of DRY years also increased from 2 to 4. Over Kerala, the WET years increased from 3 to 8 after 1976. Over Rayalaseema also the number of WET years increased. Except Tamil Nadu, south and north Interior Karnataka, all subdivisions have experienced lesser number of DRY years after 1976 compared to the period 1951-75. The mean and Std. dev. increased after 1976 except over south and north interior Karnataka, where they decreased. Over Coastal Andhra Pradesh, the mean rainfall increased but the SD decreased.

Over Kerala subdivision, the number of WET years during the NEM season increased from 3 in the pre 1976 phase to 8 in the post 1976 phase, whereas the number of DRY years decreased

from 4 to 2 during the same periods. Above normal years have also increased during 1977-2001. Wet years during the SWM season have decreased from 4 (1951-1975) to 2 (1977-2005). Meanwhile the number of DRY years has increased to 6 (1977-2005). Also the below normal years have increased drastically after 1976.The mean rainfall of SWM over the subdivision has decreased from 1928.6 mm to 1870.4 with a decrease of 97 mm in Std. dev., whereas the NEM mean increased by 37mm with an increase of 19 mm in Std. dev. The trend of rainfall for the SWM and NEM rainfall shows that the SWM has a decreasing and NEM rainfall has an increasing trend with an increase in mean rainfall. These statistics point that during the SWM season, an increase in dry years has occurred after 1976, whereas an increase in the number of WET years is observed in the NEM rainfall.

Materials and methods

Sub-divisional rainfall from IITM (website: http://www.tropmet.res.in/) for the period 1951-2005 was used to study the rainfall variability. Also the 1° x 1° high resolution gridded rainfall from IMD was used (Rajeevan et al., 2005). The mean and standard deviation was calculated and the trend analysis was also conducted. The number of heavy rainfall events, during the period 1951-1975 (pre-1976) and 1977-2001 (post 76) were also determined.

Results

The Southwest monsoon (SWM) and Northeast monsoon (NEM) rainfall over peninsular India experienced more number of WET /DRY years (The WET (DRY) years are classified as years with rainfall greater (less) than 1 standard deviation from mean) after the climate shift (Nitta and Yamada 1989) of 1976. During SWM Coastal Andhra Pradesh, coastal Karnataka and Rayalaseema had more WET years after 1976 with a decrease in the number of DRY years. Rayalaseema had 8 Wet years after 1976 in comparison to 2 Wet years during 1951-1975. All other subdivisions experienced more DRY years after 1976. An increase in the mean rainfall and Standard Deviation (Std. dev.) is observed over these subdivisions except Coastal Karnataka, where the mean and Std. dev. decreased by about 211mm.

During NEM, the number of WET years decreased over coastal Andhra Pradesh and coastal Karnataka while in all other subdivisions the number of WET years increased. It is noticeable that Tamil Nadu experienced 6 WET years after 1976, compared to 1 WET year during the period 1951-75. The number of DRY years also increased from 2 to 4. Over Kerala, the WET years increased from 3 to 8 after 1976. Over Rayalaseema also the number of WET years increased. Except Tamil Nadu, south and north Interior Karnataka, all subdivisions have experienced lesser number of DRY years after 1976 compared to the period 1951-75. The mean and Std. dev. increased after 1976 except over south and north interior Karnataka, where they decreased. Over Coastal Andhra Pradesh, the mean rainfall increased but the Std. dev. decreased.

Over Kerala subdivision, the number of WET years during the NEM season increased from 3 in the pre 1976 phase to 8 in the post 1976 phase, whereas the number of DRY years decreased from 4 to 2 during the same periods. Above normal years have also increased during 1977-2001. Wet years during the SWM season have decreased from 4 (1951-1975) to 2 (1977-2005). Meanwhile the number of DRY years has increased to 6 (1977-2005). Also the below normal years have increased drastically after 1976. The mean rainfall of SWM over the subdivision has decreased from 1928.6 mm to 1870.4 with a decrease of 97 mm in Std. dev., whereas the NEM mean increased by 37mm with an increase of 19 mm in Std. dev. The trend of rainfall for the SWM and NEM rainfall shows that the SWM has a decreasing and NEM rainfall has an increasing trend with an increase in mean rainfall (Fig. 1). These statistics point that during the SWM season an increase in dry years has occurred after 1976, whereas an increase in the number of WET years is observed in the NEM rainfall.

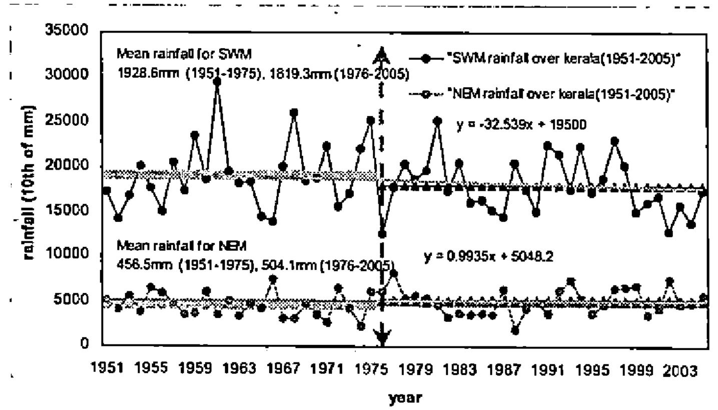

Fig 1. SWM and NEM rainfall over Kerala subdivision for the period 1951-2005. Solid line shows the trend of the rainfall series. The dotted line demarcates the year 1976. The mean rainfall before (blocks) and after (triangles) the year 1976 has shown for SWM and NEM rainfall series.

The number of rainfall events for the pre-1976 and post-1976 period has also been studied. The rainfall events are classified as below.

Class	Rainfall in cm
High rainfall	5-10 cm
Heavy rainfall	10-15 cm
Very heavy rainfall	> 15 cm

Number of rainfall events during the SWM season and for individual months were also considered. The results during the pre- and post-1976 periods are compared. An increase in the number of very heavy rainfall events in the post-1976 period has been found over the study region (Fig 2). Over north Kerala, the number of heavy rainfall (>10cm<15cm) events decreased from 60 in the pre-1976 phase to 26 during the post-1976 phase. Rest of the study region has an increase in heavy rainfall events. Over West coast, there is a decrease in the number of high rainfall events (>5cm <10cm) up to 12° N and also between 14-6° N latitude belt. But an increase in the number of high rainfall events is observed from 12-14° N latitude belt. Eastern parts of south interior Karnataka, Rayalaseema, Tamil Nadu and Coastal Andhra Pradesh have increase in high rainfall events, whereas their number decreased in most parts of the west coast.

Monthly analysis of rainfall events was carried out: For June, a decrease in the number of very heavy rainfall events over peninsular India is noticed, but the high rainfall events have increased all over the Western Ghats. During the month of July, noticeable difference in very heavy or heavy rainfall events is not observed. But the high rainfall events have drastically decreased from a range of 200-100 to 60-30 (Fig. 3). During August, the high rainfall events in the latitude belt 12-15° N are found to increase during the post-1976 period. With an exception of one or two grid boxes, there are no very high events in the month of September and an increase / decrease in high rainfall events are noticed over few grid boxes.

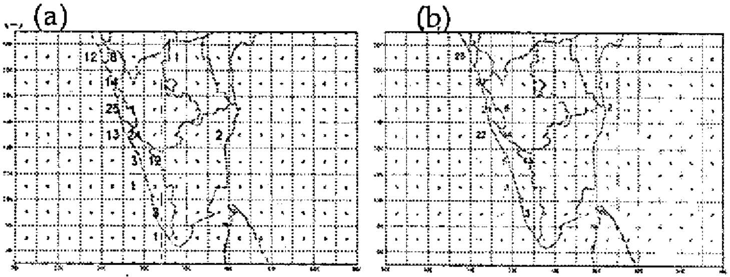

Fig 2. The number of Very High rainfall events during Southwest monsoon for the (a) pre76 and (b) post76 period.

(a) (b)

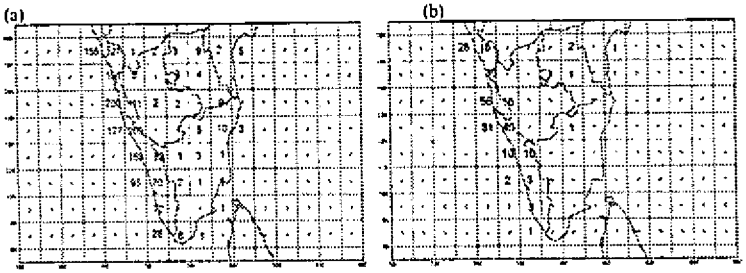

Fig 3. The number of High rainfall events during June for the (a) pre-1976 and (b) post-1976 period.

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Seasonal variability and trend in rainfall and temperature at Vellayani

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Abstract

Attempts were made to analyze the temporal variation in rainfall recorded over twenty-five years (1984-2008) at the Regional Agricultural Research Station (Southern Zone), Vellayani, Thiruvananthapuram, Kerala. A declining in trend is observed in rainfall and the number of rainy days during the month of June and an increasing trend in October. In recent years the monsoon exhibits a shy trend during the initial phase. The diurnal temperature variation has narrowed significantly during April and May. The study indicated the possibility of advent of slight changes in commencement of cropping season and varietal choice. The trend of rainfall and rainy days over the years (N=25) was estimated using linear regression models and the significance of their coefficients tested.

Introduction

The southern zone of Kerala can be considered as having humid tropical climate with an oppressive summer and plentiful seasonal rainfall. The entire southern zone except few pockets in the eastern part falls under wet-dry tropical climate with 4.5-7.0 humid months as per Troll's classification. According to KAU (1989) the zone receives an annual rainfall of 2700 mm in 124 rainy days, mainly from the South West (57 per cent) and North East monsoon (21 per cent).The rainfall distribution has been reported to have two maxima, one in June and the other in October. The cropping season of the zone depends mainly on the two monsoons as the crops are predominantly rainfed. Any shift in the amount of the rainfall and/ or temperature will adversely affect the crop productivity of this region. In this context rainfall and temperature analysis in terms of variability and trend was attempted.

Methods

Rainfall and temperature data of twenty-five years (1984-2008) recorded at the Regional Agricultural Station (Southern Zone), Vellayani, Kerala were analyzed. As a primary step the statistical parameters of mean, standard deviation and coefficient of variation were computed for each month. The monthly data were pooled over the months in a season and parameters for seasonal rainfall and rainy days were also computed. The trend of rainfall, rainy days and temperature parameters over the years (N=25) was estimated using linear regression models and the significance of their coefficients tested.

Results

On an average 117 days were recorded as rainy and the total annual rainfall at Vellayani was estimated to be 1629.33mm (Table 2). The South West monsoon season comprising the four months from June to September recorded the highest number of rainy days and largest quantity of rainfall. However, while the monthly rainfall during South West monsoon season was 186.92mm the North East monsoon season followed very closely with 182.62mm(Table 2). The winter season (January - February) had practically no rains at all with just 3 rainy days and 1.60mm of rainfall. The pre-monsoon season extending from March to May is not however as dry as winter since there was more than 100mm of rainfall in 8 rainy days. It was also observed that about three- fourths of the rainy days fell in the two crop seasons namely the South West and North East monsoon seasons. About four-fifths of the total rainfall was experienced during the two monsoon seasons leaving the crops thirsty for the rest of the year. Thus the rainfall at Vellayani is only about half of what is being enjoyed by the whole State of Kerala (3225 mm as per FIB, 2009) and the bulk of the rainy days fall during the South West and North East monsoon seasons. As the pre-monsoon shower was found to be substantial it might be possible that the onset of monsoon was advanced to the month of May rather than June.

Trend analysis of rainfall and rainy days (Table 4) showed that the rains in June exhibited a strong declining trend both in terms of quantity (Fig. 1) and rainy days, although statistically not significant. This strongly points towards a possibility of shift in cropping season and varieties, however slight it may be. Varieties with shorter duration may become a norm for the *Virippu* season (first crop season) commencing in May-June so as to ensure timeliness of the second crop during the *Mundakan* season. A preliminary analysis of the standard week wise rainfall of the South West monsoon (Table 5) showed that the decreasing trend of rainfall in June could be attributed to the decline in rainfall during the 23rd and 24th standard weeks, which mark the beginning of the South West monsoon. The decline was also observed to be very sharp during 2004-'08, the percentage deviations from normal being –60.2 per cent and –36.2 per cent during the 23rd and 24th standard weeks respectively.

Fig.1 Trend in rainfall in June over the years (1984-2008)

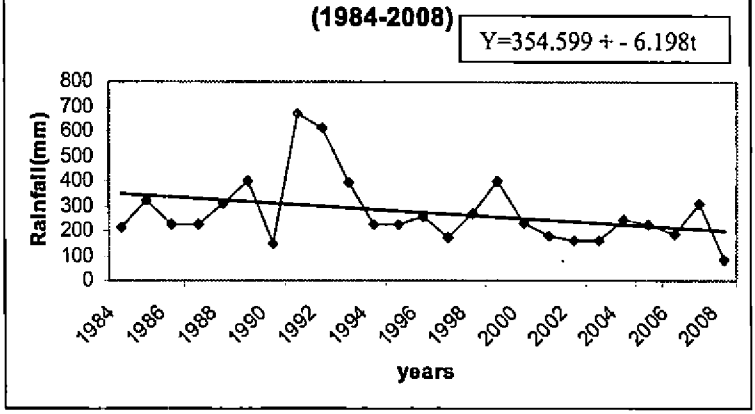
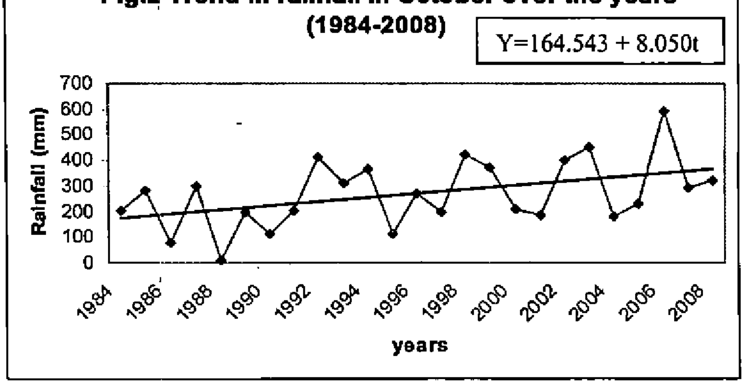


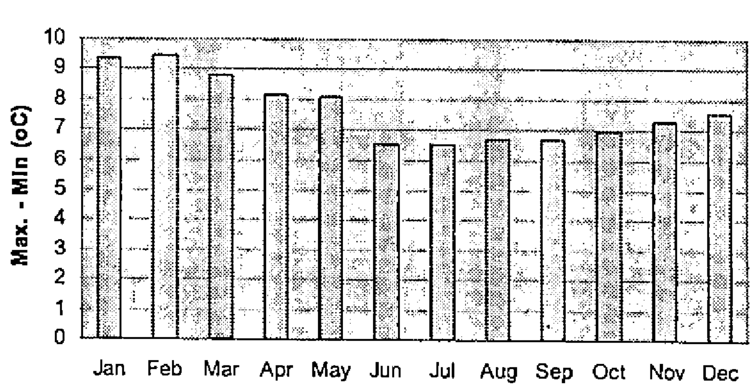
Fig.2 Trend in rainfall in October over the years (1984-2008)



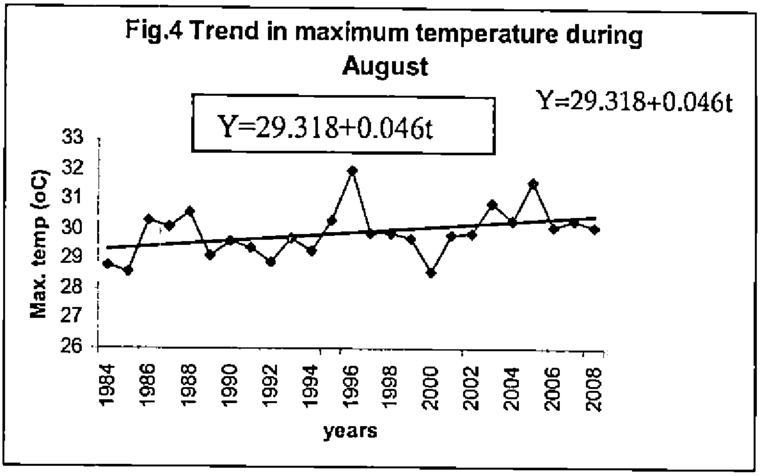
On the other hand the rainfall (Fig. 2) and rainy days during October showed a significant increasing trend. This may warrant the need for the development of better drainage facilities especially for crops like banana. The predominant decline in rainfall during the month of June and an increasing trend during the post monsoon season over Kerala was reported by Krishnakumar et al. (2009). The increase in frequency of tropical cyclones during the North East monsoon season over the Bay of Bengal (Singh et al., 2001) may be one of the factors contributing to the increase in trend of rainfall in October.

The mean annual maximum and minimum temperature at Vellayani was observed to be 30.87°C and 23.19°C respectively over the 25 year period extending from 1984 to 2008. On an average, the diurnal variation in temperature was 7.68°C annually. While the month of April faired with the highest mean monthly temperature (32.54°C), the rainiest month of July recorded the least (29.86°C). The monthly diurnal variation in temperature was observed to be the least during the period from June to September (Fig.3) which coincides with the SW monsoon season and highest during the winter and pre-monsoon seasons.

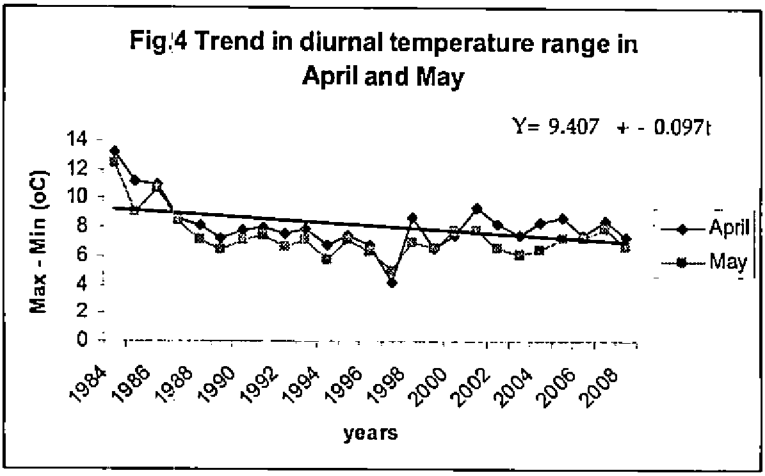
Fig.3 Diurnal temperature variation



A trend analysis of the maximum temperature showed a significant increase in August (Fig.4). The month of June is also on the rising side though not significant (Table 6).

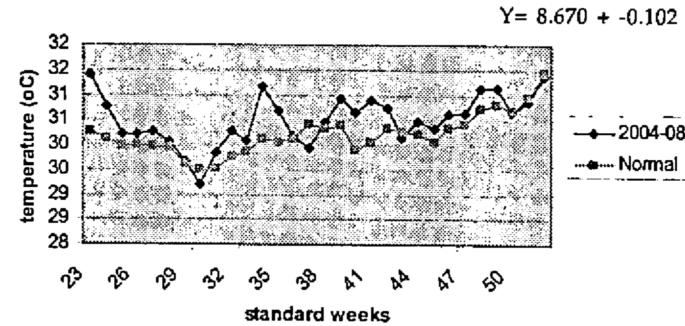


Commendable increasing trend is observed in the minimum temperature recorded during April and May. This also explains the significant drop in the diurnal variation in temperature observed during April and May



A standard week wise comparison of the maximum temperature was made over the years (Fig.5) and it revealed that the maximum temperature during the initial and latter part of the SW monsoon is higher than the normal.

Fig.5 Comparison of maximum temperature during the rainy season with normal



A higher temperature clubbed together with a shy initiation of monsoon indicates the need for changes in the cropping period especially during the first crop season.

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Table 3 Trend in rainfall and number of rainy days

Month	Rainfall			Rainy Days		
	b	a	t- value	b	a	t- value
April	1.505	65.624	0.90	0.221	5.29	1.93
May	4.765	126.402	1.52	0.195	8.58	1.51
June	-6.198	354.599	-1.71	0.205	20.26	-1.44
July	3.525	130.313	1.63	0.256	12.79	1.99
August	0.831	122.552	0.29	0.038	11.26	0.30
September	6.773	76.101	1.78	0.287	7.19	1.71
October	8.050	164.543	2.41*	0.297	11.22	2.20*
November	-1.408	244.388	-0.41	0.019	13.07	0.23
December	-1.488	71.916	-0.85	0.061	5.59	-0.39

b – regression coefficient a – constant

Table 6 Trend in temperature and diurnal variation (1984-2008)

Month	Maximum temperature (oC)			Minimum temperature (oC)			Max.temp. – Min. temp. (oC)		
	b	a	t value	b	a	t value	b	a	t value
January	0.005	31.057	0.36	0.007	21.687	0.202	-0.001	9.37	-0.046
February	-0.007	31.827	-0.424	-0.01	22.27	-0.297	0.003	9.557	0.101
March	-0.006	32.428	-0.221	0.015	23.322	-0.518	-0.021	9.106	-0.636
April	-0.025	32.875	-0.73	0.071	23.468	1.877	-0.097	9.407	-2.181*
May	-0.035	32.329	-1.29	0.067	23.659	2.034	-0.102	8.67	-2.709*
June	0.045	29.518	1.871	0.007	23.466	0.257	0.038	6.052	1.103
July	-0.021	30.133	-0.836	0.001	23.301	0.054	-0.022	6.832	-0.59
August	0.046	29.318	2.123*	-0.008	23.317	-0.361	0.053	6.001	1.698
September	0.007	30.415	0.279	-0.032	24.003	-1.807	0.039	6.412	1.658
October	0.005	30.121	0.185	0.0001	23.210	-0.009	0.005	6.911	0.201
November	-0.009	30.375	-0.574	-0.013	23.166	-0.85	0.004	7.209	0.202
December	-0.043	31.048	-0.241	-0.008	22.230	-0.212	-0.035	8.818	-0.82

b – regression coefficient a - constant

Astrometeorology – Search for planetary influence on weather

Unnikrishnan T and Prasada Rao GSLHV
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Abstract

Growth of every living organism has some correlating factor with weather and heavenly bodies. Sun being the major source of energy and moon having high influence on earth, these things are unavoidable. Astrology is considered as the eyes of Vedas since most of the treasure of knowledge lies in it was came through the analysis of heavenly bodies. While the study of the celestial bodies and their compositions, motions and origins is called astronomy, astrology is the applied astronomy. Many people made different attempts to predict weather using astrometeorology and most were highly accurate.

Research going on and the planetary influence on weather were very well studied by the ancient astronomers. The new branch of astronomy called Muhurtha was developed using this concept. According to this in a good muhurtha time, there will not be rain or other vagaries of weather like lightning, earthquake etc. The muhurta will vary for different purposes according to the star of the persons related and age, place etc. This will lead to the prediction of weather using astrology. For example we cannot predict rain in a desert using the concept of astrometeorology alone. In such situations we should use our common sense.

It is believed that the rotation and revolution of the earth are the main factors towards the changes in weather. Studies revealed that when a planet seemed to rest in cancer it will influence well in the northern hemisphere while the entry of a planet in Capricorn will highly influence the southern hemisphere regions. This was tested and found highly effective as in 2007 as Venus which is considered as watery sign planet in astrology was in Cancer during that period and high rain was in Kerala. But in

2008 and 2009 monsoon period, Mars and Ketu were in Cancer which caused less rainfall. As a forecast for 2010, since Mars is in Cancer, there is high possibility of increasing warm condition and drought in Kerala and India as a whole up to June 1.

Introduction

Growth of every living organism has some correlating factor with weather and heavenly bodies. Sun being the major source of energy and moon having highg influence on earth these things are unavoidable.. Astrology is considered as the eyes of Vedas since most of the treasure of knowledge lies in it was came through the analysis of heavenly bodies. When the study of the celestial bodies and their compositions, motions, and origins etc is called astronomy, astrology is the applied astronomy. Many people made different attempts to predict weather using astrometeorology and most were highly accurate.

Measurement of time and determination of the number of days in a year were two important discoveries that the world witnessed. This made a huge advancement in many fields. The basis for the determination of measuring the time was only the movement of earth alone which was imaginarily assumed as the movement of sun, moon and other planets and the change of climatic conditions. The fixation of the number of days in a year was also by using the changes in weather. The classification Utharayana and Dhakshinayana for a year was using the concept that the length of day is more than normal during Utharayana and vice verse during Dhakshinayana in the northern hemisphere. The division of a year in to six seasons (Vasantham, Greeshmam, Varsham, Sarath, Hemantham and Sisiram) was based on the changes in weather in a year.

They divided the entire elliptical orbit in to 12 equal sectors and named as different months according to the sector in which the sun seemed to be resting. This was scientifically true as the heat from sun varies significantly from one sector to other. Each Sector they divided in to nine sub sectors so that four sub sectors will form a star. The star for that day was calculated using the sub sector in which the moon seemed to rest. The sub sector in which the sun is seemed to rest was called a njattuvela. The inclination of the axis of earth was also a main contributor towards climate changes.

Along with the effect of Sun and Moon the sages used other planets also using their keen wisdom for this purpose. Using these ideas in mind they explained the cause and effect relationship of atmospheric changes through repeated occurrence of planetary positions. By the term planet they mean only tharagrahas (Mercury, Venus, Mars, Jupiter and Saturn. The meaning of graha and planet are different as in the case of God and daivam (in Sanskrit daiva mean fortune). Graha means "that which influences". So some planets are removed from grahas and sun, moon and thamograhas(Rahu and Ketu) are included in it as only these have high influence on earth. Also it should be noted that the position of planets are recorded as it is viewed from where the observer stands.

As the changes in weather lead to the discovery of calendar, people used it for the purpose of forecasting weather. Since the calendars were at best of limited usefulness for the timing of seasonal activities, Greeks, Romans, Mesopotamians, and Egyptians all turned to the observation of the fixed stars in order to determine the best times for planting, harvesting, pruning, sailing, and more. This is because what are called the phases of the fixed stars are very closely tied to the agricultural seasons, and so are good indicators of when those seasons begin and end. Indeed, Greeks and Romans would often link their seasons to particular stellar phases, rather than, as we do it, to just the two solstices and two equinoxes

Research going on and the planetary influence on weather were very well studied by the ancient astronomers. The new branch of astronomy called Muhurtha was developed using this concept. According to this in a good muhurtha time, there will not be rain or other vagaries of weather like lightning, earthquake etc. The muhurta will vary for different purposes according to the star of the persons related and age, place etc. This will lead to the prediction of weather using astrology. For example we cannot predict rain in a desert using the concept of astrometeorology alone. In such situations we should use our common sense.

It is accepted that when Jupiter is in the perihelion there is a great chance for drought and when in aphelion cloudy atmosphere is expected. When angle between Mercury and Venus is less than 30^0 there is high probability for rain and is very well accepted for the last few centuries. Variations in radiation received over different regions of the globe due to its position with respect to sun together with other features of earth produce changes in weather and climate. When the angle between Sun and Mercury is small there will be winds along the ocean and form difference in pressure system. But when this happens with Sun and Venus there is possibility of rain. When Sun and Mars are near there will be high hot and if this happen in Aries it will be very warm and drought. This was the case during February – May season of 1983, 1987, 2002 and 2004. During Sun and Saturn combination pressure will be stagnated over long periods and will be colder than usual. If Jupiter and Sun conjoins the atmosphere will be warm and dry. These are very well affected in ocean and its nearer sides and as Kerala is concerned these changes will very easily affect here.

It is very clear that the rotation and revolution of the earth are the main factors towards the changes in weather. Studies revealed that when a planet seemed to rest in cancer it will influence well in the northern hemisphere while the entry of a planet in Capricorn will highly influence the southern hemisphere regions. This was tested and found highly effective as in 2007 as Venus which is considered as watery sign planet in astrology was in Cancer during that period and high rain was in Kerala. But in 2008 and 2009 monsoon period Mars and Ketu were in Cancer which caused less rainfall. As a forecast for 2010 since Mars is in Cancer there is high possibility of increasing warm condition and draught in Kerala and India as a whole up to June 1.

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SESSION III

Climate change adaptation in natural resources management

Possible impacts of climate change on water resources of Kerala

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Abstract

The climate change is having overwhelming influence on the global water resources scenario. Water resources of Kerala are solely depending on rainfall. The amount of rainfall received over Kerala may vary spatially and temporally and the impact of climate change may have pronounced impact on agriculture and availability of water for human requirements. Being a coastal state having a coastline of about 600km, the impact of sea level rise due to climate change will affect the coastal ecosystems including dynamic ground water regime of the coastal area. The Kuttanad area with a spatial extend of 500 sq.km lies below the sea level and the sea level rise due to climate change will adversely affect the salinity of the back water system which will adversely affect the biotic community and more and more land area will be submerged under water. The rainfall of Kerala is about 2.78 times of national average. The per capita water availability of Kerala is decreased to five fold during the last 100 years while at the national level it is decreased to four fold only. It has been reported that the available ground water and surface water resources of Kerala is under great stress and the onset of climate change would aggravate the situation. Integrated Water Resources Development and Management (IWRDM) is the only option and necessary master plan has to be prepared for meeting the above challenges with due input of scientific expertise. This has to be done on war foot basis following the line of Winning Augmentation and Renovation of water (WAR) programmes of Department of Science and Technology (DST)

Introduction

The rising concentration of green house gases in the atmosphere has established through scientific observations and the level increased from 280ppm by volume to about 369ppm volume and global temperature of the earth has increased to about 0.6 degree C. The global mean sea level has risen by 10 - 20 cm. The average global surface temperature is estimated to increase by 1.4-3 °C. From 1990 to 2010 at lower estimates which is as high as 2.5-5.8 °C for higher emission estimates. The resultant rise in global mean sea level is projected between 9 -88 cm. According to fourth assessment report of the Inter Governmental Panel on Climate Change the percapita water availability in the country would decline from 1820 M^3 per year in 2001 to 1140 M^3 in 2050. Geological observations ascertain that every 10,000 years earth's climate warms up and is called interglacial period. At the end of the last ice age earth's temperature has risen to about 9 °C and sea level was up by about 100m. Global warming and climate changes are due to natural cyclic process. Human activities especially after the industrial revolution substantially accelerated the increase of concentration of greenhouse gases (GHG) in the atmosphere. The resultant sea level rise due to rising temperature and melting of glaciers would have an impact all over the world and the socio economic conditions and environmental conditions of the people. It is one of the greatest challenges for the prosperity of the human being. With rapid growing population and improving living standards of the people the pressure on water resources is increasing to a great extent.

Impact of climate change on water resources

Kerala state is situated in the humid tropics with two predominant rainfall seasons during the south west monsoon (June-September) and the north east monsoon(October-December). On an average, the state receives 3000 mm annual rainfall of which 70% is obtained during the south west monsoon, 20% during north east monsoon and the remaining as summer showers. The average annual rainfall decreases from North to South of Kerala. Compared to national average, Kerala receives 2.78 times of rainfall. While compared to Rajasthan and Tamil Nadu, Kerala receives respectively five and three times of the annual rainfall. In recent years Kerala is experiencing changes in the rainfall pattern and its intensity. In the year 2007 the state had received third highest excess south west monsoon rainfall during the period 1901 to 2007. Kerala received a rainfall of 268 cm compared to the normal rainfall of 214 cm registering an excess rainfall of 30%. As per the Indian Institute of Tropical Metrology norms if there is a deficit of rainfall of 10% in a year it is called as drought year. There is a long term and short term changes in the occurrence of drought years during the last 100 years period. It has been noticed that deficit of rainfall and the occurrence of drought years are more pronounced in the Southern districts of Kerala. It has been reported that the incidence of cyclones are increasing since 1991 and even cyclone eye was formed in the western coast during 2009.

Impacts of climate change on freshwater

The impacts of climate change especially variation in distribution and amount of rainfall would directly influence the hydrologic cycle which in turn would affect the water availability of the region. With greater availability of moisture in the atmosphere, increasing occurrence of rainfall would increase the potential for floods. The change in climate will affect the soil moisture, ground water recharge, frequency of flood & drought episodes and influence the Ground water levels in different areas. However no work has been done in Kerala impacts of climate change on hydrologic cycle and resulting damages. According to the 4th assessment report of the IPCC the impact of climate change on freshwater resources is given in table 1.

Table 1 The impact of climate change on freshwater resources (IPCC report)

Region/condition	Impact	% Change	Degree of confidence
High latitude, some wet tropical areas	Increase in annual average river run-off and water availability	10-40	Very high
Dry regions at mid-latitudes and in the dry tropical areas, some of which are presently water-stressed.	Decrease in annual average river run-off and water availability	10-30	Very high
Drought-affected areas	Increase in extent	-	Very high
-	Increase in frequency of heavy precipitation events	-	Very high

Sources of water

There are 44 rivers in Kerala having length more than 15 kms. Out of 44, three rivers flow towards East and the remaining 41 flowing towards the West. Most of these rivers are ephemeral in nature having input of water from rainfall only during the monsoon. The annual discharge from all the rivers of Kerala is estimated to be around 78,000 MCM. It is to be noticed that single river like Godavari in Andhra Pradesh has an average discharge of 1,05,000 MCM. The utilizable surface water in Kerala is estimated as 40,000 MCM (PWD, 1974). The estimated ground water potential is about 8000 MCM. in which 1000MCM is the present draft (CWRDM, 1995). There are 6 million open wells existing in the state. Besides traditional water sources like surangams, vallams and springs also acts as water sources for the population of the state.

The erratic rainfall pattern and intensity as a result of climate change and disruption of hydrologic cycles would have direct impact on the water availability of the rivers of Kerala as the rainfall is the only source of water. Most of the river courses in Kerala are narrow and straight which would be incapable to absorb the greater energies acquired by the rivers due to variation of rainfall pattern and intensity resulting in flash floods. As a result the flood hazards would affect the lower part of the river basin and would affect the hamlets of the people residing in the downstream regions of rivers.

As a result of sea level rise more and more sea water will be intruded into the rivers and greater freshwater regions of the river would remain under the tidal influence from the sea water. This will have disastrous effects as the change in salinity conditions of the rivers would influence the ecological factors there by the flora and fauna of the region. The interconnection between rivers water and adjoining formation water would also be adversely affected. The above phenomena would have an direct effect on the agricultural practices existing along the course of the river. In order to control the seawater incursions into the rivers, suitable controlling structures may be constructed across the rivers after conducting detailed scientific studies. It is to be noted that many of the groundwater extraction structures and pumping stations are located along the river courses. Such extraction structures would turn to be unproductive due to saline water incursions.

Kerala has one of the highest well density in the world to the tune of 200 wells/sq.km. In Kerala there is for every seven persons have 15 a well. The well density is highest in the coastal area. Due to sea level rise the groundwater flow towards sea would be reduced due to the lower gradient between sea water and freshwater interface which may increase the availability of the groundwater resources in the coastal phreatic aquifers. Similarly, when the sea level rises, there will be lower gradient in the confined aquifers of coastal region. This lower gradient results in lower subsurface flow of groundwater.

The lower gradient results in lower subsurface flow of the groundwater towards sea, it may result in higher residence time of water in the aquifer which will influence the water quality due to rock water interaction. It may also influence the groundwater holding capacity of coastal aquifers. The changes in the hydro chemical equilibrium in the coastal area of the aquifer water would have drastic consequences. Further, the rising sea level may take away more and more coastal regions under the influence of seawater. The reduction in the freshwater holding capacity of the coastal area as a result of rising sea level would affect the water availability and adversely affect the coastal population especially of islands like Vypeen, Lakshadweep etc.

Areas vulnerable to climatic change

The low lying areas in particular are susceptible to the effects of climate change and resultant sea level rise. Kuttanad is one such region with an aerial extent of 500 km^2 lying below the sea level with an elevation ranging from 0.6m to 2.2m below msl. It is a deltaic formation of 4 major rivers viz., Pampa, Achenkovil, Manimala and Meenachil confluence into the Vembanad Lake. The region is enclosing in a vast stretches of backwater bordering mangrove formations and rice fields. The latter mostly reclaimed from the larger stretches of lake during the recent past. Though the economy of the region is dependent on rice, being the only crop, can be cultivated in low-lying areas, it is also supported by coconuts in puraidams and inland fisheries. Most of the area is covered with water through out the year, so Kuttanad is one of the few places in the world where farming is carried out below sea level. Already the Kuttanad area is reeling under an aquatic drinking water facility and a drastic depletion of groundwater table with greater saline water incrusions is into the wells. The sea level rise in the erstwhile rice bowl of Kerala, would affect over 1/3 of State total rice production. Similarly the kole lands of central Kerala and the Kaippad regions of North Kerala would also be affected due to the illeffects of sea level rise.

Management issues

To achieve natural resource management for sustainability of Kerala it is necessary to prepare and develop integrated management plans for every river basins. The emphasis may be given on the need for water resource assessment, for protecting fresh water from over exploitation by improving drinking water supply and sanitation, impact of urban development, water for food security. The integrated resource management is based on the concept of water being an integral part of an ecosystem, a natural resource and social and economic good, whose quantity and quality determine the nature of its utilization. (UN. 1992)

The holistic management of freshwater, being a finite and vulnerable resource, and integration of sectoral water plants and programs within the framework of national and international economic and social policy area of paramount importance to ensure sustainable use of water. The interconnected nature of river systems involves the water management and adoption of methodologies which consider all the activities within an area instead of focussing only on a small number of limited objectives. The river basin provides a natural unit for such an approach. Govt. of Kerala is making attempt to achieve integrated management of river basin with the formation of river authorities.

In spite of failure in deriving mechanisms to implement the river action plan, there is a need to look into the various issues pertaining to integrated water resources management especially river basin management in Kerala context. The unique characteristics of Kerala like rainfall distribution, geomorphology and geology, sources of water, absence of hydrologic database, lack of basin plans, socio economic and environmental factors etc will be taken into account while developing integrated management of river basins. The conservation of different ecosystems would be taken with due care. The Environmental Monitoring Programme on Water Quality and Soil Quality undertaken by the Kerala State Council for Science, Technology and Environment would generate sufficient database needed for developing integrated river basin plans. The non availability of sufficient hydrologic database shortfall of sufficient hydrologic database on river basin should be addressed by R&D organizations on priority which would till the existing gap in the available database. Besides rejuvenation of traditional water harvesting structures, rainwater harvesting groundwater recharge measures, implementation of proper land management practices and afforestation programs conducting water literacy programs would together enable the state to overcome the threats of climate change on water resource status to a great extent.

Problems of water challenge require immediate solutions. The Department of Science and Technology, Government of India therefore, had developed the Technology Mission WAR for water which explores scouting and sourcing of technologies available and accessible from the global experience under real life situations while developing in parallel, home grown solutions through laboratory research. Various approaches planned for finding out viable solutions for water related challenges faced by the community are

- Mapping the scale, scope and seriousness of the problem in select regions
- Priority profiling and setting
- Spotting and scouting feasible solutions from national and international technology sources
- Expert Study and Evaluation
- Matching of solution with problems in real field locations
- Resource planning and flow arrangements
- Pilot under trial examination under real life conditions
- Data analysis and scope for applications of technical solutions
- Finalization of selection of options of technical solutions for each water related challenge along with site specificity

The selected approach plan includes selection of about 25 different water related challenges in select locations and matching most appropriate technology solutions within the capacity of the local community to apply the solution in a sustainable manner followed by technical scale evaluation and proving of viabilities incredible sizes.

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Effect of a low cost sub surface dyke using plastic film in conserving soil moisture along the timeline in a sloppy terrain

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Although the total amount of water on Earth is generally assumed to have remained virtually constant, the rapid growth in population, together with the extension of irrigated agriculture and industrial development, are putting stress on the quality and quantity aspects of natural system. In the face of growing problems, society has begun to realize that it can no longer subscribe to a 'use and discard' philosophy – either with water resources or any other natural resources. Compared to the national average, unit land of Kerala is receiving 2.5 times more rainfall. Despite the heavy rainfall received the state experiences severe drought in summer which can be attributed to the inefficient utilization of rain water. In Kerala, where pressure on land is very high, surface storage of water in large reservoirs with adverse ecological impact is not an economical proposition. In this context, the construction of sub surface dyke can offer a solution. Subsurface dyke is the structure that is built in an aquifer with the intention of obstructing the natural flow of ground water, thereby increasing the amount of water stored in the aquifer. Ground water availability in small valleys can be effectively increased by improving the storage potential, by construction of sub surface Dykes with impervious material like clay, bitumen, or polythene sheets besides bricks and concrete. The structure need not be thick or project above the surface. The ideal location for the dyke is a well defined, wide, greatly sloping valley with a narrow outlet having limited thickness of loose soil or porous rock on the top with massive or impervious rock below. It has many advantages. It does not require additional surface reservoir. There is no loss of agricultural land. There is minimum evaporation loss since the storage is subsurface. There is no siltation and loss of reservoir capacity. The cost of construction is low and maintenance is negligible. It is environment-friendly and it can be implemented with locally available materials.

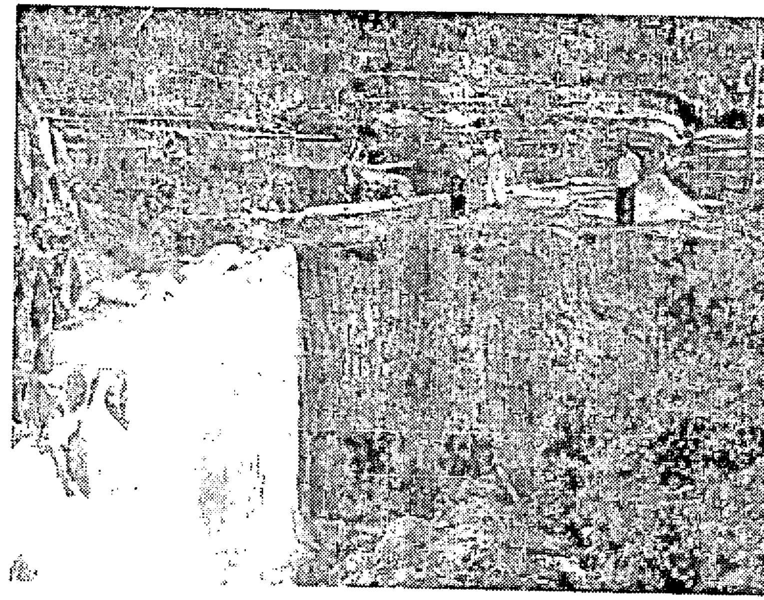
Materials and methods

In the present study, subsurface dyke was constructed at Krishi Vigyan Kendra Kannur (Kerala Agricultural University) located inside the campus of the world famous Pepper Research Station, Panniyur. As elsewhere in Kerala, the farm attached to the Kendra, is characterized by its sloppy terrains. The campus has a total farm area of 25.5 ha and the entire area is a slope in North - South direction. Pepper, Cashew, Coconut and Arecanut are the major crops in the area. As per the meteorological data recorded in the campus, the farm receives an average annual rainfall of 3250 mm and evapo-transpiration of 4 mm/day. Due to the sloppy terrains even though the area receives good amount of rain fall bulk of the water is lost as surface run off and hence as soon as the monsoon receeds the entire area experiences moisture stress.

On the top side of the terrain there is a 3 ha rocky patch with shallow soil, where severe soil erosion occurs. Hence this top most portion of the farm is the most critical factor adversely affecting the hydrological balance of the farm. On the bottom line of the slope, there is a narrow stream covering the entire length of farm and it originates from a spring at the western side of the farm. The spring point is surrounded by hill slope on north, west and eastern side. The dyke was constructed in the valley portion of the three hills across the stream. The exact location was identified through the survey conducted and by drawing the contour map of the area.

The stream becomes active during June and dries up during December. The irrigation source of the entire farm is one pond of 15 x 12 x 5 m, constructed near the stream line supported by over head tank and irrigation net work. The entire farm has an average slope of 35% (19°). Such a steep slope and shallow soil depth at the top makes it mandatory for water harvesting measures to overcome moisture stress of the entire farm. This pond dries up during peak summer and hence irrigation is rarely practiced in the farm. The valley portion of undulating topography in hilly region was identified as the ideal site for constructing a subsurface dyke. A trench of 40 m length and 8 m wide was made across the valley in vertical position to the stream lying in midst of the two oppositely facing hilly areas down to the bedrock and the mean depth was 7.5 m (Plate1) .

Plate 1 The construction of the sub surface dyke – preparation of the trench for spreading the plastic film



Three layers of plastic film, ie, one layer of 500 G and two layers of 200 G were inserted or spread on to the wall of the trench towards the downstream side (Plate 2). After these films, one layer of hard board was placed and the excavated soil was filled

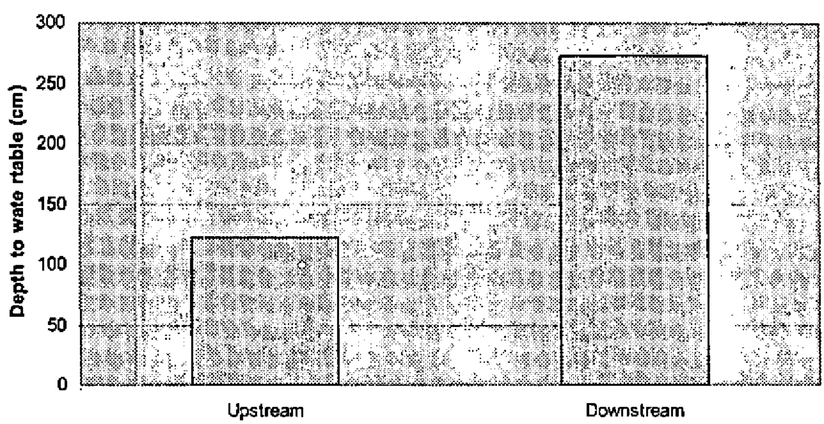
Plate 2 The construction of the sub surface dyke – spreading of the plastic films on to the wall of the trench

back to the trench so that the construction was complete. At the top portion of the dyke, in line with the surface soil concrete was placed so as to fix the sheets in position. This impounds water and reduces seepage. Three pairs of PVC pipes having holes plugged with nylon nets were inserted both upstream and down stream sides of the dyke which could serve as the water level recorder. Weekly data on the water table was recorded by measuring the water level in these tubes. The data was statistically analysed.

Results and discussion

The depth to water table in the downstream area was significantly higher than that in the upstream area (Fig. 1). Thus significantly higher level of water was maintained in the catchment area (upstream) compared to down stream area as a

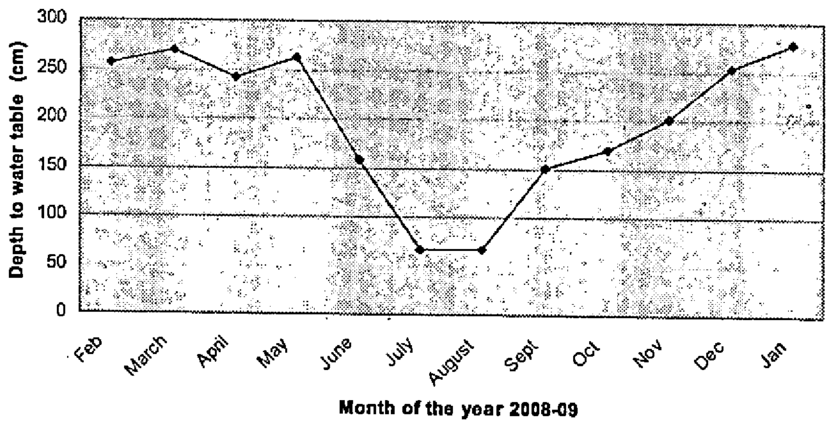
Fig 1 Average depth to water table level in the upstream and downstream sides of the subsurface dyke



consequence of the obstruction of the runoff seepage losses of soil moisture. The plastic sheets in the dyke obstruct the flow of sub-surface water raising water table in the catchment area. The existing pond in the upstream side of the dyke which usually gets dried up in summer is now maintaining higher water table throughout the year as the dyke ensures incessant supply of water to the pond.

The depth to water table was higher in summer and decreased with the onset of rainy season and again increased after cessation of the rains (Fig.2). Thus it is evident that the water level was lower in the months of summer ie, January to May, got increased in rainy periods.

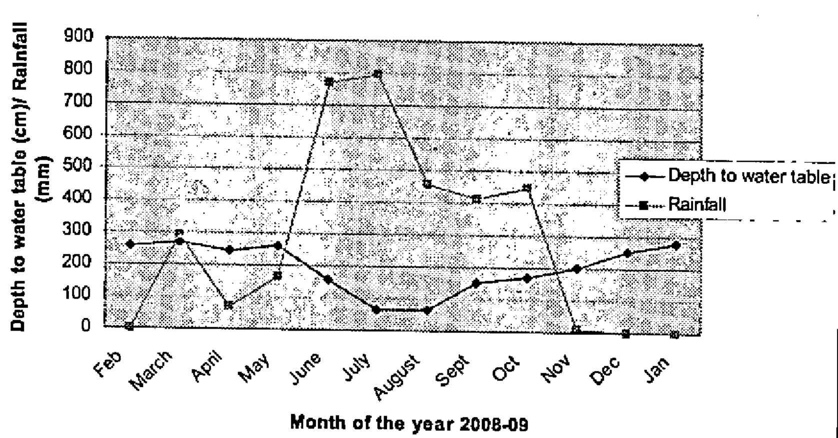
Fig 2 The change in average depth to water table along the timeline

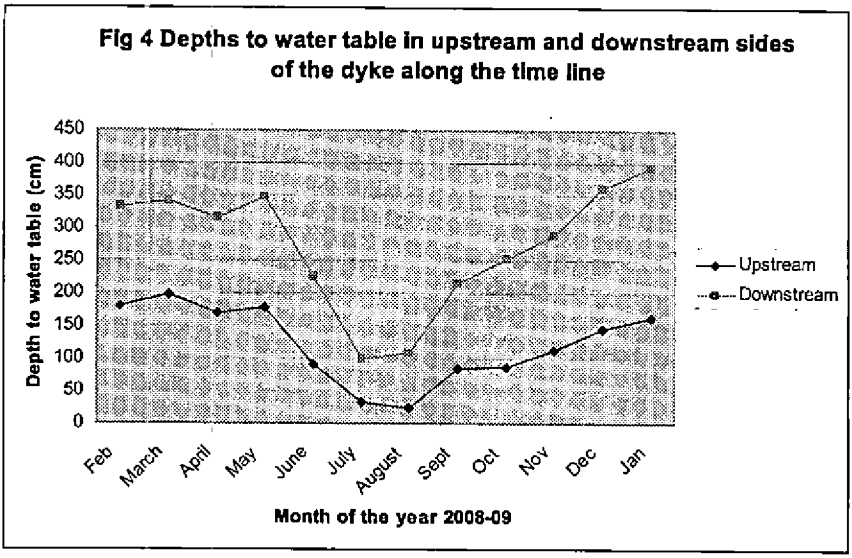


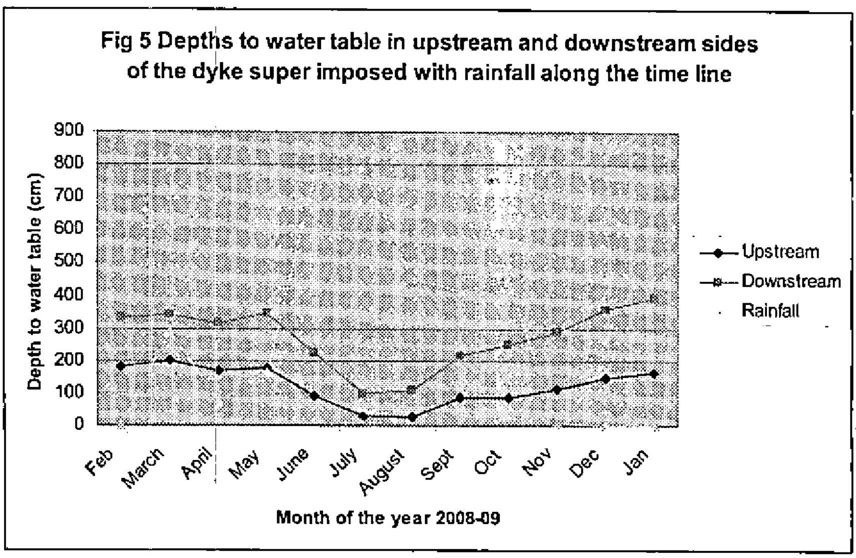
and thereafter decreased after cessation of the rains. Change in depth to water table along the time line is in consensus with the trend in the amount of accumulated rainfall (Fig.3). The depth to water table decreases with increase in rainfall and vice versa.

Upstream side always maintained a lower value as the subsurface flow of water got obstructed by the dyke (Fig.4). Thus the ground water table fluctuations on the upstream and downstream sides of the subsurface dyke during all seasons indicated that higher

Fig 3 The change in average depth to water table superimposed with rainfall along the timeline







water table was maintained in the catchment area (upstream side) due to the dyke. When the data on the depth to water table in both upstream and downstream sides were superimposed with rainfall, the data were in consensus with the amount of accumulated rainfall (Fig 5). The depth to water table decreases with increase in rainfall in both upstream (inside the dyke) and downstream (outside the dyke) sides and vice versa. As described previously, the ground water table fluctuations on the upstream and downstream sides of the subsurface dyke during all seasons indicated that higher water table was maintained in the catchment area due to the dyke (inside the dyke). Thus, the water table fluctuation during non rainy periods reflected rapid depletion of drainable water in the area both upstream and downstream sides. This rate of depletion could be considerably reduced by the dyke indicated by the wide gaps between the water tables on upstream and downstream sides in non rainy periods compared to rainy periods. The water thus conserved could be utilized for irrigation and other purposes.

The study revealed that water level during summer season at the dyke upstream rose by about 60 - 80 cm. The wells constructed near the dyke, both for drinking water supply and lift irrigation yielded more water for longer duration. (Suseela V and Vishalakshy, 2006)

Storage potential of the dyke in rainy periods

Length of the subsurface dyke constructed = 40 m

Average depth of the dyke in rainy periods (water table reached surface level in rainy Periods) = 7.5 m

The Mean area of storage = 200 m

Porosity = 15 %

Water Storage potential = 40 x 7.5 x 200 x 15/100

= 9000 m^3

= 90 lakh l of water

Storage potential of the dyke in non-rainy periods

Length of the subsurface dyke constructed = 40 m

Average depth of the dyke in rainy periods (average difference taken as 1.5 m)

	= 6 m
The Mean area of storage	= 200 m
Porosity	= 15 %
Water Storage potential	= 40 x 6 x 200 x 15/100
	= 7200 m^3
	= 72 lakh litres of water

The water level in the dug out pond which is just 10m away from dyke in the upstream side showed an increase by about 1.5 m during summer months. This pond is the source for domestic & irrigation water for the KVK farm as a whole. Before construction of the dyke, the water available in the pond was not in sufficient quantity so as to meet the water requirement of irrigation of the farm. During summer months, there were restrictions, undertaken regarding the minimal use of water even for domestic and drinking purposes. After construction of the subsurface dyke, water in the pond was available for pumping continuously for 6 hours in summer months and the problem of water scarcity/ shortage is solved. In the last two years, water available in the pond was sufficient enough for irrigating the KVK farm and for meeting the drinking and domestic requirements of water as well. The stream passing the down hill portion of the sloppy terrain usually dries up in December and become active in June. But after the introduction of the dyke the stream never got died up. The stream was found to be perennial as a result of the increased water storage and recharge potential of the farm.

Conclusion

In areas of a well defined watershed with a narrow outlet and undulating topography, which is typical of Kerala, subsurface dyke is an efficient system to prevent water losses so as to conserve and utilize the rainfall that is received in a watershed. The water conserved in the upstream side of the dyke can be utilized for irrigation and other purposes. It also allows for recycling of irrigation water and nutrients in the catchment area. Plastic films can serve as a cheaper alternative to masonry wall as an efficient barrier against the subsurface flow of water.

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Rainwater harvesting to combat the vagaries of monsoon – A case study

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Abstract

Studies were conducted to assess the efficiency, durability and acceptability of different types of roof catchments, storing capacity of different types of storage structures with respect to quality of water, under the ICAR adhoc Project on "Technological and Institutional Interventions in Rainwater Harvesting in Kerala", during 2005-07 at the Kerala Agricultural University. Motivating models of rainwater harvesting from rooftops and land rain harvesting were established at the Campus which can enlighten on the scope and importance of conservation of rainwater in Kerala. The runoff coefficient of sloping aluminium sheet roof was observed as 0.91 and that of flat RCC roof slab as 0.73. Water quality analysis showed that the physico-chemical parameters of rainwater stored in all types of storage structures were within permissible limits as per the BIS even after six months of storage, whereas the microbial analysis showed that the water stored only in ferro cement tank and lined (750 micron HDPE) underground tank were free from e-coli, colliform bacteria and streptococcus. The evaporation loss from lined pond could be reduced up to 50% by providing 75% shade net on top, compared to the pan evaporation. An additional area of 0.8 ha could be brought under cultivation using rainwater collected in a renovated pond at the seed farm.

Introduction

Water resources are coming under increasing pressure due to the changing climate. The erratic monsoon leads to extreme hydrological events (large-scale droughts and floods) resulting in serious reduction in agricultural output and affecting the vast population and national economy. Due to the uniqueness in physiography, the sustenance and eco development of Kerala State are largely dependent on her own water resources. The State is having a surplus of about 8506 million cubic meters of rainwater during monsoon and a deficit of about 78142 million cubic meters in summer (Sudhakaran, V.A and Ramadas, T.N. 2004). Due to steep and undulating topography, rainwater is not much retained on the land, thereby obviating the advantages of having high rainfall to a great extent. More over, the vagaries of monsoon are expected to increase in the future due to possible climate change, making the monsoon less reliable as an assured source of water. Hence rainwater harvesting and conservation is the viable solution in the monsoon rich state of Kerala to meet the drinking, domestic, agricultural and industrial needs of the State.

Materials and methods

Motivating models of low cost rainwater harvesting and storage systems have been established at the Kerala Agricultural University Campus under the ICAR adhoc Project on "Technological and Institutional Interventions in Rainwater Harvesting in Kerala" during 2005 - 07 and the efficiency, and acceptability of these systems were assessed (Visalakshi, 2007).

Results

Rooftop rainwater harvesting

Rain harvesting from Aluminum sheet roof catchments: Aluminum sheet roof of ladies hostel in the campus with a roof area of 1019 sq m was utilized for harvesting rainwater. The harvesting potential of the catchment, with the run-off coefficient of 0.91 was 2559 cubic meters. Out of this, storage facilities for a total quantity of 188 cubic meters were provided for in situ rain harvesting for direct use:

Ferro cement storage tank: A 25 cum capacity ferro-cement tank was constructed at ground level with filtering, and manhole units. Besides a common tap, another outlet was provided to the kitchen, through a micro filter. The total number of stakeholders in the hostel is about 250. It is expected that the water stored could be utilized in the kitchen for cooking purpose during scarce periods. The overflow from this tank was conveyed to a masonry tank of 10 cum capacity and this water could be utilized for life saving irrigation of the garden of the hostel during summer.

Provision can also be made to divert the rooftop water during rainy days to the three existing RCC tanks, which is connected to the supply system so as to reduce pumping cost during monsoon. The excess flow of 2371 cum from the roof catchments could be contributed to groundwater through percolation pits.

Rain harvesting from flat RCC roof slab catchments

The flat RCC roof slab (360 sq.m area.) of the Mess Hall of the Men's Hostel, College of Forestry, Vellanikkara was utilized for rain harvesting, as during summer, the hostel suffers from acute water scarcity which occasionally causes even for the closing of the mess. The existing drainage outlets from the roof were connected through PVC pipes and water was conveyed to a newly developed underground lined storage tank through filter media.

Under ground lined tank

An under ground tank of 48.75 cum capacity was constructed to store the rainwater harvested from the above rooftop. The tank is rectangular, of size 13 m x 1.5 m x 2.5 m. Pre-cast ferro cement slabs were inserted between interlocking pillars on all the four sides for retaining the soil behind. It was lined with 750-micron UV stabilized black HDPE sheet and the top of the tank was covered with pre cast ferro cement slabs. The filter for this tank was of size 1m x 1m x 1m filled with sand, activated carbon, and small rubble/gravel. The withdrawal of water was done by pumping to the existing overhead tank for use in the kitchen of the hostel. This type of tank can be recommended for a small family with small sized house holding, by constructing along the side of compound wall, taking the advantage of using the foundation of wall as one side of the tank, thus saving space and money. The cost of this tank is estimated to be Rs. 0.60 / liter. Observations on rainfall and runoff from the roof catchments resulted in a runoff coefficient of 0.73 from the roof terrace.

Land rainwater harvesting

In order to conduct studies on land rainwater harvesting, two locations were selected, one at the Seed Production Farm of the Department of Olericulture, College of Horticulture (3.2 ha) and the other at the Water Management Research Unit (7.0 ha) of AICRP on Water Management.

One abandoned well which had an original storage capacity of 126 cubic meters was developed and increased the capacity to 755 cubic meters. Using the rainwater collected in this pond an additional area of 0.8 hectares could be brought under cultivation for producing vegetable seeds during summer.

Another pond of trapezoidal section with 1:1 side slope was dug out with a capacity of 100 cum. The pond was lined with 300-micron geo-membrane, to reduce seepage losses. The top of the pond was covered with 75% shade net for minimizing evaporation losses and preventing any entry of debris. It was seen that the evaporation loss could be controlled up to 50% by providing the shade net at top compared to open pond. The cost of construction of this pond was Rs. 0.20 /liter.

Quality of harvested rainwater

Water quality analysis showed that the physico chemical parameters of rainwater stored in all types of the above storage structures were within permissible limits as per the BIS even after six months of storage, where as the microbial analysis showed that the water stored only in ferro cement tank and lined (750 micron HDPE) underground tank were free from e-coli, colliform bacteria and streptococcus.

Conclusions

Motivating models of rainwater harvesting structures could be established at the KAU campus, which can enlighten on the importance and scope of rainwater harvesting in Kerala. The runoff coefficient of sloping aluminium sheet roof was observed as 0.91 and that of flat RCC roof slab as 0.73. Water quality analysis showed that the physico chemical parameters of rainwater stored in all types of storage structures were within permissible limits as per the BIS even after six months of storage, where as the microbial analysis showed that the water stored only in ferro cement tank and lined (750 micron HDPE) underground tank were free from e-coli, colliform bacteria and streptococcus. The evaporation loss from lined pond could be reduced upto 50% by providing 75% shade net on top, compared to the pan evaporation. An additional area of 0.8 ha could be brought under cultivation using rainwater collected in a renovated pond at the seed farm.

Acknowledgement

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National Seminar on Climate Change Adaptation Strategies
in Agriculture and Allied Sectors, held at KAU during 03-04 December 2009

Climate change and adaptation for better drinking water resource management perspectives: A case study in Thiruvananthapuram district, Kerala

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Abstract

Resultant effects of climate change are, deviations in weather observations leading to uncomfortable living conditions and loss in overall economic growth and prosperity especially in agriculture and human health. Kerala state with rich rainfall pattern compared to other parts of Indian states, with lush green environment and extensive wetlands, also record fewer natural calamities as devastating cyclones and intense droughts and floods in comparison to other parts of India and outside. The present study is mainly focused on the impact of climate change on drinking water resources in Thiruvananthapuram District with an emphasis on feasible adaptations for the future. The study area falls in southern part of Kerala with an average annual rainfall of 150 cm of rainfall with two distinct SW and NW monsoon peaks. It has three major rivers and four taluks and twelve developmental blocks with seventy eight Panchayats. The region has drinking water scarcity in many parts during summer months. The paper discusses various issues on water harvesting and water conservation practices for adaptation and assesses water resource potentials and present status.

Introduction

Drinking water is fast becoming a scarce commodity in many arid and semi arid regions of the world, due to the impact of climate change and the green house effect. Especially drinking water shortages are felt often in urban areas, attributed to fast changing urban land use, and increased population pressure on surrounding urban environments. Depletion in surface and ground water resources due to over exploitation and in adequate maintenance and distribution of water supply for growing population is real challenge before the planners. Sustained water quality is another major worrying factor of ambient sources and their mindless use as receptacles of human and industrial waste is another dark zone that needs to be tackled and regulated. Delayed occurrence of monsoon rains and increase in dry spells and inadequate water conservational practices to meet safe water demand are some of the issues need to be addressed in detail with good database and analysis. A forestation and river catchment protection and management, restoration of all possible water bodies and hydrological environment, their prevention from getting polluted, will have considerable improvement in resource utilization and management during hot summers.

Study area, data and methods

Thiruvananthapuram, the southernmost district, of Kerala state with an area of 2192 square kilometers, with four taluks, twelve blocks and eighty four panchayts (Fig1). It has three distinct zones as eastern high lands, central mid lands and low lying coastal areas. Three major rivers namely Vamanapuram, Krmana and Neyyar, flowing through the district from eastern high lands, mid lands in to the Arabian sea. The district receives an annual rainfall around 1500mm mainly during two monsoons of south west and north east monsoon respectively in addition to summer showers. The study was taken up to understand the effects of climate change on drinking water resources and watersheds were considered as base unit, over laying administrative boundaries to see the regional variations. Available secondary data on rainfall, temperature, number of rainy days were analyzed and interpreted. Data on surface and ground water resources collected from concerned agencies were analyzed and thematic analytical maps prepared in GIs format for noting changes over time and space.

Results and discussion

The monsoonal effect on drinking water resources is fairly noticeable during summer months in many parts the study area every year and is recurring in nature. It is seen Adhiyannur block along the Coastal region experiences more severity in drinking water shortages. Decentralized water schemes in rural areas are managed by local panchayts and Kerala water authority catering in major urban towns through pipelines. It was reported The meteorological factors have a major impact on the availability of fresh water resources, except for rainfall data all other information related to hydro meteorological parameters is however scanty and inadequate. There are about 910 ponds and tanks in Kerala with a minimum of 0.5 ha water spread area and about fifty percent of these water bodies call for rejuvenation (2004, James E.J). Effective management of watersheds and river catchments will boost the ground and surface water recharge at suitable sites after careful study of surface and subsurface features for storing and re directing to the nearest recharged water reservoirs, ideally along rich alluvium valley floors with clay lining or sub surface reservoirs with structural control crevices.

The Kerala state is under a sever localized and intense water pressure in as much as 180 days of the year and per capita availability is not better even compared to states known for water shortage. The surplus of water sources, often argued on the basis of the 3000mm rainfall gauged is a myth and which needs to be broken (2004, Ashok B). Intensive Rain water harvesting practices and water conservational management with awareness campaign among masses can considerably reduce the burden of drinking water supply at places of acute shortages.

Conclusions

The study area experiences summer water scarcity in many parts which can be handled by appropriate water harvesting techniques at suitable sites and creating awareness about water resource conservation among the general public.

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Effect of soil and water management practices on temperature and moisture flux in humid tropical latosols

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Abstract

Crop water deficit during summer season and low soil fertility are among the major limiting factors for higher crop productivity in Kerala. Climate change and global warming phenomenon is gradually increasing the atmospheric evaporative demand, which will lead to higher crop water deficits and lower productivity. A study was conducted in a coconut plantation in Kozhikode district to evaluate the effect of sustainable soil and water management practices like cover cropping and post-monsoon tillage on temperature and moisture flux in soil. Cover cropping, post-monsoon tillage, and unploughed area as control were compared. Soil temperature at different soil depths (2.5, 5, 10, 20, 30 and 50 cm) was recorded daily at 8.30 am and 2.30 pm using soil thermometers installed in each treatment plot. Soil moisture content at each depth was measured. Rainfall and ambient temperature were recorded.

Cover cropping is found to have significant effect on controlling the soil temperature. The daytime soil temperature in cover-cropped plot is lower than that of ploughed and unploughed plots. The morning soil temperature of cover-cropped plot is also lower than that of other plots, but the difference is narrower in surface soil. Soil temperature in surface layers is found to fluctuate significantly between day and night. Diurnal fluctuation of subsoil temperature is minimal. Cover-cropped plot is found to have the lowest soil moisture content, which can be attributed to the transpiration from cover crop.

Post-monsoon tillage significantly influences the soil moisture

content, and the ploughed plot is found to have the highest moisture content, followed by the control and cover-cropped plots. Post-monsoon tillage creates soil mulch over the surface, thereby helping in the conservation of soil moisture. High soil moisture content in ploughed treatment may be due to the disruption of the soil-atmosphere-continuum, and thereby minimizing the capillary rise of water from the sub-soil and its loss. Higher soil temperature in the ploughed plot may be due to higher thermal conductivity of the moist soil.

Though cover cropping controls soil temperature, it hastens soil moisture loss. Therefore, it is advisable to practice cover cropping during monsoon season for controlling soil erosion, and use the cut dry shoots for mulching during summer season. Post-monsoon tillage is effective in conserving soil moisture.

Introduction

Kerala experiences humid tropical climate, characterized by high annual rainfall, and humid, warm weather condition almost throughout the year. The high intensity rainfall causes severe erosion of topsoil and organic matter, and leaching of nutrients from the agricultural areas in the State. Though there is abundant rainfall, its uneven distribution coupled with highly undulating topography and low water holding capacity of soils create soil moisture stress condition for about 14 to 15 weeks in the southern parts and 18 to 21 weeks in the northern parts of the State.

Perennial crops like plantation crops and spices occupy about 85% of the agricultural area in the State. The average productivity of most of these crops is low in Kerala, compared to that in other regions of the country or the world. The major limiting factors for higher crop productivity in the State are presumed to be poor fertility of soil and crop water deficit during summer season. Water deficit during October to May period for the major crop of coconut, for instance, ranges from 259 mm in Alapuzha district to 546 mm in Palakkad district (Varadan, 1997). With evapotranspiration component forming more than one-third of the annual rainfall in Kerala, crop water deficit would increase in future with increase in atmospheric evaporative demand under conditions of climate change and global warming, which in turn would affect crop productivity.

Since all the physical, chemical and biological processes in the soil are influenced by soil temperature and soil moisture, they are of fundamental importance to crop growth and productivity. The functional activities of plant roots, such as absorption of water and nutrients are affected at high soil temperature (Baver et al., 1972). The realization that soil temperatures will rise as a part of global warming has led to renewed interest in studying the mechanisms and effects of terrestrial ecosystem responses to changes in soil temperature. The adoption of specific soil management practices will improve soil conditions and minimize the ill-effects of water scarcity and high soil temperature, which in turn will increase crop yield (Fernandez et al., 2005; Sonia Aggarwal et al., 2003; Verma and Acharya, 2004). This paper describes the results of a study conducted to evaluate the effect of traditional soil management practices like cover cropping and post-monsoon conservation tillage on soil temperature and soil moisture.

Materials and Methods

The study was conducted in a monocrop coconut plantation on laterite soil at Manassery in Kozhikode district. The effects of leguminous cover crop *(Mucuna bracteata)*, post-monsoon conservation tillage, and no-tillage (as control) were compared under the study. Soil temperature at different soil depths (2.5, 5, 10, 20, 30 and 50 cm) was recorded daily at 8.30 am and 2.30 pm during the period from December 2005 to May 2006 using soil thermometers installed at each depth at three locations in each treatment plot. Soil moisture content at each depth was measured gravimetrically during March and April. The ambient air temperature and rainfall during the period were collected from the nearby meteorological station. The area receives a mean annual rainfall of 3000 mm. The annual mean maximum and minimum temperature in the area were 31°C and 23°C, respectively.

Results

The three treatments viz., cover cropping, post-monsoon conservation tillage, and no-tillage (control) were compared with respect to their effect on soil temperature and soil moisture content.

Weather

During the experimental period from December to May, there were 1, 1, 6 and 2 rainy days with 8.8, 6.8, 158.8 and 95.2 mm of rainfall during January, February, April and May, respectively.

The monthly mean maximum and minimum temperatures from December to May were 33.3, 33.2, 33.8, 34.9, 34.3 and 33.8°C, and 19.5, 21.5, 22.0, 24.3, 24.8 and 25°C, respectively.

Soil temperature

Cover cropping is found to have significant effect in controlling the soil temperature. During the month of January, the monthly mean afternoon (2.30 pm) soil temperature at 2.5 cm depth in cover-cropped plot was less than that of tilled plot and control plot by 7°C and 4.5°C, respectively (Figure 1). Cover-cropping also reduced the soil temperature below the atmospheric temperature by 7.7°C. This significant effect of cover cropping in reducing daytime soil temperature was observed in deeper soil layers also. However, there was only narrow difference between plots with respect to the monthly mean morning (8.30 am) soil temperature during January, both at surface and deeper soil layers. This is due to the cooling of soil at night, which takes time to get warmed up again on the following day. During the hottest month of March, the monthly mean afternoon soil temperature at 2.5 cm depth under cover cropping was less than that of tilled plot, control plot and atmospheric temperature by 10.6°C, 6.0°C and 6.2°C, respectively (Figure 2). Significant differences in soil temperatures between the above sets of treatments were also observed at all other soil depths monitored. In this case also, the differences in the monthly mean morning soil temperature of the three treatments were small, both in surface and subsoil layers. Under cover cropping, the thick canopy intercepts and also reflects considerable portion of the incoming solar radiation,

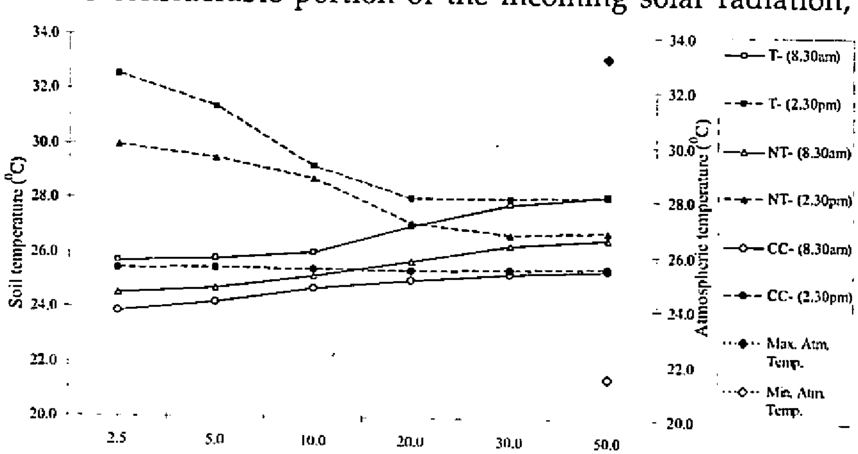

Figure 1. Mean soil temperature in different soil layers under cover cropping (CC), conservation tillage (T) and no-tillage (NT) during January

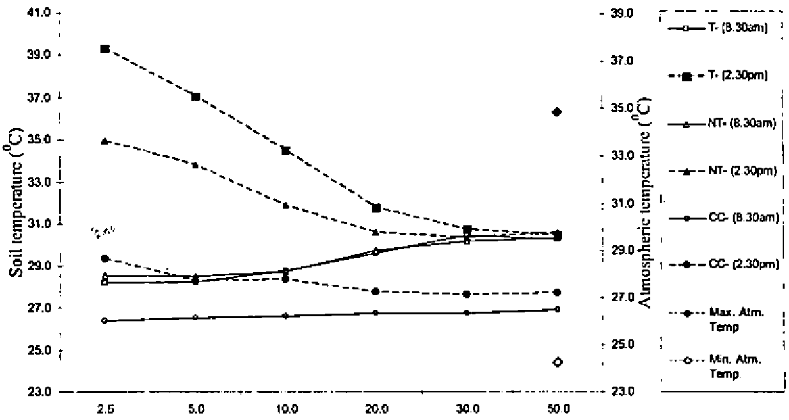

Figure 2. Mean soil temperature in different soil layers under cover cropping (CC), conservation tillage (T) and no-tillage (NT) during March

which prevents the covered soil from becoming as warm as open soil during the daytime.

Soil temperature in surface layers of soil is found to fluctuate significantly between day and night. The diurnal variation in soil temperature was found to be wider under tillage treatment, followed by control plot, and least under cover cropping. The diurnal temperature variations of the soil decrease very quickly with depth, which becomes narrow by 20 cm and negligible by 50 cm depths. During the month of December, February, April and May also similar trend in soil temperature was observed under different treatments (Table 1).

Though atmospheric temperature was fairly high during April and May, the soil temperature did not increase as high as in March, because the summer rainfall, which started from the mid of April, influenced the microclimatic conditions, soil moisture content and soil temperature fluctuations.

Soil moisture

Cover cropping and conservation tillage have distinct influence on the moisture content in soil. During the period under study, the soil moisture content was found to be highest in the plot under conservation tillage, followed by the control plot, and the least in cover-cropped plot (Figure 3). The mean soil moisture content for the March-April period, between 2.5 cm and 50 cm depths, ranged from 11.3 to 15.9% in cover-cropped plot, 13.4 to 18.6%

Table 1. Mean soil temperature in different soil layers under conservation tillage, cover cropping and no-tillage

Month	Depth / Time	Mean soil temperature (°C)														
		2.5 cm			5 cm			10 cm			30 cm			50 cm		
		T*	NT*	CC*	T	NT	CC	T	NT	CC	T	NT	CC	T	NT	CC
Dec.	8.30 am	24.7	23.3	23.3	25.3	23.5	23.9	24.9	23.5	23.8	26.8	24.4	25.0	27.8	25.1	25.7
	2.30 pm	30.3	27.0	24.9	29.7	26.9	25.2	28.0	26.4	25.0	26.3	26.0	25.0	27.8	25.2	25.3
Jan.	8.30 am	25.7	24.5	23.9	25.8	24.8	24.2	26.0	25.1	24.7	27.8	26.4	25.3	28.2	26.6	25.4
	2.30 pm	32.5	30.0	25.5	31.4	29.5	25.5	29.2	28.7	25.4	28.2	26.7	25.5	28.1	26.6	25.5
Feb.	8.30 am	26.0	25.5	24.5	26.3	25.9	24.6	26.7	26.0	24.9	28.7	27.5	25.2	28.9	28.1	25.5
	2.30 pm	35.0	34.0	25.9	33.8	32.9	25.9	30.7	31.4	25.8	29.1	28.7	25.8	29.5	29.1	26.0
Mar.	8.30 am	28.2	28.6	26.0	28.3	28.5	26.2	28.7	28.7	26.2	30.3	30.3	26.5	30.3	30.3	26.5
	2.30 pm	39.5	35.0	28.7	37.1	33.8	27.7	34.5	31.9	27.8	30.6	30.5	27.2	30.6	30.5	27.2
Apr.	8.30 am	28.2	27.6	26.9	28.0	27.6	26.9	28.0	27.7	27.2	29.5	29.1	27.9	29.8	29.4	28.2
	2.30 pm	33.4	32.7	29.0	32.6	32.3	29.0	31.5	31.0	28.7	30.0	29.7	28.5	30.1	29.9	28.8
May	8.30 am	30.0	28.5	27.7	29.7	28.6	27.9	29.5	28.6	27.9	30.8	30.1	28.8	31.9	30.1	28.9
	2.30 pm	35.1	33.8	29.1	34.3	33.3	29.1	32.7	32.5	29.1	30.9	30.6	29.1	32.0	30.4	29.0

* T- Conservation Tillage, CC- Cover cropping, NT – No Tillage (Control)

in tilled plot and 12.2 to 17.1% in control plot. Conservation tillage was found to maintain high soil moisture content at all soil depths. The loose surface soil in tillage treatment acts as dry soil mulch, which breaks the soil-atmosphere-continuum and minimizes the capillary rise of water from the sub-soil to the atmosphere. In spite of low soil temperature, the soil moisture content in the cover-cropped plot was lower in all soil layers due to the transpiration demand of the cover crop. It was observed that the summer rainfall received during mid April increased the moisture content in the soil profile in cover-cropped plot more than that in the tilled and control plots. This could be attributed to better porosity that is facilitated by root and faunal activity under cover crops.

As explained earlier, the soil temperature in tilled plot is higher

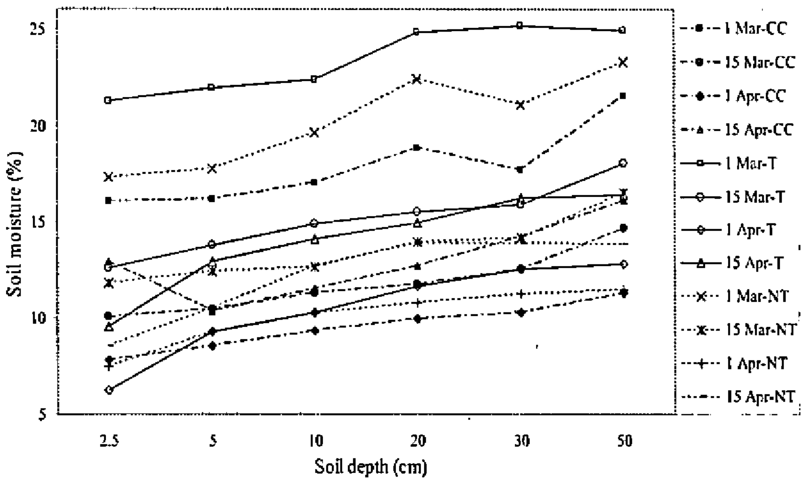

Figure 3. Soil moisture content in different soil layers under cover cropping (CC), conservation tillage (T) and no-tillage (NT)

than the cover-cropped and control plots. This is because of the fact that the magnitude of heat flux in the soil is related to its thermal conductivity, calorific capacity and vertical thermal gradient, which is influenced by the water content in the soil profile (Qi Huand and Song Feng, 2002). The thermal conductivity of soil under tillage treatment will be higher because of high soil moisture content. Since the thermal conductivity of water is about 23 times that of air, the increase in soil moisture improves the thermal contact, which increases the thermal conductivity of moist soil resulting in higher soil temperature (Ghildyal and Tripathi, 1987). The soil temperature in the surface layers of soil was found to fluctuate significantly between night and day as evidenced by the morning and afternoon data. The diurnal fluctuation of subsoil temperature was found to be less in all the treatments because of the higher heat capacity of soil in the moist deeper layers (Figures 1 & 2). Since the heat capacity of dry soil is only about one-fifth of the heat capacity of water (Baver et al., 1972), the deeper layers having higher soil moisture will have higher heat capacity than surface layers. Due to the lower heat capacity of surface dry soil, the temperature of surface soil rises and falls faster than that of deep moist soils. Moreover, the surface layers are also exposed to the direct effect of solar radiation. As a result, the surface soil is much warmer than subsoil during daytime, while the subsoil is warmer than surface soil at night.

Conclusions

All processes occurring in soil, from the weathering of primary minerals to plant nutrition and storage of organic carbon, are strongly influenced by soil temperature and soil moisture and hence they exert a major influence on crop productivity. The study brought to light the scientific basis of the beneficial effects of soil management practices like post-monsoon conservation tillage and cover cropping in coconut gardens. Conservation tillage practice is effective in conserving the soil moisture. Though cover cropping is useful in controlling soil temperature, soil moisture depletion during summer season is more under cover cropping. Therefore, it is appropriate to practice cover cropping in mono cropped coconut plantations during monsoon season for controlling soil erosion and cut the shoot portion with the cessation of rainy season for use as dry mulch during summer. Adoption of techniques / practices in different cropping systems, which can minimize soil erosion during rainy season, and control soil temperature and maintain higher soil moisture during summer season are essential for sustainable agriculture for higher productivity in the State, especially in the context of climate change and global warming.

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Climate change projections and possible adaptive measures – A case study over Indo-Gangetic Plains in India

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Abstract

The IPCC in its fourth assessment reported that under climate change the chances of occurrence of extreme climatic events would increase in the Indian Subcontinent. The Indo-Gangetic Plain extends over four countries – India, Pakistan, Nepal and Bangladesh. The IGP in India occupies nearly 20% of the total geographical area of the country and encompasses five States: West Bengal, Bihar, Uttar Pradesh, Haryana and Punjab. Rice-wheat is the major cropping system in the IGP. The influence of climate change on rice-wheat cropping system for five locations of IGP has studied using the modelling approach.

Minimum temperature in rice showed a negative trend at two sites, with one (Kanpur) statistically significant whereas three sites showed a positive trend, with two sites, Samastipur and Ludhiana showing significantly positive trend of 0.03 ^{0}C/year and 0.06 ^{0}C/year, respectively. In wheat season, three sites showed a negative trend, while Ludhiana and Samastipur showed statistically significant positive trend ($P < 0.01$). The maximum temperature in rice remained stable over the years at Faizabad and Ludhiana showing a negative trend and three positive (Kanpur, Hisar and Samastipur). But during August and September, most of the sites showed increasing trend of maximum temperature. These significant changes in weather parameters during different stages of the crop result in declining trend of potential simulated yield of rice. The simulated rice yield for

Faizabad, Kanpur, Ludhiana and Hisar showed a decreasing tendency of 7.2, 8.5 3.8 and 5.8 per cent, respectively by 2025 when compared to the base year 2007. Samastipur showed an increasing simulated rice yield of 11.4 per cent from 2007 to 2025. The simulated wheat yield for Faizabad, Kanpur, Hisar and Samastipur showed an increasing tendency of 13.9, 14.4, 8.9 and 9.6 per cent, respectively during 2025 when compared to 2007. The expected yield decline during the ensuing decades is a matter of serious concern and improved variety with more adjustability in the changed climate should be developed. The projected decrease in rice yield at four sites and decrease in wheat yield at one site provided an insight into the possible food insecurity threat of the region and measures should be taken to improve the yield based on integrating biotechnological advancement, precision farming and use of advanced and scientific crop cultural and management practices.

Introduction

India is endowed with a rich and vast diversity of natural resources, particularly soil, water, weather, agro-biodiversity and ecological regimes. India is a largely agrarian society with nearly 64 per cent of the population dependent on agriculture, although the share of agriculture in the gross domestic product has been continuously declining over the last 50 years. The Indian subcontinent is predominantly characterized by a tropical monsoon climate, where climatic regimes are governed mainly by the differences in rainfall both in quantity and distribution. The Indo-Gangetic Plains (IGP) extends over four countries – India, Pakistan, Nepal and Bangladesh. The IGP in India occupies nearly 20% of the total geographical area of the country and encompasses seven States: West Bengal, Bihar, Jharkhand, Uttar Pradesh, Uttarakhand, Haryana and Punjab. The IGP has come into existence as a result of continuous deposition of alluvium from the hills and mountains from both sides of the Plains, i.e. the Himalayas in the north and the ranges of the Deccan Plateau in the south. It is one of the most fertile agricultural regions of the country and is also a densely populated region. Rice-wheat is the major cropping system in the IGP. With the advent of the "Green Revolution", these two crops have come to occupy a significant area in the region, which is the "food bowl" or "food basket" of India. Rainfed rice predominates in the abundant rainfall zones of the eastern part where there is scope for growing rice under ponded water conditions during the rainy season, while irrigated rice is grown in the western part. Wheat assumes greater prominence in the western part, where it is normally grown with irrigation in winter, in rotation with rice. About two-thirds increase in output of rice and wheat in the country during the last two decades has come from this region which reveals its importance in the country's food security. During the same period, along with the spread of green revolution technology, rice-wheat crop rotation has emerged as the dominant crop sequence in the IGP. The production potential of a crop is largely determined by the climatic, edaphic and soil properties and their interactions. Crop Growth Simulation Models (CGSM) deal with interactions of crop growth with climatic factors, soil characteristics, agronomic management, and therefore can be used to estimate climatic limitations to growth and yield (Aggarwal and Kalra, 1994). The IPCC in its fourth assessment reported that under climate change the chances of occurrence of extreme climatic events would increase in the Indian Subcontinent. Under this scenario, the influence of climate change on rice-wheat cropping system for five locations of IGP has studied using the modelling approach.

Data and methods

Five sites covering important agro-ecological sub-regions of the IGP-India were selected for the study, based on the availability of soil, weather and crop management data. The sites were distributed from 25.88 to 30.93 ^{0}N latitude and 75.73 to 85.80 ^{0}E longitude. The length of growing period (LGP) varies from 60-90 days at Hisar to 180-210 days at Samastipur. The annual rainfall varies from 745.8 mm at Ludhiana to 1199.5 mm at Samastipur. Daily weather data viz., rainfall, maximum and minimum temperature and sunshine hours recorded in the meteorological observatories located in the region were collected from CRIDA, Hyderabad. The district rice and wheat yield data were collected from Directorate of Rice and wheat, respectively during the study period. Normally rice was transplanted on 1st July and wheat sown on 15th November every year. Even though, this will also depends on the onset of monsoon and these are the optimum dates of planting rice and wheat in the IGP (Aggarwal and Kalra, 1994).

Mann-Kendal test has been used by several researchers to detect trends in hydrological time series data (Serrano *et al.*, 1999;

Brunetti *et al.*, 2000a.b). Trend test was carried out for monthly (June-March), annual, kharif and rabi seasons for maximum and minimum temperatures, rainfall and sunshine hours for all the study sites and based on slopes, the changes of weather parameters per year have been computed. Based on these changes, the projected rainfall, maximum and minimum temperatures, sunshine hours have been worked out for the years 2010, 2015, 2020 & 2025 and the corresponding daily weather has been generated by inbuilt weather generator of DSSATv4.0.

The production of rice-wheat depends on non-meteorological parameters such as type of seeds used, crop area, availability of irrigation facilities, fertilizers, pesticides and also on the government incentives to the farming sector during the year as well as the previous year and meteorological parameters such as rainfall, temperature, relative humidity and solar energy. The total non-meteorological parameters i. e., the total technological inputs to the farming sector have been growing steadily and are difficult to quantify. Therefore, to know the pattern of trends and to quantify the growth rate of total technological inputs to the agricultural sector the actual productivity was fitted into an linear curve.

DSSATv4.0 is used to simulate crop growth for rice and wheat. CO_2 concentration in the atmosphere was considered as 310 ppm in 1970 and increasing with an annual increment of 1.5 ppm (Jones et al., 1994). Rice variety PR 106 and wheat variety HD 2329, which were popularly grown over the region is used in this study and the genotypic coefficients were selected based on past field experiments by repeated iterations until a close match between simulated and observed phenology and yield was obtained (Pathak et al., 2003).

Results and discussion

Trends in weather parameters

Analyses of weather data during the period showed that there was no significant change in rainfall over the years in both the rice and wheat growing seasons at all the sites except Hisar. The annual change in the rainfall trend was -28.9 mm/year ($P < 0.05$) and during the rice season it was -20.5 mm/year ($P < 0.01$) for Hisar. The distribution of rainfall for these sites showed no clear significant trends during June, but negative trends were observed in Kanpur, Ludhiana and Hisar. In July, however, all the sites except Samastipur showed a decreasing trend of rainfall. Negative trends were observed in all the five sites during August, only one (Hisar) of which was statistically significant ($P < 0.01$). The rainfall distribution during the wheat season showed no clear significant trend, but two sites (Kanpur and Samastipur) showed increasing trend while three sites (Faizabad, Ludhiana and Hisar) showed decreasing trend during December, which coincides with the CRI (Crown Root Initiation) stage of wheat in most of the IGP, in which the first irrigation is very much important.

Analyses showed that sunshine hours decreased over the years during rice season at three sites (Faizabad, Ludhiana and Samastipur), though statistically not significant. During wheat season, a significant decreasing trend was noticed for Ludhiana and Hisar ($P < 0.01$) (-0.04 hours/day/year). On the other hand, positive trends were noticed at three sites, though statistically not significant. The minimum temperature in rice showed a negative trend at two stations (statistically significant at Kanpur) whereas three sites showed a positive trend, with two sites, Samastipur and Ludhiana showing significantly positive trend of 0.03 ^{0}C/year and 0.06 ^{0}C/year, respectively. In wheat season, three sites showed a negative trend, Hisar being significantly different from 0 ($P < 0.05$). Two sites (Ludhiana and Samastipur) showed statistically significant positive trend ($P < 0.01$). The distribution pattern indicated that all sites except Kanpur showed an increasing trend of minimum temperature during June, July and August months and for Ludhiana and Samastipur, it is highly statistically significant for all the months. The minimum temperature change ranges from 0.01 ^{0}C/year (Samastipur) to 0.07 ^{0}C/year (Ludhiana). Interestingly, Samastipur and Ludhiana showed increased minimum temperature trend in all the rice and wheat season months with high statistical significance ($P < 0.01$). During the wheat season, at Hisar, all the months showed statistically significant negative trend in minimum temperatures. But all the sites except Hisar, showed an increasing trend of minimum temperature during February and March, which coincides with the grain filling stage of wheat in IGP.

The maximum temperature in rice remained stable over the years, with two sites (Faizabad and Ludhiana) showing a negative trend and three positive (Kanpur, Hisar and Samastipur): only at Kanpur and Hisar was significant increasing trend The monthly distribution indicated that all sites except Hisar showed negative trend during June, but all are statistically not significant. However, for Hisar a significant change of maximum temperature of 0.13 ^{0}C/year has been noticed during the period. In July, three sites (Kanpur, Hisar and Samastipur) showed increasing trend while two sites (Faizabad and Ludhiana) showed decreasing trend. Moreover, for Hisar a significant change of 0.07 ^{0}C/year has been noticed during the period. But during August and September, all sites showed increasing trend of maximum temperature except in Ludhiana where negative trend was seen in September. This indicated that the grain filling stage of rice in the western part/vegetative phase in the eastern part of the region may coincide with this period. The increase of higher sunshine hours and minimum temperature will definitely increase the water requirement of rice and any break in the monsoon will adversely affect the rice yield. But in wheat growing season, all stations except Kanpur showed negative trend, with trend at Samastipur being statistically significant. The monthly distribution of maximum temperature during wheat season showed that an increasing trend in November for all sites: statistically significant at all the sites except Faizabad. During December, three sites (Faizabad, Ludhiana and Hisar) showed decreasing trend (all statistically not significant) while two sites showed increasing trend. Kanpur showed a significant increasing trend of 0.04 ^{0}C/year during the period ($P < 0.01$). All sites showed decreasing trend during January with three stations Ludhiana, Hisar and Samastipur showing statistically significant decreasing trend ranging from -0.04 ^{0}C/year (Ludhiana) to -0.11 ^{0}C/year (Hisar). The increasing trend during February (Faizabad, Kanpur and Ludhiana) and March (Faizabad, Kanpur, Ludhiana and Hisar) may coincide with the grain filling period of wheat.

Simulated rice and wheat yields

The technological advancement factor in observed yield of rice and wheat were removed by linearly regressing the yield with the year and removing the contribution of trend from the observed yield. In the case of observed rice yields, the standard deviation was more for Hisar (671 kg/ha) followed by Faizabad (589 kg/ha), but coefficient of variation was higher for Samastipur (37.8 %) followed by Faizabad (35 %) (Table 2). However, Ludhiana which was showing a decreasing trend of observed rice yield showed less coefficient of variation (10.1 %). The same low value of coefficient of variation was also observed in the simulated rice yield of Ludhiana. The results also indicated that the coefficient of variation of simulated rice yields were low compared to observed rice yields in all the sites.

Table 2: Mean, Standard deviation and coefficient of variation of observed and simulated rice and wheat yield during 1974 to 2005 at various sites of IGP

Site	Rice			Wheat		
	Mean Yield (kg/ha)	Standard deviation (kg/ha)	Coefficient of variation (%)	Mean Yield (kg/ha)	Standard deviation (kg/ha)	Coefficient of variation (%)
			Observed			
Ludhiana	3786	383	10.1	4087	683	16.7
Hisar	2753	671	24.4	3341	801	24.0
Kanpur	1664	483	29.0	2935	301	10.3
Faizabad	1684	589	35.0	2060	380	18.5
Samastipur	894	338	37.8	1940	238	12.3
			Simulated			
Ludhiana	4302	440	10.2	4542	683	15.0
Hisar	3829	687	18.0	3935	700	17.8
Kanpur	2817	441	15.7	3599	304	8.4
Faizabad	3063	554	18.1	3208	337	10.5
Samastipur	2655	371	14.0	2612	104	4.0

The standard deviation of the observed wheat yield was higher for Hisar (801 kg/ha) followed by Ludhiana (683 kg/ha). A higher coefficient of variation was observed for Hisar (24 %) followed by Faizabad (18.5 %). The higher standard deviation and coefficient of variation indicated that there were high uncertainties in year-to-year rice yield. The higher coefficient of variation of rice yields over the eastern part of IGR may be due to more rainfed areas in these parts of the region. But in the case of observed wheat yields, higher year-to-year variability was noticed for Ludhiana and Hisar compared to eastern sites.

Year-to-year deviation in observed and simulated rice and wheat yields were calculated and compared. The comparison of observed and simulated rice and wheat yield shows that there is very good agreement (Fig. 1) between them based on Spearman correlation coefficient (rs), significant at $P < 0.05$ level for all the sites except Samastipur (Table 3). In the case of Samastipur, the simulated and observed wheat yields follow the same pattern during lower yield years, but not in agreement during higher yield years.

Table 3: Spearman correlation coefficient between observed (de-trended) and simulated rice and wheat yields during the period 1974-2005 at various sites of IGP

Site	Spearman Correlation Coefficient, rs, between observed and simulated yields of	
	Rice	Wheat
Ludhiana	0.81 *	0.99 *
Hisar	0.98 *	0.97 *
Kanpur	0.96*	0.98 *
Faizabad	0.91 *	0.95 *
Samastipur	0.98 *	0.55

**Significant at $P < 0.05$*

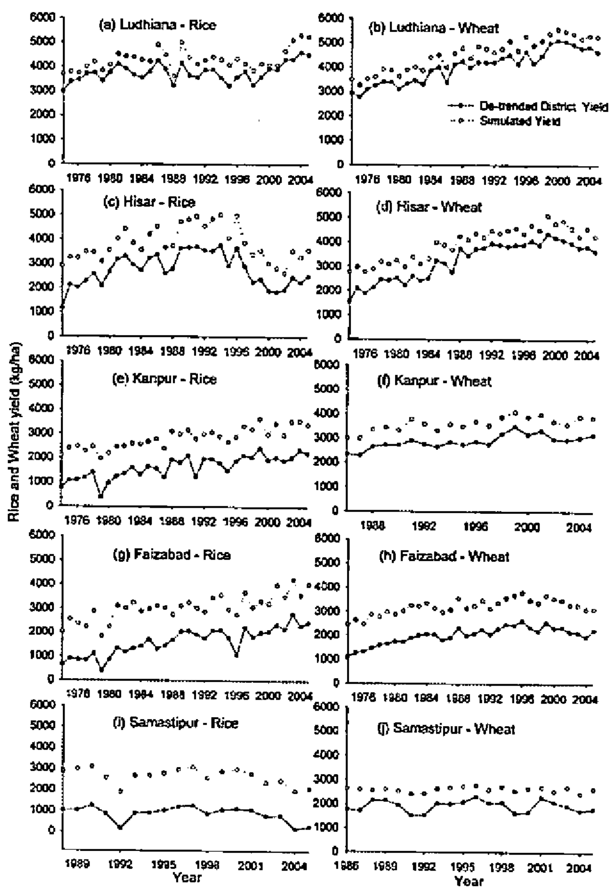

Fig. 1: Actual (de-trended) and simulated rice and wheat yields at various sites of the IGP

Projected Rice and Wheat yields

The projected rice and wheat yields were simulated using the DSSATv4.0 model using the above daily weather generated for 2010, 2015, 2020 and 2025 for all the stations, keeping all the management and other initial conditions constant as explained above sections.

Projected rice and wheat yields during 2010: The simulated rice yields for Faizabad, Kanpur and Hisar stations show a decline of 0.2, 2.6 and 1.5 per cent, respectively during 2010 compared to 2007 (Table 4). This may be due to the combined effect of decreasing trend in rainfall and increasing trend of maximum and minimum temperature during kharif season. The significant increase of mean temperature increases the degree days and thereby reduces the duration of crops which ultimately results in decrease in grain size as well as yield. Ludhiana and Samastipur showed increase in yields by 1.0 and 1.9 per cent, respectively, perhaps due to increasing trends in rainfall. The simulated wheat yield for Faizabad, Kanpur, Hisar and Samastipur show an increasing tendency of 7.5, 2.7, 7.0 and 1.3 per cent, respectively during 2010 when compared to 2007 (Table 5). This may be due to combined effect of decreasing trend in maximum and minimum temperature during the season. The significant decrease of mean temperature increases duration of crops which increase the grain size as well as yield. But as far as Ludhiana is concerned, the significant increasing trends in minimum temperature may have more control over other small changes in maximum and sunshine hours and influence the simulated rice yield causing a decreasing trend of 2.2 per cent from 2007 to 2010.

Table 4: Simulated rice yield (kg/ha) during 2007, 2010, 2015, 2020 and 2025 at selected stations of IGP *(Figures in parenthesis indicates the per cent decline/increase over 2007)*

Year	Rice yield (kg/ha)				
	Faizabad	Kanpur	Ludhiana	Hisar	Samastipur
2007	4010	3620	5210	3567	2090
2010	4000(-0.2)	3526(-2.6)	5261(1.0)	3512(-1.5)	2130(1.9)
2015	3912(-2.4)	3427(-5.3)	5572(6.9)	3420(-4.1)	2220(6.2)
2020	3860(-3.7)	3360(-7.2)	5120(-1.7)	3400(-4.7)	2290(9.6)
2025	3720(-7.2)	3312(-8.5)	5012(-3.8)	3360(-5.8)	2327(11.3)

Table 5: Simulated wheat yield (kg/ha) during 2007, 2010, 2015, 2020 and 2025 at selected stations of IGR *(Figures in parenthesis indicates the per cent decline/increase over 2007)*

Year	Wheat yield (kg/ha)				
	Faizabad	Kanpur	Ludhiana	Hisar	Samastipur
2005	3134	3856	5278	4234	2656
2010	3370(7.5)	3960(2.7)	5160(-2.2)	4500(7.0)	2690(1.3)
2015	3412(8.9)	4020(4.3)	5012(-5.0)	4530(6.3)	2830(6.6)
2020	3490(11.4)	4170(8.1)	4927(-6.7)	4620(9.1)	2890(8.8)
2025	3570(13.9)	4412(14.4)	4812(-8.8)	4612(8.9)	2910(9.6)

Projected rice and wheat yields during 2015: The simulated rice yields for Faizabad, Kanpur and Hisar show a decline of 2.4, 5.3 and 4.1 per cent, respectively during 2015 compared to 2007. But Ludhiana and Samastipur show an increase of 6.9 and 6.2 per cent, respectively. The simulated wheat yield for Faizabad, Kanpur, Hisar and Samastipur show an increasing tendency of 8.9, 4.3, 6.3 and 6.6 per cent, respectively during 2015 when compared to 2007. However, at Ludhiana there is a decline of 5.0 per cent.

Projected rice and wheat yields during 2020: The simulated rice yields for Faizabad, Kanpur and Hisar show a decline of 3.7, 7.2 and 4.7 per cent, respectively during 2020 compared to 2007. But at Ludhiana a decline of 1.7 from 2007 to 2020 has been noticed. Samastipur shows an increase of 9.6 per cent from 2007 to 2020. The simulated wheat yield for Faizabad, Kanpur, Hisar and Samastipur show an increasing tendency of 11.4, 8.1, 9.1 and 8.8 per cent, respectively during 2020 when compared to 2007. However, at Ludhiana there is a decline of 6.7 per cent.

Projected rice and wheat yields during 2025: The simulated rice yield for Faizabad, Kanpur, Ludhiana and Hisar show a decreasing tendency of 7.2, 8.5 3.8 and 5.8 per cent, respectively during 2025 when compared to 2007. Samastipur shows an increasing simulated rice yield of 11.4 per cent from 2007 to 2025. Since Samastipur receive an average 1069.9 mm rainfall during kharif season and the area is usually affected by floods during the entire crop season, decrease of rainfall during the season may have helped the rice crop to project a higher simulated rice yield in 2025.

The simulated wheat yield for Faizabad, Kanpur, Hisar and Samastipur show an increasing tendency of 13.9, 14.4, 8.9 and 9.6 per cent, respectively during 2025 when compared to 2007. This may be due to combined effect of decreasing trend in either maximum or minimum temperature during the season. The significant decrease of mean temperature increases the growing period and thereby duration of crops and ultimately increases the grain size as well as yield. But as far as Ludhiana is concerned, the significant increasing trends in minimum temperature of the order of 1 ^{0}C may have more control over other small changes in maximum and sunshine hours and influence the simulated rice yield: thus a decreasing trend of 8.8 per cent from 2007 to 2025.

Conclusions

The expected yield decline in the year 2025 is a matter of serious concern and improved variety with more adjustability in the changed climate should be developed. Steps to improve the natural resource/input use efficiency and to adopt modern management technologies such as zero tillage, timely sowing/ transplanting, adoption of critical stage approaches for irrigation, use of irrigation water for nursery preparation during kharif season etc. should be encouraged Since all these five locations are representative sites for the entire IGP, the decreasing trend of rice productivity of four stations and decreasing trend of wheat productivity of one station may adversely affect the food security of the region and measures should be taken to stabilize the productivity under changing climatic scenario. Measures should be advocated to improve the productivity by integrating biotechnological advancement, precision farming and use of advanced scientific crop and cultural management practices. Even though, these projected yields don't consider the technological advancement as well as the incidence of pest and diseases, they still provide an indication of yield uncertainty and risk under possible projected climatic conditions. Even though, there is good agreement of actual and simulated rice and wheat yields, the district yield data represents the average of all the varieties of that district. Hence, sampling methods should be adopted to collect yield data pertaining to popular varieties. Regular monitoring of crops and climatic factors in farmer's fields would help in predicting problems and allowing measures to be taken to improve productivity and thereby minimize the impact of climate change on productivity. Climate change and climatic variability and increasing non-farm demands for water affect supply-demand and the resulting vulnerability of the rice-wheat production system of this region. Adoption of efficient water management, water conservation and land use strategies and energy-efficient technologies are essential to reduce the vulnerability of rice-wheat system to climatic stresses.

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SESSION IV

Climate change adaptation in Agriculture

National Seminar on Climate Change Adaptation Strategies
in Agriculture and Allied Sectors, held at KAU during 03-04 December 2009

The wanted change against climate change: Assessing the role of organic farming as an adaptation strategy

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Abstract

Conventional input intensive agriculture practiced over the last century has been a major contributor to climate change, second only to energy sector. The communities engaged in pesticide and synthetic input rich agriculture is most vulnerable to the impacts of climate change. Many emerging economies including India have had the opportunity to develop National Adaptation Plans of Action in the context of the United Nations Framework Convention on Climate Change but implementation of those programmes and strategic links to resourcing actions are often lacking. Adaptation in the agricultural sector can be seen in terms of both short-term and long-term actions. Changing to organic farming systems is the most efficient and long term adaptation strategy. Organic agriculture is believed to be the most sustainable approach against climate change ensuring food security; it employs low external input and high output strategies.

This paper attempts to review the potent role of organic agriculture as an adaptation strategy to deliver a tangible and hopeful alternative towards sustainable livelihood in the backdrop of climate change. The methodology involves thorough review of scientific literature. The study discusses the carbon sequestration achieved as well as reduction in emission with respect to low pesticide use and fossil fuel based farm machinery use in organic farming. The analysis of results concludes that the organic system of farming is the most resilient adaptation strategy against climate change and offer greater potential as a sustainable livelihood mechanism in times of climate transition.

Introduction

The Bali Road Map should lead to a Copenhagen agreement that commits to climate stabilisation, and an efficient result at COP 15 in Copenhagen in December is expected. It should address feasible policies for effective climate change adaptation and mitigation. Conventional input intensive agriculture practised over the last century has been a major contributor to climate change, second only to energy sector (World Development Report 2008). The communities engaged in pesticide and synthetic input rich agriculture is most vulnerable to the impacts of climate change. As adaptation is unavoidable, one key point is the integration of agriculture which accounts for 10-12% of global emissions (Smith et al. 2007) in a post-2012 agreement. Its main potential lies in its significant capacity to sequester CO_2 in soils, and in its synergies between mitigation and adaptation. This potential is best utilized employing sustainable agricultural practices such as organic farming or organic agriculture (OA). Conservative estimates of the total mitigation potential of OA amount to 4.5-6.5 Gt CO_2eq/ yr, i.e. of ca. 50 Gt CO_2eq total global greenhouse gas emissions (Muller A. et al., 2009). Depending on agricultural management practices, much higher amounts seem however possible. Sustainable, organic, ecological friendly agriculture, which is owned, controlled and managed by small men and women farmers, and supported by government policies and programs, is a strategic agricultural measure to adapt and mitigate climate change, ensure food security and sustainable livelihood and to reduce poverty among smallholder farmers.

Study objective

The objective of the study is to review the potent role of organic agriculture as an adaptation strategy to deliver a tangible and hopeful alternative towards sustainable livelihood in the backdrop of climate change.

Methods and scope

The methodology involves thorough review of scientific literature. The research done in Europe, United States and developing countries in Asia and Africa are collated and extrapolated as background information for future research. Many emerging economies including India have had the opportunity to develop National Adaptation Plans of Action in the context of the United Nations Framework Convention on Climate Change but implementation of those programmes and strategic links to resourcing actions are often lacking. Apropos, the present study may initiate positive policy implications towards climate change adaptation in India.

Review results and analysis

The research results from various parts of the globe on organic farming and its adaptation potential against climate transition has been presented. The results has been analysed with respect to carbon sequestration, energy efficiency, emission reduction and livelihood security.

Climate change adaptation race: organic farming versus conventional farming

Organic farming differs primarily from conventional farming in terms of fertilizer type and usage, pest and disease management, crop rotation and use of fossil fuel based agro machinery (Elmaz et al., 2004). One goal of organic farming is to reduce the dependency of agricultural production on external inputs. It is frequently claimed that organic farming provides environmental benefits, many of which relate to soil properties. Adopted crop rotations may reduce soil erosion (Eltun et al., 2002). Replacement of mineral fertilizer and pesticides by organic fertilizers enhance soil biological activity, efficiency, and rate of microbial substrate use (Gunapala and Scow, 1998). Positive effects of organic farming on soil carbon have been reported repeatedly (e.g., Drinkwater et al., 1998; Liebig and Doran, 1999; Wells et al., 2000).

The FAO report 2007 found that, "Organic agriculture performs better than conventional agriculture on a per hectare scale, both with respect to direct energy consumption (fuel and oil) and indirect consumption (synthetic fertilizers and pesticides)", with high efficiency of energy use.

Carbon sequestration capacity of organic farming

One of the best-documented, longest-lasting planned comparisons of organic vs. conventional farming is the DOK (D: biodynamic, O: bioorganic, K: conventional) experiment in Switzerland (Mäder et al., 2002). In a 7-yr crop rotation study, conventional systems with or without organic fertilizer are compared with organic and biodynamic farming practices. The study showed that organic agriculture increases soil organic matter and observed to have increased carbon sequestration capacity. As a result, soils in organic agriculture capture and store more water than soils of conventional cultivation. OA production is thus less prone than conventional cultivation to extreme weather conditions, such as drought, flooding, and water logging. Soils under organic management practices are also less prone to erosion. Organic agriculture accordingly addresses key consequences of climate change, namely increased occurrence of extreme weather events, increased water stress and drought.

Research on established organic crop farming systems shows superior soil carbon sequestration over both conventional and no-till systems (Comis, D. 2007). One of the longest running and most notable studies comparing the carbon sequestration ability of organic and conventional systems is the Rodale Institute's Farming Systems Trial®. In this study, organic systems showed an increase of almost 30 percent in soil carbon over 27 years while the conventional system showed no significant increase in soil carbon over the same time period.

The 9-years study by John Teasdale and colleagues at the USDA Agricultural Research Service's Sustainable Agricultural Systems Laboratory of data comparing various 19 no-till systems to organic systems indicate that despite the need for tillage to control weeds in the organic system, the carbon and available nitrogen concentrations were higher at all soil depths in the organic system. Work at other research centres, including the University of California at Davis, University of Illinois, and Iowa State University corroborate the results of the Rodale study (Khan, S. et al 2007). Their research demonstrates a vast, untapped potential of organic farming systems to adapt to climate change by increasing soil carbon storage. The Rodale Institute estimates that organic agriculture, if practiced on the planet's 3.5 billion tillable acres, could sequester nearly 40 percent of current CO_2 emissions. Current estimates are that 70 to 220 Tg CO_2 eq could be added to agricultural soils over two decades (Paustian, K. et al. 2006).

Organic agriculture and emission reduction

Organic systems avoid the use of synthetic fertilizers, relying on practices such as green manures, the addition of nitrogen fixing crops to rotations and the use of composted animal manures. In addition, organic systems avoid the use of synthetic pesticides and rely on practices such as crop rotations which break up pest cycles and increase beneficial insects. These restrictions on fossil-fuel based fertilizer and pesticide inputs can significantly reduce the overall GHG footprint of organic systems in comparison to conventional production systems. The U.S EPA estimates that once on soils, synthetic fertilizers generate over 304 million tons of GHG emissions each year. Current estimates are that over one billion pounds of synthetic pesticides are used by agriculture each year (Ritter, Steven, 2009). Organic agriculture has lower N_2O emissions from nitrogen application, due to lower nitrogen input than in conventional agriculture. This leads to a potential emission reduction of 1.2-1.6 Gt CO_2eq (Niggli et al., 2009). In organic agriculture, biomass is not burned. This reduces the CH_4 and N_2O emissions by ca.0.6-0.7 Gt CO_2eq in comparison to conventional agriculture, where crop residues are often burnt on the field (Smith et al. 2007). Ca. 1% of global fossil energy consumption is used for chemical nitrogen fertilizer production, emitting ca. 0.23 Gt CO_2eq (IPCC, 2007b). Organic agriculture avoids these emissions, as no chemical nitrogen fertilizers are used and nitrogen input stems from application of manure and compost, or is fixed from the air by leguminous plants.

Conventional stockless arable farms depend on the input of synthetic nitrogen fertilizers, while manure and slurry from livestock farms create additional environmental problems. For both these farm types, high emissions of CO_2, N_2O and CH_4 are likely. Organic farms prevent such problems by on-farm or cooperative use of farmyard manure between both crop and livestock operations.

Organic agriculture and climate change induced livelihood risk

Organic agriculture is a low-risk farming strategy based on lowering external chemical inputs and optimizing biological functioning (Muller A., 2009). Besides lowering toxicity, reduced input costs make organic agriculture competitive economically. In addition, organic price premiums can be realized. These factors working together lower the financial risks and improve the rewards. They provide a type of low cost but effective insurance against crop reduction or failure (Refer Fig. 1). A comparison of energy use efficiency of different production systems shows that low input , less fossil fuel based organic agriculture is more energy efficient than conventional/chemical farming (Refer Fig.2). Thus it clearly depicts an optimistic picture on organic farming as the most wanted adaptation strategy against climate change ensuring sustainable livelihood among vulnerable communities.

Since the coping capacity of the farms is increased, the risk of indebtedness in general is lowered. Organic agriculture is thus a

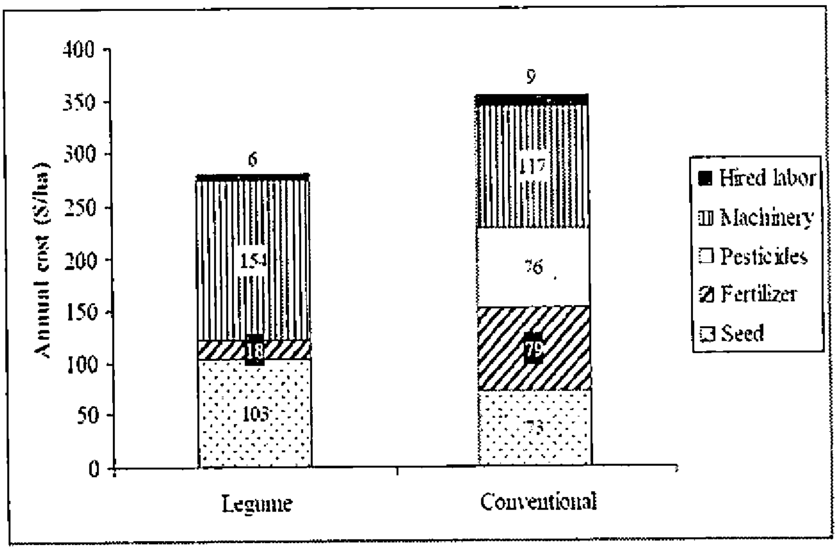

Figure 1: Annual input costs ($/ha) for the organic –legume system and conventional system of farming, The Rodale Institute Farming Trial (Source: Hanson and Muller 2003)

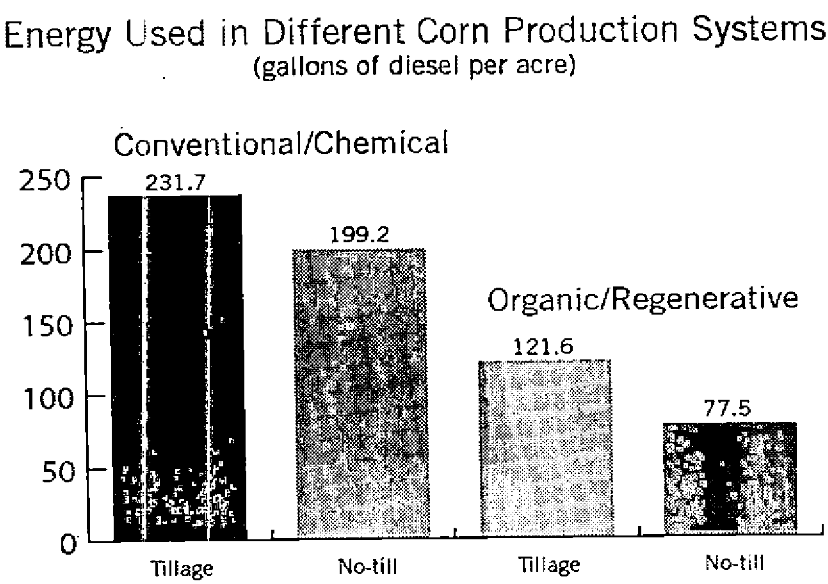

Figure 2: Energy used in different crop production systems

Source: Pimentel. D., 2006, Impacts of organic faming on efficiency and energy use in agriculture. www.organicvalley.coop /fileadmin/pdf/ENERGY_SSR.pdf. 40 pages.

viable alternative for poor farmers. Risk management, risk-reduction strategies, and economic diversification to build resilience are also prominent aspects of adaptation, as mentioned in the Bali Action Plan (UNFCCC 2007).

OA has the best premises to utilize local and indigenous farmer knowledge, adaptive learning and crop development, which are seen as important sources for adaptation to climate change and variability in farming communities. In addition, the certification available for products of OA allows realization of higher prices (Muller A, 2009).

Organic agriculture the resilient system

Organic agriculture is a resilient system of agriculture that uses crop rotation, green manure, compost, biological pest control, and mechanical cultivation to maintain soil productivity and control for pests. Organic agriculture does not use synthetic fertilizers or pesticides, plant growth regulators, livestock feed additives or genetically modified organisms. Research also indicates that organic production systems are more resilient than conventional systems under both flood and drought conditions (Bescansa P. et al. 2006). This resilience is crucial in the backdrop of a changing climate where more weather extremes are projected. The permutation of practices, including crop rotation and crop diversification, create a system that can literally "weather" the extremes. Organic agricultural systems with organically managed soils are better adapted to weather extremes. These soils can better retain moisture, which can alleviate the impact of periodic droughts. These systems also retain more water during high rainfall events and release the water more slowly. At the landscape level, this increased water retention capacity helps decrease the severity of flooding from high rainfall events (The National Sustainable Agriculture Coalition, 2009). This is particularly significant with regard to humid tropics with undulating terrain and heavy precipitation as Kerala.

Many organic systems also incorporate a wider array of multi-season crops. The greater biodiversity of most organic systems increases their ability to adapt to climate change, while continuing to provide both economic and ecosystem benefits (International Trade Centre, 2007). Without sacrificing the yields of conventional agriculture (Delate, K., C.A. Cambardella. 2004) organic farming systems provide benefits to water quality, biodiversity, rural communities and human health. Organic systems provide a promising solution to mitigating the progression of climate change and adapting to its effects (Niggli, U. and et al 2009). The advantage of OA is that it comprises a bundle of mutually adapted and optimized practices and is thus a whole operational farming system with a proven record of good performance.

Conclusion

The study concludes that the organic system of farming is the most resilient adaptation strategy against climate change and offer greater potential as a sustainable livelihood mechanism in times of climate transition.

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Biomass yield, carbon partitioning and dynamics of soil carbon under elevated atmospheric CO_2 in rice and wheat in a typic haplustept

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Abstract

To study the impacts of elevation of CO_2, a pot culture and field experiments were conducted in open top chambers (OTC) and Free Air Carbon dioxide enrichment facility of the South Asian Network, New Delhi at Indian Agricultural Research Institute, New Delhi raising rice and wheat in two seasons. A decomposition study was also conducted in phytotron chambers (at the National Phytotron facility, New Delhi) wherein ambient and elevated CO_2 grown rice and wheat residues were allowed to decompose in litterbags. The data obtained were used for evaluating the ability of CERES-N model to simulate carbon and nitrogen mineralization from those residues.

Average biomass yield of all the plant parts increased due to exposure to elevated CO_2 in both the crops. Carbon content in different plant parts (except grain in both the crops and root in rice) either remained unaffected or increased marginally due to increase in atmospheric CO_2, which suggests absence of dilution effect in spite of increase in biomass yield. All the active carbon fractions were positively influenced by increase in atmospheric CO_2. The gains in soil carbon pools under elevated (both under OTCs and FACE) over ambient CO2 were MBC > DOC > CHC > LBC in rice and DOC > MBC > CHC > LBC in wheat rhizospheres. However, there were no significant changes in total C in soil under both the crops. In case of decomposition study inside phytotron, the amount of residues remained inside the litter bags showed comparatively higher values for the elevated CO_2 grown residues indicating their slow rate of decomposition. The decreased rate of decomposition of elevated CO_2 grown residues were clearly visible from the values of TOC and MBC

contents in soil. However the difference between the values associated with ambient and elevated residues was higher for rice as the effect of elevation of CO_2 was more prominent during its decay. Ambient CO_2 grown residues had lower C/N ratios during decomposition as a result of which an increase was observed in the rate of mineralization. Hence, lower C/N ratios of RA and WA in comparison to RE and WE at all stages of decomposition had enormous consequences in nitrogen cycling in soil. The process of decomposition and N mineralization from ambient and elevated grown rice residues were found to fit well to the modified CERES model with an exception in case of N mineralization from WE.

Thus, elevation of atmospheric CO_2 concentration brought an increase in the biomass and belowground partitioning and all active carbon pools in crop rhizosphere; the extent of gains were related to the relative liability of the active pools. Though marginal, significant increase in total soil carbon in upper layers of FACE indicates a definite possibility of carbon sequestration. Decreased rate of decomposition might increase the residence times of the elevated CO_2-grown residue decomposition systems, thus supplementing sequestration of carbon in soil.

Introduction

One of the major challenges of modern ecological research is to understand how the biosphere is responding to human-induced global environmental changes. One of such global changes is the rapid rate of increase in atmospheric CO_2 concentration since pre-industrial times, currently amounting to 370 ppm. The drastic increase in human population, since the pre industrial revolution increased the concentration of CO_2 due to large-scale use of fossil fuels, deforestation, industrialization and urbanization. Burning of fossil fuel puts 5.8-6.2 Gt C year^{-1} into the atmosphere and tropical deforestation adds another 1.5-3.0 Gt C year^{-1} accumulating about 8.0 Gt C year^{-1} with atmospheric level. Of this 4.7 Gt C is being absorbed by the oceanic and terrestrial biota per year and 3.3 Gt C year^{-1} remains in the atmosphere leading to the rise in its concentration (Tans et al., 1999).

Terrestrial ecosystem structure and function is highly dependent on the relationship between plants and soil systems. Increasing CO_2 levels typically lead to significant increases in photosynthetic rates, and can lead to changes in the growth of whole plants.

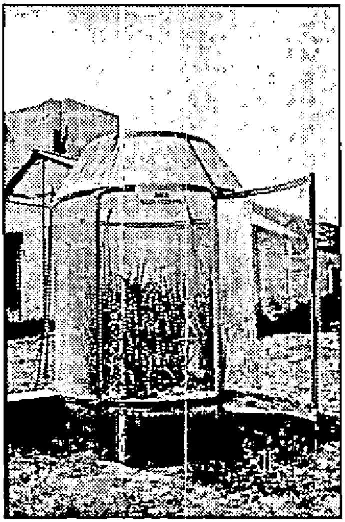
and plant community structure. Recently, there has been much interest in determining the capacity of sequestering carbon from the atmosphere. If terrestrial vegetation responds to increasing CO_2 levels with increased net primary production leading to storage of carbon, then terrestrial vegetation might play a significant role in preventing the effects of global warming, though to a limited extent. Another possibility is that CO_2 enrichment might alter the quality of organic matter, thereby indirectly affect the rate at which carbon and nitrogen are cycled within the soil plant system. The effects of elevated CO_2 on aboveground physiological processes have been well studied. However, to date, soil ecosystems have received much less attention.

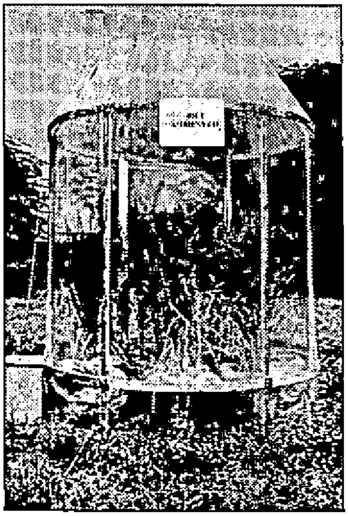
Litter decomposition plays a great role in ecosystem processes and carbon cycling and is therefore an important determinant of soil fertility and plant productivity. Thus factors, which regulate litter decomposition, are important to ecosystem functioning (Swift et al., 1979). Decomposition rate is mainly affected by climate (temperature and precipitation) and by the chemical composition of leaf litter (Melillo et al., 1982; Taylor et al., 1989; Kemp et al., 1994).

Materials and methods

The experiments were undertaken at Indian Agricultural Research Institute (IARI), New Delhi. To study the impacts of elevation of CO_2 on soil system, a pot culture experiment (rice-wheat sequence), a field experiment (rice-wheat sequence) and a decomposition study (rice and wheat residues) were undertaken. The pot culture experiment was conducted in open top chambers (OTCs) (Plate 1) with surface soils collected from a Typic Haplustept. Rice and wheat were grown as test crops at ambient (approx. 370 ì mol mol^{-1}) and elevated (600±50 ì mol mol^{-1}) levels of atmospheric CO_2. Wheat and rice residues grown at elevated CO_2 were incorporated in soil at the rate of 9 g kg^{-1} soil in rice and wheat crops, respectively, under elevated CO_2 conditions, and the ambient CO_2-grown rice and wheat residues were incorporated in crops grown under ambient CO_2. Destructive sampling was done at four physiological stages of crop growth namely tillering (rice) /crown root initiation (wheat), anthesis, grain filling and maturity. Biomass yield, carbon content and its uptake by different plant parts (viz. root, stem, leaf and grain) and various carbon fractions in rhizosphere soil, namely,

Plate 1. Open Top Chambers (ambient and elevated CO_2) used in the study with rice crop at maximum tillering stage (*Kharif* season, 2004).





microbial biomass carbon (MBC), dissolved organic carbon (DOC), carbohydrate carbon (CHC), labile carbon (LBC) as well as total soil carbon (TSC) were determined for both the crops at each of the crop growth stages.

Rice and wheat crops were grown in field also under free air carbon dioxide enrichment (FACE) (Plate 2) and ambient CO_2 conditions. Soil samples were collected from four depths (0-5, 5-10, 10-15 and 15-20 cms) and analyzed for the same parameters (MBC, DOC, CHC, LBC and TSC).

The crop residue decomposition study was conducted in phytotron chambers (Plate 3) of National Phytotron Facility, IARI, New Delhi. The litterbags with ambient and elevated CO_2-grown rice and wheat residues were inserted into soil in pots, which were arranged in racks inside the phytotron chambers maintained at respective CO_2 levels. After every fifteen days destructive sampling of the pots along with litterbags was done, and the decomposition was then continued for 5 months. The collected soil samples and plant residues remaining inside the litterbags were analyzed for different parameters. Soil samples were analyzed for total organic carbon, microbial biomass carbon, ammoniacal and nitrate nitrogen, while left over in litterbags were analyzed for carbon and nitrogen contents. The rates of

Plate 2. Free Air Carbon dioxide Enrichment (FACE) facility with rice crop in *kharif* season, 2004.

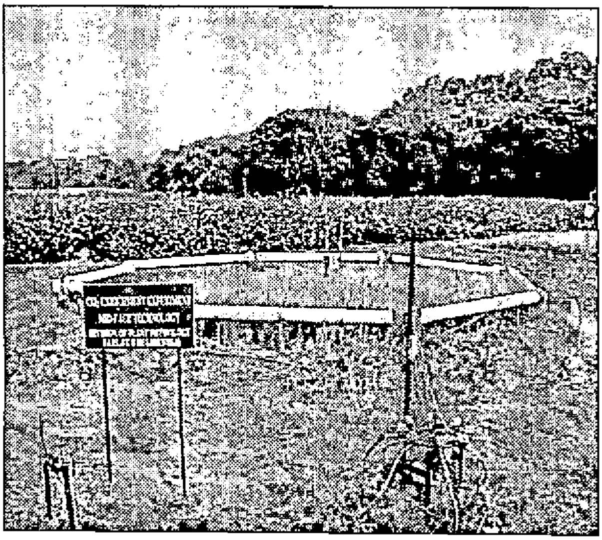
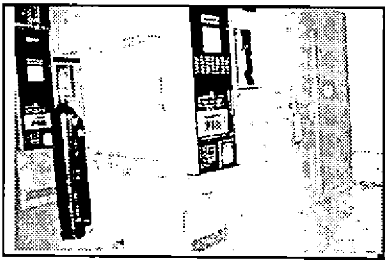


Plate 3. Phytotron chamber (maintained at elevated CO_2) used in the decomposition study



decomposition of elevated and ambient CO_2 grown residues were computed from the data related to kinetics of decomposition and comparisons were made.

Data generated was used to evaluate the ability of CERES-N model to simulate carbon and nitrogen mineralisation from rice and wheat residues grown under ambient and elevated CO_2 concentrations. The model could predict these processes after certain modifications (obtained through repeated runs of the model) were made.

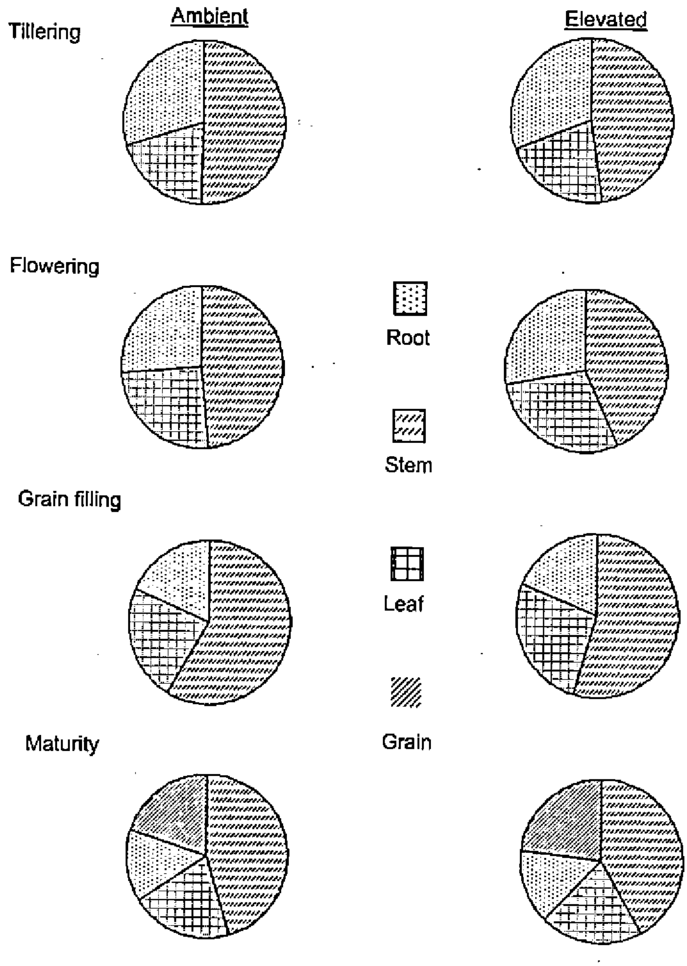
Results and discussion

The data related to plant parameters are derived solely from the pot culture (OTC) experiment. Total biomass yield was increased by 32.26 and 32.98 per cent as a result of elevation of CO_2 concentration in the micro climate of rice and wheat, respectively. Various plant parts differed with respect to their relative gain in yield, and the order varied in the two test crops. The relative gains in biomass of different plant parts on exposure to elevated CO_2 were in the order of: Rice: Grain (48.11) > Leaves (43.97) > roots (34.95) > stem (18.80) and Wheat: Root (70.54) > Leaves (42.50) > grain (35.39) > stem (21.00). The fresh root weight was increased by 35.31 and 73.01 per cents, respectively, for rice and wheat. The carbon uptake by both rice and wheat were increased by the increased concentration of CO_2 in atmosphere. The per cent carbon content of different plant parts did not differ significantly excepting the root dry matter of rice, which exhibited a small but statistically significant increase in its carbon content under elevated CO_2. Total C uptake by rice was increased by 33.83 per cent, while in wheat an increase of 33.25 per cent was recorded. As the gains in the economic parts were relatively higher when compared to the gains in total biomass yield, an improvement in harvest index was obtained under elevated CO_2 in both rice and wheat, enhancement being more prominent in rice crop under elevation of CO_2 concentration in atmosphere. The root volume was also increased by 36.56 and 77.13 per cents in rice and wheat, respectively under elevated CO_2. The data on biomass partitioning indicated a higher rate of translocation of the dry matter towards root at all stages of growth in both rice (Figure 1) and wheat. However the below ground partitioning was comparatively more in wheat crop.

As a result of elevation of CO_2 concentration in atmosphere during rice growth, per cent carbon allocated below ground increased from 37.62 to 43.30 per cent at tillering, while the corresponding increases were from 25.12 to 27.47, 19.78 to 21.43 and 15.60 to 17.15 per cents at flowering, grain filling and maturity, respectively. As a consequence of higher CO_2 concentration in atmosphere, per cent carbon allocated below ground increased from 26.29 to 30.94 per cent at CRI stage of wheat growth, while the corresponding increases at anthesis, grain filling and maturity were from 13.10 to 16.26, 9.21 to 13.74 and 4.07 to 4.30 per cents, respectively.

Per cent nitrogen content of different plant parts was slightly lower under elevated CO_2 conditions and this effect was more prominent in the case of rice. The lower nitrogen content resulted in higher values of C:N ratio for all plant parts when rice was grown under elevated CO_2. Though comparatively small, the C:N ratios of wheat plant parts were also increased as a result of

Figure 1. Biomass partitioning to different plant parts at various stages of rice grown in OTC as affected by elevation of atmospheric CO_2 concentration



Significant at *P=0.01*

elevation of CO_2 concentration in atmosphere.

Cotrufo and Ineson (2000) reported that elevated CO_2 significantly affected the chemical composition of beech twigs, which had 38% lower N and 12% lower lignin concentrations than twigs grown under ambient [CO_2]. The decrease in N concentration resulted in significant increase in the C/N and lignin/N ratios of the beech (Fagus sylvatica) wood grown under elevated [CO_2]. The increase in root to shoot biomass ratio and preferential partitioning of biomass and carbon belowground has considerable impacts on carbon dynamics in soil. Root turnover is one of the most important mechanisms of carbon transfer to the rhizosphere soil (Van Veen et al., 1991). Gorrisen (1996) found that regardless of the total biomass response to elevated CO_2, total net ^{14}C-CO_2 uptake increased by an average of 41 per cent and the carbon transferred to root and to the soil increased by 31 and 35 per cent, respectively, in elevated CO_2 treatments over the ambient ones. Although a relatively minor pathway for transferring carbon to soils, the nature of exudates may be more important for ecosystem than their overall quantity (Cardon, 1996). An increase in root growth as well as belowground partitioning had been observed in the present experiment and this might have certain implications on the carbon pools in soil.

Gains in carbon pools of rhizosphere soil

The results were obtained from the analysis of the soil samples collected from pot culture (OTC) as well as field experiments (FACE). All active carbon fractions in soil increased as a result of the increased atmospheric CO_2 concentration (Figure 2). The specific gains in these carbon pools on exposure of the crops to increased CO_2 concentration were in the order of:

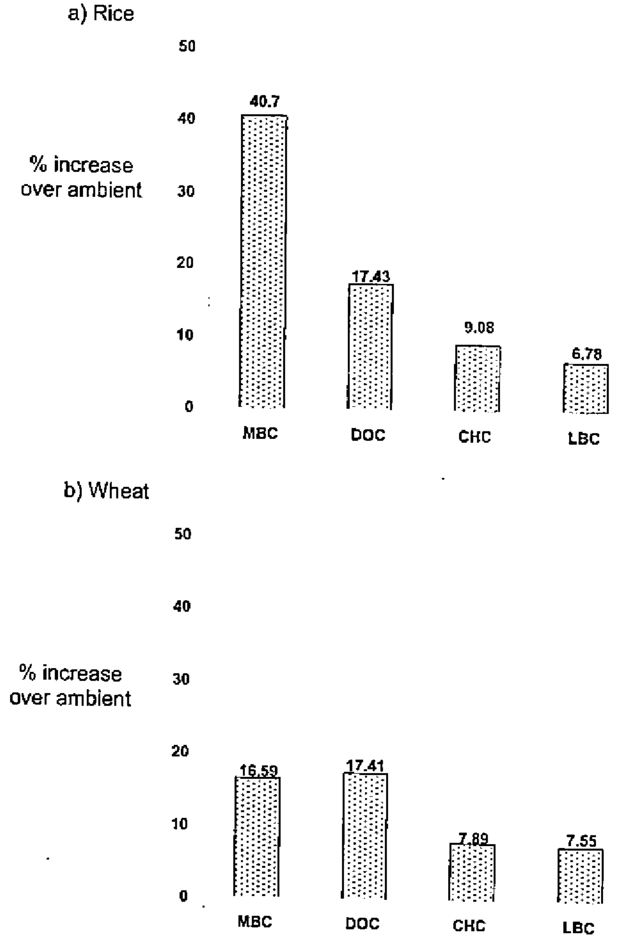
Rice: MBC > DOC > CHC > LBC

Wheat: DOC > MBC > CHC > LBC

The recalcitrant total soil carbon (TSC) content did not differ significantly in OTCs (pot culture study) in response to the elevation of atmospheric CO_2 concentration. Interestingly, in the field experiment a significant increase in total carbon contents in surface (0-10 cm) soil was observed under FACE. The soil in field under FACE has continuously been exposed to higher CO_2 for the past seven years. This long-term exposure to CO_2 with crop-stand might have increased the calcitrant carbon pool in soil.

All carbon pools in soil collected from field declined in their quantity down the soil profile. The relative gains in the active carbon pools on exposure to elevated CO_2 also declined with increase in soil depth. This clearly indicated that the relative advantage of elevation of CO_2 is restricted to the upper layers of soil, symptomatic of the importance of rhizosphere effect in terms of root exudations and turn over. When rice crop was grown, the per cent response in active carbon pools to elevation of

Figure 2. Per cent increase in different carbon fractions in the rhizosphere soils of both crops as influenced by elevation of CO_2 when grown in OTC



Significant at *P=0.01*

atmospheric CO_2 concentration was highest in 0-5 cm soil layer, while in wheat, it was highest in 5-10 cm layer (with an exception in DOC content). The two topmost layers of soil did not differ with respect to the per cent response in DOC content during wheat growth.

As a result of elevation of CO_2 concentration in rice microclimate, a decrease in NH_4-N content by 16.66 per cent was observed in rhizosphere soil during pot culture experiment while nitrate nitrogen did not exhibit any significant change in its values. As the level of CO_2 was increased in crop atmosphere, a decrease in NO_3-N content by 11.76 per cent was recorded in wheat rhizosphere soil while, ammoniacal nitrogen content was not affected significantly.

Zak and coworkers (1993) hypothesized that greater soil carbon availability under elevated CO_2 could elicit an increased size of soil microbial biomass. Results of the current study revealed that all the active carbon pools were influenced positively by the elevation of atmospheric CO_2 concentration. It was hypothesized that increased root growth and consequent increased microbial activity under elevated CO_2 would have caused such influence on these pools. Results emanating from the pot culture supported this hypothesis. However, relative advantages were of different order and magnitude in the rhizosphere soils of the two crops studied.

Decomposition study

Ambient and elevated CO_2-grown rice and wheat residues were compared with respect to their degradability under ambient and elevated atmospheric CO_2 conditions, respectively. Ambient CO_2-grown rice (RA) and wheat (WA) residues were found to decompose at a faster rate compared to the corresponding elevated CO_2-grown residues (RE and WE) (Figures 3 & 4). The amount of residues remaining inside the litterbags showed comparatively higher values for the elevated CO_2 grown residues indicating their slower rate of decomposition. The effect was more prominent for rice residue. The per cent carbon content of the left-over residues in litterbags at various times of sampling during decomposition did not differ significantly between the ambient and elevated CO_2 grown rice and wheat residues.

After 150 days of decomposition, the weight of the residues and the amount of plant carbon inside the litterbags got decreased to 18.73 and 17.08 per cent of their initial values, respectively in case of ambient CO_2-grown rice residues (RA). The respective values for RE, WA and WE were 22.61 and 20.61, 26.90 and 24.67 & 29.50 and 27.17 per cents. The plot of logarithm ie., expression of rate of residue carbon remaining in litterbags with time confirmed the slower rate of decomposition of elevated CO_2-grown residues. The decreased rate of decomposition of elevated CO_2-grown residues was corroborated with the values of total organic carbon and microbial biomass carbon contents in soil.

Figure 3. Amount (g) of ambient grown (RA) and elevated grown(RE) rice residues and carbon remained (g) in litter bags during decomposition

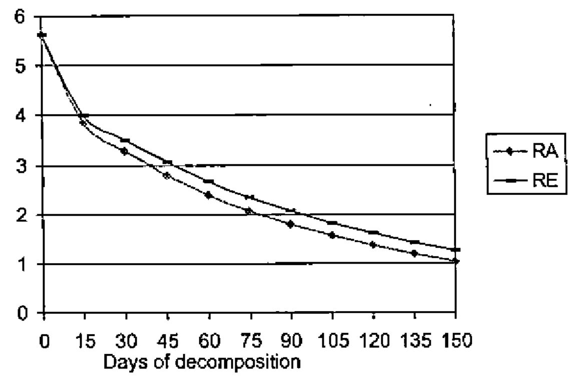
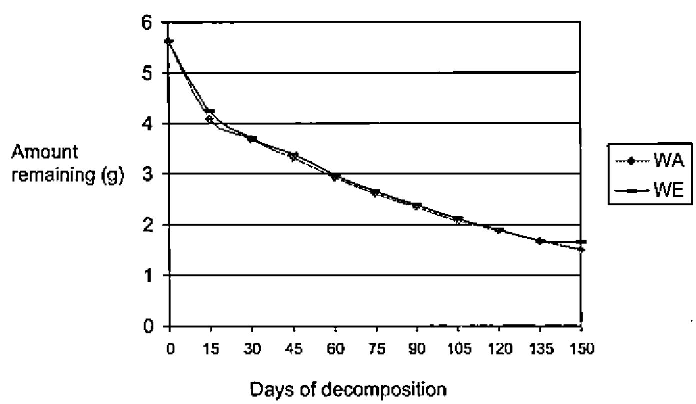


Figure 4 Amount (g) of ambient grown (WA) and elevated grown(WE) wheat residues and carbon remained (g) in litter bags during decomposition



Significant at *P=0.01*

However, such difference between the values associated with ambient and elevated residues was higher for rice as the effect of elevation of CO_2 was more prominent during its decay.

Ambient CO_2-grown residues had lower C:N ratios, as a result of which an increase was observed in its rate of minearlisation. Hence lower C:N ratios of RA and WA in comparison to RE and WE at all stages of decomposition, as obtained in the current study has enormous consequences in nitrogen cycling in soil. There are many views by different scientists regarding the degradability of the elevated CO_2 grown residues. One possibility is that increased soil microbial activity due to additional carbon entering the soil in an elevated CO_2 environment (priming effect) would lead to increased decomposition of soil organic matter (Lekkerkerk et al., 1990). Alternatively, decreased plant residue C/N and lignin/N ratios were found in ambient CO_2 grown residues, thus supporting the increased degradation of the ambient grown residues. Substrate quality has been recognized as one of the most important factors regulating decomposition processes (Swift et al., 1979), and quality parameters such as nitrogen concentration, C/N and lignin/N ratios have been correlated with decomposition rates (Melillo et al., 1982., Taylor et al., 1989). The effect of increasing CO_2 levels on plant material quality has been the subject of many studies and a general reduction of N concentration, with a concomitant increase in C/N ratio is likely to occur (Coleman et al., 1993). A similar reduction in N concentration and concomitant increase in C/N ratio in elevated CO_2 grown residues was observed in the current investigation also.

Modelling experiment

CERES-N with the original rate constants for carbohydrate (CARB), cellulose (CELL) and lignin (LIGN) pools overestimated the decomposition and minearlisation processes.

The modified decay constants for carbohydrate, cellulose and lignin were 0.38, 0.01899 and 0.0035 in case of RA. The respective values were; 0.32,0.01691 and 0.00266 for RE; 0.31, 0.01561 and 0.0013 for WA and 0.29, 0.01508 and 0.0011 for WE.

A modification was done to include the proportional intake of ammoniacal nitrogen for immobilization. The limiting value of BB, nitrification factor was also changed from 0.8 to 0.6.

The data related to the decomposition and N mineralisation from ambient and elevated CO_2-grown rice residues were found to fit quite closely to the modified CERES model. In case of wheat, the data pertaining to the decomposition from ambient and elevated CO_2-grown residues were found to fit well into the modified CERES model, while that related to N mineralisation from wheat residues did not fit well; especially in case of elevated CO_2-grown residues.

Conclusions

Elevation of atmospheric CO_2 concentration brought an increase in all active carbon pools in crop rhizosphere; extent of gains was related to the relative availability of the active pools.

Though marginal, significant increase in total soil carbon in upper layers of FACE indicates a definite possibility of increase in carbon sequestration arising out of the active pools on long-term exposure to elevated CO_2.

Decomposition of crop residues was marginally faster in ambient CO_2 conditions and this effect was more prominent with rice residues. Such decreased rate of decomposition might increase the residence times of the elevated CO_2-grown residue decomposition systems, thus supplementing sequestration of carbon in soil. During decomposition of the residues, C:N ratios were lower for ambient CO_2-grown residues and that significantly increased the rate of minearlisation from those residues. Such alterations in C:N ratio have enormous consequences on nitrogen cycling in soil.

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Plate 1. Open Top Chambers (ambient and elevated CO_2) used in the study with rice crop at maximum tillering stage (*Kharif* season, 2004).

Simulation modeling of growth parameters for rice genotypes at different nitrogen level and different dates of transplanting using CERES 3.5 v for eastern Uttar Pradesh

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Abstract

The present investigation was carried out at Agrometeorological Instructional Farm of Narendra Deva University of Agriculture & Technology Kumargang, Faizabad during Kharif season of 2005-06 to investigate the CERES 3.5 v model validations for rice at different dates of transplanting and different genotypes. Treatment consisted of three genotypes *viz.* Sarjoo-52, NDR-359 and Pant Dhan-4, two date of transplanting viz. July 5th, 2005 and July 25th, 2005 & three nitrogen levels viz. 80 kg/ha, 120 kg/ha and 160 kg/ha. The experiment was laid out in Randomized Block Design. Among the genotypes prediction accuracy of Pant Dhan-4 was found better in respect of No. of tillers/m^2, 50 % Flowering Date After Transplanting (DAT), Panicle initiation (DAT) and Physiological maturity (DAT) on 5th July transplanting at 120 kg/ha nitrogen as comparison to 25th July transplanting. The simulation modelling was subsequently validated against observed data from field experiment. From the response of simulation model it was observed that accuracy of simulated value decreases with late transplanting in all the genotypes.

Introduction

Crop growth simulation models, properly validated against experimental data have the potential for tactical and strategic decision making in agriculture. Improved production technology at the farm level is the most crucial starting point for the fulsome further growth of Rice which can be triumphed by adopting suitable crop growth simulation models. Some techniques used for dynamic simulation model in rice validated the simulation of plant growth and crop production. (Goydrian, 1982). CERES (Crop Estimation through Resource & Environment Synthesis) model were the result of an attempt made in the user oriented;

general simulation models for various crops. These models predict the performance of a particular cultivar, sown at any time in any climate, which would lead to transfer of agro-technology information. The advantage of crop modeling has been illustrated in the works of Nix (1976). CERES-Rice model is a process based management oriented model that can simulate the growth and development of rice as affected by varying levels of nitrogen (Ritchie *et al.*1998). Wickham (1973) and Ahuja (1974) clearly show that the yield variation in Rice crop production due to weather, management and biotic factors can be addressed through a modeling approach.

Materials and methods

In the present study an experiment was carried out during Kharif season 2005-06 at Agrometeorological instructional farm of N. D. University of Agriculture and Technology, Kumarganj, Faizabad (U.P.)(26^0 47′ N latitude , 82^0 12′ E longitude and 113 m altitude from mean sea level). The area come into semi-arid zone, receiving a mean annual rainfall of about 1130 mm, out of about 82.5 % of the total rainfall is being received during south-west monsoon season alsone. (Tripathi *et al.*, 1998)

In the CERES-Rice model, the entire programme is divided into weather file, soil file, crop file or genotype coefficient file and crop management file. The details of different files are as follows.

Weather files – This file demands one year daily weather data on sunshine (hr), maximum and minimum temperature (Ú C), rainfall (mm), wind speed (m/s), humidity (%) and pan evaporation (mm)

Soil file- This file demands soil data allied to soil classes, soil evaporation, soil albedo, runoff curve, soil profile, drainage coefficient, soil layer thickness, field capacity, wilting point, bulk density organic carbon (%) and sand, silt clay (%).

Plant file: This file demands soil data related to date of sowing, date of emergence, date of floral initiation, date of anthesis, date of physiological maturity, plant population, plant height , LAI, leaf weight , culms weight, dry matter, grain weight, grain yield and grain ear per head.

Management file- Data on date and amount of irrigation, fertilizer application, herbicide /insecticide application, weeding, row spacing and sowing depth (mm) by the previous crop are needed for this particular file.

Genotype coefficient file- The file required the cultivar specific coefficient. Eight genetic coefficients are required for describing the various aspects of performance a particular genotype for running the CERES-Rice v 3.5 model (table 1).

Table 1: Genetic coefficients used in simulation modeling for different genotypes.

Table 1: Genetic coefficients used in simulation modeling for different genotypes.

VAR#	VAR-Name	ECO#	P_1	P2R	P5	P_2o	G_1	G_2	G_3	G_4
IN0020	NDR-359	IB0001	600	150	410	12.0	42	0.02	1	0.80
IN0021	Sarjoo-52	IB0001	670	200	400	12.7	45	0.02	1	0.80
IN0022	Pant-4	IB0001	620	160	300	12.0	45	0.02	1	0.80

Where

VAR#	Identification code or number for a specific cultivar.
VAR-NAME	Name of cultivar.
ECO#	Ecotype code for this cultivar points to the ecotype in the ECO file (currently not used).
P1	Time period (expressed as growing degree days [GDD] in ØC above a base temperature of 9Ø) from seedling emergence during which the rice plant is not responsive to changes in photoperiod. This period is also referred to as the basic vegetative phase of the plant.
P_2O	Critical photoperiod or the longest day length (in hours) at which the development occurs at a maximum rate. At values higher than P_2O developmental rate is slowed, hence there is delay due to longer day lengths.
P_2R	Extent to which phasic development leading to panicle initiation is delayed (expressed as GDD in ØC) for each hour increase in photoperiod above P_2O.
P_5	(Time period in FDD) from beginning of grain filling (3 to 4 days after flowering) to physiological maturity with a base temperature of 9° C.
G_1	Potential spikelet number coefficient as estimated from the number of spikelets per g of main calm dry weight (less lead blades and sheaths plus spikes) at anthesis. A typical value is 55.
G_2	Single grain weight (g) under ideal growing conditions, i.e. nonlimiting length, water, nutrients, and absence of pests and diseases.
G_3	Tillering coefficient (scalar value) relative to IR64 cultivar under ideal conditions. A higher tillering cultivar would have coefficient greater than 1.0.
G_4	Temperature tolerance coefficient. Usually 1.0 for varieties grown in normal environment. G4 for japonica type rice growing in warmer environment would be 1.0 or greater. Likewise, in the season it would be less than 1.0.

Results

The result of present investigation entitled "Simulation Modeling of Growth Parameters for Rice Genotypes at different nitrogen level and different dates of transplanting using CERES 3.5 v for Eastern Uttar Pradesh" has been presented in this part. The results have been presented through tables. The salient findings of experimental have been categorized and presented under: In simulation modeling validation was intended for No. of tillers/ m^{2}, 50% Flowering (DAT), Panicle Initiation (DAT) and Physiological maturity (DAT).

Data pertaining to comparison of perceive with simulated values for no. of tillers/m^2 at different date of transplanting of rice have been represented in Table-2.1. It is quite obvious that in 5th July transplanting closeness decreases with increase in nitrogen level (80kg/ha to 160 kg/ha nitrogen) in all genotypes. While on 25th July transplanting Pant Dhan-4 at 80 kg/ha nitrogen was found close prediction of simulated value over observed (9.5%) followed by 120 kg/ha nitrogen (15.3%) and 160 kg/ha nitrogen (17.2%). But in Sarjoo-52 close prediction of simulated value was found over observed at 160 kg/ha nitrogen (19.1%) followed by 80 kg/ ha nitrogen (20.0%) and 120 kg/ha nitrogen (22.2%). In NDR-359 also similar closeness over observed as minimum error at 160kg/ha nitrogen (19.3%) followed by 80 kg/ha nitrogen (20.4%) and 120 kg/ha nitrogen (23.1%) were recorded.

Data relating to comparison of observed with simulated values for 50% flowering (DAT) in rice have been exemplified in Table-2.2. It is revealed that from data on 5th July transplanting that closeness of observed value with simulated value in all the varieties decrease with successive decrease of nitrogen level from 160 kg/ha nitrogen to 80 kg/ha nitrogen. In Pant Dhan-4, 160 kg/ha nitrogen level was found to have close prediction over observed value (8.5%) followed by 120 kg/ha nitrogen (14.3%) and 80 kg/ha nitrogen (24.7%). In Sarjoo-52 the error % of closeness were 5.4%, 17.7% and 17.2% at 160 kg/ha, 120 kg/ ha, and 80 kg/ha nitrogen respectively. From table it is seen that in NDR-359 better response of simulation was recorded over observed at 160 kg/ha nitrogen (9.9%) as compared to 120 kg/ ha nitrogen (14.4%) and 80 kg/ha nitrogen (16.8%). On 25th July transplanting also in Pant Dhan-4 was found to have close prediction over observed value (13.1%) at 160 kg/ha nitrogen level followed by 120 kg/ha nitrogen (15.6%) and 80 kg/ha

Table-2.1: Comparison of observed with simulated value for No. of tiller/m^2 at different dates of transplanting and nitrogen level.

Varieties	5th July						25th July					
	Nitrogen level (Kg/ha)											
	80 Kg/ha		120 Kg/ha		160 Kg/ha		80 Kg/ha		120 Kg/ha		160 Kg/ha	
	O	P	O	P	O	P	O	P	O	P	O	P
Pant Dhan-4	430.1	380.5 (11.5)	505.5	410.4 (18.8)	535.2	425.6 (20.4)	415.1	375.5 (9.5)	490.6	415.5 (15.3)	520.4	430 (17.2)
Sarjoo-52	440.6	345.4 (21.6)	480.6	360.6 (24.9)	524.6	378.6 (27.8)	425.6	340.4 (20.0)	470.5	365.6 (22.2)	470.6	380.6 (19.1)
NDR-359	480.5	350.4 (18.7)	510.4	390.5 (23.4)	545.6	410.5 (24.7)	465.5	370.2 (20.4)	495.3	380.5 (23.12)	515.5	415.5 (19.3)

* Figure in the parenthesis shows the error % of simulated over observed value.

Table-2.2: Comparison of observed with simulated value for 50% flowering (DAT) at different dates of transplanting date and nitrogen level.

Varieties	5th July						25th July					
	Nitrogen level (Kg/ha)											
	80 Kg/ha		120 Kg/ha		160 Kg/ha		80 Kg/ha		120 Kg/ha		160 Kg/ha	
	O	P	O	P	O	P	O	P	O	P	O	P
Pant Dhan-4	60.1	75 (24.7)	65.6	75 (14.3)	68.2	74 (8.5)	60.5	73 (20.6)	63.1	73 (15.6)	65.4	74 (13.1)
Sarjoo-52	61.4	72 (17.2)	63.7	75 (17.7)	68.3	72 (5.4)	62.4	72 (15.3)	64.1	73 (10.4)	66.7	73 (9.4)
NDR-359	62.5	73 (16.8)	63.8	73 (14.4)	66.4	73 (9.9)	58.7	72 (22.6)	65.8	72 (9.4)	64.2	70 (9.0)

*Figure in the parenthesis shows the error % of simulated over observed value.

nitrogen (20.6%) level. In case of Sarjoo-52 160 kg/ha nitrogen level was found to have close prediction over observed (9.4%) followed by 120 kg/ha nitrogen (10.4%) and 80 kg/ha nitrogen (15.3%). In NDR-359, 160 kg/ha nitrogen level found to have close prediction over observed value (9.0%) followed by 120 kg/ha nitrogen (9.4%) and 80 kg/ha nitrogen (22.6%).

Data belonging to comparison of observed with simulated values for panicle initiation at different dates of transplanting of rice genotypes have been shown in Table-2.3. It is exposed from data in 5th July transplanting in Pant Dhan-4 (10.3 %) was found to have close prediction over observed value at 80kg /ha nitrogen level followed by 120 kg/ha nitrogen (18.7 %) and 160 kg/ha nitrogen (21.3). In Sarjoo-52 80 kg/ha nitrogen level was found to have close prediction over observed (13.9 %) followed by 120 kg/ha nitrogen (16.7 %) and 160 kg/ha nitrogen (18.7 %). In case of NDR-359 also 80 kg/ha nitrogen level was found to have close prediction over observed (19.6 %) followed by 120 kg/ha nitrogen (23.6 %) and 160kg/ha nitrogen (26.8 %). While in the 25th July transplanting Pant Dhan-4 at 80 kg/ha nitrogen level was found to have close prediction over observed (6.8 %) followed by 120 kg/ha nitrogen (23.2 %) and 160 kg/ha nitrogen (25.9 %). In Sarjoo-52 also 80 kg/ha nitrogen level was found to have close prediction over observed (20.6 %) followed by 120 kg/ha nitrogen level (23.8 %) and 160 kg/ha nitrogen (24.8 %). NDR-359 at 80 kg/ha nitrogen level found close to prophecy over observed (22.4 %) followed by 120 kg/ha nitrogen (25.6 %) and 160 kg/ha nitrogen (27.4 %).

For physiological maturity, it is quite obvious on 5th July transplanting Pant Dhan-4 was found to have close prediction over observed value (6.8%) at 160 kg/ha nitrogen level followed by 120 kg/ha nitrogen (9.8%) and 80 kg/ha nitrogen (10.9%). In Sarjoo-52 also similar behavior of nitrogen level was reported as Pant Dhan-4, that means 160 kg/ha nitrogen level was found to have close prediction observed value (8.5%) followed by 120 kg/ha nitrogen (12.6%) and 80 kg/ha nitrogen (17.7%). Likewise in NDR-359 160 kg/ha nitrogen level was found to have close prediction over observed value (9.1%) followed by 120 kg/ha (10.3%) nitrogen and 80 kg/ha nitrogen (12.8%). In 25th July transplanting also 160 kg/ha nitrogen level was found to have literal prediction over observed value in all the genotypes followed by 120 kg/ha nitrogen and 80 kg/ha nitrogen (Table 2.4).

Table-2.3: Comparison of observed with simulated value for Panicle Initiation DAT at different transplanting dates and nitrogen level.

Varieties	5th July						25th July					
	Nitrogen level (Kg/ha)											
	80 Kg/ha		120 Kg/ha		160 Kg/ha		80 Kg/ha		120 Kg/ha		160 Kg/ha	
	O	P	O	P	O	P	O	P	O	P	O	P
Pant Dhan-4	50.2	45 (10.3)	55.4	45 (18.7)	57.2	45 (21.3)	48.3	45 (6.8)	53.4	41 (23.2)	55.4	41 (25.9)
Sarjoo-52	52.3	45 (13.9)	54.2	45 (16.7)	55.4	45 (18.7)	50.4	40 (30.6)	52.5	40 (23.8)	53.2	40 (24.8)
NDR-359	53.5	43 (19.6)	56.3	43 (23.6)	58.6	43 (26.8)	51.6	40 (22.4)	53.8	40 (25.6)	55.1	40 (27.4)

* Figure in the parenthesis shows the error % of simulated over observed value.

Table-2.4: Comparison of observed with simulated value for Physiological Maturity (DAT) at different transplanting date and nitrogen level.

Varieties	5th July						25th July					
	Nitrogen level (Kg/ha)											
	80 Kg/ha		120 Kg/ha		160 Kg/ha		80 Kg/ha		120 Kg/ha		160 Kg/ha	
	O	P	O	P	O	P	O	P	O	P	O	P
Pant Dhan-4	89.2	99 (10.9)	94.1	99 (9.8)	96.6	100 (6.8)	86.4	100 (15.7)	88.4	100 (13.1)	91.2	103 (12.9)
Sarjoo-52	88.3	104 (17.7)	95.3	104 (12.6)	97.5	105 (8.5)	87.4	107 (22.4)	90.2	108 (19.8)	93.5	109 (16.56)
NDR-359	90.4	102 (12.8)	93.4	102 (10.3)	98.4	102 (9.1)	85.1	107 (25.7)	89.6	109 (21.6)	92.4	109 (17.9)

* Figure in the parenthesis shows the error % of simulated over observed value.

O- Observed Data

P- Predicted Data

Conclusions

It may be deduced that the model was found to predict the phenological occurrence of the crop well enough to facilitate the farmers to make broad decision on the crop management operations, which can be directly linked to crop phenology in the CERES Rice model.

For no. of tillers/m^2 on 5th July transplanting 80 kg/ha nitrogen level was found to have close prediction over observed value followed by 120 kg/ha nitrogen and 160 kg/ha nitrogen in all genotypes. But on 25th July transplanting 80kg/ha nitrogen level was again found to have close prediction over observed followed by 160 kg/ha nitrogen and 120 kg/ha nitrogen in all genotypes. Among the genotypes Pant Dhan-4 was found to have maximum closeness of simulated value over observed followed by Sarjoo-52 and NDR 359 at different transplanting dates.

For 50% flowering (DAT) 160 kg/ha nitrogen level found to have close prediction over observed value followed by 120 kg/ha nitrogen and 80 kg/ha nitrogen. On 5th July transplanting Sarjoo-52 was found to have close prediction over observed value followed by Pant Dhan-4 and NDR- 359. While on 25th July transplanting NDR- 359 was found to have close prediction over observed value followed by Sarjoo-52 and Pant Dhan-4 at 160 kg/ha, 120 kg/ha nitrogen and 80 kg/ha nitrogen level respectively.

In Panicle initiation (DAT) among the genotypes the Pant Dhan-4 was found to have maximum closeness to close to observed value followed by Sarjoo-52 and NDR-359 at all nitrogen level on 5th July transplanting. However, on 25th July transplanting, among the genotypes simulated value for Pant Dhan-4 was much closer to the observed value over rest of varieties while at higher dose of Nitrogen (120 and 160 kg/ha nitrogen) with observed value of Sarjoo-52 is much close to the simulated value as compare other varieties under investigation.

Pant Dhan-4 was found to have close prediction over observed value followed by NDR-359 and Sarjoo-52 at different nitrogen level and transplanting dates for physiological maturity.

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Impact of climate change on soil degradation and rice productivity at Pattambi

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Abstract

No doubt the climatic aberrations will severely set back agricultural development in most of the tropical countries particularly India, where an increasing share of the poorest and most vulnerable population resides. We analyzed weather data at the Regional Agricultural Research Station, Pattambi for the period of 81 years (1927 to 2008) of rainfall data and 58 years (1950 to 2008) of temperatures. We found that the decreased trends of rainfall and temperatures were changed abnormally and influenced the soil fertility and rice yield in Pattambi. Here we report that last five years (2003 to 08) the annual mean minimum temperatures have increased by 0.5°C and 0.42°C, respectively during the month of July and June months when compared to 58 years of data. Decreased values were observed annual mean maximum temperature were decreased almost all the months to the maximum of 1.3°C when compared to 58 years of observed values. Grain yield was declined to the maximum of 280 and 360 kilos per acre respectively in kharif and rabi seasons. Changed climate also degraded the soil over the period of years and reflected in decreased yield were also observed. This report provides a direct evidence of decreased rice yields from increased nighttime temperature associated with global warming. It is evident that improved knowledge is needed to effects of changes in climate on crop yields and physical process such as soil erosion and nutrients degradation.

Introduction

In Kerala two-thirds of the rice needs were met out by importing from neighboring rice-rich States such as Andhra Pradesh, Karnataka and Tamil Nadu. Palakkad and Kuttanad had about 1,21,000 hectares under rice and produced about 2,62,500 tonnes per annum, a mere 2.2 t/ha as against the expected harvest of

5.0 t/ha. Changed weather parameters and its impact on soil degradation and unforeseen pest and disease problems are the reasons for decreased productivity. Interrelationship of the changed climatic parameters and its effect on rice yield is not yet known. An understanding of the net global impact of recent climate trends would help to anticipate impacts of future climate changes, as well as to more accurately assess recent technologically driven yield progress.

Climate change scenario

Rainfall

Rainfall data for the period of 81 years from 1927-2008 was taken and mean was worked out to estimate the difference in rainfall pattern with respect to last ten years (1999-2008) and then grouped to annual (Jan-Dec), Southwest monsoon (Jun-Sep) and Northeast monsoon (Oct-Dec).

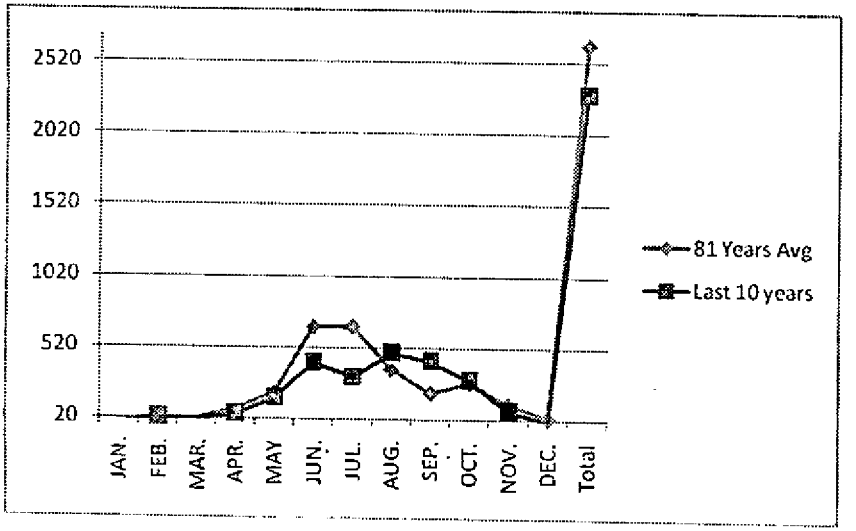

Fig. 1 Mean monthly and total rainfall (mm)

Rainfall at Pattambi exhibits diverse changes in Southwest monsoon by delayed onset and reduced quantum of rainfall, particularly during June and July rainfall was lowered in the last ten years compared to mean of past 81 years (Table 1 and Fig. 2)

Table 1. Seasonwise rainfall in mm

	Winter	Summer	Southwest	Northeast	Total
Normal (81 Yrs)	15.56	301.75	1894.83	425.22	2637.36
Last 10 Years	27.30	236.00	1652.51	391.22	2307.03
Difference	11.74	-65.75	-242.32	-34.00	-330.30

Rainfall is expected to decrease over the period of years. Delayed onset of Southwest monsoon and extended rains during Northeast monsoon is observed in this study. Consequences to this, start of the first crop rice is varying or delayed and the crop maturity phase is coincided with Northeast monsoon during the month of October and November. All other processes of harvesting to grain storage have adversely affected the rice cultivation at Pattambi.

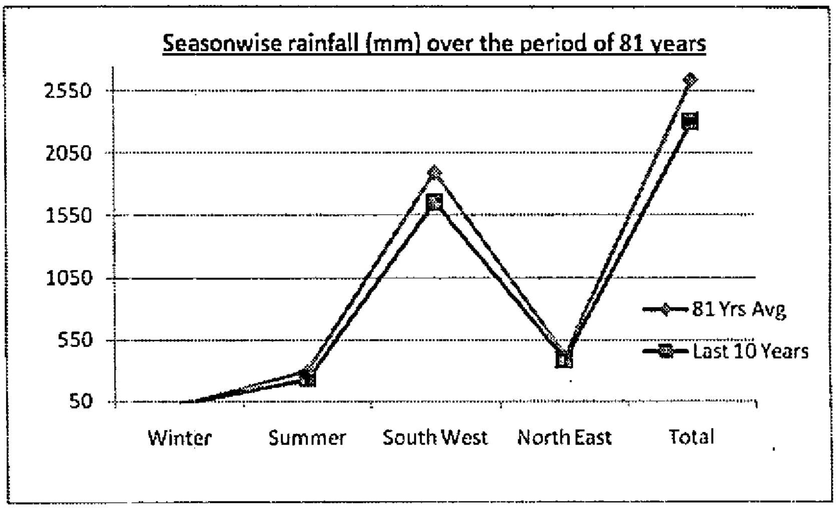

Fig. 2 Seasonwise rainfall (mm) over the period of 81 years

Maximum and minimum temperature

Monthly maximum and minimum temperature data for the period of 58 years from 1950-2008 and also for the last five years 2004 – 2008 were taken and mean was worked out. Monthly mean maximum temperatures (Fig. 3) are decreased for the past years in almost all the months to the tune of 0.2 °C to 1.27 °C.

Contrast to this the monthly mean minimum temperatures (Fig. 4) have increased by 0.15°C to 0.50. Grain yield is declined from 280 to 360 kilogram per acre. Rise in mean minimum temperature for 0.5°C increase in growing-season minimum temperature in the dry season, whereas the effect of maximum temperature on crop yield was insignificant. This report provides a direct evidence of decreased rice yields from increased nighttime temperature associated with global warming.

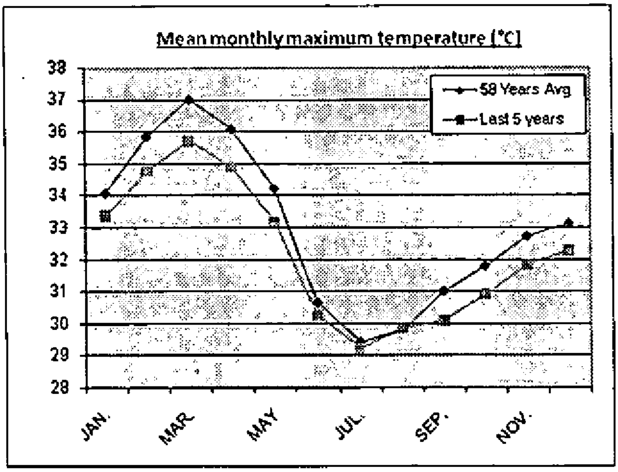

Fig. 3 Mean monthly maximum temperature (°C)

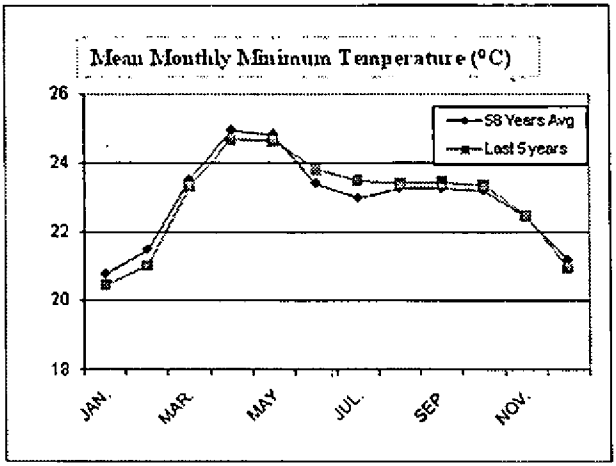

Fig. 4 Mean monthly minimum temperature (°C)

Impact of climate change on rice yield and soil fertility

Impact of rice yield on climate change was reviewed for nine years of average mean yield data for two rice growing season viz., Kharif and Rabi from Regional Agricultural Research Station, Pattambi. Change in climate is expected to create both positive as well as negative on rice yield of Pattambi (Table 2 and Fig. 5). Decline trend in yield is observed during the year 2004 to 2008 during Kharif and yield decline in Rabi during the year 2003 to 2006. This could be due to the delayed onset of Southwest and more rain during the month of October – November coincided with harvest of Kharif crop. Similar trends were studied and reported by Geethalakshmi and Dheebakaran (2008)

Table 2 Average yield of rice in Kharif and Rabi (t/ha)

Year	Kharif	Rabi
2000	4.93	3.48
2001	4.75	2.93
2002	4.04	3.14
2003	4.97	2.48
2004	3.97	1.94
2005	3.14	1.94
2006	3.67	2.27
2007	3.22	2.99
2008	3.70	2.58
Average	4.04	2.64

Soil fertility status particularly the phosphorous and potassium is degraded adversely because of varied climate over the period of years. As reported in NARP report volume II (National Agricultural Research Program – Released by Kerala Agricultural University) the available P is 20 kg/ha and K is 146 kg/ha. It was decreased now and recorded only 12 kg P and 86 kg of K during the year 2008. Also observed the top fertile soil removal was prominent every year leading to the decline in effective soil depth for rice cultivation.

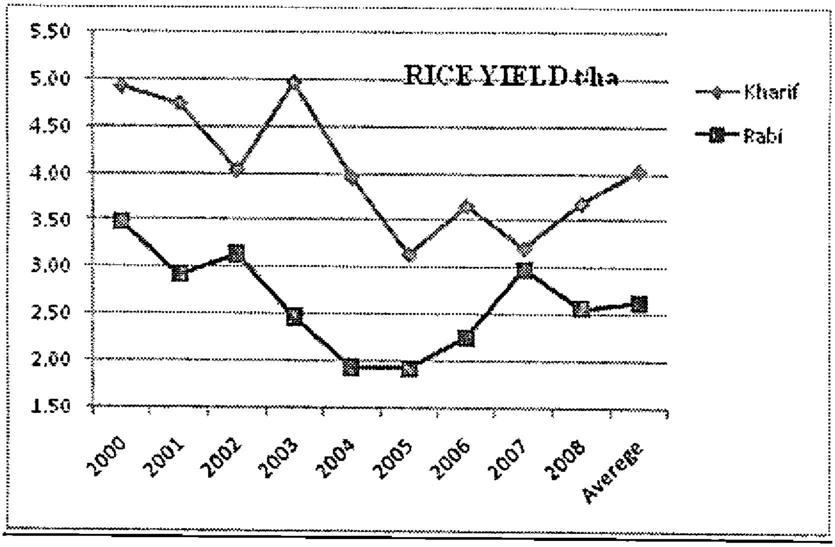

Fig. 5 Yield (t/ha) average over the period

Conclusions

The change of weather parameters has definitely begun, although the projected extent of change and its effect on rice productivity not been conclusively studied. Trend analysis studies clearly showed decreased rainfall quantity and its distribution and increased minimum temperature. Based on the principles of rice cultivation in Kerala, the Kharif cultivation timing may be delayed and altering the start of second Rabi crop which could affect food security of the State. It is therefore, highly suggest that the emerging conditions need to be studied well in totality as climate change influences from soil characters to post harvest period of rice cultivation

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Effect of CO_2 enrichment and seed scarification on nitrogen composition of four avenue tree species

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Abstract

The growth rate of many avenue tree species is very slow during seedling phase and is not adequate before transplanting, which creates a constraint for field establishment. Presently, there is an increasing concern over the raising levels of major green house gas CO_2 in the atmosphere. Indiscriminate and extensive deforestation and the burning of fossil fuels are the two major sources of increasing CO_2 levels. Since CO_2 level is the primary substrate for photosynthesis in green plants, it would offer a great potential for increasing the growth of many annual and perennial species. The ambient CO_2 level available to the tree seedlings was enhanced by trapping the CO_2 released during dark respiration of seedlings and soil respiration. For many of the avenue tree species belonging to the family leguminosae that exhibit seed dormancy due to impermeability of their hard seed coats, seed scarification was carried out by acid / hot water treatment. In the present investigation four tree species namely gulmohar (*Delonix regia*), tamarind (*Tamarindus indica*), Yellow gulmohar (*Peltophorum ferrugineum*) and Subabul (*Leucaena leucocephala*) were taken up for study to understand dry matter accumulation and nitrogen composition during their seedling growth period. CO_2 enriched seedlings recorded significantly increased dry matter accumulation than the seed scarification. CO_2 enrichment combined with seed scarification resulted in a marginal increase in dry matter accumulation compared to CO_2 enrichment alone.

Maximum seedling dry matter accumulation of these four avenue tree species was observed with the combination of CO_2 enrichment and seed scarification. The increasing dry matter results in reduction in nitrogen concentration due to dilute effect but the total nitrogen uptake and NUE were increased due

efficient utilization of nitrogen. Among the four avenue tree species, gulmohar responded well and had higher seedling dry matter. Tamarind, yellow gulmohar and subabul responded less. Thus, gulmohar could be preferred for avenue plantations and for social forestry purposes.

Introduction

The successful implementation of afforestation and agroforestry programmes depends upon a continuous supply of healthy seedlings. The growth rate of many avenue tree species is very slow during seedling phase and is not adequate before transplanting, which creates a constraint for field establishment. Many of the avenue tree species belonging to the family leguminosae exhibit seed dormancy due to impermeability of their hard seed coats. There is considerable information demonstrating that elevated CO_2 levels have a positive effect on growth rates of many annual and perennial plant species (Rogers *et al.* 1993). This study assessed the effects of seed scarification and CO_2 enrichment on nitrogen composition of four avenue tree species.

Materials and methods

Seeds of four avenue tree species, viz., gulmohar, tamarind and Subabul were scarified with concentrated (98%) H_2SO_4 for 60, 90, and 120 minutes, respectively, while those of yellow gulmohar were soaked in water at 80 °C for 2 minutes. Seedlings were raised in seed beds for a period of 30 days ,then transferred to poly bags containing 4 kg of pot mixture (black soil, sand and farm yard manure in the proportion of 2:1:1) per bag . Seedlings were acclimatized under shade for 30 days. At 75 days after sowing (DAS), half of the seedlings were transferred to an iron frame (1.5 x 1.5 x 1.0 m size) fully covered with polythene sheet of 600 guage thick to trap the CO_2 released during dark respiration of seedlings and soil respiration for enhancing CO_2 and RH as per Prassanna *et al.*(1990). Cow dung was added to soil to enhance CO_2 level by soil respiration. The seedlings were covered with polythene sheet from 5.00 pm- 10.00 am daily. The amount of CO_2 enrichment achieved was found to be around 600ppm on an average in the morning .To avoid an unnatural rise in temperature and relative humidity because of CO_2 enrichment , the polythene sheet was removed during the rest of the period so that the plants were exposed to a natural environment from 10.00 a.m - 5.00 pm . The treatments, seed scarification with acid or hot water, and CO_2 enrichment were as follows:

T1 : Control (seedlings raised from seeds soaked in water for 12 hours).

T2 : Seedlings raised from seeds subjected to acid/hot water scarification .

T3 : CO_2 enrichment

T4 : Seed scarification and CO_2 enrichment

Plant samples were taken at 120 days after sowing (DAS). Dry matter accumulation, nitrogen concentration, nitrogen uptake and nitrogen use efficiency (NUE) were estimated and calculated in different seedling parts. Data was analysed statistically as per Panse and Sukhatme (1985) using a completely randomized experimental design.

Results

The data on the dry matter accumulation, nitrogen concentration (%), uptake and NUE for four avenue tree species in seedling parts (leaf , stem, and root) at 120 DAS are given in Table 1, 2 , 3 & 4 respectively. All the treatments differed significantly with each other. Nitrogen concentration was found to decrease in all the seedling parts (leaf, stem and root). The increasing dry matter results in reduction of nitrogen concentration due to dilution effect but the total nitrogen uptake and NUE were increased due to efficient utilization of nitrogen. Among the four species, subabul was found to record more leaf nitrogen concentration, thus indicating more proteinaceous value of leaves as fodder than the rest of avenue species. Gulmohar and yellow gulmohar recorded more stem and root nitrogen concentration. This might be due to redistribution of nitrogen from leaf to stems and roots. Gulmohar recorded more nitrogen accumulation and uptake due to increased dry matter production. This is followed by tamarind, Yellow- gulmohar and subabul recorded less nitrogen concentration and uptake. Tamarind recorded more NUE due to efficient utilization of nitrogen for dry matter production followed by yellow – gulmohar and subabul . Jain et al .2007 reported that the overall nitrogen concentration in plants usually decreases when they are grown in enhanced CO_2. Similar results of CO_2 enrichment were reported by Norby *et al* (1986) in white oak seedlings and sage *et al* (1989) in *Phaseolus vulgaris* , *Solanum* *tuberosum , Solanum melongena and Brassica oleracea* . The *Seed* scarification was found to decrease the nitrogen concentration in seedling parts (leaf, stem and root). However, the values of nitrogen accumulation, uptake and NUE were increased with seed scarification when compared to the control.

CO_2 enrichment recorded significantly decreased nitrogen concentration whereas increased nitrogen accumulation, uptake and NUE than seed scarification. CO_2 enrichment significantly increased N uptake and NUE than seed scarification due to increased RUBP carboxylation and photosynthetic rate and efficient seedling growth.

CO_2 enrichment with seed scarification resulted in marginal change of nitrogen concentration, uptake and NUE over CO_2 enrichment alone. Among the four avenue species, gulmohar recorded more concentration and uptake of nitrogen in different seedling parts (leaf, stem and root). Tamarind on the other hand, recorded less nitrogen concentration in different parts but uptake of nitrogen and NUE were more. Among the four avenue tree species, gulmohar responded well and had higher seedling dry matter. Tamarind, yellow gulmohar and subabul responded less. Thus, gulmohar could be preferred for avenue plantations, and for social forestry purposes

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SESSION V

Climate change adaptation in Horticulture

National Seminar on Climate Change Adaptation Strategies
in Agriculture and Allied Sectors, held at KAU during 03-04 December 2009

Climate change adaptation strategies in agriculture: Influence of ecological variables on productivity in tea

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Abstract

Tea, a rain fed plantation crop cultivated over 0.56 million hectares provides food security to millions and offer employment opportunities to more than eight million people in the country besides earning a considerable amount of foreign exchequer. Undue anthropogenic activities and burning of fossil fuels resulted in global warming in turn affecting the environmental conditions. Climatic variables are interrelated and hence their compounded effect imposed deleterious impact on living organism. Even though adjacent to forest ecosystem, tea plantations experienced an unprecedented ecological imbalance. Comparative analysis of the change in climatic variables between the 2008 and the decennial mean of immediate earlier years exhibited a lot of variation. Overall mean minimum temperature increased by 0.2°C while mean maximum temperature rose by 0.8°C. Naturally, overall mean sun shine hours increased by 0.53 hours per day which reflected on ambient temperature. Relative humidity declined from the decennial average and varied from 0.6 to 1.3%. Number of wet days during the year 2008 was 150 which had declined to 140 leading to total rainfall lesser by 75.2 cm.

Earlier, tea plantations of south India experienced two high cropping periods intervened by low cropping seasons which coincides with the favorable and unfavorable environmental variables. In the recent past, the cropping pattern had changed due to unpredictable climatic factors. Comprehensive analysis of crop data of the Anamallais revealed that there was a paradigm shift in yield from as high as 3403 kg made tea/ha in 1997-98 recorded to 2522 kg during 2007-08 with a huge variation of 804 kg made tea. Obviously, cultural operations carried out in plantations will also account for the variation in the productivity to an extent. Impact of climate change on tea

plantations, strategies to be launched for adaptation with respect to sustenance of tea plantations are presented and discussed.

Introduction

Beverage crop tea is cultivated in south India along the Western Ghats encompassing 0.125 million ha. Tea being a rain fed plantation crop is grown beside the forest ecosystem. Cultural operations and anthropogenic activities imposed in the plantations contribute a specific microclimate under tea ecosystem. South Indian tea plantations were categorically grouped into six tea districts on the basis of rainfall pattern and soil factors viz., 1. The Anamallais, 2. The Nilgiris (both in Tamil Nadu), 3. The High Ranges, 4. Central Travancore (both in Kerala state), 5. Wayanad (partially belongs to both Tamil Nadu (Nilgiri-Wayanad) and Kerala (Wayanad) and 6. Karnataka (particularly Chickmagalur district). Both Wayanad and Karnataka enjoy the south west monsoon with a mean rainfall of 250 and 300 cm/ annum, respectively, and also experienced with extended dry months, 3 to 5 months. On the other hand, The Anamallais, Central Travancore, High Ranges and the Nilgiris recorded rainfall both from south west and north east monsoons. However, considerable area under cultivation remained to be either SW or NE shadow area (Muraleedharan et al., 2007).

In general, the Anamallais experience the Lion's share of rainfall from SW monsoon with supplemented contribution of NE monsoon accounting to 200 to 600 cm per annum. On the other hand, the Nilgiris receives a mean of 150 cm rainfall/annum and the number of rainless days extended up to 4-5 months. Irrespective of the tea growing districts, the elevation ranges from 600 to 2500 m above mean sea level and the soil is loamy/clay loam to clayey and/or heavy clay loam to clayey. With the above ecology and topography, tea sector of south India contributes nearly one third of commercial teas with an average productivity of 2000 kg/ha. Present study deals with ecological barriers on tea productivity and how far it deviated from the general cropping pattern with particular reference to the Anamallais. Impact of climatic variables and anthropogenic activities on crop productivity in tea plantations, strategies to be adopted with respect to clean development mechanism are presented and discussed.

Materials and methods

For the case study, data on meteorology and crop were used for computation. Agro-meteorological data recorded by meteorological observatory of UPASI Experimental Station, Valparai, Coimbatore District were used which is authorized by Indian Meteorological Department (Annual Reports 1997-2008). Unlike the Nilgiris, Nilgiri-Wayanad and Central Travancore regions, small grower's contribution towards tea productivity is negligible in the Anamallais. Hence, the crop details pertaining to the corporate sectors and tea plantation owned by the Tamil Nadu Government (TANTEA) consolidated by the Anamalai Planters' Association (APA), Valparai were considered for computation and comparison (APA yield statements, monthly circulars, 1997-2008). With regard to crop data, influence of pruning the plants does not arise because every year 25% area under cultivation and the entire tea plantations undergo this operation within four years. For the comprehensive analysis related to climatic change on crop productivity, 2008 year data was compared with the decennial mean of immediate preceding years. Data were subjected to a) analysis of the variations in the climatic variables, b) regression analysis to establish the relationship between the climatic variables and crop productivity and c) factor analysis in order to confer the variables responsible for deviation and their cumulative effect on crop productivity besides the annual cropping pattern.

Results and discussion

Data on decennial mean (1998-2007), climatic variables recorded during 2008 and variation among them are furnished in Table 1. From the table, it was evident that the decennial mean minimum and maximum temperatures were 15.3 and 25.5°C with a mean sunshine period of 5.0 hours/day (irrespective of the season) and registered 293 sunny days. Relative humidity recorded during 08.30 hours (maximum) was 88.5% while it was 78.5% during 14.30 hours (minimum), respectively. As mentioned earlier, planting district, the Anamallais experienced 410.4 cm rainfall which occurred in 150 days. Of which 15.1 cm accounts for scattered showers (3.7%) during dry period (December to March), 49.7 cm (12.1%) recorded as pre-monsoon showers (April, May), and a major share of 292.0 cm (71.2%) as SW (June to September) and 53.6 cm (13.1%) as NE (October – November) monsoon, respectively.

Table 1 Decennial mean, climatic variables recorded during 2008

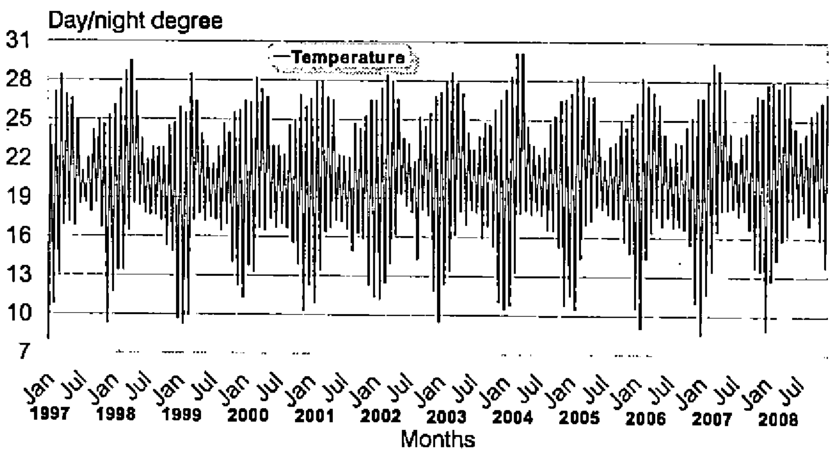
Month/ Year	Mean temperature (°C) Min.	Max.	Relative humidity (%) 08.30 h	14.30 h	Total rainfall (mm)	Rainy days (No.)	Mean sunshine (h/day)	Sunny days (No.)
1998-2007:								
Jan	10.7	26.6	85.2	64.0	21.7	1.4	7.6	30.7
Feb	11.3	27.5	84.0	57.6	28.8	1.7	7.7	27.8
Mar	13.2	28.7	85.0	60.0	76.1	3.7	7.7	30.9
Apr	16.5	27.8	86.5	71.4	158.8	8.9	6.3	28.8
May	17.5	26.3	87.7	79.7	338.3	13.2	4.9	26.3
Jun	17.8	23.4	92.1	85.6	795.4	23.2	2.1	15.8
Jul	17.8	22.3	94.4	88.8	940.5	27.0	1.3	11.6
Aug	17.4	22.9	93.7	86.5	746.7	23.3	2.4	18.3
Sep	16.5	24.2	90.6	84.0	437.5	18.0	3.9	22.2
Oct	16.9	24.6	90.6	85.3	377.3	17.6	3.6	25.3
Nov	15.2	25.7	88.0	78.7	158.2	9.4	5.1	26.3
Dec	12.3	26.2	83.8	68.0	24.6	2.4	6.9	29.1
Total/mean	15.3	25.5	88.5	75.8	4103.9	150	5	293
Jan 2008:	8.9	27.7	83	54	8.4	1	8	31
	(-1.8)	(1.1)	(-2.2)	(-10.0)	(-13.3)	(0.4)	(0.4)	(0.3)
Feb	12.7	27.9	86	57	17	3	6.1	28
	(1.4)	(0.4)	(2.0)	(-0.6)	(-11.8)	(1.3)	(-1.5)	(0.2)
Mar	14.3	27.5	79	69	221.2	14	4.41	27
	(1.2)	(-1.2)	(-6.0)	(9.0)	(145.1)	(10.3)	(-3.2)	(-3.9)
Apr	15.8	27.9	87	78	84.2	4	5.44	28
	(-0.7)	(0.1)	(0.5)	(6.6)	(-74.6)	(-4.9)	(-0.9)	(-0.8)
May	16.2	27.7	85	80	74	8	5.33	31
	(-1.3)	(1.4)	(-2.7)	(0.3)	(-264.3)	(-5.2)	(0.5)	(4.7)
Jun	17.6	24.4	93	86	569.6	26	1.56	16
	(-0.2)	(1.0)	(0.9)	(0.4)	(-225.8)	(2.8)	(-0.5)	(0.2)
Jul	17.8	23.4	94	87	810.7	25	1.44	13
	(0.0)	(1.1)	(-0.4)	(-1.8)	(-129.8)	(-2.0)	(0.2)	(1.4)
Aug	18.1	24	94	88	711.8	23	2.31	19
	(0.7)	(1.1)	(0.3)	(1.5)	(-34.9)	(0.3)	(-0.1)	(0.7)
Sep	17	25.4	89	80	422.4	15	4.33	22
	(0.5)	(1.2)	(-1.6)	(-4.0)	(-15.1)	(-3.0)	(0.5)	(0.2)
Oct	17.8	25.8	88	81	327.4	16	3.46	22
	(0.9)	(1.3)	(-2.6)	(-4.3)	(-49.9)	(-1.6)	(-0.2)	(-3.3)
Nov	15.9	26.4	84	75	37	2	4.44	24
	(0.7)	(0.8)	(-4.0)	(-3.7)	(-121.2)	(-7.4)	(-0.6)	(-2.3)
Dec	13.8	27	84	67	68.6	3	6.07	28
	(1.5)	(0.8)	(0.2)	(-1.0)	(44.0)	(0.6)	(-0.9)	(-1.1)
Total/mean	15.5	26.3	87.2	75.2	3352.3	140	4.42	289
	(0.2)	(0.8)	(-1.3)	(-0.6)	(-751.6)	(9.8)	(-0.5)	(-4.1)

Figures in parentheses denote deviation +/- from the decennial mean

While analyzing the climatic data of 2008, mean minimum and maximum temperatures were 15.5 and 26.3°C with an increase in temperature of 0.2 and 0.8°C, respectively. Irrespective of the seasons, mean sunshine hours declined to 4.4 hours/day with a variation of 0.9 hour/day and registering 289 sunny days with a marginal (4 days) decline in total number of sunny days. Relative humidity recorded during 08.30 hours was 87.2% while it was 75.2% during 14.30 hours with a decline of -1.3 and -0.6%, respectively. The Anamallais experienced 335.2 cm rainfall *in toto* with a deficit rainfall of 75.2 cm from the decennial mean which showered in 140 days, again 10 days lesser than the decennial average. Of course, rainfall pattern changed differently where well distributed rains of 31.5 cm (9.4%) accounts during dry months, 15.8 cm (4.7%) recorded as pre-monsoon showers (April, May) and 251.5 cm (75.0%) as SW monsoon and remaining 364 cm which accounts for 10.9% as NE monsoon. In general, soil moisture stress in the Anamallais was moderate from December 2007 to mid-March 2008. Summer showers received during the second week of March were useful for the entire district. Total number of rainless days was 93 from December 2007 to March 2008 as against 135 days during the previous year (Ann Rep. 2008).

Mean monthly variations in the day degree and night temperatures were projected in Fig.1. It is obvious that wide

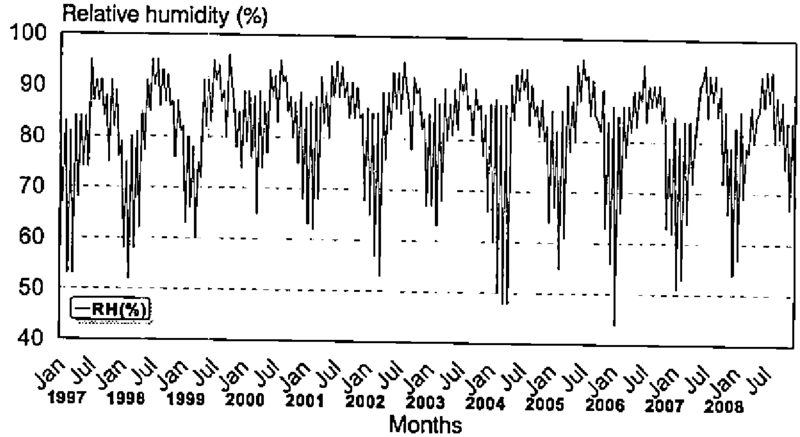
Fig. 1. Mean monthly variations in day and night degree over a period between 1997 and 2008



diurnal variation in temperatures was recorded due to fall in night temperatures and bright sunshine during day time. In certain occasions mean minimum temperature dipped down below 10°C and mid-day temperature crossed beyond 30°C. Variation during monsoon period was found to be narrow. When compared to mean minimum and maximum temperatures over a period, during 2006 it recorded extended period of narrow diurnal variation while in 2008 the trend had reversed.

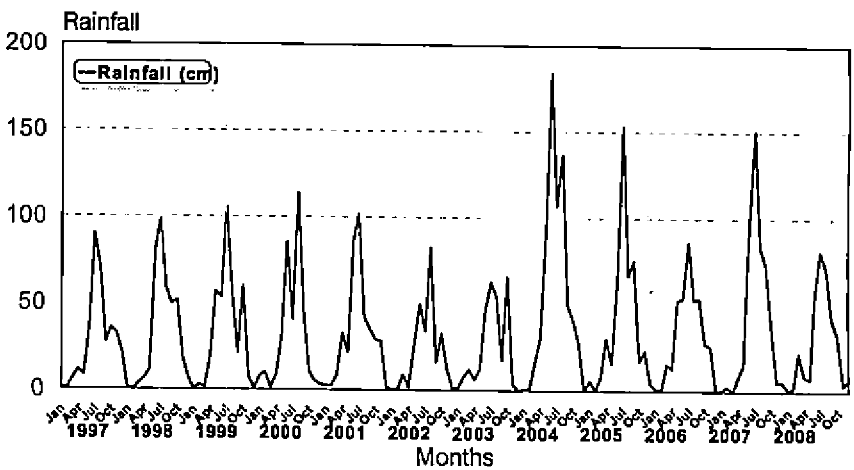
Mean monthly variations in relative humidity recorded at 08.30 and 14.30 hours was presented in Fig. 2. It is quite interesting that wide variation in relative humidity was observed between

Fig. 2. Mean monthly variations in relative humidity (at 8.30 and 14.30 hours) between 1997 and 2008



1997 and 2008. Considering the pattern of relative humidity, during monsoon relative humidity crossed 95% and descended to below 50% during 2004 and 2006. During winter and onset of summer, relative humidity ranged between 60 and 80%. Number of rainy days, rather than intensity of rainfall account the extent of favourable relative humidity during pre-monsoon and monsoon periods. During the last decade, only three times (2004, 2005 & 2007) higher rainfall was recorded crossing the decennial mean of 410 cm (Fig. 3). No rhythmic pattern of rainfall

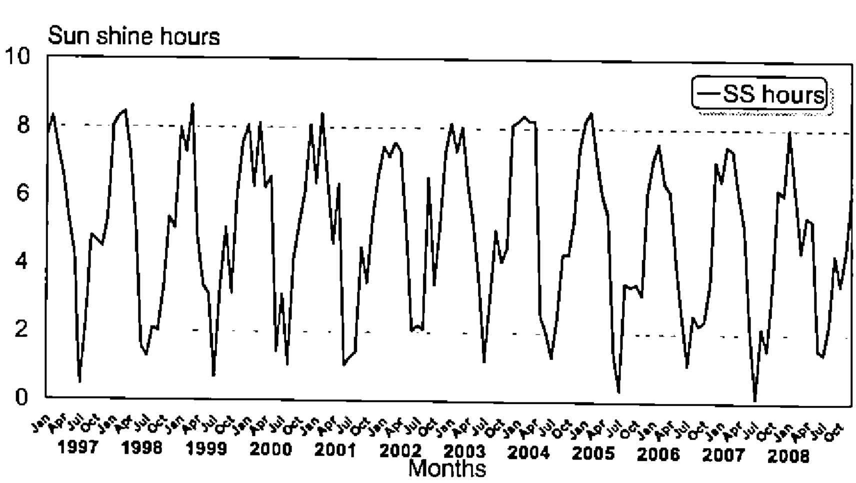
Fig. 3. Changing rainfall pattern over a period from 1997 to 2008



could observe from 1997 to 2008. For the last three years, there was no distinct gap between south west and north east monsoon which reflect as a single dominant peak. As the south west monsoon accounts lion's share (Baby and Ajay, 2002), in most of the years under observations, north east monsoon peak appeared as shoulder peak, unless the south west monsoon failed (2003). Sporadic and intermittent rains during winter and summer account a fraction of rainfall contribution in the Anamallais which appeared baseline peaks. In the Anamallais, the monsoon failed successively for two years (2002 & 2003) which was highly deviated from the decennial mean (Baby and Ajay, 2004). During that time, Tamil Nadu Government launched ground water harvesting scheme to ensure to raise the ground water level.

During the last decade, mean monthly sunshine recorded was 0.14 hours during July (Fig. 4). No rhythmic sunshine hour's pattern could be noticed between 1997 and 2008. Since no intermittent rainy days during 1997, 1998, 2004, 2005 and 2006, there was only one dominant peak observed from the Figure. Obviously, rainfall pattern and number of rainy days negatively correlated with sunshine hours, the figure presented herein is mirror image of the rainfall pattern. Broad peaks represent extent of number of sunny days indirectly which in turn manifest on soil moisture stress during particular period.

Fig. 4. Pattern of sun shine hours between 1997 and 2008



Crop distribution pattern in the Anamallais

Tea productivity depends upon well distributed rainfall and favourable climatic conditions. Tea plantations suffered due to inadequate soil moisture requirement to cope with growth and development where drought prolonged up to 120 days. High ambient temperature and radiant energy manifest on transpiration loss which in turn affect the metabolic activity of the plants thereby the crop yield. Pre-monsoon showers activate the metabolism and its periodic growth resulted in first crop period. During monsoon and due to lack of inadequate mean sunshine hours, crop yield declined. A privileged gap between south west and north east monsoon impart favourable conditions consequently discharge the second crop season (Jibu Thomas *et. al.* 2009; Muraleedharan *et. al.* 2007). It is very common under south Indian conditions that crop distribution has two peak seasons with intervening lean season (Fig. 5-6).

Cropping pattern of the Anamallais is not an exceptional one from the said trend. However, the data pertaining to 2005-09 revealed that first crop period took off during April, attained the peak in May and sustained till June. Again second crop period deviated from the south Indian crop distribution pattern. From July onwards, there was a marginal decline in the crop when compared to the south Indian pattern while in January marginal improvement was noticed. This is mainly because of unpredictable ecological variables.

Crop productivity: Mean agricultural yield pattern of the Anamallais was presented in Figure 6 and it was clear that there were ups and downs in the yield level per unit area. For the past 11 years, only in 1997-98 agricultural year recorded magnificent productivity per unit area followed by 1999 to 2000 where it registered 3403 and 3326 kg made tea/ha. Leave alone the crop depression during 1998-99, from the agricultural year 2000 onwards, the productivity declined from 3326 kg to 2522 kg with a huge margin of 804 kg/ha. On the whole out of 11 years of crop data, six agricultural years registered <3000 kg made tea per hectare and past two years, on an average 200 kg made tea declined when compared to the previous agricultural years.

Relation between crop productivity and ecological variables: Among the number of ecological variables, maximum temperature exerted significant and negative correlation with

Fig. 5. Changing pattern of crop distribution in the Anamallais

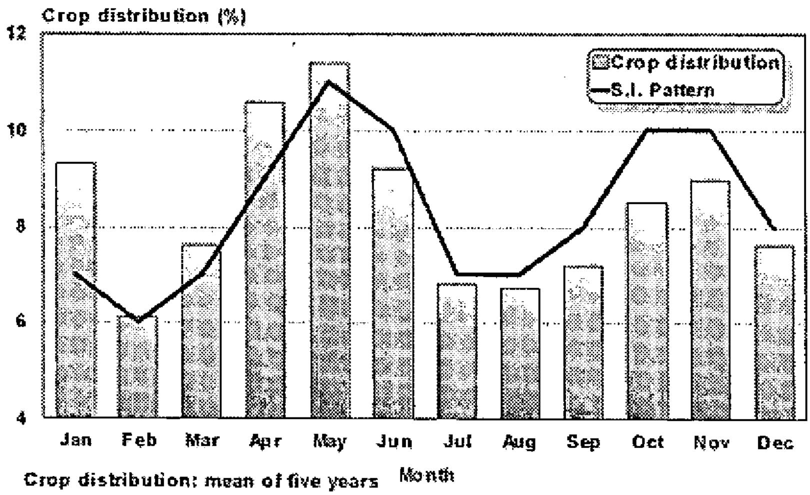
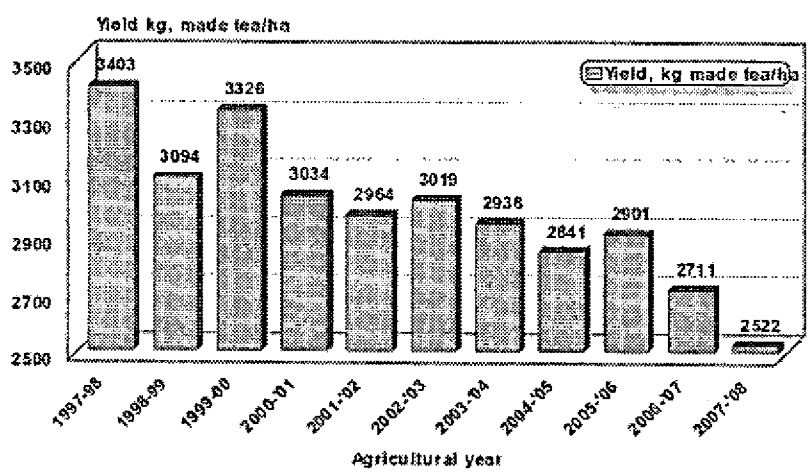


Fig. 6. Yearwise (April to March) agricultural productivity of the Anamallais



yield while relative humidity recorded during 8.30 a.m. registered positive relation (Table 2). Even though, relative humidity recorded at 2.30 p.m., mean sunshine hours and number of sunny days exhibited positive relationship with yield, the relationships were not statistically significant. On the other hand, rainfall and number of rainy days had negative correlation with crop yield recorded over the period but they were not statistically significant. Based on the relation that existed among the various ecological parameters, a multiple regression model was developed to forecast

Table 2 Correlation matrix between ecological variables and the crop yield

	Variable number								
	1	2	3	4	5	6	7	8	9
1. Mean Min. T (°C)	1.000	-0.097	-0.190	-0.035	0.512	0.472	-0.310	-0.483	-0.110
2. Mean Max. T (°C)		1.000	-0.187	-0.716	0.069	-0.358	0.267	0.073	-0.674
3. RH (%) at 8.30 am			1.000	0.347	-0.214	-0.309	0.481	0.706	0.517
4. RH (%) at 2.30 p.m.				1.000	-0.396	-0.268	0.145	0.337	0.799
5. Rainfall (mm)					1.000	0.736	-0.307	-0.429	-0.343
6.Rainy days						1.000	-0.689	-0.752	-0.232
7. Sunshine hours							1.000	0.833	0.510
8. Sunny days								1.000	0.539
9. Yield, kg/ha									1.000

Values >.666* and >.798** are statistically significant at 5 and 1% probability, respectively

the crop yield. On the other hand, the compounded effect of climatic variables on crop productivity can be predicted using the formula; Yield (kg made tea/ha) = 11534.144 + Temperature minimum X (41.001) + Temperature maximum X (-433.782) + RH at 8.30 am X (-8.244) + RH at 2.30 p.m. X (9.339) + rainfall X (-0.096) + sunshine hours X (387.659) which is significant at 1.0% level (r=0.989). It may be noted that this formula may not be applicable to all tea growing regions in south India; even in the Anamallais, it may not be applicable to tea gardens which are located at SW monsoon shadow area. Further more, adoption of agricultural operations periodically, without any deviation may substantiate the prediction formula which has to be evaluated further. In earlier prediction model, RH minimum was excluded since it has a very weak relationship with yield (Jibu Thomas, 2008). Moreover, the model was developed using only four years climatic variables. Even then the model had a higher confidence level of 85%. About 15% of variation occurred mainly due to the diversified populations and recently introduced labour productivity management system (Jibu Thomas, 2008).

Driving forces of crop productivity: Factor analysis confirmed that the ecological variables are independent in nature which influenced the yield either singly or in combination. Out of eight variables attempted three variables (RH at 8.30 am, number of rainy and sunny days) were excluded while for stepwise computation their contribution to yield was found to be negligible. Initial eigen values, per cent variation contributed by each variable and cumulative values are furnished in Table 3. First component (mean max temperature) accounted for predominant variation (45.3%) followed by other components. Cumulative effect of first three variables (mean max temperature, RH at 2.30 pm and rainfall) contributed 83.26% variation. Considerable amount of variation was contributed by the sunshine hours (8.25%) while other variables which include temperature (minimum), RH (at 8.30 a.m.), number of rainy and sunny days collectively contributed to 8.61% variation.

Table 3 Cumulative impact of ecological variables on crop productivity

Component	Initial eigen values		
	Total	Variance (%)	Cumulative variance (%)
Temperature max	4.089	45.30	45.30
RH at 2.30 pm	2.312	25.69	70.99
Rainfall	1.093	12.14	83.13
Sunshine hours	0.743	8.25	91.38
Other components	0.759	8.61	100.00

From the above analysis, it is evident that ecological variables are independent and cumulative effect of each variable was found to influence the crop yield significantly. Even though there was no giant leap shift in the climatic variables considering the Anamallai conditions, there was precise variation observed between the decennial mean and prevailing conditions. When analyzing the data it is quite obvious that one can be questioned about the sharp decline in yield. Soil characteristics particularly, physical and nutrient status, play an important role in influencing crop productivity. Considering the importance of scenario on climate change, soil characteristics are not included as a variable on crop productivity. It is true that climatic variables not only affect the yield, but their indirect contribution towards pests and disease menace cannot be denied by anybody. Of course, tea plantations experienced revolution in cultural operations which might have contributed to an extent towards the crop loss (Muraleedharan, 2009).

Impact of tea cultivation vis-à-vis changing environmental conditions

Global warming and shift in climate pattern are the burning issues which are mainly related with anthropogenic activity and burning of fossil fuels. As mentioned earlier, precise shift in environmental variables was noticed this turned down the productivity to a greater extent in the Anamallai range. Considering the atmospheric pollution, tea is a potential carbon sequestrating plantation crop. It has been reported that emission of green house gases (GHG) in tea sector is due to inefficient energy management with particular reference to processing. Among the GHG emission, CO_2 occupies the first rank followed by SO_2 (0.016 kg/ton made tea), CO (6 g/kg made tea) while liberation of NO_2, NOx and CH_4 are negligible in quantum (Asian Institute of Technology, 2002).

Theoretically, about 26.3 million tons of CO_2 sequestrated per annum as against 1.4 million tons CO_2 emission by fuel consumption. CO_2 emission by tea processing accounts about 5.1% and other cultural operations contribute 2.3% with a grand total of 7.4% as against the total CO_2 sequestrated by the tea plants. Assuming that 35% of the organic matter converted in to organic carbon, it generates a total of 0.91 t OC/ha/year (Mohan Kumar and Raj Kumar, 2009). On pruning, OC added to the soil accounts 4.01 million tons. Organic matter accumulated in the soil is a source of nutrients on their decomposition thereby improves the soil fertility and reduces runoff. Reduction in runoff will minimize soil erosion. Two to 5% waste is encountered during processing; methodologies available to utilize the waste as organic fertilizers which would arrest NO_2 emissions that would have been generated while using the synthetic fertilizers. Considering the GHG emissions with respect to global scenario, tea plantations are eco-friendly in nature and preserving the tea ecosystem is as important as to reduce the GHG emissions.

Conservation strategies in relation to environmental conditions

Several recommendations issued upon strategic issue on crop improvement. At this juncture of changing scenario of climate, it is very essential to sustain the crop productivity in relation to clean development mechanism. Energy utilization practices, emission of green house gases and consequent environmental impacts on sustenance of tea sector are given due importance. As an immediate and interim measure, the following recommended policies would benefit the tea sector.

- Adoption of no tillage planting
- Extensive new clearings/replanting
- Maintenance of proper drainage
- Mulching of young tea plantations
- Periodical application of organic manures
- Growing cover crops
- Maintenance of shade and co-cultivation of native shade species
- Using energy efficient equipments in day-to-day cultural operations
- Utilizing solar /alternative renewable energy sources for processing instead of burning fossil fuels
- Efficient resource use management will definitely sustain crop productivity in tea plantations

First seven approaches relate with soil health and microclimate which may preserve the soil conditions by physical, chemical and biological means besides they conserve the soil moisture through improving the organic matter content. Remaining three approaches relate with environmental concern. These strategies could pay rich dividends not only in terms of productivity but also it could pave the foundation for healthier environment in terms of carbon sequestration and clean development mechanism which are the needs of the hour.

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Screening tomatoes for rainshelter cultivation

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Abstract

Tomato is one of the most important vegetable crops suited for protected cultivation. Indeterminate tomatoes are usually grown in polyhouses, so as to utilize its vertical space also. But most of the indeterminate tomatoes bred for polyhouses are susceptible to bacterial wilt. Moreover being F_1 hybrids their seed cost is very high and the farmers have to depend on the private/public sector organisations every time. These factors ultimately affect the cost benefit ratio and interest of tomato polyhouse growers.

Investigation on screening indeterminate tomatoes for rainshelter was started in the Department of Olericulture, College of Horticulture, Vellanikkara during 2004-2005. Tomato varieties released so far from KAU are determinate and semi determinate types. Most of the indeterminate tomatoes available in the market are F_1 hybrids and most of them are susceptible to bacterial wilt also. Hence this study was undertaken to select an indeterminate, bacterial wilt resistant and open pollinated tomato variety suited for rainshelter cultivation.

Many exotic and indigenous indeterminate tomatoes were collected and after two preliminary evaluations and seven accessions were selected. They were grown in pots under three growing conditions viz. open field (T_1), rainshelter cladded with UV stabilised sheet and shade net(T_2), rainshelter cladded with UV stabilised sheet alone(T_3), along with semideterminate varieties'Anagha' and 'Sakthi'. Among these varieties LE643-1 was identified as high yielding one with an average yield of 3.54kg/plant in the rainshelter and 2.48 kg/plant in open field.

Introduction

Kerala is a high rainfall state. The season wise rainfall contribution over the state indicates that sixty eight per cent of annual rainfall is received during the monsoon followed by post monsoon. Diverse climatic conditions prevailing in different parts of the state results in the cultivation of a large number of vegetables differing in temperature requirement, cultivation practices, parts used etc. But during rainy season, apart from tuber crops, only very few vegetables like cowpea, okra, bitter gourd etc. are grown in the state. Majority of vegetables are cultivated in summer rice fallows or river beds commercially. Most small and marginal farmers follow homestead vegetable cultivation.

High rainfall and high humidity during June, July months result in many biotic stresses, which inhibit vegetable production during this season. Water logging also leads to scarcity of land for cultivation. Untimely and erratic rainfall also hampers both vegetable and vegetable seed production in the state. Hence protected cultivation will be an answer to all these problems. A protected structure to be designed for Kerala needs much consideration on high rainfall and humidity. Considering all these factors a naturally ventilated polyhouse, named as rain shelter was found ideal for the climatic condition of Kerala, which is suitable for off season cultivation of vegetables.

Tomato is one of the most important and suitable vegetable crops for protected cultivation. Indeterminate tomatoes are usually grown in polyhouse for utilizing the vertical space also. But most of the indeterminate tomatoes bred for polyhouse are susceptible to bacterial wilt disease which is a serious menace for tomato cultivation in Kerala. Most of the polyhouse tomatoes available in the market are F_1 hybrids with a high seed cost, which the small farmers of Kerala could not afford .So far Kerala Agricultural University has released only determinate and semi-determinate tomato varieties for open field cultivation in the state. The first and basic step in any breeding programme is to identify cultivars more responsive to the environment in which it is to be grown. Hence the present study was undertaken to identify an indeterminate bacterial wilt resistant variety suitable for cultivation in rain shelter.

Materials and methods

Investigation on screening indeterminate tomatoes for rainshelter was started in the Department of Olericulture, College of Horticulture, Vellanikkara during October-January 2004-'05. Twenty five tomatoes genotypes (indigenous and exotic) were subjected to preliminary evaluation.

Among these seven high yielding genotypes were selected and they were grown in pots under three growing conditions viz. open field (T_1), rain shelter cladded with 200 micron UV sheet and shade net (50%) (T_2) and rainshelter cladedd with 200 micron UV stabilized sheet alone (T_3). Semideterminate varieties Anagha and Shakthi released from KAU were also grown in pots. There were five plants under each genotype .The experiment was laid out in CRD.

Results and discussion

The yield data of these nine accessions are given in Table (1). The genotype LE 643-1 gave the highest yield per plant (1003.4g) under T_3 (UV sheet alone). Among the growing conditions rain shelter cladded with 200 micron UV stabilized sheet(T_3) was superior to all other treatments. This is in accordance with the reports of Pandya and Kothari (2005).

Table 1 Yield data (g/plant) of Tomato accessions (2005-2006)

Acc. No	T_1	T_2	T_3
LE 642	568.2	388.8	794.6
LE 643-1	664.0	624.0	1033.4
Pant T_3	938.4	652.2	851.8
VT 20	549.6	773.6	871.8
LE 644	739.8	784.6	902.0
LE 645	699.4	448.6	745.4
LE 646	567.6	419.4	556.0
Anagha	968.8	815.4	709.6
Sakthi	794.4	869.0	938.2

T_1- Open field, T_2- UV sheet+ shade net, T_3- UV sheet
Treatment CD 142.97, Varieties CD 213.07

Another experiment was laid out during October –January, 2006-2007 to study the comparative performance of LE 643-1 and Anagha under rain shelter and open field conditions. Rain shelter with a side height of 2m, ridge height of 3.5m and cladded with 200 micron UV stabilized sheet was utilised for the study. The sides were kept open and the roof was ventilated. The ground area was $100m^2$. One month old seedlings of LE643-1 and Anagha were transplanted into the rain shelter and open field simultaneously. Observations on plant height, days to flower, days to first harvest, number of inflorescence, yield per plant and bacterial wilt incidence were recorded and are presented in Table(2). Plant height was in rainshelter grown crop was higher than that of open field (189 cm and 100cm). Plant height is a function of number of nodes and length of each internode and both are strongly influenced by temperature. Light intensity is 25-40% lesser in rain shelter which has an influential role in plant height and growth. Similar results are reported by Lara *et al.*, (1999). There is not much variation for days to flowering and days to harvest under two different growing conditions. But yield contributing characters like number of inflorescence and average fruit weight showed an increasing trend inside the rain shelter. Lower night temperature (16.1-24.5^{0}C) prevailed inside the rainshelter through out the growth period. Ho (1996) reported that lower night temperature could induce higher flower number in tomato. Lewis (1953) reported that higher number of inflorescence resulted in more number of fruits in polyhouse, which in turn resulted in increased number of harvests and yield in polyhouse.

Table 2 Comparative performance of LE 643-1 and Anagha (2006-2007)

Characters	LE 643-1		Anagha	
	Rain shelter	Open field	Rain shelter	Open field
Plant height at final harvest (cm)	189.00	115.00	100.00	87.00
Days to flower (after transplanting)	30.70	26.45	31.45	29.65
Days to harvest	66.48	66.05	67.00	65.88
Number of inflorescence	17.20	13.40	15.35	10.73
Average fruit weight (g)	59.20	56.00	45.10	42.00
Yield\ plant (kg)	3.54	2.48	2.34	1.98
Fruit cracking (%)	3.52	7.88	0.00	1.63
Bacterial wilt incidence (%)	5.00	10.00	0.00	5.00

Fruit cracking was more in LE 643-1 when compared to Anagha in the open field. But in the rain shelter Anagha was free from fruit cracking while LE 643-1 recorded 3.52 per cent cracking. Nashath (2005) found that tomato raised in rain shelter was excellent in appearance than that of open field crop. Bacterial wilt incidence was not at all noticed in Anagha inside the rain shelter but LE 643-1 recored 5 per cent wilt incidence. Thus the rain shelter grown tomatoes performed better than open field crops and LE 643-1 recorded highest yield /plant (3.54 kg) than that of Anagha (2.34kg).

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Implications of climatic change and adaptations in medicinal plants

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Abstract

Global climate change has considerable implication on Indian agriculture and biodiversity hence on our food security and farmers livelihood, we need to take steps to increase our adaptive capacity. Small changes in temperature and rainfall could have significant effect on quality of fruits, vegetables, tea, coffee, aromatic and medicinal plants with resultant implications on their prices and trade. In medicinal plants, quality and quantity are equally important and quality is at the expense of quantity and vice versa. The abiotic factors have profound influence on the secondary metabolite production and quality development of medicinal plants and so the climate change also influence. Abiotic stresses affect the quality positively with respect to some medicinal plants. The increased CO_2 concentration enhances the photosynthetic production of medicinal plants which have C_3 pathway and correspondingly the quality. Climate change also affects the flowering of many plants. *Cassia angustifolia,* which used to regularly flower in the month of April coinciding with the festival of Vishu in Kerala, is now flowering in all the seasons, which is considered to be due to climate change.

Greater attention is needed on adaptations to climate change. Adaptation measures in agriculture include introduction of more resistant crops, integrated crop management, crop diversification and increasing efficiency in irrigation. These measures may not be sufficient to meet the challenges of climate change. Income alternatives are another opportunity to adapt the climate change. Livelihood diversification and additional employment need to be created in the rural areas. Cultivation and value-addition of medicinal plants is an emerging area for rural employment generation and livelihood improvement. Homestead herbal farming is to be encouraged. Simple adaptations such as change in planting time and crops with herbal species could help in reducing the impacts of climate change to some extent.

Development of resource conserving technologies can be another adaptation. Medicinal plants require low resources as inputs for their proper growth and quality development. Greenhouse gas emission from agriculture can be mitigated by changing land use by increasing area under biofuels crops, tree medicinal plants, agroforestry and others.

Introduction

Intergovernmental Panel on Climatic Change (IPCC) in its recently released report reconfirmed that the global atmospheric concentrations of CO_2, methane and nitrous oxide, green house gases have increased markedly as a result of human activities since 1750 (IPCC, 2007). The global increase in CO_2 concentrations are primarily due to fossil fuel use and land use change, while those of methane and nitrous oxide are primarily due to agriculture. The IPPCC projections on temperature predict an increase of 1.8 to 4.0°C by the end of this century. Some changes will affect agriculture. Tropical countries are likely to be affected more compared the countries situated in temperate regions. The burnt of environmental changes is expected to be very high in India due to greater dependence on agriculture, limited natural resources, alarming increase in human and livestock population, changing pattern in land use and socio-economic factors that pose a great threat in meeting food, fuel fibre and fodder requirements.

Such global climatic change will affect agriculture through direct and indirect effects on plants, crops, soils, livestock and pests. Increase in atmospheric CO_2 concentration has a fertilization effect on crops with C_3 photosynthetic pathway and thus promotes their growth and productivity. Increase is temperature can reduce crop duration, increase crops respiration rates, alter photosynthetic partitioning to economic products, hasten nutrient mineralization in soils and increase evapotranspiration. Indirectly there may be considerable effects on land use due to snowmelt, availability of irrigation, frequency and intensity of droughts and floods and availability of energy. All these can have a tremendous effect on crop growth and production systems.

Extinction of medicinal plants

According to an article published by the American Botanical Council in its latest issue of herbal grams some key species of plants could even be lost as a result of climate change. It is revealed that species most at risk are those endemic to regions or ecosystems that are especially vulnerable to climate change. Climate change is affecting medicinal and aromatic plants around the world and could ultimately lead to losses of some key species (ABC, 2009). India is recognized as one of the countries having the oldest, richest and most diverse cultural traditions associated with the use of herbal medicines. But due to over exploitation in these natural habitat, many medicinal plants have been on the endangered list of IUCN (Debnath, 2009). Climate change is threatening the existence of several Indian herbs which are key ingredients in the traditional ayurvedic system of medicine. Climate change is disturbing the ecological balance which is making herbs, used in ayurvedic medicine extinct (Patel, 2009).

The shifts in seasonal timing arrangements could ultimately endanger some wild medicinal populations. Extreme weather events are also having an effect on the production and harvesting of various medicinal plants. According to ABC, recent abnormally hot summers have prevented the reseeding of some medicinal plants (ABC, 2009).

Climate changes affect the biodiversity of medicinal plants throughout the world. Many medicinal plants are on the verge of extinction due to over exploitation, anthropogenic factors and climate change. Conservation of biodiversity should be one of the criteria for protecting them. Wild plants play a fundamental role to sustain delivery of social and economic development and climate change magnifies the significance of this role. Ayurveda, Indian system of medicine is facing a crisis due to the shortage of many species of medicinal plants and herbs most of which are seasonal. They reach the wilting point before they could produce seeds. Efforts are needed to protect such environment.

Conservation

The success of mankind's ability to meet the challenges of climate will depend on how it will conserve the world's plants. The wild plant conservation has three mutually dependant aims of maintaining plant species and their genetic diversity, achieving sustainable use of wild plant resources and securing medicinal plants and natural vegetation as providers of ecosystem services. A continuing shift in the potential ranges of many medicinal plant species causing them to become extinct in their existing locations. Many of the medicinal plants lack adequate means of dispersal and finally their path impeded by human distraction of wild habitats. In developing countries like India 80% population depend on natural herbs for their health care systems.

Conservation international has declared the Western Ghats as one of 34 global biodiversity hot spots in the world. The Western Ghats evolved into one of the richest centers of endemism owing to their isolation from other moist areas. The hills of Western Ghats are embedded in a landscape that has much drier climatic conditions. The topography creates several enclaves that have acted as refuges for species over the years as surrounding areas have steadily grown drier. Variation in the degree of endemism in the Western Ghats depends on both the latitudinal length of dry season gradient as well as the temp/elevation gradient. The tall Western Ghats mountain range intercepts the moisture from the S.W. monsoon so that the eastern slope and the Deccan plateau receive relatively little rainfall.

In a survey conducted revealed that the angiosperm diversity of India includes 17,672 species with 5,640 species in Tamil Nadu which ranks first among all the states in the country. This includes 533 endemic species, 230 red listed species, 1559 species of medicinal plants and 260 species of wild relatives of cultivated plants. There is threat to diversity of species including medicinal plants in Western Ghats due to climate change (Anandan, 2007).

Climate change on medicinal plants

In medicinal plants quality and quantity are equally important and quality is at the expense of quantity and vice versa. The abiotic factors have profound influence on the secondary metabolite production and quality development of medicinal plants and so the climate change also influence. The abiotic stresses affect the quality positively with respect to some medicinal plants. In *Datura somnifera* the quality was improved due to moisture stress. In *Adathoda beddomei* the vasicine content was maximum when temperature increases in summer months and the harvesting time can be adjusted accordingly to obtain maximum quality (KAU, 2005). In the context of climate change, the stress effect positively influenced their secondary metabolite production and hence quality in Njavara, the medicinal rice (Table

1). The amino acid content of Njavara was more in upland condition than in low land which was due to stress effect (Menon, 1996). The increased CO_2 concentration enhances the photosynthetic production of medicinal plants which have C_3 pathway and correspondingly the quality. The climate change also affects the flowering of many plants. *Cassia angustifolia,* which regularly flowers in the month of April along with the festival of Vishu in Kerala, is flowering in all the seasons now, which is considered to be due to climate change.

The small changes in temperature and RF could have significant effect on quality of fruits, vegetables, tea, coffee, aromatic and medicinal plants with resultant implications on their prices and trade. In medicinal plants where input use remains low, the direct impact of climatic change would be small (Easterling *et al.,* 2004).

Adaptation

A greater attention is needed on adaptations to climate change. Developing adaptation strategies exclusively for minimizing the negative impact of climatic changes may be risky. Adaptation measures in agriculture include introduction of more resistant crops, integrated crop management, crop diversification and increasing efficiency in irrigation. These measures may not be sufficient to meet the challenges of climate change. Income alternatives are another opportunity to adapt the climate change. Lively hood diversification and additional employment need to be created in the rural areas. There are possibilities for crop diversification as value added from different crops is gaining importance under globalization and supply chain management (Agarwal, 2007).The cultivation and value addition of medicinal plants is an emerging area for rural employment generation and livelihood upliftment. Homestead herbal farming is to be encouraged.

Simple adaptations such as change in planting time and crops with herbal species could help in reducing the impacts of climate change to some extent. Development of alternate species of herbs and farming systems involving tree medicinal plants that are more adaptable to changes in the environment can further ease the pressure (Sharma, 2008).

Development of resource conserving technologies can be another adaptation. Medicinal plants require low resources as inputs for their proper growth and quality development. Green house gas emission from agriculture can be mitigated by changing land use by increasing area under biofuels, tree medicinal plants, agro forestry etc.

Conclusions

Global climate change has considerable implication on Indian agriculture and biodiversity hence on our food security and farmers livelihood, we need to take steps to increase our adaptive capacity. This induces enhanced research on seasonal weather forecasts and their applications for reducing production risks evolving land use systems including medicinal plants, conservation of endangered and extinct medicinal plants etc. For mitigation of green house gases, substitution of food crops with other crops including medicinal plants in the vulnerable agro ecological situation and involvement of biofuel and tree medicinal plants in agro forestry systems etc. are some of the strategies for adaptation of climate change.

Table 1 Effect of situation on yield and quality of Njavara

Situation	Grain yield ($kgha^{-1}$)	Straw yield ($kgha^{-1}$)	Total free aminoacid
Wetland	2401.3	2770.8	0.316
Open upland	841.8	1746.8	0.670
70% shaded upland	684.5	1327.4	0.814
20-40-%shaded upland	728.8	1354.8	0.334

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Identification of morpho-physiological traits contributing towards water stress tolerance in Nendran clones

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Abstract

One-third of the total land area is considered potentially suitable for agriculture. Yield reductions due to drought stress are already serious, and agricultural production scenario may become worse as the most significant impacts of climate change are decline in rainfall and increase in temperature. An understanding of the physiological control of tolerance to the key stresses is of paramount importance for undertaking any crop improvement programme. In general, water extraction, conservation, water use efficiency and difference in intrinsic cellular tolerance characters like membrane stability, protein synthesis, proline accumulation etc. determine drought tolerance. Identification of existing crop varieties with such tolerance characters will be the most suitable strategy for getting prepared for the future water limiting, high temperature climatic conditions. In this angle, evaluation of germplasm in banana gains importance. Cultivation of banana is gaining importance because of its export potential and food value. In Kerala, Nendran occupies top position among cultivated varieties. Nendran banana exhibits intraclonal variation with respect to growth and yield and in Asia, South India is the only area where this variability is exhibited. The highest yield is reported in Quintal Banana, among the Nendran clones. A screening was undertaken for physiological traits contributing towards stress tolerance in Nendran clones at the Instructional farm, College of Agriculture, Vellayani, and the results are presented in this paper.

Introduction

One third of the total land area is considered potentially suitable for agriculture. But abiotic stress in one form or another limits production on most of the world's cultivated land. Yield reductions due to drought stress are already serious, and the agricultural production scenario will still become worse as the most significant impacts of climate change are decline in annual rainfall and increase in temperature. An understanding of the physiological control of tolerance to the key stresses is of paramount importance for undertaking any crop improvement programme. In general, water extraction, conservation, water use efficiency and difference in intrinsic cellular tolerance characters like membrane stability, protein synthesis, proline accumulation etc. determine drought tolerance. Identification of existing crop varieties with such tolerance characters will be the most suitable strategy for getting prepared for the future water limiting, high temperature climatic conditions. In this angle, evaluation of germplasm in banana gains importance. Cultivation of banana is gaining importance because of its export potential and food value. In Kerala, Nendran occupies top position among cultivated varieties. Nendran banana exhibits intraclonal variation with respect to growth and yield and in Asia, South India is the only area where this variability is exhibited (Stover and Simmonds, 1987). The highest yield is reported in Quintal Banana, among the Nendran clones. A screening was undertaken for physiological traits contributing towards stress tolerance in Nendran clones at the Instructional farm, College of Agriculture, Vellayani.

Materials and methods

Collection and establishment of clones: Suckers of nine different cultivated clones of Nendran in Kerala viz. Quintal Banana, Changanasseri Nendran, Manjeri Nendran, Chengazhikodan, Kaliethan, Thiruvodan, MysoreEthan, Attu Nendran and Nedu Nendran were collected from Banana Research Station, Kannara and Instructional farm, College of Agriculture, Vellayani. The experiment was laid out in Randomized Block Design with three replications. Each replication consisted of four experimental plants per clones per block from which various biometric and physiological observations were recorded. Cultivation practices were followed according to the package of practices recommended by Kerala Agricultural University.

Examination of morpho-physiological characters: For studying the stomatal distribution, a thick mixture of thermocol and xylene was smeared on both surface of leaves and allowed to dry. It was peeled gently after drying and the peel was observed under microscope and counted. Stomatal Resistance was recorded using Porometer and expressed in Sec/cm. Stable Isotope

Discrimination Studies were undertaken utilizing the national facility at the Department of Plant Physiology, UAS, Bangalore using the Isotope Ratio Mass Spectrometer coupled with the elemental analyzer for the continuous flow measurement of carbon isotope ratios in plant samples. Extent of wax deposition was studied with the help of Scanning electron Microscopy.

Result and discussion

In the present investigation different plant processes and parameters which contribute to better water use efficiency and water conservation like leaf area, stomatal distribution, stomatal functioning, mesophyll efficiency and epicuticular wax deposition were undertaken. Significant variations were observed in case of leaf area and stomatal distribution among the different clones (Table 1).

Table 1 Clonal variations in stomatal frequency and stomatal index

Clones	Parameters			
	Stomatal frequency (cm^2)		Stomatal Index (%)	
	Upper surface	Lower surface	Upper surface	Lower surface
Quintal Banana	407.25	1512.75	5.15	17.85
AttuNendran	452.50	1540.25	5.52	17.70
Changanasseri Nendran	405.25	1395.00	5.25	16.65
Chengazhikodan	347.25	1568.25	4.50	19.25
Kaliethan	405.50	1482.75	5.25	18.15
Manjeri Nendran	290.00	1278.00	3.57	14.85
Thiruvodan	465.50	1715.50	6.15	20.05
Mysore Ethan	493.50	1685.25	6.15	19.45
Nedu Nendran	318.50	1588.00	3.97	18.35
Mean	404.90	1524.70	5.13	17.95
C.D (5%)	1.344	1.657	0.091	0.095

Quintal Banana recorded maximum values in the cases of light intercepting area, least stomatal resistance, facilitating easy diffusion of CO_2 from the atmosphere into the intercellular spaces. It is evident from several studies that the assimilation rate is substrate limited under non stressed conditions (Farquhar et al.1982; Sheshashayee et al. 2003) and altered stomatal behavior was reported by Uprety et al. (1986) under modified environments. Quintal Banana also recorded the least stable isotope discrimination values (Table 2) showing very high mesophyll capacity in fixing the internal CO_2. Scanning Electron Microscopy showed high deposits of epicuticular wax and sunken type of stomata in the case of Quintal banana suggestive of high water use efficiency and drought tolerance.

Table 2 Clonal variation in yield, Stomatal resistance and isotope discrimination

Clones	Stomatal Resistance (Sec cm^{-1})	Yield (Kg)	CO_2 Isotope discrimination
Quintal Banana	2.47	17.75	17.54
AttuNendra	4.55	8.13	18.52
ChanganasseriNendran	2.50	5.40	19.17
Chengazhikodan	4.65	5.77	19.12
Kaliethan	9.70	6.62	19.47
Manjeri Nendran	7.17	5.5	18.09
Thiruvodan	5.07	6.02	18.41
Mysore Ethan	2.50	9.32	19.19
Nedu Nendran	5.27	7.00	18.01
Mean	4.59	7.62	18.55
C.D (5%)	1.25	1.74	0.86

This study reveals the potential of Quintal banana in terms of high photosynthetic efficiency, high water use efficiency and high drought tolerance which could be further exploited in future crop improvement programmes.

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Effect of weather on the productivity of black pepper and coffee under Wayanad conditions

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ABSTRACT

The effect of temperature and rainfall on yield of pepper and coffee were studied under Wayanad conditions. The amount of rainfall and maximum temperature during the entire growth period were correlated with pepper and coffee yields during the period 2000 to 2008. It was observed that the temperature and amount of rainfall during the second fortnight of March determined the productivity of the pepper considerably. Increase in maximum temperature (18 March to 31 March) had a significant positive correlation and resulted in good yields whereas the amount of rainfall adversely affected the yield. The yields were further reduced considerably if it is followed by a dry spell. On the other hand a total monthly rainfall more than 15 mm during February had a significant positive correlation and resulted in high yield of coffee. Multiple linear regression models were developed based on maximum temperature and rainfall and can be used for predicting the productivity of the above crops.

Introduction

Coffee and pepper mixed cropping is one of the most prevalent farming systems in Wayanad district of Kerala. Both these crops are grown under rainfed condition by the marginal farmers and thus the productivity of these crops are highly dependant on the vagaries of weather parameters particularly rainfall.

Kerala is the second largest producer of coffee in India. It produces 23 percent of the total coffee output in the country. The coffee economy of Kerala is virtually the coffee economy of Wayanad. Wayanad produces 90 percent of the total coffee output in the State. India produces about 3.2 percent of the global coffee output. In 1998-'99 the total production in the country was 0.23 million tonnes, of which Arabica constituted 9.7 thousand tones and Robusta 13.3 thousand tonnes. The total production in 1999-2000 was estimated at 285 thousand tonnes, 120 thousand tonnes of Arabica and 165 thousand tonnes of Robusta. The per hectare productivity of coffee increased from 204 kg in 1970-'71 to 801 kg in 1991-'92, but fell back to 615 kg in 1994-'95. Productivity of Robusta had not registered any increase till 1954-'55. A small increase in production was recorded due to expansion in area. But after the 1960s, yield rates were highly fluctuating with the trend growing due to introduction of intensive cultivation. The yield of the Robusta variety was much higher than that of the Arabica species. Robusta used to be comparatively unaffected by pests like white stem-borer diseases like leaf rust. Robusta coffee very quickly responds to changes in weather. Timely rainfall with adequate intensity raises the yield of the Robusta variety. Production and productivity are deeply related to the timing of the blossom showers. If blossom showers fail, production also falls heavily.

The production of pepper has declined considerably in the country owing to climatic changes and various diseases that affected the pepper vines in recent years. The total production of pepper in the country in the 2001-02 financial year was 80,000 tonnes against 50,000 in 2005-06. In the total production of pepper 80 to 90 per cent is contributed by the State. The pepper is mainly grown in Idukki and Wayanad districts. Owing to the drastic decline in the pepper production, the lands which were utilized for pepper cultivation also shrank considerably. Wayanad, which is considered as land of spices produced 22,385 tonnes of pepper from 43,039ha in 1995-96, harvested just 9,828 tonnes from 36,488ha in 2006-07, according to data available with the state directorate of economics and statistics. Black pepper produced from this hill station is famous in the world of spices because of its unique quality and aroma.

The pepper plant is very sensitive to climatic parameters especially the rainfall pattern. The yield of pepper is highly dependent on the amount and distribution of rainfall. The flowering and fertilization is highly synchronized with rainy season and water is acting as pollinating agent in pepper. Considering the yield a dry spell before flowering season is advantages to the crop (Rema menon 1981 and Nalini 1983). Nalini (1983) also noticed a positive correlation of rainfall with flower bud differentiation process which is started during April – May with the receipt of pre monsoon showers. The period required for flower bud to differentiate was forward to be about 20 days (Sukumara Pillay *et al.*, 1987).

Materials and methods

Yields of dried pepper and coffee recorded at Regional Agricultural Research Station, Ambalavayal from the year 2000-2008 are correlated with weekly and monthly values of temperature and rainfall. The variety Panniyur I (pepper) and Robusta (Coffee) were selected to study the effect of rainfall and temperature on productivity.

Results and discussion

Productivity of coffee and black pepper is shown in Table 1, Highest productivity was recorded during the year 2001 followed by 2000 and 2007 in which the crops experienced a day spell during 12th and 13th Standard week (March 18-30). The above mentioned crops received a total rainfall of more than 70 mm, required for flower bud differentiation only by the end of 15th STD week (April 15 to 21). They received sufficient amount of rainfall through out the critical period (16 weeks from flower bud initiation) and resulted good yields. Where as during the years 2003 and 2008 the crops received more than 70 mm rainfall during the last fortnight of March and the flower bud differentiation was started between 1 to 21 April and the berry yields were adversely affected. The Stress experienced by the year 2008 during the early stages of flower bud differentiation (20 days after the receipt of 70 mm rainfall) further reduced the yield.

Table 2 Productivity of coffee and black pepper

Year	Dried coffee (Kg/ha)	Black pepper (Kg/ha)
2000	656	387
2001	802	398
2002	639	326
2003	739	285
2004	690	324
2005	660	334
2006	598	318
2007	705	357
2008	703	198

The other weather parameter that affected pepper productivity is maximum temperature. Positive correlation between maximum temperature (12th and 13th STD week) and production of pepper is also noticed. Even through, the maximum temperature is greatly dependent upon the quantity and distribution of rainfall, it is seen that a temperature above 30° C is required by crop to prolong the bud differentiation and the get away from the stress during the early stages of flower bud development. Minimum temperature during the period has no significant affect on the berry yield.

Productivity of pepper was estimated using multiple regression models. Rainfall and maximum temperature are used as independent variables to develop regression model. The following regression model was developed to predict to the yield.

Pepper yield (Kg/ha) = -610.265 + 31.344 Max T - 1.085 RF (R^2 = 0.88)

Max T = Mean maximum temperature during the last fortnight of March

RF = Total rainfall during the last fortnight of March

Monthly rainfall and weekly temperatures (Minimum and maximum temperature) are correlated with coffee yield. No blossom showers were received in 2006 which resulted in poor coffee yield (598 kg/ha). From the Table 2 it can be noticed that a minimum of 15 mm monthly rainfall during February is a must for better coffee production. During the study period there was no shortfall in backing up showers. The highest productivity (802 kg/ha) was recorded in the year 2001 which experienced a total monthly rainfall of 47.2mm during the month of February and there is no dearth in backing up showers in April. The coffee yield is also affected by minimum temperature. Minimum temperature during April has a significant negative correlation with coffee yield under Wayanad conditions. But maximum temperature during the entire growth period has no significant relation with coffee production.

Table 2 Monthly rainfall data from 2000 to 2008

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	0.8	1.4	1.4	110.8	107	335	222.4	395.3	271.5	138.2	53.8	106.2
2001	0	47.2	12	206.2	101.6	232	313	194.1	140.8	100.2	88.8	10.2
2002	0	0.6	29	93.4	89	170.4	168.2	219.4	48.2	266.1	24.2	0
2003	4.8	16	104.2	131.4	74.6	208	281.4	211.8	55.6	349.63	83.2	0
2004	0	10	35.8	132.4	258.6	384.2	299.4	357.8	142	171.2	108.4	0
2005	25.6	2.8	54.2	147	96.6	270.6	697.2	278.8	166.2	317.6	99	12.6
2006	30	0	85.4	97	349.2	333	375.8	272	240.4	99.4	165.6	0
2007	1.2	16.2	5.2	94.8	135.2	284.8	619.4	398.8	262.4	170.4	26.8	8
2008	0	41.2	178.8	75.2	66.2	224.2	277.4	358.4	89.6	401.8	15.2	3

The following multiple regression model was developed based on rainfall during February and April,

Coffee yield (Kg/ha) = 579.681+ 2.266 Rain (Feb) + 0,614 Rain (April) (R2= 0.82)

Rain (Feb) = Total rainfall during February

Rain (April) = Total rainfall during April

From this investigation it was noticed that summer rains during February and April were favourable to both coffee and pepper. Rainfall in March adversely affected the black pepper yield. In order to cope up with varying climatic conditions, mixed farming of coffee and pepper are highly advisable to ensure a reasonable net return from unit area.

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Yield of promising somaclones in ginger as influenced by weather parameters

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Abstract

Investigations on the influence of weather parameters on yield of selected somaclones in ginger were attempted at College of Horticulture, Kerala Agricultural University. Yield data of selected somaclones recorded for four seasons (2005 -08) were correlated with weather parameters of respective seasons. Strong correlations existed between yield of somaclones and weather parameters. Performance of clones was found to vary in the varied weather situations of the four seasons, suggesting situation specific recommendation of clones for large scale cultivation.

Introduction

Ginger (*Zingiber officinale* Rosc.) is predominantly cultivated as a rainfed crop in Kerala. The growth and productivity of the crop are highly influenced by the climatic parameters. Advanced Variety Trials of promising somaclones of ginger were in progress at College of Horticulture, Vellanikkara from 2005 onwards. Evaluation of yield performance of clones for four seasons (2005-08), showed that yield was better in some seasons for the clones evaluated. Hence the present study is aimed to make an in depth analysis of weather parameters during the four seasons (2005-2008), to study the influence of weather parameters on yield of selected somaclones and to assess the performance of selected clones under varied weather situations.

Materials and methods

The promising somaclones of ginger were raised in 3x 1 m beds with 40 plants/ bed. In all the four seasons of study, planting was done in May last week and harvesting in January first week of subsequent year. The crop was managed as per Package of Practices recommendations of Kerala Agricultural University. The monthly weather data during the four seasons of study were collected from the meteorological observatory of College of Horticulture, Vellanikkara. The yield recorded for the four selected disease tolerant somaclones viz. M VI, 970 M, B3 and 364 R were subjected to correlation analysis with weather parameters. The meteorological data collected for the entire growth period of the crop (May-December) and active growth phase / critical growth period of the crop (June-September) were separately analysed and correlation coefficients were worked out.

Results and discussion

In the growth cycle of ginger, three growth phases were observed. An active growth phase up to four months after planting followed by a slow growth phase from fourth to sixth months after planting and senescence phase from sixth month to harvest of the crop (Johnson, 1978). The weather parameters at active growth phase of the crop significantly influenced yield in ginger.

The yield data of selected promising somaclones of ginger for the four seasons (2005-08) are furnished in Table 1. The yield of different somaclones evaluated was found higher in 2005 and 2007 seasons as compared to 2006 and 2008 seasons. Irrespective of the seasons studied, the clone B_3 recorded higher yield (11.20 kg/ 3m²) followed by M VI (10.48) , 970 M (9.67) and 364 R (6.92).

Table 1 Yield of promising somaclones of ginger during 2005 to 08 seasons

Clones	Yield (kg/ 3m²)				Mean
	2005	2006	2007	2008	
M VI	11.79	9.14	13.16	7.82	10.48
970 M	11.04	7.58	11.99	8.06	9.67
B_3	12.45	10.50	12.80	9.03	11.20
364 R	7.31	5.12	6.58	8.68	6.92
Mean	10.65	8.09	11.13	8.40	9.57

The weather parameters were found to vary in the four seasons analysed. Of the ten variables analysed, total rainfall, number of rainy days, relative humidity, total sunshine hours and mean sunshine hours / day influenced the yield significantly. Highly significant positive correlations with yield were observed for total rainfall, number of rainy days and relative humidity, while highly significant negative correlations were observed for total sunshine hours and mean sunshine hours/ day during the period from June to September of each season (Table 2).

Table 2 Weather during June to September and correlations with yield

Year	Mean Relative Humidity (%)	Total rainfall (mm)	Total number of rainy days	Total sunshine hours	Mean sunshine hours/day
2005	85.25	2201.5	83	368.2	3.02
2006	84	2200.4	78	430.7	3.52
2007	85.5	3274.0	93	303.2	2.47
2008	82.75	1689.1	73	411.1	3.38
Correlation with yield	0.4966	0.4165	0.4958	-0.52752	-0.5257

Better yields recorded by the clones during 2005 and 2007 seasons might be thus be attributed to high rainfall, more number of rainy days, high humid condition and less sunshine hours recorded for the seasons and vice versa for the low yield realised for the clones in 2006 and 2008 seasons. Even though, the rainfall recorded was almost uniform in 2005 and 2006 seasons, the more number of rainy days and less sunshine hours recorded in 2005 season might have favourably contributed to yield.

The performance of clones was found to vary in the different weather conditions of the four seasons. High rainfall (3274 mm), more number of rainy days (93) and high relative humidity (85.5 %) during June to September period were found to give higher yield in all the three clones studied except the clone 364 R. The clone M VI and 970 M responded more to climatic variables than other clones studied. Under situations of medium rainfall (2200 mm) with less number of rainy days (80), the clone B_3 performed better than M VI. The clone 364 R was not found to perform well in high rainfall, high humid situation. Instead, it preferred a low rainfall (1689 mm) situation with less number of rainy days (73). At very low rainfall situation experienced in the year 2008, the clones B_3 and 364 R performed better than M VI and 970 M. The favourable effect of high rainfall and high relative humidity for achieving higher yield from ginger was also reported by Ravindran *et.al* (2006).

All the clones recorded higher yield at low sunshine situation (total sunshine hours of 300 and mean sunshine hours of 2.5 h/day). Yield was found to decrease when there was more sunshine hours during the active growth phase of the crop. The reduction in yield was more pronounced in the clone M VI and 970 M as compared to the clone B_3. The clone B_3 could tolerate high exposure to sunlight than M VI and 970 M during the active growth phase of the crop. The clone 364 R preferred high sunshine situation for better yield.

It could be concluded from the present investigations that weather parameters were found to vary in the four seasons studied. There existed strong correlations between weather parameters at active growth phase and yield in ginger. High rainfall (3274 mm), more number of rainy days (93) , high relative humidity (85.5 %) and less sunshine hours (2.5 h/day) during June to September were found ideal for getting higher yield from ginger. However, variations in the performance of clones were observed under varied weather situations of the four seasons. The clones, M VI, B_3 and 970 M performed better under high rainfall, high humid and low sunshine situations. The clone B_3 also performed better under medium rainfall, less humid and more sunshine situations. The clone 364 R even though was poor in performance under high rainfall and high humid situations, performed better in very less rainfall situation with more sunshine hours.

This study helped to get an insight into seasonal variations in weather parameters, correlation of yield in ginger with weather parameters and performance of selected clones under varied weather situations and paved way for the situation specific recommendation of clones for large scale cultivation.

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Influence of micro meteorological factors on flowering and quality of cured beans in vanilla

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Abstract

Investigations on the influence of micro meteorological factors on flowering and quality of cured beans in vanilla were under taken at College of Horticulture, Kerala Agricultural University, Vellanikkara and in selected farmers' fields at Thrissur, Palakkad and Malappuram districts during 2004 to 2007. The micro meteorological parameters were found to vary in the experimental fields of three districts selected for the study. Flower initiation, flower opening and quality of cured beans in vanilla were influenced by micro meteorological parameters. The ideal micro meteorological parameters identified in the present study could be extended to other areas to improve production and productivity of vanilla. The information gathered on micro meteorological situations of vanilla gardens of different districts could be utilized for manipulation of micro climate.

Introduction

Vanilla (*Vanilla planifolia* Andrews), the tropical orchid spice grows better in a warm humid climate with an annual rain fall of 150-300 cm and a temperature range of 25-32°C. Areas which receive rains for 8-9 months and which have a dry climate in the remaining 3-4 months are ideal for growing vanilla. It grows well under trees which provide filtered sun light of about 50 per cent. Vanilla could be cultivated from sea level up to an altitude of 1500 meters above MSL. In southern parts of peninsular India, places like Wayanad and Idukki districts of Kerala, Coorg, North and South Kanara districts of Karnataka are best suited for cultivation of vanilla (Spices Board, 2003).

Due to high price prevailed for the crop during 2000 to 2003, large scale expansion of the crop took place in almost all districts of Kerala. In new areas, where the cultivation of the crop was expanded, the above requirements of the crop were often not met with. Hence, studies on microclimate and its influence on growth , yield and quality and manipulation of microclimate to achieve high and sustained production are of great significance in vanilla in the changed environmental conditions. Investigations on the influence of micro meteorological factors on flowering and quality of processed beans in vanilla were hence taken up at College of Horticulture, Kerala Agricultural University, Vellanikkara and in selected farmers' fields at Thrissur, Palghat and Malappuram districts during 2004 to 2007.

Materials and methods

Three progressive vanilla growers, one each in Thrissur, Palghat and Malappuram districts were selected for the investigations through Krishi Bhavans of respective areas. Vanilla was grown as inter crop of coconut and arecanut in the selected plots. The selected farmers maintained more than 800 vanilla vines in their garden and were well versed with the techniques of cultivation. Uniform plants from the selected fields were marked for imposing treatments and recording observations.

Single Stevenson screens were installed, one each in selected farmers' fields at three locations and one in Plantation Crops & Spices farm of College of Horticulture to study the micrometeorological situations of vanilla gardens. Farmers were given training for recording dry bulb, wet bulb, maximum and minimum thermometer readings. Digital Light meter were also distributed to selected farmers and light intensity measurements were recorded in various blocks of the experimental fields, divided based on infiltration of light. A moisture stress for a period of one and a half month was given to vanilla plants during November - December to induce flowering.

Observations on maximum temperature, minimum temperature, Relative Humidity, Light intensity and light infiltration were recorded. The micrometeorological situations of different locations were compared. The influence of micrometeorological factors on flower initiation and flowering were worked out using Pearson correlations. The cured beans of vanilla from different locations were analysed for important flavour compounds like vanillin, vanillic acid, *p*-hydroxy benzoic acid and *p*-hydroxy benzaldehyde using HPLC analysis.

Results and discussion

Studies on micro meteorological parameters of selected gardens

The micrometeorological parameters were found to vary in the experimental fields of three districts selected for the study. The mean maximum temperature varied from 31.35 to 32.60°C, minimum temperature from 22.71 to 23.52°C and Relative Humidity from 68.81 to 86.92 per cent in the locations studied. The mean temperature recorded in different locations showed not much variation but Relative Humidity showed high variation.

The weekly observations on maximum temperature, minimum temperature and Relative Humidity were recorded year round to know the trends in variation of different parameters in the selected plots. The maximum temperature showed high variation in different plots during summer months from January to May. Minimum temperature showed variation during November to July. Relative humidity showed variation during November to May in different locations. The relative humidity was significantly different in the selected plots of different districts. Very high temperature (> 35°C) and very less Relative humidity (<50 %) which are not congenial for vanilla were observed in the selected plots.

Light intensity readings were found to vary in different plots in the four locations studied. Light intensity readings from different directions followed the same trend in all the four selected plots recording high intensity readings after the two loppings of standards in May and September. The light intensity readings from various directions in the selected plots were in between 50 to100 Lux for most part of the year, except for the period of lopping. Similarly, light infiltration was found more in the garden after the lopping of standards. Barring the lopping period, percentage light infiltration in selected plots varied from 20 to 60.

Based on analyses of growth, flowering, fruit growth and yield of vanilla, the micro meteorological conditions of experimental plot of Palghat district were found better which could be extended to other areas to improve production and productivity of vanilla. The micro meteorological parameters recorded in the ideal location is furnished in Table 1.

Table 1 Micrometeorological parameters in ideal plot of Palakkad district

Sl.No	Parameters	Values (Mean)
1.	Maximum temperature (°C)	31.35
2.	Minimum temperature (°C)	22.84
3.	Relative humidity (%)	86.92
4.	Light intensity (Lux) - North	77.23
5.	Light intensity(Lux) - South	73.22
6.	Light intensity(Lux) - East	89.62
7.	Light intensity(Lux) - West	89.17
8.	Light infiltration percentage (Range)	20 -30

The micro climate of vanilla garden could be adjusted to some extent by manipulating the micro climate. Shade regulation and misting of water are the two practices that could be adopted to manipulate the micro climate of the garden. The period at which the different micro meteorological parameters showed variation also should be taken into consideration while manipulating the micro climate.

Influence of micro meteorological factors on flowering in vanilla

The influence of micro meteorological factors on flower initiation and flowering were worked out using Pearson correlations and correlations are depicted in Fig. 1a and 1 b.

Flowering in vanilla is a complex phenomenon which is influenced by physiological maturity of the plant, the extent of moisture stress in the garden, microclimate of the garden and management practices. Flower initiation in vanilla was observed in December last week to January. From flower initiation to flowering, it took 30-45 days. Flower initiation and flowering in vanilla were influenced by micrometeorological factors.

Flower initiation in vanilla was found positively correlated with minimum temperature, soil temperature, relative humidity, rainfall and cloud and negatively with maximum temperature and wind speed. The positive correlation of minimum temperature and relative humidity with flower initiation was highly significant. The favourable effect of low minimum temperature for flower bud initiation was reported in crops like mango (Rameshwar, 1988) and pine apple (Freend,1981). Flower opening / flowering in vanilla was positively correlated with

Fig. 1a Flowering vs. meteorological parameters during 2005

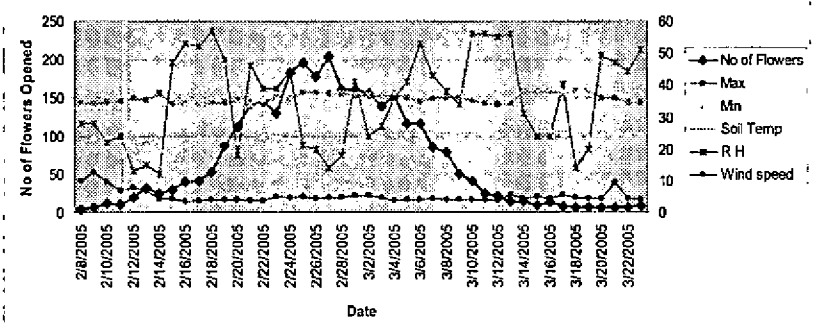
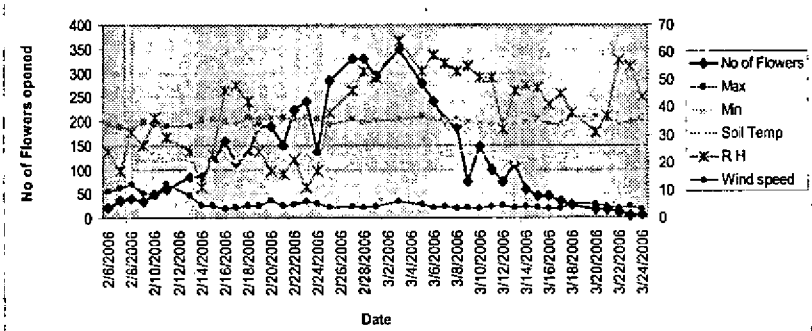


Fig. 1b Flowering vs. meteorological parameters during 2006



maximum temperature and negatively with minimum temperature, soil temperature, relative humidity, wind speed and cloud. The peak flowering in vanilla was observed during February - March. Flower opening is hence positively correlated with maximum temperature. Requirement of a lower temperature for flower bud initiation and a higher temperature for flower opening was reported in citrus by Okuda *et.al* (2004) and in saffron by Molina *et.al* (2005).

Flower opening in vanilla showed highly significant positive correlation with light received from North and South directions and percentage of light infiltration. This showed the essential requirement of undertaking the second lopping of standards in vanilla gardens during September- October. This would help for better light intensity and infiltration in the garden which in turn helped for getting proper flowering and growth of beans. The requirement of high light intensity for proper flowering was

Fig. 2a Light intensity vs. flowering in vanilla

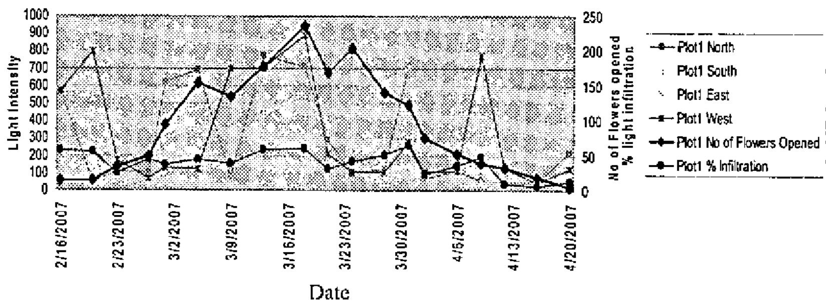
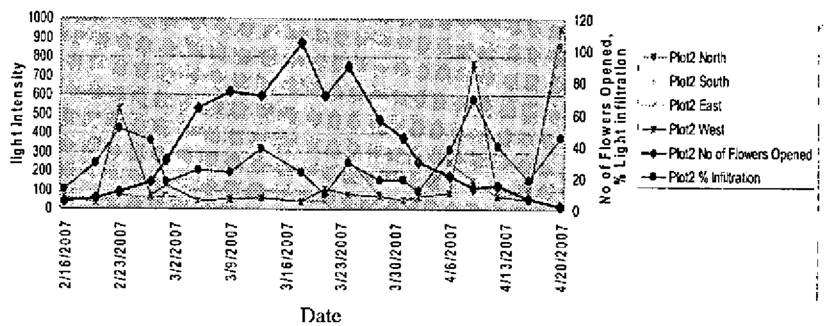


Fig. 2b Light intensity vs. flowering in vanilla



reported in *Oncidium* spp. by Song *et.al.* (1988) and in miltonia by Matsui and Yoneda (1999).

Influence of micro meteorological factors on quality of cured beans in vanilla

Vanilla flavour is a highly complex mixture consisting of more than 200 volatile aromatic compounds (Klimes and Lamparsky, 1976). Of these, vanillin is the most abundant one. Other important volatile constituents of vanilla aroma are *p*-hydroxy benzoic acid , *p*-hydroxy benzaldehyde and vanillic acid. The quantity of the above flavour compounds and the ratios of the flavour compounds with vanillin are important in flavour industry. The quality of vanilla beans is greatly influenced by the source of origin, climatic conditions and curing procedure adopted.

The cured beans of vanilla from three districts were analysed for different flavour compounds like vanillin, vanillic acid, *p*-hydroxy benzoic acid and *p*-hydroxy benzaldehyde. The results indicated that the quantity of flavour compounds differed in bean samples of various locations. So micrometeorological factors of different locations influenced the quality of vanilla (Table 2). The highest vanillin content was recorded in the beans from Thrissur (2.57%), followed by Palghat and Malappuram. Para-hydroxy benzoic acid showed no variation in beans of Malappuram and Palakkad districts. Vanillic acid was found highest for the beans from Thrissur. However, elabourate studies including more locations and more number of samples are required for detailed location specific assessment of quality in vanilla.

Table 2 Quality of vanilla beans as influenced by locations

Locations	Vanillin (%)	P-hydroxy benzoic acid (ppm)	P-hydroxy benzaldehyde (ppm)	Vanillic acid (ppm)
Palakkad	2.50	74	654	642
Thrissur	2.57	180	676	1390
Malappuram	2.45	72	802	701

It could be concluded from the present investigations that the micrometeorological parameters were found to vary in the experimental fields of three districts selected for the study. Very high temperature (> 35°C) and very less Relative humidity (<50 %) which are not congenial for vanilla were observed in the selected plots Considerable variation was observed in light intensity readings and light infiltration percentage in different plots within the experimental field. The light intensity and infiltration in the garden influenced vine growth, flowering, fruit growth and yield in vanilla. Flower initiation in vanilla was positively correlated with minimum temperature and relative humidity. Flowering/ flower opening in vanilla was positively correlated with maximum temperature and negatively with minimum temperature, relative humidity and wind speed. Flowering in vanilla showed highly significant positive correlation with light received from North and South directions and percentage light infiltration in the garden. The micrometeorological factors influenced flavour compounds in cured beans of vanilla.

The ideal micro meteorological parameters identified in the present study could be extended to other areas to improve production and productivity of vanilla. The information gathered on micro meteorological situations of vanilla gardens could be effectively utilized for manipulation of micro climate of vanilla garden.

Acknowledgement

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Climate variability and cocoa in Kerala

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Abstract

Increase in maximum and minimum temperatures while decrease in monsoon rainfall and increase in post monsoon rainfall were the trends observed in Kerala. Interestingly, cyclic trends of 40-60 years were observed in annual rainfall of Kerala. Such trends differed widely from location to location and season to season within the State of Kerala. It was more so when short periods' data were analysed due to high variability in annual rainfall in recent years.

High rainfall appeared to be adversely affected the annual cocoa production of the State as the difference in cocoa yield during rainy months was very significant, followed by post monsoon between good and poor yield years. Also, the maximum temperature during summer plays a major role in deciding the annual yield of cocoa. The mean maximum temperature during summer was high (34.7°C) in poor yield years while less (34.2° C) in good yield years. A mean maximum difference of 1.1° C was noticed in April between good and bad yield years. An increase of 1-3°C in maximum temperature from January to March against the normal led to a decline of 30-40% in annual cocoa yield under rainfed conditions as noticed in 2004 (Severe summer drought). It revealed that high maximum temperature during summer, followed by heavy rains during the monsoon period is the major climatic constraint limiting the cocoa production and productivity in the humid tropics of Kerala. Under the projected climate change scenario, uncertainties in monsoon rainfall and increase in maximum temperature during the summer are likely to influence cocoa production adversely to a considerable extent in the humid tropics.

Introduction

Cocoa was introduced in India as a profitable mixed crop in coconut and arecanut plantations in 1960s across Kerala. Kerala ranked first in production, accounting for 33% of area and 57% of production in India. Cocoa needs equitable climate with wel distributed rainfall. It requires an annual rainfall of 1500-2000 mm with a minimum of 90-100 mm rainfall per month. However, it is grown under uneven distributed rainfall with fairly well defined dry and wet seasons. Such seasonal changes exert marked effects on the growth of the cocoa tree, and on its cycle of flushing, flowering and fruiting. The optimum temperature range for cocoa varies from 21.1 °C to 32.2 °C, with mean monthly minimum of 15 °C as the lower limit and an absolute minimum of 10 °C. It also performs well under open conditions and yields better when compared to shaded conditions. However, young cocoa plants need shade for better survival (Nair et al. 2002). Cocoa productivity may be adversely affected due to occurrence of floods and droughts as it is sensitive to waterlogging as well as soil moisture stress. High summer temperature is also not conducive for better cocoa production as noticed in summer 2004 (Amma et. al, 2005). All these reveal that crop is highly sensitive to weather aberrations. Under the projected climate change scenario, the frequency of occurrence of floods and droughts is likely to increase in the ensuing decades (Shukla et al 2002). It may not only lead to decline in area but also low cocoa production. Therefore, strategies on mitigation and adaptation against weather extremes are to be chalked out on war footing (Rao, 2008 and Rao et al, 2008). Keeping the above in view, an attempt has been made to understand the effect of climate on cocoa production in Kerala.

Materials and methods

Area, production and productivity of cocoa in Kerala were collected for the last 25 years, commencing from 1982-83 to 2007-08. Monthly cocoa yield of the Cadbury – KAU Co-operative Cocoa Research Project farm were also collected for 100 trees from 1991 to 2007 along with the weather data. The annual rainfall of Kerala was collected for the last 140 years. Data on surface air temperature were also collected for the selected stations since last 49 years (1956-2004). The yield data were subjected to the Student-t distribution to understand the effect of alternate bearing on cocoa yield. Trend analysis was carried out to understand the behaviour of rainfall and temperature during the study period. Crop weather relationships were also worked out.

Results and discussion

The area under cocoa was very high and revolved around 18,000 ha. in 1980s. Thereafter, a sharp decline was noticed and reached to its low in 1994-95. The cocoa had experienced the market crisis in early 1970s, 1980s and 1990s during which most of the cocoa plantations were cut and removed. The percentage decline in area was 62 per cent. A gradual regain in cocoa area was noticed since 1995-96 onwards and stabilized at 10,500 ha in 2007 - 08. Overall there was sharp decline (42%) in area during the study period. The production and productivity was the lowest in 1982 - 83 (82kg/ha), followed by 1983-84 (215kg/ha). The maximum (6000 t) cocoa production was recorded in 2007 - 08 with lesser area (Fig.1). The trend was similar in the case of productivity, recording the maximum in recent years (570 kg/ ha). It revealed that there was a sharp decline in cocoa area while increase in production and productivity.

The annual pod yield of Vellanikkara farm during the study period (1991-2007) showed a declining trend, indicating that the yield

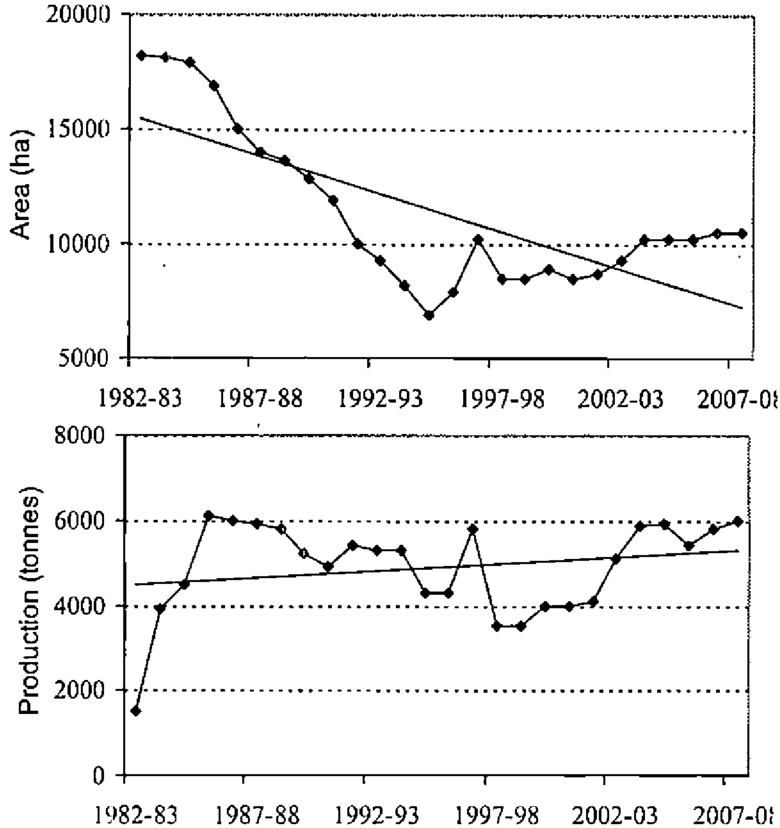

Fig 1 Area, production of cocoa over Kerala from 1982-83 to 2007-08

potential of the trees came down year-after-year due to age of the trees. It was predominant after 2000 onwards (Fig. 2). The annual number of pods was low during 2004 (28.2 pods/tree), 1998 (40.4 pods/tree), 2002 (41.1 pods/tree), 2006 (41.1 pods/

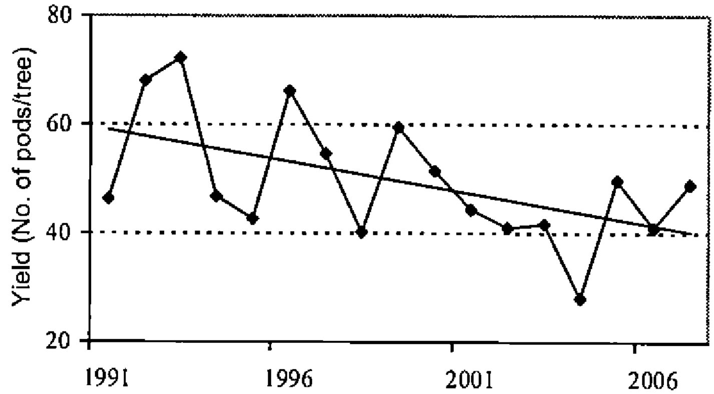

Fig 2 Annual cocoa yield at CCRP farm, Vellanikkara from 1991-2007

tree), 2003 (41.7 pods/tree) and 1995 (42.7 pods/tree) while more during 1993 (72.2 pods/tree), 1992 (68.2 pods/tree), 1996 (66.1 pods/tree) and 1999 (59.6 pods/tree). The annual yield was intermediary in 1991 (46.3 pods/tree), 1994 (46.8 pods/tree), 1997 (54.7 pods/tree), 2001 (51.4 pods/tree), 2000 (44.4 pods/ tree), 2005 (49.8 pods/tree) and 2007 (49.2 pods/tree). The coefficient of variation was vary high (48.9 – 124.3%) in monthly pod yield of cocoa while it was less (23%) in the case annual yield of cocoa. It indicated that the monthly cocoa yield is very sensitive to extreme weather conditions unlike in the case annual yield. The cocoa yield is also highly variable during the rainy season (June-August) as the coefficient of variation is very high, varying between 88.6 and 124.3%. It also showed no significant difference in cocoa yield between alternate years, indicating that cocoa is a regular yielder with no biennial bearing tendency (Table 1). It revealed that the inter-annual/seasonal/monthly variation of cocoa yield could be attributed to weather aberrations.

Increase in maximum and minimum temperatures and decrease in monsoon rainfall were the trends observed in Kerala. Interestingly, cyclic trends of every 40- 60 years were observed in annual rainfall. Such trends differ widely from location to location and season to season based on short period climatological data (Fig. 3). Annual rainfall was highly variable in recent decades and no trend was noticed at Vellanikkara.

Table 1 Annual cocoa yield in alternate years at Vellanikkara farm

Odd years		Even years	
Year	Yield (Pods/tree)	Year	Yield (Pods/tree)
1991	46.3	1992	68.2
1993	72.2	1994	46.8
1995	42.7	1996	66.1
1997	54.7	1998	40.4
1999	59.6	2000	51.4
2001	44.4	2002	41.1
2003	41.7	2004	28.2
2005	49.8	2006	41.1
2007	49.2	-	-
Mean	51.2	Mean	47.9

Student t value = 0.28; not significant

It is a complex phenomenon to workout relationship between the climate trends and the cocoa production at the State level as the crop had undergone a market crisis in 1980s and 1990s and cocoa plantations were cut and replaced with other profitable crops like rubber. It was a neglected crop for long because of the low price in the market. Recently only, farmers started to take care of cocoa plantations on commercial angle. However, high rainfall appeared to be adversely affected the annual cocoa production of the State. For example, the annual rainfall recorded during 1994-95 was high (3183mm) in which annual cocoa production was low (4300 t). It was also true in the case of 1997-98 (2887mm), 1998-99 (3027 mm) and 1999-2000 (2898 mm) as the cocoa production during the above years was recoded as 3500, 3500 and 4000 t, respectively. In contrast, the annual cocoa production was more (6100 t) when the rainfall recorded was low (2481 mm) during 1985-05(2571 mm) and cocoa production recorded was 6000, 5870 and 5900 t, respectively. Similar trend was noticed in experimental plots too. The difference in cocoa yield during rainy months was significant, followed by post monsoon between good and bad yield years and thus the adverse influence of heavy rains and cocoa yield. It revealed that high rainfall, heavy cloudiness, low bright sunshine and high relative humidity appeared to be detrimental to cocoa.

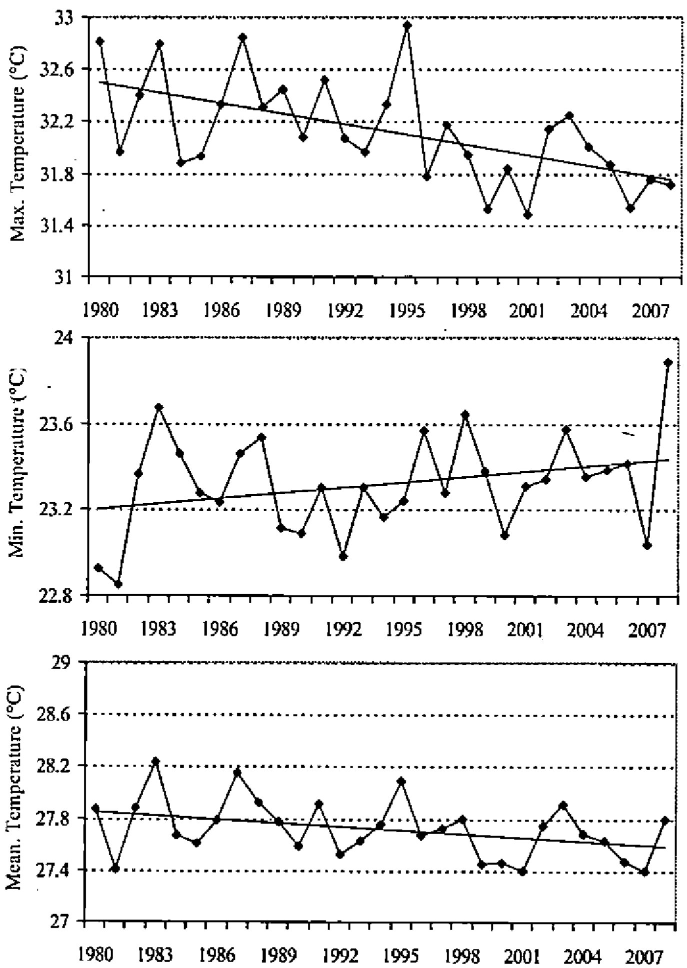

Fig. 3 Annual maximum, minimum and mean temperature at Vellanikkara

In the case of surface air temperature, it had influenced the annual yield negatively. For example, the annual cocoa production was less (3500 t) when mean temperature was high (28.1°C) during 1998-99. Similar was the case in 1995-96 (27.9°C) when the production was low (4300 t). In contrast, the production was more (5800 t) during 1996 when the surface air temperature was low (27.7°C). The maximum temperature during summer was high (34.7°C) in poor yield years while less (34.2°C) in good yield years (Table 2). A mean maximum difference of 1.1°C was noticed in April between good and poor yield years.

Table 2 Monthly maximum temperatures in summer in good and bad yield years

Months	Max. temp. in good yield years (°C)					Max. temp. in poor yield years (°C)				Normal (°C)
	1992	1993	1996	1999	Mean	2004	1998	1995	Mean	
January	32.6	32.7	33.1	32.4	32.7	33.4	33.1	32.9	33.1	32.8
February	34.4	34.1	34.7	34.5	34.4	35.2	34.4	35.4	35.0	34.8
March	36.9	35.4	36.4	35.5	36.1	36.5	36.2	37.6	36.8	36.1
April	36.3	35.6	34.6	33.4	34.9	34.8	36.5	36.6	36.0	35.4
May	33.8	34.4	32.8	30.7	33.0	30.4	34.2	33.5	32.7	33.8
Mean	34.8	34.4	34.3	33.3	34.2	34.1	34.9	35.2	34.7	34.5

Whenever there was an increase in maximum temperature against the normal, the annual cocoa yield recorded was low. For example, the maximum temperature recorded between January and March was high (35.3°C) in 1995 against the normal (34.6 °C) and the annual cocoa yield was low (42.7 pods/tree). It was also true during 2004 (35.0 °C) in which low yield (28.2 pods/tree) was obtained. An increase of 1-3°C in maximum temperature from January to March against the normal led to a decline of 30-40% in annual cocoa yield under rainfed conditions as noticed in 2004 (Severe summer drought). Whereas, the maximum temperature recorded in 1993 was low (34.0 °C) and the annual cocoa yield was high (72.2 pods/tree). Similar was the case in 1997 and 2000 as the annual cocoa yield during the above years were 54.7 pods/tree and 51.4 pods/tree, respectively. The study revealed that high maximum temperature during summer with heavy rainfall during the monsoon season is likely to affect the annual cocoa yield adversely. Under the projected climate change scenario, the cocoa production is likely to be adversely affected as it is influenced by rise in maximum temperature and uncertainties in monsoon rainfall pattern in the form of occurrence of floods and droughts. Hence, there is need to develop climate adaptation strategies at the plantations/farm level to mitigate the ill effects of climate change/climate variability.

Acknowledgement

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Climate variability and cardamom across the Western Ghats of India

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Abstract

A marginal decline in rainfall was noticed at all locations during the southwest monsoon except at Madikeri. In contrast, a marginal increasing trend in rainfall from October to March (Post monsoon and winter) at Pampadumpara, Ambalavayal (October and November), Madikeri, Saklespur (December – March) and Mudigere across the cardamom tract was noticed. If such trend continues at the above locations, it may be beneficial to cardamom producers. The decline, though insignificant, in summer showers (March-May) at all the locations across the cardamom tract except at Saklespur was the concern of the cardamom growers for sustenance of cardamom plantations. The marginal decrease in annual rainfall was more evident since last one-and- a-half decade across the cardamom tract at many locations. Increase in surface maximum and minimum temperatures was phenomenal at Pampadumpara since 1990 onwards irrespective of seasons. The difference between the maximum and minimum temperature was widening at several locations across the Western Ghats. Rainfall uncertainties and widening temperature change are the concern, which may adversely affect the cardamom production.

Introduction

The natural habitat of cardamom is characterised by cool-humid-microclimate and the Western Ghats provide an ideal conditions for cardamom cultivation. It is mainly grown in the States of Kerala, Karnataka and Tamil Nadu, accounting for an area of 41,362 ha, 26,661 ha and 5,255 ha, respectively (Spices Board, 2008). Among these States, Kerala accounts for the major portion of production (76 %), followed by Karnataka (16 %) and Tamil Nadu (8 %). The forests of Western Ghats exert a domineering influence on soil, water resources and microclimate of cardamom. The fast-dwindling forest cover and its consequence over climate (associated environment problems) are the concern across the cardamom tract of the Western Ghats since last two decades. On the other hand, the projected global warming and rainfall changes may adversely affect forest ecosystems. The studies in India predict that there are shifts in boundary of forest and climate types during the transient periods (Ravindranath, 2002). Though there are uncertainties with respect to projections of climate change on forest ecosystems, evidence is growing to show that climate change couples with socio-economic and land use pressures is likely to affect the forest ecosystems adversely. A study of the Western Ghats region, based on bio-climatic models concluded that for Nilgiris, the projected change was an increase in area under evergreen and dry thorny forests due to increased rainfall and temperature, respectively. In Uttara Kannada part of Western Ghats, the projections indicate a shift from dry to moist vegetation types (Ravindranath *et al.*, 1997). Keeping the above in view, an attempt has been made to understand the effects of rainfall and temperature variability on cardamom production across the Western Ghats.

Materials and methods

Monthly rainfall and surface air temperature (maximum and minimum temperature in °C) were collected from six Cardamom Research Stations located across the Western Ghats comprising of Kerala (Ambalavayal and Pampadumpara), Karnataka (Sakleshpur. Mudigree and Madikeri) and Tamil Nadu (Thandikudi). The study period varied from 10 years to 43 years depending upon availability of data. The year wise area under cardamom and its production were collected from Spices Board, Kochi for the period from 1970 to 2006 for all the three cardamom growing states viz., Kerala, Karnataka and Tamil Nadu. The linear trend method given in MS-Excel was used to find out the trends. Crop weather relationships were also worked out to understand the effects of climate change and variability their impacts on cardamom production across the Western Ghats of India.

Results and discussion

Rainfall trends: Out of six locations, four locations viz., Ambalavayal, Saklespur, Mudigere and Thandikudi showed a marginal declining trend in annual rainfall. In contrast, the other two locations viz., Pampadumpara and Madikeri showed a marginal increasing trend. However, the annual rainfall was one of the lowest during 2002 at all the locations. Except Madikeri, all other five locations showed a declining trend in southwest monsoon rainfall. Saklespur and Thandikudi showed a declining trend in post monsoon rainfall and all other four locations showed an increasing trend. Ambalavayal and Thandikudi showed a declining trend in winter rainfall and all other four locations showed an increasing trend. Except Saklespur, all other five locations showed decreasing trend in summer rainfall.

The study revealed that rainfall trends were not uniform and varied from one location to another and from season to season across the Western Ghats, where cardamom is predominant. However, a marginal decreasing trend is noticed at majority of the locations in annual and monsoon rainfall, while increasing trend in post-monsoon and winter. During summer, decreasing in rainfall was noticed at all the locations except at Saklespur.

Maximum temperature trends: The annual mean maximum temperature recorded was high in 1983 and 1985 (25.4 °C) while the lowest in 1990 (23.5°C) at Pampadumpara. A decrease of 0.5 °C in 25 years was noticed during the period from 1978 to 2002. An increase of 0.2 °C in 19 years was noticed during the period from 1984 to 2002 at Ambalavayal. At Madikeri, the highest maximum temperature was observed in 1995, 1996 and 2002 (27.9°C) while the lowest in 1986 (26.7 °C). An increase of 0.9° C in 17 years was noticed during the period from 1986 to 2002 (Table.1). At Saklespur, decreasing trend of 1.1 ° C in 11 years was noticed during the period from 1992 to 2002. The highest maximum temperature was recorded in 1993 (27.9 °C) while the lowest in 1979 (26.2°C) at Mudigere. An increase of 0.9 °C in 32 years was noticed during the period from 1971 to 2002. An increase of 0.8 °C in 10 years was noticed during the period from 1993 to 2002 at Thandikudi.

All the locations except Saklespur showed an increasing trend (0.9 to 2.6 °C) in maximum temperature during southwest monsoon season as influenced by decrease in rainfall. Pampadumpara, Ambalavayal and Saklespur showed a decreasing trend (0.2 to 1.8 °C) while increase (0.9 to 1.1 °C) over Madikeri, Mudigere and Thandikudi in maximum temperature during post monsoon season. All the locations except Mudigere showed a decreasing trend in maximum temperature

Table 1 Extremes of maximum temperature (°C) in different seasons across the cardamom tract of the Western Ghats

Location	ANNUAL		SWM		PM		WINTER		SUMMER	
	High	Low	High	Low	High	Low	High	Low	High	Low
Pampadumpara	25.4 (1983,1985)	23.5 (1990)	23.8 (2002)	21.6 (1990)	25.3 (1985)	22.4 (1993)	25.9 (1995)	23.0 (1993,1994)	29.9 (1983)	26.2 (1999)
Ambalavayal	27.7 (1998)	26.9 (1986,1994)	25.7 (1997, 1999)	24.5 (1989)	27.3 (1984)	25.7 (1989,1992)	28.6 (1985)	26.7 (1997)	31.3 (1998)	29.1 (1994)
Madikeri	27.9 (1995,1996, 2002)	26.7 (1986)	25.3 (1995)	23.6 (1989)	27.8 (2000)	25.7 (1992)	29.0 (2000)	27.3 (1987)	31.8 (1996)	30.0 (1986)
Saklespur	30.8 (1995)	29.3 (2000)	26.7 (1995)	25.2 (2001,2002)	31.3 (1997)	28.8 (1998)	33.1 (1995)	30.7 (2000)	34.2 (1992)	33.0 (2002)
Mudigere	27.9 (1993)	26.2 (1979)	25.2 (1993)	22.4 (1981,1984)	27.9 (1997)	25.1 (1974,1979, 1985)	29.4 (1991)	26.6 (1987)	32.1 (1992)	29.7 (1997)
Thandikudi	24.6 (2000)	23.6 (1993)	26.7 (2000)	23.9 (1993)	24.1 (1996)	21.6 (2001)	22.3 (2001)	19.8 (2002)	27.3 (2001)	25.1 (2000)

Table 2 Extremes of minimum temperature (°C) in different seasons across the cardamom tract of the Western Ghats

Location	ANNUAL		SWM		PM		WINTER		SUMMER	
	High	Low	High	Low	High	Low	High	Low	High	Low
Pampadumpara	18.1 (1990,1991, 1998)	17.0 (1984,1986)	18.5 (1983)	16.5 (1984)	18.6 (1990)	15.9 (1984)	17.2 (1998)	14.8 (1982)	20.1 (1991)	18.2 (1986)
Ambalavayal	18.8 (1998)	16.9 (1995)	19.3 (1998)	17.2 (1984)	18.9 (1997)	17.2 (1984)	17.6 (1998)	13.4 (1996)	20.2 (1998)	17.8 (1984,1995)
Madikeri	17.9 (1986)	16.3 (1991)	19.4 (1994)	16.9 (1997)	19.3 (1986)	16.0 (1999)	15.9 (1987)	12.7 (1992)	18.9 (1994,2002)	17.0 (1993)
Saklespur	18.3 (2001)	17.0 (1995)	19.2 (2001)	18.0 (1995)	18.4 (1992,2001)	16.8 (1995)	16.4 (1998)	14.3 (1997)	19.8 (1992)	17.3 (1997)
Mudigere	17.5 (2001,2002)	15.9 (1974)	18.8 (1995)	17.0 (1991)	18.2 (2001)	15.4 (1983)	16.3 (1972)	12.8 (1976)	19.5 (1972)	16.4 (1974)
Thandikudi	15.9 (1993,1994)	14.9 (1996,1999, 2002)	17.8 (1994)	15.1 (1997)	17.4 (1993)	14.9 (1999)	13.7 (1998)	11.8 (2000)	16.3 (1994)	15.5 (2002)

(0.4 to 1.6 °C) during winter season. All the locations except Madikeri and Mudigere showed a decreasing trend (0.4 to 0.8 °C) in maximum temperature during summer. The unprecedented drought during summer 1983 over Kerala recorded high temperature as seen at Pampadumpara. Similarly, the highest maximum temperature at Thandikudi in 2001 was in tune with the global warm year, which was noticed at Ambalavayal also.

Minimum temperature trends: Madikeri and Thandikudi showed a declining trend (0.2 to 0.8 °C) in annual minimum temperature while increasing trend (0.4 to 0.8 °C) at other four locations viz., Pampadumpara, Ambalavayal, Saklespur and Mudigere. All the locations except Thandikudi showed an increasing trend (0.4 to 0.9 °C) in minimum temperature during the southwest monsoon season. All the locations except Madikeri and Thandikudi showed an increasing trend (0.4 to 1.2 °C) in minimum temperature during the post monsoon season. Out of six locations, four locations recorded the highest minimum in 1998, which was the global warm year. All the locations except Pampadumpara and Thandikudi showed an increasing trend (0.3 to 0.8 °C) in minimum temperature during summer.

Temperature range: A relatively uniform temperature range was maintained (6.9 -10.7 ° C) over Tamil Nadu, followed by Kerala (5.2 -11.7° C). It is high (5.3 -15.9° C) over Karnataka (Fig.1). It is evident that the surface air temperature is high over Karnataka and Kerala when compared to that of Tamil Nadu across the cardamom tract. Thandikudi in Tamil Nadu appears to be favourable environment in terms of surface air temperature for growing cardamom. It can be attributed to the altitudinal advantage.

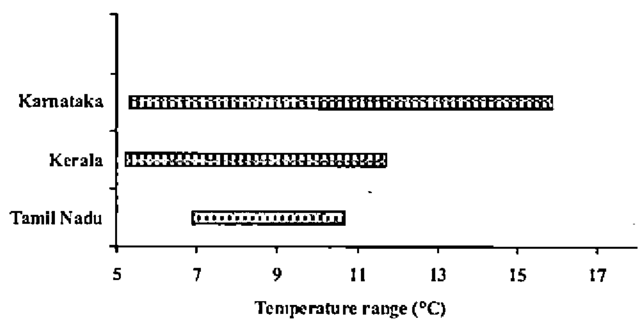

Fig 1 Temperature range (°C) across the cardamom tract of the Western Ghats

A sharp decline in area under cardamom was noticed over Kerala and Tamil Nadu. It is true in the case of Karnataka also in recent years though a marginal increase was seen as a whole. A sudden decline in area of cardamom was noticed in 1989 over Kerala and Tamil Nadu while 1996 over Karnataka. Nevertheless, the production as well as productivity of small cardamom was increasing over a period of time. This could be attributed to the technologies generated for sustenance of cardamom production since last three decades. However, the inter annual fluctuations in cardamom production was not uncommon due to weather aberrations. For example, the cardamom production was badly hit during 1983 due to unprecedented drought that occurred during summer 1982-83 across the cardamom tract of the Western Ghats. It is also understood that the cardamom production over Kerala in recent years was highly variable due to erratic monsoon and dry spells during summer since 2002 onwards. It might be one of the reasons for price hike of cardamom in recent years.

It was found that rainfall during winter (Dec-Feb), summer (Mar-May) and rainfall from December to May were positively correlated with cardamom production. Though the annual rainfall and rainfall during southwest and post monsoon had the positive correlation with production and productivity, it was not significant. In cardamom, the important phenological phases viz., panicle emergence, its elongation and flowering are very important in deciding final yield, which fall mostly in winter and summer seasons. Hence, it is evident that rainfall from December to May plays a critical role in cardamom production and productivity. This is in agreement with the reports given by Mathew (1989) and George and Mathew (1996).

In the case of surface air temperature, only maximum temperature during summer season had a negative correlation with production and productivity. Interestingly, the annual and summer temperature range also showed a negative correlation with small cardamom production while southwest monsoon season had the positive correlation with production. The multi-collinearity effect among different weather variables was eliminated through stepwise regression and the regression equation so obtained is given below:

$$Y = 6534.674 + 4.071\, x_1 + 724.931\, x_2 - 591.622\, x_3$$
$(R^2 = 0.78)$

Where, Y – Annual cardamom production (t); x_1 – Dec-May rainfall (mm); x_2 – Temperature range during southwest monsoon season (°C); x_3 – Annual temperature range (°C)

From the above, it is understood that rainfall from Dec-May, temperature range during southwest monsoon and annual temperature range could explain the variability in cardamom production by 78 per cent.

Conclusions

A marginal decline in rainfall was noticed at all the locations during the southwest monsoon except at Madikeri. However, it is insignificant as the amount of rainfall received was very high during the southwest monsoon at all locations except at Thandikudi. In contrast, a marginal increasing trend in rainfall from October to February (Post-monsoon and winter) at Pampadumpara, Ambalavayal (October and November), Madikeri, Saklespur (December–February) and Mudigere across the cardamom tract was noticed. If such trend continues at the above locations, it may be beneficial to cardamom producers. The decline, though insignificant, in summer showers (March-May) at all the locations across the cardamom tract except at Saklespur was the concern of the cardamom growers for sustenance of cardamom plantations. a marginal decrease in annual rainfall was more evident since last one-and- a-half decades across the cardamom tract at many locations. Increase in surface maximum and minimum temperature was phenomenal at Pampadumpara since 1990 onwards irrespective of seasons. It was true in case of the minimum temperature at Ambalavayal while such trend was only evident in annual as well as southwest monsoon in the case of maximum temperature. In contrast, the minimum temperature showed a declining trend at Thandikudi though increase in maximum temperature was noticed except during winter and summer seasons. The maximum temperature at Madikeri recorded an increasing trend in all the seasons except in winter while such trend was not seen in the case of minimum temperature. At the same time, it is quite interesting to note that increase in minimum temperature while decrease in maximum temperature was noticed in all the seasons at Saklespur. At Mudigere, both maximum and minimum temperature showed an increasing trend. Rainfall from Dec-May, temperature range during southwest monsoon and annual temperature range could explain the variability in cardamom production by 78 per cent. It revealed that monsoon uncertainties, declining summer rainfall, increase in annual and summer temperatures, widening the temperature difference between the maximum temperature in summer and minimum temperature in winter are the concern at several locations across the cardamom tract and it is detrimental to cardamom production under the projected climate change scenario.

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Shifting pattern of rainfall – an ecological indicator affecting plant regeneration – case study of a medicinal orchid

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Abstract

Performance of Jeevakom (*Seidenfia rheedii* Sw.), a medicinal orchid, under the changed rainfall regimes in central Kerala is presented in this paper. Domestication trials on this valuable medicinal plant were taken up at Kerala Agricultural University during 2004-2009. Growth and yield were correlated with the daily showers received during growing season which was divided into four quarters in accordance with the growth phases of Jeevakom. Number of dry spells and total rainfall received in each of these quarters were worked out. Quarterly pattern of dry spells followed a trough pattern imitating a tick mark. In contrast, the quantum of rainfall had peaked and positively skewed distribution, the peakedness typical of the trough, a more or less mirror image. From the pattern observed over a five-year period, it could be inferred that an evenly distributed summer showers, followed by timely and good southwest monsoon with lesser dry spells, again followed by a timely and good northeast monsoon seem to be ideal for jeevakom. The spatial and temporal distribution of rainfall and not the total rainfall is critical for highly rainfall dependant species like jeevakom.

Introduction

Our agricultural practices have been developed over time, in consonance with the local weather and regions climate. Plants require certain amount of minimum rain at particular times of their growth. It is the rain on time that matters. Each species has its own cardinal points and climate rhythms. For their potential performance, they should be placed in ideal ecological niches or grown in ideal conditions. This paper depicts the performance of jeevakom (*Seidenfia rheedi,* Sw), a rare medicinal orchid under the changing rainfall regimes of central Kerala.

Materials and methods

Jeevakom, (*Seidenfia rheedii*, Sw) is a lithophytic orchid found in the evergreen forests of Western Ghats. It is a vegetatively propagated seasonal herb which regenerates from pseudobulbils. Domestication trials on this rare but valuable medicinal plant were taken up at the Department of Plantation Crops & Spices, College of Horticulture, Vellanikkara during 2004-09. Performance of this plant was correlated with the daily showers received during the season. The growing season was divided into four quarters in accordance with the growth phases of jeevakom. Number of dry spells and total rainfall received in each of these quarters were worked out. Regeneration, growth, development, phenology and senescence of the crop were recorded and the single plant yield was correlated with the rainfall data. Simultaneous observations were recorded on the regeneration and growth of this species in the natural habitat also.

Results and Discussion

Year wise pattern of dry spells in each quarter, quarterly total showers received and the recorded yield of jeevakom are presented in Table 1.

Table 1 Quarterly pattern of dry spells and showers and yield of jeevakom (*Seidenfia rheedii* Sw.) over years

Year	Actual onset of SWM	Quarter	No of dry spells	Rainfall in the quarter mm	Yield g	Remarks
2004-05	May 18	I	18	548	12.9	Good summer showers, very early onset of SWM, good SWM, bad NEM Planting done only on June 5th. By that time, tubers which were in the dormant stage in the forest sprouted and grew. Transplanting not proper, no proper vegetative growth, low yield
		II	15	1751		
		III	21	565		
		IV	51	8		
		Total	105	2872		
2005-06	June 5	I	27	1103	15.0	Reasonable summer showers, timely onset of SWM, good SWM, bad NEM, poor vegetative growth, early senescence, low yield
		II	11	2202		
		III	24	190		
		IV	44	3		
		Total	106	3498		
2006-07	May 26	I	26	331	21.5	Reasonable summer showers, timely onset of SWM, good SWM, good NEM, vegetative growth sufficient, good yield
		II	14	2200		
		III	17	403		
		IV	44	0		
		Total	101	2934		
2007-08	May 28	I	28	275	25.3	Reasonable summer showers, timely onset of SWM, good SWM, good SWM & NEM, good yield
		II	7	3274		
		III	15	409		
		IV	42	38		
		Total	92	3996		
2008-09	May 29	I	28	276	13.3	Reasonable summer showers, timely onset of SWM, bad NEM, poor vegetative growth, low yield
		II	14	1689		
		III	21	402		
		IV	44	3		
		Total	107	2370		

Quarter I – March 15 to onset of SWM
II – Onset of SWM to September
III – October to November
IV – December to March 15th

SWM – Southwest monsoon
NEM – Northeast monsoon
Dry spell – two consecutive days without rains

Quarterly pattern of dry spells and showers

Quarterly pattern of dry spells followed a trough pattern imitating a tick mark. The trough was deeper as the number of dry spells in the first quarter increased. In contrast, the quantum of rainfall had peaked and positively skewed distribution, the peakedness typical of the trough, a more or less mirror image. From the pattern observed over a five year period, it could be inferred that an evenly distributed summer showers, followed by timely and good southwest monsoon, with lesser dry spells, again followed by a timely and good northeast monsoon seem to be ideal for jeevakom. Rainfall in the fourth quarter seemed to have practically no impact on this species as the life span would be over by that time.

Pattern of growth and yield of jeevakom

It is seen from the Table 1 that the spatial and temporal distribution of rainfall and not the total rainfall is critical in highly rainfall dependant species like jeevakom. Distribution of rainfall in the first quarter of the growth period when the crop is in the dormant phase actually decides its sprouting which in turn decides the date of planting / sowing in this species. If this quarter is followed by a timely or even early onset of south west monsoon with less number of dry spells, the species puts forth good vegetative growth and enters into the reproductive phase (usually during August-September). The third quarter, where usually we receive the north east monsoon is also critical, in that only lesser number of dry spells allows the species to complete its life cycle and enter into senescence. Good yields obtained during 2006-07 and 2007-08 testifies this aspect. 2004-05 pattern of rainfall should have been ideal and should have produced good yields, but due to very early onset of south west monsoon, timely planting could not be undertaken, which badly affected the growth and yield.

Regeneration and growth of jeevakom in the wild habitat

In the natural habitat, the dormant pseudobulbils of the plant break its dormancy and begin to sprout with the first monsoon showers. In undisturbed habitats, the regeneration and growth was good. But in disturbed habitats (due to anthropogenic or other factors) regeneration and further growth depended very much on rainfall. In undisturbed habitats the plant may adopt to the changes in environment in a better way unlike the already disturbed habitats where further changes in climate especially rainfall turns detrimental.

Implications of the study

Study of the annual growth cycles of plants in response to the seasonal changes in the environment has gained importance in the context of climate change. Plants differ in their sensitivity to weather elements. Rainfall is one parameter on which we practically have no control. It could be seen that the distribution of rainfall must be looked into and not the total rainfall, especially in weather sensitive herbs. In rainfall dependant seasonal crops (Zingiber, Curcuma, Kaemferia, Nervilia, Herberia, etc.) agricultural technology must orient towards the shift in monsoons and the distribution of rainfall. It also warrants judicious planning of planting dates depending on the distribution of rains in the first quarter (summer showers) of crop growth. Result of the study is a pointer towards designing crops and crop technology in the altered climatic regimes.

Acknowledgement

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Response of sowing date and spacing on yield of cabbage

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Abstract

Cabbage crop sown on 15th October produced significantly higher yield than delayed sowing on 30th October and 15th November. Planting of cabbage with spacing of 45 x 45 cm^2 recorded significantly higher yield than 60 x 30 cm^2 and 60 x 45 cm^2. The interaction between the sowing of cabbage crop on 15th October with spacing of 45 x 45 cm^2 produced significantly higher cabbage yield than the remaining treatment combinations.

Introduction

In Konkan region, Cabbage is grown mostly in *rabi* season after kharif rice. Since, this crop is thermosensitive, shows an adverse effect on growth and head formation with increasing temperature towards summer season. De Moel and Everaarts (1989) reported that the cabbage cultivation planted late in the season resulted in substantially reduced yield at the end of the season. It was, therefore, necessary to study its optimum sowing time for better head formation and more yield. Similarly, planting geometry also plays a vital role on growth and development and yield of cabbage crop. The present investigation was undertaken to decide the optimum sowing time and spacing for cabbage in the Konkan region under irrigated condition.

Materials and methods

A field trial was carried out during the *rabi* seasons of the years 2004-05, 2005-06 and 2006-07 at Agronomy Farm of College of Agriculture, Dapoli in Factorial Randomized Block Design with three replications. The soil of the experimental plot was lateritic having 221.56, 12.34 and 201.19 Kg, N, P_2O_5, K_2O ha^{-1}, respectively. The soil was acidic in reaction with P^H 6.28 and organic carbon content was 0.86 per cent. Three sowing dates viz. 15th October, 30th October and 15th November and three spacings viz. 45 x 45 cm^2, 60 x 30 cm^2 and 60 x 45 cm^2 with nine treatment combinations were tested. The gross plot size was 5.40 x 3.60 m^2 and the net plot sizes were different according to different spacings such as 3.60 x 2.25 m^2, 3.30 x 2.55 m^2 and 3.30 x 2.25 m^2. Sowing of the crop in nursery was done as per the prescribed sowing dates and transplanted at 30 Days after sowing (DAS) as per the treatments. In nursery, 53.7 kg N, 53.3 kg P_2O_5 and 50 kg K_2O ha^{-1} was applied at sowing. The manures and fertilizer doses of 10 tones FYM, 120 kg N, 60 kg P_2O_5 and 60 kg K_2O ha^{-1} were uniformly applied to all the treatments. Out of which, 1/3 rd dose of nitrogen and full dose of phosphorus and potassium was applied as basal dose and 1/3 rd nitrogen was applied 30 days after transplanting (DAT) and remaining 1/3 rd dose of nitrogen was applied 60 DAT. Need based weeding and plant protection measures were carried out. Pooled data for three years on yield was used for interpretation of results. Growing Degree Days (GDD) was calculated by following formula with 10^0C as the base temperature of the Konkan region.

Results and discussion

Sowing time influenced significantly the yield of cabbage during all the three years of experimentation and in the pooled data. The crop sown on 15th October (D_1) recorded significantly higher yield as compared to delayed sown crop on 30th October (D_2) and 15th November (D_3) during all the three years and in the pooled data. On pooled mean basis the magnitude of increase in yield due to sowing on 15th October over 30th October and 15th November were 8.58 and 178.38 per cent, respectively. Similar observations were recorded by Dixit *et. al.* (2005) and De Moel and Everaarts (1989).

Spacing significantly influenced the yield of cabbage. The crop sown at the spacing of 45 x 45 cm^2 (S_1) recorded significantly higher yield as compared to the spacings of 60 x 30 cm^2 (S_2) and 60 x 45 cm^2 (S_3) during all the three years and in the pooled data. On pooled mean basis, the magnitude of increase in yield due to 45 x 45 cm^2 spacing over remaining two spacings viz, 60 x 30 cm^2 and 60 x 45 cm^2 were 13.04 and 51.48 per cent, respectively, indicating that the spacing of 45 x 45 cm^2 is better for obtaining higher production of cabbage than the remaining spacings. Similar results were reported by Hamid (2002) and Bradshaw (1984).

Interaction effects between sowing dates and spacing were

Table 1 Growing Degree Days in cabbage under different sowing dates

Growth Stages	2005-06		
	D1	D2	D3
Seedling Stage (0-30 days)	398.4	343.7	342.3
Vegetative Stage (31-45 days)	599.7	537.4	524.1
Head formation and development stage (46-94 days)	767.8	1115.7	1206.4
Total	1765.0	1996.7	2072.8
Yield (q/ha)	332.4	296.0	92.5
	2006-07		
Seedling Stage (0-30 days)	418.1	442.1	461.3
Vegetative Stage (31-45 days)	557.7	651.2	673.2
Head formation and development stage (46-94 days)	1167.9	1208.1	1269.0
Total	2163.7	2301.4	2403.5
Yield (q/ha)	323.9	300.9	224.8
	2007-08		
Seedling Stage (0-30 days)	416.5	469.8	531.2
Vegetative Stage (31-45 days)	604.8	614.7	640.6
Head formation and development stage (46-94 days)	1282.1	1310.3	1354.4
Total	2303.4	2394.8	2526.4
Yield (q/ha)	312.1	287.4	210.0

significant for all the three years and in the pooled data under study. The treatment combination between sowing on 15th October with spacing of 45 x 45 cm^2 ($D_1 S_1$) produced significantly higher yield of cabbage than the remaining treatment combinations.

It can be seen from Table 1 that the crop sown on 15th October during 2005-06 received 1765.9 growing degree days (GDD) and were proved to be optimum to produce higher cabbage yield. Out of this total GDD, the utilization pattern was to the extent of 22.6 per cent, 34 per cent and 43.4 per cent at seedling, vegetative and head formation stages, respectively. Further, the differences in cabbage yields were also recorded in early sown crop on 15th October (D_1) during all the three years and it was more during 2005-06 than during 2006-07 and 2007-08 where lower yield was obtained due to the increase in GDD. It has been proved that the crop is thermosensitive and therefore, the cabbage yield was reduced with advancement of sowing dates towards summer season due to increase in GDD during all the three years.

Correlation and regression analysis of cabbage yield with AGDD during 2005-06 indicated strong negative correlation (-0.786) with GDD at seedling stage (-0.634) and GDD at Head formation and development (-0.713) whereas strong positive correlation (0.738) with GDD in vegetative stage, thus during this year GDD contributed 62 per cent variation in the yield. Whereas, during 2006-07 AGDD indicated strong negative correlation (-0.786), GDD at Seedling stage (-0.634) and GDD at head formation and development stage (-0.683) with yield, where as strong positive correlation (0.678) with GDD at vegetative stage. Thus during this year GDD contributed 60 per cent variation in the cabbage yield. The correlation and regression analysis of yield with AGDD during 2007-08 indicated strong negative correlation (-0. 643), with GDD at Seedling stage (-0.571) and GDD at head formation and development (-0.805) whereas strong positive correlation (0.646) with GDD in vegetative stage, indicating that the GDD during this year contributed 53 per cent variation in the yield. On an average, during all the three years the cabbage yield was reduced with increasing GDD to the extent of 58.33 per cent than optimum. From the above investigation, it can be concluded that under Konkan conditions the cabbage crop should be sown on 15th October with spacing of 45 x 45 cm^2 for higher yield.

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Effect of weather parameters on coconut yield

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Weather data for six years (2003-2008) from the RARS Plicode agromet observatory were taken for the study. Coconut yield data from the RARS farm for six years (2003-2008) were collected for studying the crop weather relation. Correlations were worked out between the coconut yield and weather parameters and regression equations were developed for predicting coconut yield.

The rainfall data during the study period (2003-2008) was analyzed. It was found that the annual average rainfall during the period was 3370 mm. The season-wise average rainfall was also worked out for the above period. It was 2675 mm for Southwest monsoon, 274 mm for northeast monsoon, 420 mm for summer season and 2 mm for winter. Under rainfed condition, rainfall is the most important factor which determines the coconut yield. Results of the study revealed that the rainfall during the southwest monsoon season was positively correlated with the coconut yield whereas the rainfall during the northeast monsoon season showed a negative correlation with the yield. By monitoring the weather parameters during the southwest and northeast monsoon seasons, coconut growers can predict the future yields in advance with good skill.

SESSION VI

Climate change adaptation in Fisheries and Animal Sciences

Impact of climate change on fishery at Cuddalore coast

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Introduction

Fisheries and aquaculture play an important role in economics around the world, in both developed and developing countries. Our country is marching towards blue revolution, by exporting 6, 02,835 tonnes with values of 8607.94 crores of rupees during 2008. The export of marine products has steadily grown over the year - from a mere Rs.3.92 crores in 1961-62 to Rs. 8, 607.94 crores in 2008-09. Indian fish production increased from 0.75 million tonnes in 1950-51 to 6.90 million tonnes in 2006-09. Fisheries sector occupies a very important place in the socio economic development of India. India is the 16th largest exporter of marine products in the world and 9th largest exporter of marine products in Asia (MPEDA, 2009).

Physical and ecological impacts of climate change on marine ecosystem and fishery resources are to be studied in detail. The oceans are warming, but with geographical differences and some decadal variability. Warming is more intense in surface waters but is not exclusive to these, with the Atlantic showing particularly clear signs of deep warming. Although there are no clearly discernable net changes in ocean upwelling patterns, there are indications that their seasonality may be affected. There will be negative impacts on the physiology of fish in localities where temperatures increase, through limiting oxygen transport. This would have significant impacts on aquaculture and result in changes in distribution, and probably abundance, of both freshwater and marine species. Temperature-regulated physiological stresses and changes in the timing of life cycles will impact the recruitment success. Keeping the above in view, an attempt has been made in this paper to understand the impact of climate change on fishery at Cuddalore coast, Tamil Nadu.

CMFRI (2008) has made an attempt the study the impact of climate change on fishery in India and found that the sea water temperature in the inshore waters ranged between 23.0 to 33.5°C in the west coast and between 23.8 to 32.6 °C in the east coast. ?Salinity values ranged between 0.4 to 37.8 ppt in the west coast and between 1.71 to 37.9 ppt in the east coast. ?Dissolved oxygen (DO) content in seawater ranged 0.01 to 8.9 ml/l in the west coast. Lowest DO value was observed off Mumbai (0.01 ml/l) while highest value was observed off Veraval (8.9 ml/l). The DO content ranged from 0.01 to 8.2 ml/l in the east coast. Lowest value was observed off Chennai (0.01 mg/l) while the highest value was observed off Vishakhapatnam (8.2 ml/l).

Regarding the upwelling studies, satellite and field derived oceanographic data have shown that coastal upwelling occurs during July-September with a peak in August resulting in high nutrient concentrations and biological productivity along the south west coast. Nearly 70% of the pelagic fish catch, dominated by oil sardine and mackerel was obtained during September-December, during or immediately after the upwelling. Total pelagic fish catch in purse seine and drift gill net, and catches of fishes such as thryssa, carangids, mackerels, seer fishes and tunas showed significant positive correlations with bottom sigma t and significant negative correlations with bottom dissolved oxygen content (upwelling indicators) at Mangalore (Vivekanandan, 2008). A preliminary observation has been made on the impact of climate change on fishery at Cuddalore, which is the headquarters of South Arcot District in Tamil Nadu. It has 51 fishing villages with 55.5 km coastal area. There are 5000 Catamarans, 1000 Trawlers, and 500 FRB boats are in operation during regular days. 24,500 tones were captured per year and with that 15,000 tones were exported. Approximately, rupees one Crore worth of fish is marketed from this area.

Weather data is presented in Table 1. During October maximum rainfall was recorded. Salinity is an important factor that determines the growth and composition of marine animal in the environment. During the study period the salinity ranged from 5ppt to 33ppt. During the study period the temperature was ranged from 30 to 37.5 °C. The temperature was low in the months of November and December and high in the May and June. During the study period the pH was ranged from 7.5 to 8.

Unusual catches of the fishery resources were also noted. On 10th and 11th of September 2008 nearly 50 tones of *Himantura uarnak* (ray fish) were caught by trawl nets. Brown sea perch *Apsilus fuscus* was very rare before Tsunami, but seven tones were

Table 1 Weather data for the year 2008

Month	Temperature °C	Rainfall mm	Relative Humidity %	Wind Speed Km/h
January	31.0	0	84	9
February	31.0	24	85	10
March	33.5	0	83	9
April	34.0	0	82	8
May	37.0	0	80	9
June	37.5	11	79	10
July	37.0	34	78	9
August	34.0	58	85	10
September	34.5	50	81	9
October	32.0	607	86	7
November	30.0	107	86	8
December	30.0	206	88	8

caught in the month of October 2008. Oil sardine Sardinella longiceps forms regular catch. During March to May huge catch of 5-7 tonnes per boat was recorded. (Fig. 1)

It is interesting note that after the Tsunami there is an increasing trend of gastropod population especially *Babylonia spirata* (Fig.1).

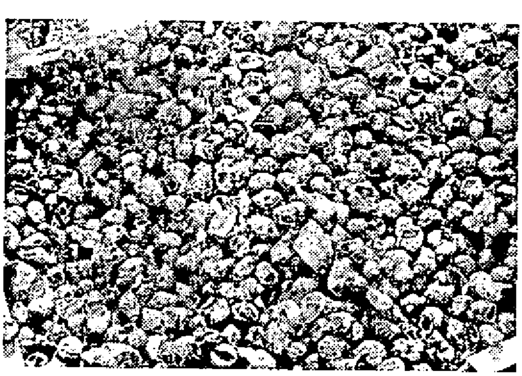

Fig. 1 Gastropod *Babylonia spirata*

It is found in the depth of 32 feet. Fisherman used to catch this animal by using special net known as "Katcha valai". They use to attach with Murrel, as bait. Gastropod is sold for 50 to 60 rupees (size 4-6cm) and 25 to30 rupees (3 cm) per kilogram. At Thazhanguda (Fish landing centre) 3 tonnes of gastropod is harvested daily. After harvesting, the animals were washed in the sea water and sizes were separated and packed with ice in the plastic troughs. From Cuddalore, the packed animals were sent to Singapore, Hong Kong and China from Chennai Airport. It is sold to Rs.500/kg in abroad. Its flesh and operculum has medicinal values and also rich in nutrition.

Jelly fish (*Rzhizostomae pulmo*) were found to be abundant during March and April 2009 (Fig. 2) and it has been observed that 400-600 tonnes per day was harvested and marketed to China and Japan. Another interesting observation was made with bulk catch of *sepia aculeate and Sepioteuthis lessoniana* with 300 tonnes caught by 100 trawlers during 3 rd July 2008.

Fig. 2 Jelly fish landings in bulk

Sand dunes with the vegetation *Ipomoea* sp (Fig. 3) were destroyed by us for bund construction (Fig. 4). These changes also have impact on ecological imbalance and leads to so many changes in the wave pattern, sea erosion etc. Sea erosion during full moon and new moon has damaged many fishermen houses and coconut trees along the coast (Figs. 6-8).

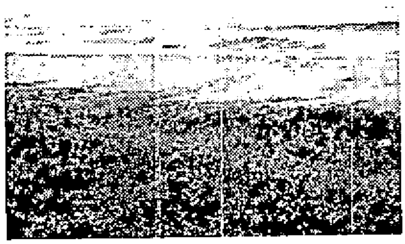

Fig. 3 Sand dune vegetation near the shore bulk

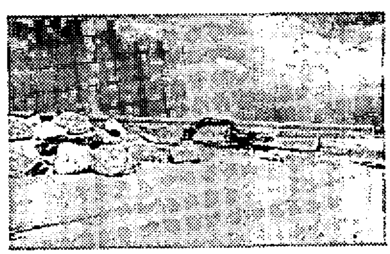

Fig. 4 Constructions with huge rocks (Manmade ecological change)

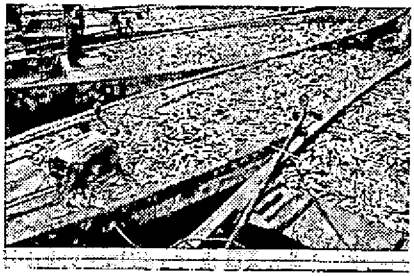

Fig.5 Bulk catches of oil sardine

Fig.6 Sea level raise causes damage to fishermen residents

Sea erosion and sea level raise caused much destruction in Cuddalore

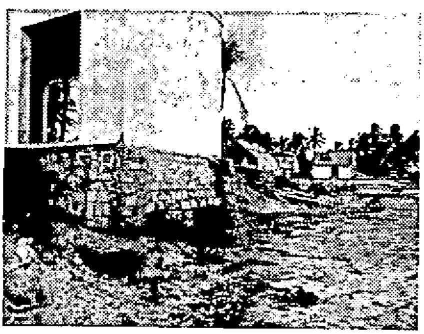

Fig.7 Sea level raise causes damage to fishermen residents

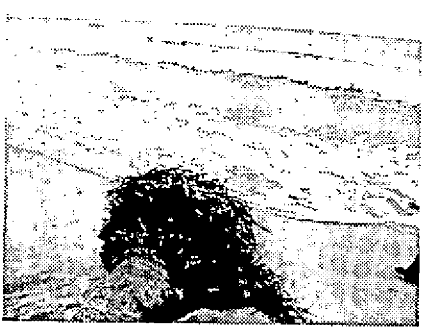

Fig. 8 Coconut trees were uprooted due to huge waves

The traditional aged fishermen told that these change in catch are due to ocean current pattern modifications and temperature fluctuations. Scientifically these finds should be interpreted. Detailed studies are needed in this area to know complete impact of climate change on fishery since it involves oceanography aspects like ocean current, upwelling etc., and also needs the help of satellite pictures and SST (sea surface temperature) chlorophyll productivity data from ISRO. An integrated approach is needed for better understanding of the nature's role and its wonders.

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National Seminar on Climate Change Adaptation Strategies
in Agriculture and Allied Sectors, held at KAU during 03-04 December 2009

Effect of climatic variations in incidences of captive elephant violence in Kerala

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Introduction

Captive elephants in Kerala play an integral role in enriching its cultural fraternity and have become indispensable item in all festivals irrespective of religion. Available data on festivals show existence of 25,000 such performances in Kerala, entertaining 1 Crore people every year in approximate. Unfortunately there were many saddening instances of elephant running amok and turning violent in our state, the mishaps in which many a lives of mahouts and that of even public were lost brutally. In view of the above facts, an exploratory study was conducted to find out the possible causes / influential factors leading to elephant violence. The forecasts and apprehensions by environmentalists in regard of elevation in ambient temperature than previous years and reports of more incidents of violence were the motivating factor to the study. The existence of physiological causes like musth and psychological causes were ruled and the role of environmental factors like boosted atmospheric temperature and relative humidity, geographical peculiarities of the venue of incidents etc were probed.

There were a significantly higher number of incidents of elephant violence, death and damages in 2007 even though the elephants involved were not in musth (until this report) as compared to 2006. Elephants involved in majority of violent incidents in 2007, had no external/physical provocation of any sort as against in 2006. Therefore, the probable causative factor for a higher incidence of violence in 2007 can only be attributed to the higher mean day temperature in the festival months of February, March and April 2007. Nevertheless, the reason for a higher incidence of violence in coastal regions could be that, high temperature coupled with high humidity in these geographical areas would be disturbing the thermoregulatory mechanism and this matter is yet to be fully discerned. The time of incidence occurrence reveals that the hotter hours of the day leads to more stress to the animals. The vulnerability and low susceptibility to temperature and humidity variations by older animals also might have catalyzed. There are studies indicating that, a higher temperature will disturb the normal physiological functions of wild elephants Vis-à-vis their communication. These results also agree with the suggestions and findings on relationship of animal behavior with change in physical atmosphere. The findings of this study shall be useful for the public, mahouts and elephant owners to come out with fruitful suggestions and deliberations for measures to be adopted for reducing thermal stress to elephants in future during these months to avoid causalities and brutal killings of man by this pachyderms.

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Materials and Methods

An investigation of incidents of injury or mortality of elephant keepers, damage to public property and elephant running amok was carried out during the period from July 06 to April 07 as the festival season falls during this period in Kerala. Accidental

Impact of climate change on fishery at Cuddalore coast

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Introduction

Fisheries and aquaculture play an important role in economics around the world, in both developed and developing countries. Our country is marching towards blue revolution, by exporting 6, 02,835 tonnes with values of 8607.94 crores of rupees during 2008. The export of marine products has steadily grown over the year - from a mere Rs.3.92 crores in 1961-62 to Rs. 8, 607.94 crores in 2008-09. Indian fish production increased from 0.75 million tonnes in 1950-51 to 6.90 million tonnes in 2006-09. Fisheries sector occupies a very important place in the socio economic development of India. India is the 16th largest exporter of marine products in the world and 9th largest exporter of marine products in Asia (MPEDA, 2009).

Physical and ecological impacts of climate change on marine ecosystem and fishery resources are to be studied in detail. The oceans are warming, but with geographical differences and some decadal variability. Warming is more intense in surface waters but is not exclusive to these, with the Atlantic showing particularly clear signs of deep warming. Although there are no clearly discernable net changes in ocean upwelling patterns, there are indications that their seasonality may be affected. There will be negative impacts on the physiology of fish in localities where temperatures increase, through limiting oxygen transport. This would have significant impacts on aquaculture and result in changes in distribution, and probably abundance, of both freshwater and marine species. Temperature-regulated physiological stresses and changes in the timing of life cycles will impact the recruitment success. Keeping the above in view, an attempt has been made in this paper to understand the impact of climate change on fishery at Cuddalore coast, Tamil Nadu.

CMFRI (2008) has made an attempt the study the impact of climate change on fishery in India and found that the sea water temperature in the inshore waters ranged between 23.0 to 33.5°C in the west coast and between 23.8 to 32.6 °C in the east coast. ?Salinity values ranged between 0.4 to 37.8 ppt in the west coast and between 1.71 to 37.9 ppt in the east coast. ?Dissolved oxygen (DO) content in seawater ranged 0.01 to 8.9 ml/l in the west coast. Lowest DO value was observed off Mumbai (0.01 ml/l) while highest value was observed off Veraval (8.9 ml/l). The DO content ranged from 0.01 to 8.2 ml/l in the east coast. Lowest value was observed off Chennai (0.01 mg/l) while the highest value was observed off Vishakhapatnam (8.2 ml/l).

Regarding the upwelling studies, satellite and field derived oceanographic data have shown that coastal upwelling occurs during July-September with a peak in August resulting in high nutrient concentrations and biological productivity along the south west coast. Nearly 70% of the pelagic fish catch, dominated by oil sardine and mackerel was obtained during September-December, during or immediately after the upwelling. Total pelagic fish catch in purse seine and drift gill net, and catches of fishes such as thryssa, carangids, mackerels, seer fishes and tunas showed significant positive correlations with bottom sigma t and significant negative correlations with bottom dissolved oxygen content (upwelling indicators) at Mangalore (Vivekanandan, 2008). A preliminary observation has been made on the impact of climate change on fishery at Cuddalore, which is the headquarters of South Arcot District in Tamil Nadu. It has 51 fishing villages with 55.5 km coastal area. There are 5000 Catamarans, 1000 Trawlers, and 500 FRB boats are in operation during regular days. 24,500 tones were captured per year and with that 15,000 tones were exported. Approximately, rupees one Crore worth of fish is marketed from this area.

Weather data is presented in Table 1. During October maximum rainfall was recorded. Salinity is an important factor that determines the growth and composition of marine animal in the environment. During the study period the salinity ranged from 5ppt to 33ppt. During the study period the temperature was ranged from 30 to 37.5 °C. The temperature was low in the months of November and December and high in the May and June. During the study period the pH was ranged from 7.5 to 8.

Unusual catches of the fishery resources were also noted. On 10th and 11th of September 2008 nearly 50 tones of *Himantura uaranak* (ray fish) were caught by trawl nets. Brown sea perch *Apsilus fuscus*_was very rare before Tsunami, but seven tones were

Table 1 Weather data for the year 2008

Month	Temperature °C	Rainfall mm	Relative Humidity %	Wind Speed Km/h
January	31.0	0	84	9
February	31.0	24	85	10
March	33.5	0	83	9
April	34.0	0	82	8
May	37.0	0	80	9
June	37.5	11	79	10
July	37.0	34	78	9
August	34.0	58	85	10
September	34.5	50	81	9
October	32.0	607	86	7
November	30.0	107	86	8
December	30.0	206	88	8

caught in the month of October 2008. Oil sardine Sardinella longiceps forms regular catch. During March to May huge catch of 5-7 tonnes per boat was recorded. (Fig. 1)

It is interesting note that after the Tsunami there is an increasing trend of gastropod population especially *Babylonia spirata* (Fig.1).

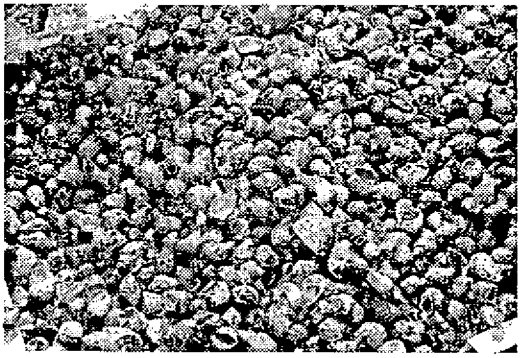

Fig. 1 Gastropod *Babylonia spirata*

It is found in the depth of 32 feet. Fisherman used to catch this animal by using special net known as "Katcha valai". They use to attach with Murrel, as bait. Gastropod is sold for 50 to 60 rupees (size 4-6cm) and 25 to30 rupees (3 cm) per kilogram. At Thazhanguda (Fish landing centre) 3 tonnes of gastropod is harvested daily. After harvesting, the animals were washed in the sea water and sizes were separated and packed with ice in the plastic troughs. From Cuddalore, the packed animals were sent to Singapore, Hong Kong and China from Chennai Airport. It is sold to Rs.500/kg in abroad. Its flesh and operculum has medicinal values and also rich in nutrition.

Jelly fish (*Rzhizostomae pulmo*) were found to be abundant during March and April 2009 (Fig. 2) and it has been observed that 400-600 tonnes per day was harvested and marketed to China and Japan. Another interesting observation was made with bulk catch of *sepia aculeate and Sepioteuthis lessoniana* with 300 tonnes caught by 100 trawlers during 3 rd July 2008.

Fig. 2 Jelly fish landings in bulk

Sand dunes with the vegetation *Ipomoea* sp (Fig. 3) were destroyed by us for bund construction (Fig. 4). These changes also have impact on ecological imbalance and leads to so many changes in the wave pattern, sea erosion etc. Sea erosion during full moon and new moon has damaged many fishermen houses and coconut trees along the coast (Figs. 6-8).

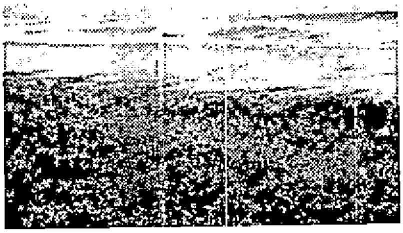

Fig. 3 Sand dune vegetation near the shore bulk

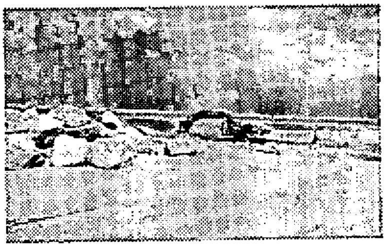

Fig. 4 Constructions with huge rocks (Manmade ecological change)

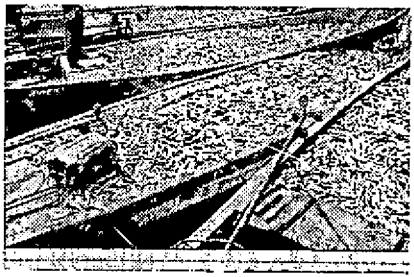

Fig.5 Bulk catches of oil sardine

Fig.6 Sea level raise causes damage to fishermen residents

Sea erosion and sea level raise caused much destruction in Cuddalore

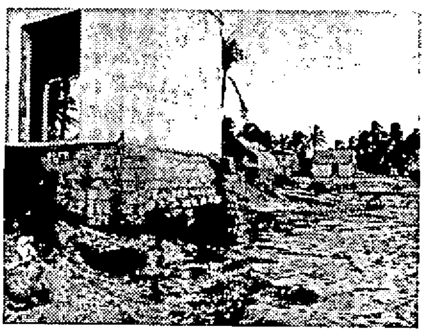

Fig.7 Sea level raise causes damage to fishermen residents

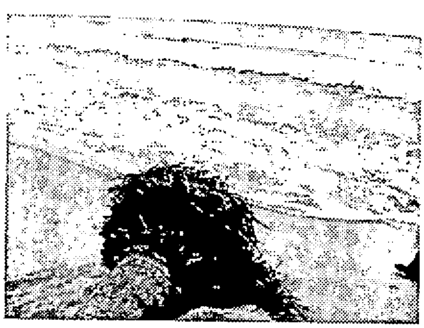

Fig. 8 Coconut trees were uprooted due to huge waves

The traditional aged fishermen told that these change in catch are due to ocean current pattern modifications and temperature fluctuations. Scientifically these finds should be interpreted. Detailed studies are needed in this area to know complete impact of climate change on fishery since it involves oceanography aspects like ocean current, upwelling etc., and also needs the help of satellite pictures and SST (sea surface temperature) chlorophyll productivity data from ISRO. An integrated approach is needed for better understanding of the nature's role and its wonders.

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Materials and Methods

An investigation of incidents of injury or mortality of elephant keepers, damage to public property and elephant running amok was carried out during the period from July 06 to April 07 as the festival season falls during this period in Kerala. Accidental prepared similarly as described for stock SRBC preparation.

Experimental design:

A total of 36 cockerels were utilized for the second trial in this study divided into 2 groups (A and B), comprising 18 birds/group.

Immunization protocol:

All birds were immunized with 1 ml of 7 % RRBC i.v. On the following day after immunization, birds of group B were subjected to heat exposure. Six birds from each group was sacrificed by cervical dislocation on days 2, 6 and 10 of heat exposure, which corresponds to 3, 7 and 11th day after immunization.

Jerne's plaque assay:

The spleen was excised out, washed with cold physiological saline (0.90%), and immersed in Hank's balanced salt solution (HBSS) under sterile conditions. The capsule of the spleen was incised and removed. A single cell suspension was prepared in HBSS by triturating spleen parenchyma in required quantity of sterile HBSS, under cold conditions (4^{0}C). The suspension was sieved and the number of viable cells was estimated by Trypan blue dye exclusion method i.e., 100ìl of spleen suspension was added to 100ìl of 1% trypan blue and 800ìl of normal saline. This was mixed well and after two min, hemocytometer was loaded. The viable cells excluded the dye, while a non-viable cell appears blue. The stained and unstained cells were counted and the percentage cell death was calculated. Cell viability generally exceeded 90 plus %. Depending upon the viability, spleen suspension was diluted with cold HBSS to get a concentration of 7.5 x 10^6 viable cells/ml. To a volume of 500 ìl of 0.50 % agarose in HBSS taken in tubes kept at 45° C, added 100ìl RRBC (15 %) in physiological saline, 300ìl of cold HBSS and 300ìl of spleen cells (H" 2.5 million viable cells) and mixed well. The contents of the tubes were poured onto grease- free slides, spread into an area of 1"x 2" and allowed to solidify. Fresh chicken serum (1:10 diluted with PBS, pH 7.4), was used as complement source.

The slides were kept upside down in an incubator rack and the space between the slides and rack was filled with complement. The slides were incubated for 1h at 37°C. In the presence of complement, antibody produced by the lymphoid cells from birds immunized with RRBC, caused lysis of red cells in its vicinity (plaques) in a solid support utilizing the presence of complement (Jerne and Nordin 1963). Plaques so formed were found as empty spaces due to hemolysis, and was counted in a colony counter and later confirmed under low power light microscope (5x), and the results were expressed not only as the number of PFC per 7.5 million spleenocytes but also as percentage PFC.

Rosette- forming cell (RFC) assay:

The method followed for RFC was immunocytoadherence assay (Dagg et al.1977). A suspension of spleen cells was prepared as for the plaque assay. A mixture consisting of 300ìl cell suspension (H" 2.5 million viable spleen cells), 500ìl of 15% RRBC suspension, and 850ìl of HBSS were prepared. The mixture was centrifuged at 2000 rpm for 1 min and the pellet was stored in the refrigerator for 30 min. It was gently resuspended with a Pasteur pipette and loaded in a hemocytometer. The number of rosettes (clusters of four or more mammalian erythrocytes adhering to a chicken lymphoid cell), spread over all the WBC counting squares was counted and the results were expressed not only as the number of RFC per 7.5 million spleenocytes, but also as percentage RFC.

Statistical analysis:

Student t test was employed for comparing the effect of heat stress on corticosterone levels in birds (Snedecor and Cochran 1994).

Results

Evaluation of heat stress:

Body temperature was found to be significantly ($P<0.05$) increased in group II chickens when compared to non-heat stressed and BR treated non-heat stressed controls. In heat stressed chickens, the body temperature reached 44 ± 0.2^{0}C by the end of 4h exposure to heat, while control birds recorded rectal temperature of 42.9 ± 0.2^{0}C.Birds exhibited a great deal behavioural changes such as gular flutter, drooping of wings, prostration and drowsiness during the period of heat stress. The heat stressed birds lost an average of 35g of body weight daily upon 4h exposure to 40 ± 1^{0}C, which accounts for an average loss of 3.4% of body weight. There was a significant increase ($P<0.05$) in the H/L ratio in group II chickens when compared to other group (Table 1) indicating that heat stress brought about a relative decrease in the number of circulating lymphocytes.Plasma corticosterone level increased significantly (P<0.01) in heat stressed birds when compared to non-heat stressed group on both day 5 and 10 heat exposure (Table 2).

Table 1 Heat stress on differential leucocyte counts of normal and HST egg type male chicken (n=6)

Groups	Lymphocytes (L) (%)	Heterophils (H) (%)	H/L ratio
I	$42.50^a \pm 7.60$	$64.63^a \pm 1.29$	$1.86^a \pm 0.11$
II	$22.88^b \pm 1.04$	$77.13^b \pm 1.04$	$3.45^b \pm 0.24$

Mean ± SE having different superscripts, differ significantly (P<0.05) between groups.
Group I: Untreated and non-heat stressed controls.
Group II: Heat stressed. (40 ± 1°C, RH 80 ± 5% for 4 h/day for 10 days)

Table 2 Heat stress on plasma corticosterone concentration of normal and HST egg type male chicken (n=6)

Groups	μg/ml
NHST (control)	31.00 ± 0.33
5 days HST	$82.50^{**} \pm 0.12$
10 days HST	78.00** ± 0.24

Mean ± SE having different symbols differ significantly when compared to control.
Student t test used for comparison. NS – Non significant, ** - highly significant at 1% level.

HA assay:

The NHST (Group I) birds showed peak $\log_2$ HA titre of 10.33 ± 0.46 (Mean ± SE) against SRBC on 11th day after immunization, while HST (Group-II) birds exhibited the peak value of 4.67 ± 0.23 on day 9 (Fig.1). Later on, titres declined to reach a $\log_2$

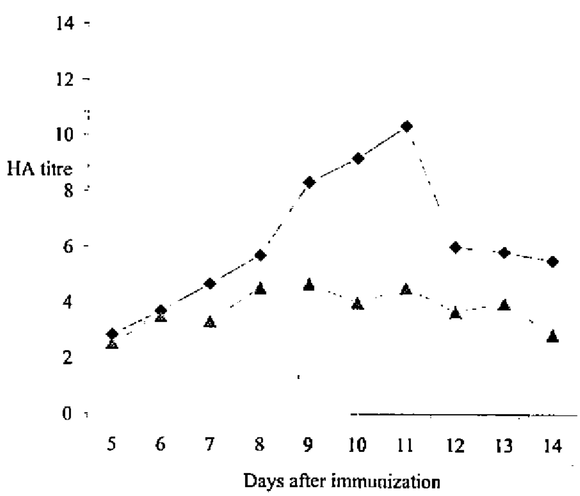

Fig.1 Effect of heat stress on haemaglutinin (HA) titre ($\log_2$)

value of 5.5 ± 0.27 and 2.87 ± 0.19 respectively by 14th day after immunization

Serum ME resistant antibody (IgG) level:

The NHST (Group I) birds, peak log_2 titre value of 6.83 ± 0.23 for IgG was observed against SRBC on 11th day and it declined to a value of 3.17 ± 0.20 by the end of the experiment (Fig.2). In HST (Group II) birds the highest log_2 titre of 3.17 ± 0.15 for IgG was reached on 8th day and it reduced to 1.83 ± 0.08 by 14th day after immunization.

Serum ME sensitive antibody (Ig M) level:

The NHST (Group I) birds showed peak log_2 titre value of 3.50 ± 0.30 for IgM on 11th day. It declined later to 1.83 ± 0.16 by the end of the experiment (Fig.3). In HST (Group II) birds the highest

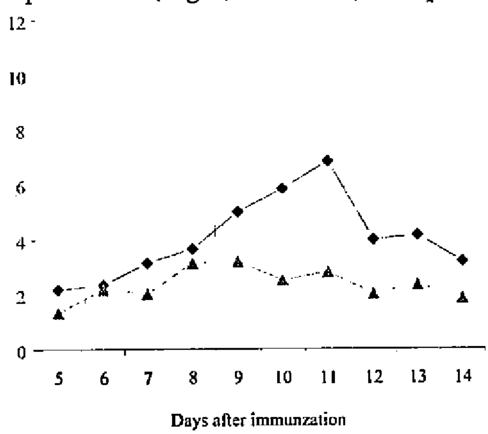

Fig.2 Effect of heat stress and BR supplementation in IgG titre (log_2)

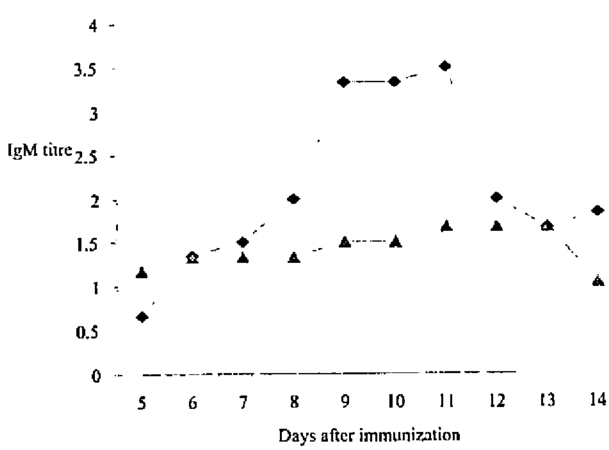

Fig.3 Effect of heat stress and BR supplementation in IgM titre (log_2)

log_2 titre of 1.67 ± 0.12 for IgM was reached on 11th day, which then reduced to 1.04 ± 0.06 by14th day after immunization.

Jerne's plaque assay:

On day 7 after immunization with RRBC, Group A (NHST) birds exhibited a maximum of 5.45 ± 0.45 $x10^6$ PFC/7.5$x10^6$ spleenocytes , which corresponds to 72.67% spleenocytes exhibiting plaque forming capability (Table 3). Similar response was exhibited by Group B (HST) which showed a peak plaque forming response on 7th day after immunization.However, on day 11 all birds showed comparatively lower PFC response.

RFC immunocytoadherence assay:

On day 7 after immunization with RRBC, Group A (NHST) birds exhibited a maximum of 4.48 ± 0.21$x10^6$ RFC/ 7.5x106 spleenocytes , which corresponds to 59.73 % spleenocytes exhibiting RFC (Table 4). Similar response was exhibited by Group B (HST) which showed a peak rosette forming response on day 7 after immunization.

Table 3 Heat stress and BR supplementation on plaque forming cells (PFC) (n=6)

Groups	Days after immunization with RRBCs				
	3	5	7	9	11
A	10.67%	26.67%	66.53%	42.67%	12.67%
B	12.13%	27.73%	60.00%	30.40%	5.33%

Group A: Non-heat stressed controls. Group B: Heat stressed. (40 ± 1°C, RH 80 ± 5 % for 4 h/day)

Table 4 Effect of heat stress and BR supplementation on rosette forming cells (RFC) (n=6)

Groups	Days after immunization with Rat red blood cells (RRBC)				
	3	5	7	9	11
A	41.20%	53.30%	64.00%	20.50%	10.53%
C	28.53%	41.73%	57.6%	18.40%	4.27%

Group A: Non-heat stressed controls. Group B: Heat stressed. (40 ± 1°C, RH 80 ± 5 % for 4 h/day)

Discussion

Every animal experiences stress, which results in the oversecretion of glucocorticoids (Chrousos 1995). This may lead to the suppression of both innate and adaptive immune functions and results in susceptibility to infections (Spehner et al.1996). It is reported that the effect of environmental temperature on immune responsiveness depends on the demand that is made on the bird's capacities to maintain homeothermia (Beard and Michell 1987). In this study it was found that body temperature was significantly ($P<0.05$) increased in HST chickens when compared to NHST. An increase in the Heterophil/Lymphocyte (H/L) ratio is one of the most accepted indicators of stress in poultry (Puvadolpirod and Thaxton 2000). It was found that HST birds exhibited significantly ($P<0.05$) higher H/L ratio. In rodents and birds the chief circulating glucocorticoid is corticosterone. In the birds exposed to heat stress, plasma corticosterone level was found to increase significantly when compared to non exposed birds. The heat stress induced increase in plasma corticosterone level significantly.

It was earlier reported (Henken et al. 1982) that preformed antibody levels could be reduced by higher environmental temperature, due to immunodepression mediated through the hypothalamo-hypophyseal-adrenal axis. Results herein showed that heating reduced HA titres. The increased IgG titre encountered in NHST birds could also be attributed to decreased rate of catabolism of antibodies (Srikumar et al. 2005).

In the HST birds there was a significant fall in the IgM titres from the peak value during heat stress. The peak $\log_2$ IgM titre exhibited by HST birds was significantly lower than that exhibited by NHST birds. Thus it can be concluded that hot and humid environment favours rapid catabolism of antigen used for challenge and a reduction in the levels of antibody production.

Haemolytic PFC is abundant in the spleen but is less frequent in other lymphatic organs of immunized birds, while cells with immunocytoadherant properties (RFC) appear in large numbers in the peripheral blood as well as in the spleen (Seto and Henderson 2005). It was found that anti-RRBC PFCs in NHST birds were considerably higher than those seen in HST birds.

Results revealed that the numbers of anti-RRBC RFCs encountered were higher than number of anti-RRBC PFCs and this observation agreed with some earlier reports (Dagg et al. 1977). The anti-SRBC RFCs in NHST birds were significantly higher than that exhibited by HST. Thus it proved that the functions of immune cells associated with PF and RF capacities could be easily perished due to adverse heat stress.

From the body's immunological point of view because of delayed attainment of peak antibody titre values against the challenged antigen, and due to increased catabolism of preformed antibodies during the period of heat stress in birds, it could be summarized that adaptation to stressful hot humid condition would be delayed.

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Effect of summer and rainy seasons of Kerala on haemogram of broiler chicken

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Introduction:

Climatic changes influence the physiological status of all living beings. Variations in temperature and humidity can affect the health and production in animals and birds. As far as poultry is concerned the changes in poultry house temperature and humidity will adversely affect the body metabolism of birds which in turn affect their physiological status as well as health and production. The climate in India is tropical mansoon type and the seasons have been classified (ICAR 1977) into three viz. winter (October to February), summer (March to June) and rainy (July to September). In South India, distinct winter season does not prevail. However, there is a distinct dry season and two wet periods. When extremes of temperature are the major problem in North India, the high temperature together with high humidity is the problem in South India. The increase in temperature as a result of the global warming is increasing stress on animals and birds. Along with these the mis-managemental practices as overcrowding induce additional stress on them. The heamatologicl parameters are the reliable, easy, as well as economic means to assess the health status of an individual. Hence a study was undertaken with the following objectives:

1. To find out the effect of seasonal variations on hematological parameters of broiler chicken.
2. To evaluate the impact of overcrowding stress on haemogram of birds during summer and rainy months of Kerala.

Materials and methods

The study was carried out in four week old broiler chicken in two phases (Phase-I- summer season-March to May and Phase II- rainy season-June to August). In each phase, twenty-four numbers of day old chicks of Vencob strain were purchased and reared in battery cages under standard managemental conditions up to four weeks of age. At fourth week of age the chicks were selected randomly, weighed, wing banded and divided into two groups comprising of twelve birds in each group (Table 1).

Table 1 Experimental groups of broiler chicken

Seasons	Groups	*Stressor*
Summer	G-I	Nil. Control (floor space 0.77 sq.ft/bird or 696 sq.cm/bird).
	G-II	Overcrowded birds (Floor space reduced by 50 per cent (0.39 sq.ft/bird or 348sq.cm/bird).
Rainy season	G-I	Nil. Control (floor space 0.77 sq.ft/bird or 696 sq.cm/bird).
	G-II	Overcrowding (Floor space reduced by 50 per cent (0.39 sq.ft/bird or 348sq.cm/bird).

From each bird the blood samples were collected initially at fourth week and at fortnight intervals up to eight weeks of age from the wing vein using EDTA (1mg/ml) as the anticoagulant. The haematological parameters such as Total erythrocyte count (TEC), Haemoglobin (Hb) concentration, Volume of packed red blood cells (VPRC), Erythrocyte indices such as Mean corpuscular volume (MCV), Mean corpuscular haemoglobin concentration (MCHC) and Mean corpuscular haemoglobin (MCH), as well as Total leucocyte count (TLC) were estimated. The estimation of TEC and TLC were done by the method suggested by Natt and Herrick (1952) and VPRC as well as Hb concentration was estimated as per standard procedures by Feldman *et al.*, 2000. Erythrocyte indices were calculated using standard formulae (Swenson and Reece, 1996). Blood smears were prepared using fresh blood at the time of blood collection. Air-dried smears were stained with Leishman-Giemsa stain solution and different leucocytes were counted and Heterophil:Lymphocyte (H:L) ratio was calculated. The data were analysed statistically using student t test (Snedecor and Cochran 1994).

Results and discussion:

The weekly environmental temperature (maximum and minimum) and relative humidity (RH) upto and during the experimental period in summer and rainy seasons are shown in table 2 and 2a respectively. The meteorological data revealed that climatograph of the locality fell within the hot humid climate.

Table 2 Weekly meteorological data during the experimental period of eight weeks*
Summer season

Period in Weeks	Temperature (°C)		Relative Humidity (RH) (%)	
	Maximum	Minimum	Forenoon	Afternoon
I	34.70±0.30	25.40±0.10	86.90±1.00	51.10±2.30
II	35.10±0.30	24.00±0.40	86.40±2.40	52.60±1.40
III	33.80±0.90	24.60±0.60	84.90±1.90	55.70±3.40
IV	35.10±0.30	26.10±0.30	81.90±1.40	54.00±1.40
V	35.00±0.60	25.20±0.50	86.90±1.00	52.90±2.30
VI	34.80±0.30	24.80±0.40	84.90±1.90	55.00±2.50
VII	29.30±0.90	23.50±0.20	91.60±1.70	81.90±3.90
VIII	31.60±0.40	24.00±0.40	89.60±1.78	68.40±4.67
[1]Mean ±SE	34.68 ±0.30	25.03±0.20	85.03±0.90	53.35 ±1.10
[2]Mean ±SE	32.68±1.17	24.38 ±0.46	88.25±1.71	64.55±5.62
[3]Mean ±SE	33.68 ±0.75	24.70 ±0.30	86.64 ±1.05	58.95 ±3.79

* From 22/3/04 to17/5/04

1 Mean values of I to IV weeks

2 Mean values of V to VIII weeks

3 Mean values of I to VIII weeks

Table 2a Weekly meteorological data during the experimental period of eight weeks*
Rainy season

Period in Weeks	Temperature (°C)		Relative Humidity (%) (RH)	
	Maximum	Minimum	Forenoon	Afternoon
I	29.30±0.20	23.30±0.20	92.40±0.20	80.60±0.20
II	30.80±0.20	23.40±0.20	92.60±0.20	66.30±0.20
III	29.70±0.40	22.90±0.20	92.40±0.40	73.40±0.20
IV	29.90±0.40	23.40±0.20	93.60±0.40	74.90±0.20
V	28.60±0.60	22.90±0.30	93.10±0.60	78.10±0.30
VI	29.50±0.40	22.80±1.00	94.40±0.40	74.70±1.00
VII	29.00±0.40	22.90±0.20	93.90±0.40	76.30±0.20
VIII	28.60±0.75	22.70±0.34	94.00±0.75	82.30±0.34
[1]Mean ±SE	29.93±0.20	23.25±0.10	92.75±0.20	73.80±0.10
[2]Mean ±SE	28.93±0.26	22.83±0.12	93.85±0.22	77.85±1.40
[3]Mean ±SE	29.43 ±0.26	23.04 ±0.10	93.30±0.29	75.83±1.74

* From11/6/04 to 5/8/04

1 Mean value of I to IV weeks

2 Mean value of V to VIII weeks

3 Mean value of I to VIII weeks

The data regarding the haemogram of unstressed and stressed (overcrowded) broilers in summer and rainy seasons are presented in table 3 and 3a. Analysis of the data showed that

Table 3 Haematological data of broiler chicken in summer and rainy seasons
Mean± SE (n = 12)

Parameters	Summer season			Rainy season		
	4th Week	6th Week	8th Week	4th week	6th Week	8th Week
Total erythrocyte count (TEC) in $10^6/\mu l$	2.88± 0.04	2.95± 0.06	2.97± 0.04	2.96± 0.04 NS	3.02± 0.04 NS	3.02± 0.06 NS
Haemoglobin concentration (g/dl)	8.54± 0.48	9.29± 0.49	9.75± 0.51	10.12± 0.20**	9.79± 0.13 NS	10.38± 0.13 NS
Volume of packed red blood cells (%)	27.42± 0.33	29.50± 0.56	29.33± 0.79	30.00± 0.21**	30.42± 0.36 NS	30.25± 0.35 NS
Erythrocyte indices						
Mean corpuscular volume(MCV) in µl	95.37± 2.40	100.34± 2.76	98.85± 2.86	101.40± 1.06*	100.94± 1.61 NS	101.43± 1.99 NS
Mean corpuscular haemoglobin concentration (MCHC) in g %	31.46± 2.08	31.73± 1.92	33.24± 1.57	33.75± 1.61 NS	33.22± 1.47 NS	34.31± 1.33 NS
Mean corpuscular haemoglobin (MCH) in pg	29.67± 1.62	31.50± 1.58	32.91± 1.80	33.23± 0.74 NS	33.51± 0.65 NS	34.79± 0.67 NS
Total leucocyte count (TLC) in $10^3/\mu l$	25.67± 1.49	25.17± 1.62	26.83± 1.27	27.33± 1.48 NS	27.67± 1.61 NS	28.17± 1.60 NS
Heterophil	31.92± 1.10	38.42± 0.43	40.75± 0.73	31.50± 1.00 NS	35.17± 1.17**	35.75± 1.05**
Lymphocyte	65.17± 0.83	59.50± 0.34	56.83± 0.89	65.33± 1.46 NS	61.92± 1.20 NS	63.00± 1.04**
H/L ratio	0.49± 0.02	0.65± 0.01	0.72± 0.02	0.48± 0.03 NS	0.57± 0.03*	0.57± 0.03**

** denote significant mean difference at 1% level of the corresponding week for two seasons

* denote significant mean difference at 5% level of the corresponding week for two seasons

NS denote no significant mean difference of the corresponding week for two seasons

Table 3a Haematological data of overcrowded broiler chicken in summer and rainy seasons
Mean± SE (n = 12)

Parameters	Summer season			Rainy season		
	4th Week	6th Week	8th Week	4th week	6th Week	8th Week
Total erythrocyte count (TEC) in $10^6/\mu l$	2.90± 0.07	2.99± 0.02	2.97± 0.04	2.98± 0.06 NS	3.04± 0.03 NS	3.00± 0.03 NS
Haemoglobin concentration (g/dl)	8.83± 0.52	9.13± 0.38	9.21± 0.40	9.83± 0.26*	9.68± 0.12 NS	10.19± 0.28*
Volume of packed red blood cells (%)	27.33± 0.72	28.25± 0.63	27.83± 0.58	30.25± 0.30**	29.97± 0.44 NS	30.05± 0.35**
Erythrocyte indices						
Mean corpuscular volume(MCV) in µl	94.70± 3.43	94.58± 2.23	93.98± 2.4	101.72± 2.43*	97.70± 1.89 NS	99.20± 1.32 NS
Mean corpuscular haemoglobin concentration (MCHC) in g %	32.80± 2.43	34.24± 1.48	33.09± 1.32	32.55± 0.95 NS	33.52± 0.98 NS	33.32± 1.10 NS
Mean corpuscular haemoglobin (MCH) in pg	30.55± 1.80	32.24± 1.33	30.99± 1.22	33.09± 0.76 NS	31.68± 0.51 NS	33.01± 1.03 NS
Total leucocyte count (TLC) in $10^3/\mu l$	25.83 ±1.51	25.17± 1.14	24.83± 1.19	27.17± 1.24 NS	25.67± 1.51 NS	26.00± 1.67 NS
Heterophil count (%)	31.75± 1.18	42.08± 0.87	43.75± 0.71	31.17± 1.39 NS	39.08± 1.44 NS	41.00± 1.08*
Lymphocyte count (%)	66.00± 1.31	55.17± 0.73	53.92± 0.74	65.83± 1.28 NS	58.33± 1.38*	57.00± 1.09*
H/L ratio	0.48± 0.03	0.77± 0.03	0.81± 0.03	0.48± 0.03 NS	0.68± 0.04 NS	0.72± 0.03*

** denote significant mean difference at 1% level of the corresponding week for two seasons

* denote significant mean difference at 5% level of the corresponding week for two seasons

NS denote no significant mean difference of the corresponding week for two seasons the haematological parameters such as Hb concentration, VPRC and MCV values in four week old birds were reduced in summer season. Even though no significant difference was noticed in the values of TEC, TLC, MCH, MCHC as well as in the number of basophils and lymphocytes, the values were lower in summer than in the rainy season. Similarly, the value of heterophil and H/L ratio were numerically higher during the summer season. High ambient temperature of 35.10 °C along with 81.90 % relative humidity (RH) to which the birds were exposed at fourth week might have resulted in reduced erythropoiesis or haemodilution, an adaptive response to heat stress as reported by Borges *et al.* (2004). Furlan *et al.* (1999) reported that acute heat stress was associated with a decrease in the values of Hb and VPRC. However, it was observed that on continued exposure to high temperature the birds could adapt to the high temperature and the seasonal variation in values of Hb concentration and VPRC were not significant in six and eight week old birds (Table 3).

In the present study the H/L ratio were not significantly ($P>0.05$) affected by the seasons. H/L ratio is the most reliable indicator of stress in birds. The H/L ratio of about 0.2, 0.5, and 0.8 characterized low, optimum, and high levels of stress, respectively (Borges *et al.*, 2004). Hence the H/L ratio of 0.68 and 0.72 observed in summer indicated moderate to high levels of stress in the summer season.

Though the high environmental temperature and humidity in summer season produced a microcytic anaemia in the initial stages (at four weeks of age), other haemogram values were not significantly affected by seasons. However, the high H/L ratio observed in summer (0.72 ± 0.02), showed that the birds are under stress during the hot humid summer months.

The eight week old stressed (overcrowded) birds in summer had a significantly low VPRC value and Hb concentration when compared to stressed birds reared in rainy season. This might be due to the combined stress of heat and overcrowding. The H/L ratio of 0.72 and 0.81 noticed in eight week old stressed broilers of rainy and summer seasons respectively indicated that the overcrowded birds in both the seasons were under high stress. The H/L ratio of eight week old overcrowded birds in summer was significantly higher than those in rainy season. From these observations it can be deduced that in future the global warming would produce severe stress on the broiler chicken and induce serious adverse effect on broiler farming leading to economic loss to the broiler farmers unless and otherwise counteracted with proper managemental alterations.

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National Seminar on Climate Change Adaptation Strategies
in Agriculture and Allied Sectors, held at KAU during 03-04 December 2009

Weather based animal disease forecasts

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Introduction

Many endemic diseases prevalent in India cause enormous loss to the livestock owners. Diseases have cascading effects on the life and productivity of the affected animals which will have serious repercussions not only on the productivity of animal husbandry sector but also on agricultural sector. All ancient civilizations bear ample testimony of intimate weather and climate dependence for the well being of man and his domestic animals. Human and livestock health depends on climate and weather conditions. Certain weather conditions are conducive to initiate or promote or aggravate certain diseases.

To derive maximum economic benefits through disease control programmes development of animal health information databank, a livestock disease information system is necessary. With this objective the project on Weather based animal disease forecasts has been envisaged to develop a weather related national disease forecasting system for enhanced livestock production through sustained reduction of animal diseases in different agro-eco zones. Disease forecasting models attributing the epidemiological disease parameters to the conventional agro-ecological and associated meteorological data of the country, when analyzed through logistic and multiple regressions have shown promising results. The methodology adopted for delineating agro-climatic influences in relation to livestock diseases have clearly shown that endemicity of livestock diseases is not uniform throughout the country but is concentrated in certain pockets influenced by weather. This type of epidemiological analysis will definitely serve as a revelation for our efforts in adopting disease control management strategies through vaccinations

India having largest animal population, the farmers are experiencing huge economic loss due to the outbreak of infectious diseases like FMD, HS, Anthrax, BQ etc. Systematic epidemiological studies on these outbreaks have not been done through out India and because of this reason proper preventive and control measures have not been adopted at various agro-climatic zones. This NATP on "Weather based animal disease forecasts" has given a momentum in studying the disease outbreak in various zones covering entire India.

Objectives of the project was to collect

- Retrospective animal disease data from the Department of Animal Husbandry from 1995 onwards for all the 14 districts in Kerala.
- Meteorological data of various parameters of all districts.
- Baseline data on infrastructure of livestock management sector
- To collect real time animal disease data from designated districts viz. Thrissur and Kannur by using random sampling survey method.
- To assess the correlation of disease outbreaks with the weather parameters in Thrissur and Kannur districts.
- To validate the forecasts made with the real time disease diagnosis in selected districts.

Materials and methods

Weather related disease forecasting deals with predicting the future based on past livestock disease data associated with meteorological and other related phenomenon. It forwarns the personnel associated with livestock activity to take up appropriate measures in controlling diseases

Retrospective data regarding animal diseases and meteorological factors were collected from 1995 onwards for all the 14 districts in Kerala and the correlation of disease outbreaks with the weather parameters was assessed. The technical know-how of the ADMAS, Bangalore, has helped in forming a disease forecasts for all the districts of Kerala, India. ADMAS Epitrak software facilitated development, dissemination and validation of the integrated and comprehensive weather associated national livestock disease forecasts. Updating and validation of forecasting models were done by using the real time animal disease data collected from designated districts viz. Thrissur and Kannur by using random sampling survey method. Attempts were made to assess the correlation of disease outbreaks with the weather parameters in Thrissur and Kannur districts.

To establish and quantify the factors associated with the disease, multiple regression analysis was carried out for specific diseases namely anthrax, blackquarter(BQ), foot and mouth disease(FMD), haemorrhagic septicaemia(HS) and rabies. The frequency of outbreaks was taken as dependent variables and all the agro-eco –meteorological parameters as independent variables

Results and discussion

Correlation of disease outbreaks with the weather parameters in two districts ie.Thrissur and Kannur was assessed using multiple regression and step down regression analyses. Month wise incidence of FMD and Rabies cases in Thrissur and Kannur districts during 2002-03 is shown in Figures 1 and 2. A positive correlation was obtained for FMD outbreaks with number of rainy days and average wind velocity, but was not statistically significant. FMD is a highly contagious disease that spreads readily by close contact with infected animals and infected products. For such spread environment has little consequence. Similar findings were also reported from other districts where FMD has not shown any correlation with any of the parameters studied. (Annual report 2001-02) However wind borne spread of viral particles over considerable distances has been established (Cannon and Garner, 1999, Garner and Beckett, 2005). Verma and pal (2008) reported high incidence of FMD during winter months in comparison to summer and rainy months during a study of outbreaks of FMD in Uttar Pradesh during 2000-06.

In the present study HS, Anthrax and BQ did not have significant correlation with weather parameters. There are reports of positive correlation between outbreaks of HS and rainfall, relative humidity and minimum temperature in other states o f India (Verma et.al, 2004)

Validation of forecasts by combining the disease surveillance data revealed that the forecast of Rabies was correlating with all the districts because most of the veterinarians diagnose this case from clinical signs and report. But other diseases like FMD, H.S, Anthrax and BQ were not correlating. One of the important reason for this discrimination could be the lack of proper diagnosis in the field condition as well as the under reporting by the veterinarians in order to avoid further problems from the higher

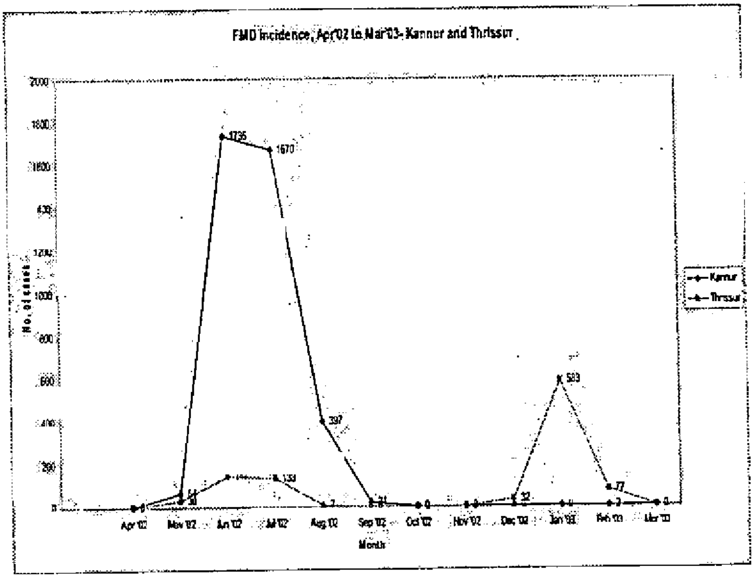

Fig.1 Monthwise incidence of FMD in Thrissur and Kannur districts during 2002-03

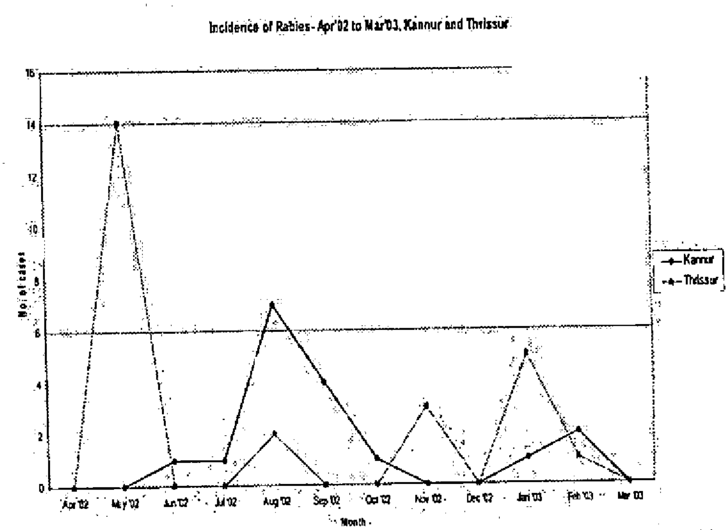

Fig.2 Monthwise incidence of Rabies cases in Thrissur and Kannur districts during 2002-03

officials. Hence further fine tuning of the forecasts as well as validation using real time disease diagnosis is essential for making this system a full-proof one.

Conclusion

The findings of the study will be useful for the farmers for adopting various control measures based on the forecast made, thereby reducing disease outbreak and subsequent economic loss. Multiple regression analysis carried out on major livestock diseases prevalent during different seasons will facilitate not only to identify but also to quantify the precipitating independent variables drawn from livestock, meteorological, agro-ecological and associated factors. This analysis by evolving the regression coefficients will facilitate forecasting of diseases quantitatively for any district in question in the entire country on seasonal basis. Once A National Animal Disease Referral Expert System (NADRES) is well established, daily animal disease forecast can be made available to the public through print as well as electronic media, thereby the farmers can adopt suitable control measures such as vaccinations well in advance. This will certainly revolutionize the animal husbandry sector for boosting up the production, in turn the economy of our country.

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Livestock to mitigate global warming

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Abstract

The livestock sector contributed over 5.26 per cent to the total GDP during 2006-07 and 31.7 per cent GDP from total agriculture and allied activities. Livestock were blamed for 18 percent greenhouse gas emissions and found to be less than five percent. The annual FYM availability 284 million adult cow units of India are 1376 million tones. NPK percentage in FYM is 1.5: 0.8: 1.9 and total NPK from livestock is equal to 205.85 lakh tonnes, 109.79 lakh tonnes and 260.75 lakh tones respectively. The annual requirement of NPK in India was estimated as70.38LMT nitrogen, 40.31 LMT phosphorous and 38.61 LMT Potash. Daily biogas yield in the Country from 284 million cattle and buffaloes is 1457 m^3. With biogas entire 300 million families of India can be provided with cooking gas and 120 million liters of petrol could be saved. The reduction in fossil fuels use, nitrous oxide release from fertilizer and energy saved would mitigate global warming.

Introduction

The livestock sector contributed over 5.26 per cent to the total GDP during 2006-07 and 31.7 per cent GDP from total agriculture and allied activities. The growth of agriculture and allied sector in 2008-09 declined to 1.6 per cent from 4.9 in 2007-08 and 4.0 per cent in 2006-07. The Eleventh Five Year Plan envisages an overall growth of 6-7 per cent per annum for the livestock sector. In 2007-08, this sector contributed 104.8 million tonnes of milk, 53.5 billion eggs, 44 million kg wool and 2.6 million tonnes of meat. The 17th Livestock Census (2003) has placed the total livestock population at 485 million and total of poultry birds at 489 million which was valued at about two lakh crore rupees. Milk accounted for 68 percent of this output and it was higher than paddy or wheat. In terms of value of the output, milk is the single largest agricultural commodity in India. Dairying contributes close to the third of the gross income of rural household and nearly half of those without land. It is estimated that over 100 million rural households earn their livelihood through livestock in India. World over 1billion people get their food through livestock enterprises.

Livestock and its long shadows

Livestock were blamed for 18 percent of greenhouse gas emissions, a bigger share than that of transport (FAO), which was strongly questioned by experts as that was not supported by sufficient benchmark data. Another myth that the livestock as the single largest anthropogenic user of land with 26 percent land use for grazing and a third of all arable land use for feed crop production is also not true developing countries where crop residues are the main feed for livestock. As more than 70% of livestock was reared by poor population comprising 60% in the world llivestock production was regarded as an expression poverty of people who have no other options and generate just under 1.5 percent of total GDP (FAO). Yes, FAO statement clearly emphases the potential of livestock to feed the people who have no other options and livestock cannot be evaluated in terms of GDP percentage of alone it has got cultural bonding with human race and continue to remain with population who value natures harmony.

Greenhouse gases

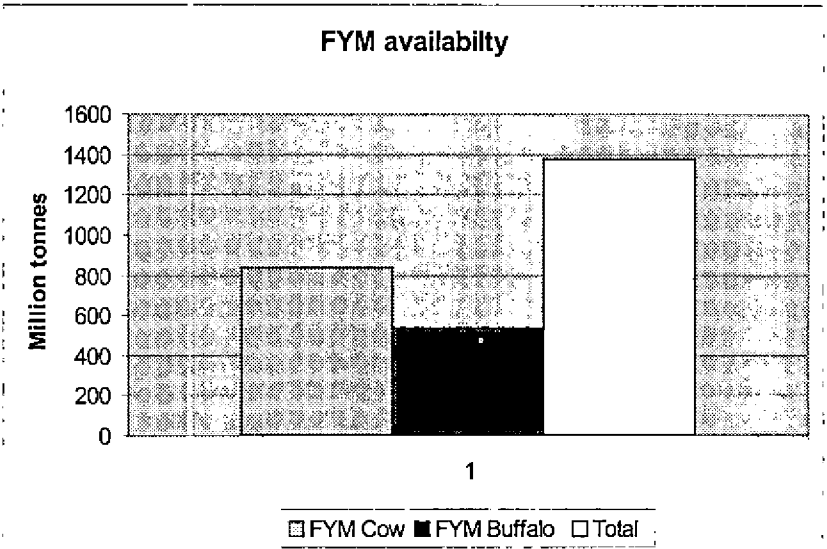
They are chemical compounds that contribute to the greenhouse effect. When in the atmosphere a greenhouse gas allow sunlight (solar radiation) to enter the atmosphere where it warms the Earth's surface and is reradiated back into the atmosphere as longer-wave energy (heat). Greenhouse gases absorb this heat and 'trap' it in the lower atmosphere. The rapid increase in atmospheric concentrations of the three main human-made greenhouse gases –carbon dioxide, methane, and nitrous oxide and hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6) are of great concern now. Energy information administration the Official energy Statistics from US Government gave the sources and its percentages of green house gases in US which clearly shows that share of livestock in methane emission may be less than five percent. Methane production from livestock could be reduced by Dietary Monensin or Chlortetracycline as per scientists Varel and Hashimoto, 1981 from the US dept of Agriculture.

Global warming potential (GWP) of greenhouse gases

Fossil fuels are made up of hydrogen and carbon. When fossil fuels are burned, the carbon combines with oxygen to create carbon dioxide. In climate science, the relative climate-forcing strength of different greenhouse gases is described relative to that of carbon dioxide released per kilogram and is expressed as Global Warming Potential (GWP). GWP of methane is 23 kilograms of carbon dioxide where as GWP of nitrous oxide which was developed through the use of nitrogen fertilizer is 296. So limiting the use of fertilizer is the key to reduce global warming.

Fertilizer value of farm yard manure

From the 284 million adult cow units of India the annual FYM availability is 1376 million tones.



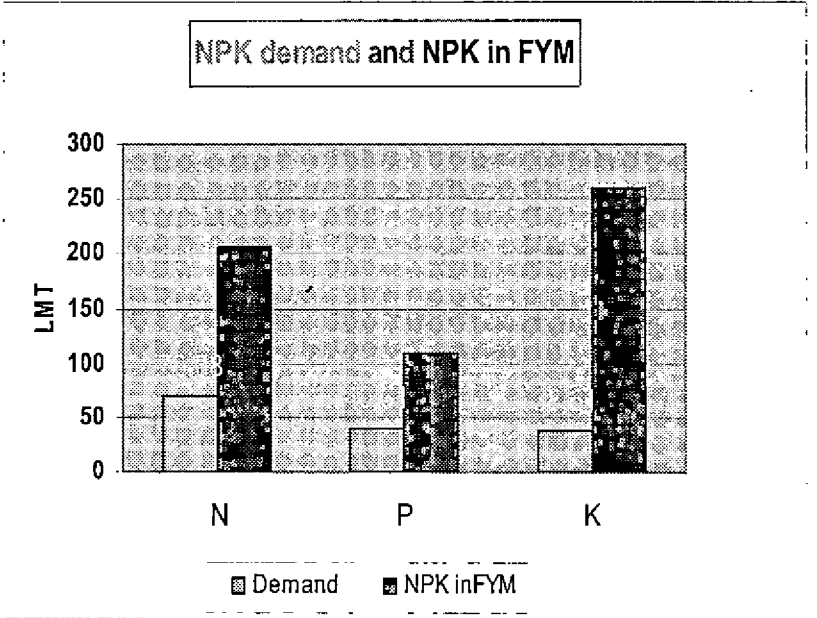
Well rotten farm yard manure contains 0.4 to 1.5 % N, 0.3-0.9% P_2O_5 and 0.3-1.9% K_2O. The maximum percentage of NPK available from farm yard manure is 1.5: 0.8: 1.9. So the total amount of nitrogen, P_2O_5, K available from 1376 MT of dung from livestock is equal to 205.85 lakh tonnes, 109.79 lakh tonnes and 260.75 lakh tones.The area under different crops in India and their annual NPK requirement is given in table. The total annual requirement of NPK in India is 70.38LMT nitrogen, 40.31 LMT phosphorous and 38.61 LMT Potash.

Table 1 Annual requirement of NPK in India

Crops	Area(M ha)	N (LMT)	P(LMT)	K (LMT)
Rice	43.6	17. 44	8. 72	8. 72
Wheat	28	22. 40	11. 20	11. 20
Jower	8.5	5. 10	3. 40	1. 70
Maize	7.9	7. 11	2. 37	2. 37
Bajra	9.5	3. 80	1. 90	1. 90
Groundnut	5.6	0. 62	4. 64	4. 64
Sugarcane	`4.9	7. 08	3.54	3.54
Cotton	9.1	6.83	4.55	4.55
Total	**117.1**	**70.38**	**40.31**	**38.61**

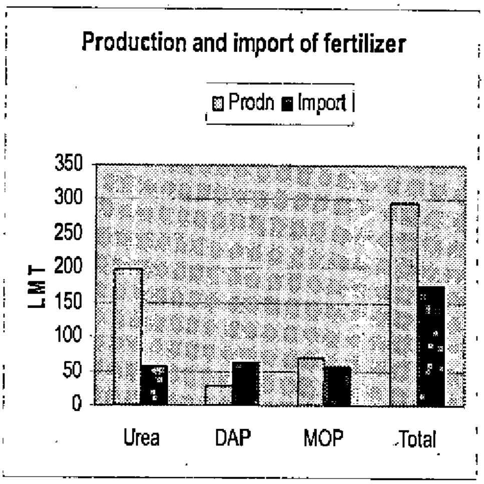
The comparative NPK requirement and its availability in FYM is given in table 1 and it is seen that with the one third of FYM collected the entire NPK requirement of the country can be met.

Comparative NPK requirement and availability from FYM in LMT



Production and import of fertilizer in India.

India is producing 300 LMT of fertilizer and importing 175 LMT of fertilizer to meet the NPK requirement. The capital cost and cost of production and its distribution has become a burden to the exchequer. Lot of energy is used for production and lot of diesel is burnt to transport the fertilizer. Farm yard manure and biogas would contribute both fertilizer and energy requirement of the country.



Energy potential of biogas

India is a country which has highest number of cattle and buffalo herds in the world producing tonnes of manure which can be converted to energy rich biogas. The United Nations Development Programme (UNDP) 1997 Report, *Energy After Rio: Prospects and Challenges* identified community biogas plants as one of the most useful decentralized sources of energy supply. The potential of daily biogas yield in the Country from 284 million cattle and buffaloes is 1457 m^3.

Table 2 Biogas yielding potential of Indian cattle and buffaloes

	Population (million)	Dung (kg/day/animal)	Dung collected/day (million kg)	Gas m^3/kg dung	Total gas/day (million m^3)
Cattle	187.38	10	1873.8	0.36	674.568
Buffalo	96.62	15	1449.3	0.54	782.622
TOTAL					1457.19

Cooking gas from livestock: According to Gujarat Energy Development Agency of Government of Gujarat, 1.2 million m^3 of biogas is sufficient for cooking purposes of 5 million families (50 lakh). At that rate with 70 million m^3 a biogas entire 300 million families of India can be provided with cooking gas. Burning out the biogas for cooking purpose will convert methane which has Global warming potential(GWP)of 23 into carbon dioxide having GWP one.

Draught power: Energy includes all forms of energy including draught power. Electricity equivalent of draught power from livestock is estimated at 71,175 megawatt at the rate of 0.5kw per bullock. 15million bullock carts in India is valued at Rs.27,000 crore rupees. Notion of bullock cart to bullock cart age lead to the neglect of this resource. Development of towns and cities denied or restricted access of bullock carts to roads and areas in cities has further damaged this mode of energy production. Even then more than 50% of rural transport and 40% of tillage is done by the bullocks. So it is still worth to conserve and upgrade this resource as one of the modes of energy generation.

Oil equivalent from livestock: As per Science Tech Entrepreneur, Centre for Rural Development and Technology, IIT, Delhi, 120 m^3 of biogas can replace 48 litres of petrol, so, with total resource of 1450 million m^3 biogas, 120 million liters or 12 Crore liters of petrol, which at rate of Rs 50/ per litre can save Rs 600 crores per annum. Appropriate use of biogas can save lot of money to the Government exchequer.

To clean environment: Biogas technology could prevent pollution of soil and water and provide pathogen free digested sludge as fertilizer for organic cultivation. The practice of containing livestock for manure collection, which might otherwise graze in the forest, both contribute to protecting the remaining forests and allowing the forests to regenerate.

On the move: Biogas contains 60-65% methane, 35- 40 % carbon dioxide, 0.5-1.0 % hydrogen sulfide and water vapor. It is about 20% lighter than air and cannot be converted to liquid state as being done for Liquefied Petroleum Gas (LPG) under normal temperature. Biogas is being used to provide power to run stationary engines and generators. Biogas can be converted into bio Compressed Natural Gas (bio CNG) after removing carbon dioxide and compressing it into cylinders. This can be used as an alternate to costly petroleum fuels to run Nano cars to container trucks

Conclusions

Livestock provides food and income for one billion of the world's poor and culturally associated with human race. Green house gas emission from livestock is less than five percentage. The dietary addition of ionsphores at less than 3% level found to reduce the methane production. Fertilizer value of farm yard manure is greater than fertilizer plants. The replacement of chemical fertilizer with FYM reduces the nitrous oxide which has green house gas potential of 296 significantly. The energy required to produce and distribute the 475 LMT of fertilizer could be saved by the use of FYM which ultimately reduce the global warming. The energy potential of biogas could provide cooking gas for the entire families of India, provide power to one fourth of the villages of India and could be used as Bio CNG. The United Nations Framework Convention on Climate Change has set up a Clean Development Fund, and the World Bank has put together a Carbon Finance Unit to allow rich countries, which are pumping more carbon into the atmosphere than is allowed under the Kyoto Protocol, to buy emissions that poor countries prevent through conserving forests or promoting renewable energy. India could earn some fund through the carbon crediting.