SACON Technical Reports No.60

# *Decline in the yield of Sapota (Manilkara sapota) from the orchards of Dahanu Taluka: Causes and Concerns*

## *An ecological investigation*

**Dr. P R Arun & Dr. P A Azeez**

*Environmental Impact Assessment Division*
SALIM ALI CENTRE FOR ORNITHOLOGY AND NATURAL HISTORY, COIMBATORE
May 2004

# *Declining yield of Sapota (Manilkara achras (Mill.) Forberg) from the orchards of Dahanu Taluka: Causes and Concerns*

## *An ecological investigation*

**Dr. P R Arun & Dr. P A Azeez**

SACON

*Division of Environmental Impact Assessment*

SALIM ALI CENTRE FOR ORNITHOLOGY AND NATURAL HISTORY, COIMBATORE

MAY 2004

## CONTENTS

## TABLES AND APPENDICES

## FIGURES

**PLATES**

## 1. INTRODUCTION

Salubrious forests and luxurious orchards dominate the landscape of Dahanu taluka, in the coastal region of northern Maharashtra (Plate 1 & 2). It has the distinction of being one of the very few last surviving coastal green havens amidst a highly denuded and industrialised neighbourhood. In spite of being a declared eco-fragile area under Dahanu notification of 1991 (Ministry of Environment and forests, Govt. of India) the Dahanu taluka continue to face various environmental challenges threatening the very sustenance of the natural ecosystem apart from severely affecting the livelihoods of the local people and their economy. Especially the fruit and fishery production from the area has been reportedly experiencing a mysterious and precipitous decline during the past few years. The sapota plantations along the coastal belt of Dahanu Taluka, which were healthy and yielding prolifically until a few years back are yielding significantly less during the recent years. A slight decline in yield perceived by the mid 1990s had become wide spread in the Taluka by the end of that decade. The decline has intensified further during the past 5-6 years affecting the local economy in toto, and it is currently a baffling crisis confronting everyone concerned about the welfare of Dahanu, its people and environment.

The precipitous decline in yields from orchards and fishery sectors has affected not only farmers and fishermen, but also people from other walks of life (such as farm labourers, transporters, businessmen and Auto/ taxi workers). Vast majority of the people here are directly or indirectly dependent on the orchards and fisheries sectors for their livelihoods and are severely affected from the plummeting yields and productivity in these sectors. Dahanu's people and economy are struggling to cope with the difficult times. Immediate and serious mitigatory measures are imperative to save, this environmentally and ecologically precious fragile costal zone of Maharashtra before it succumb to the environmental challenges.

## 2. THE PRESENT STUDY

The present report trace the trend of decline along multiple dimensions and identify the probable causes and also examines general ecological concerns of the area. It examines the problems of the Sapota (*Chicku*) orchards from an ecological perspective, on the basis of ground level information collected from the orchards of the area. The present short-term study was taken up with two major objectives;

1) Gather baseline data on the nature and extent of the yield decline in the sapota orchards of the Dahanu area and
2) Make a preliminary evaluation of various potential biotic and abiotic environmental parameters that are possibly affecting the Sapota yield

The methodology followed for the study was an extensive questionnaire survey carried out among the farmers of Dahanu during January to March 2004 using a custom made questionnaire (Appendix 1). Primary information was also collected through discussions with various people concerned, such as farmers, wholesale dealers of fruits, social workers, journalists and farm labourers (Plate 3). Data on factors, such as age of the plants, farming practices, flowering and fruiting patterns, water availability; irrigation methods, pest incidence and annual yields were recorded from the orchards. As it has been reported from elsewhere, other possible reasons such as a new pest (Horvitz and Schemske 2002) or a possible decline of natural enemies/ predator populations of the pest species (Parrotta *et al.* 2002) were also examined during the study. Stratified random sampling method was the sampling strategy followed during the study. 116 farms at various locations in Dahanu taluka were selected randomly and data was collected on various ecological aspects in a structured manner following a questionnaire designed for the study (Appendix 1). Apart from the primary data thus collected, various secondary data sources were also consulted wherever necessary.

Geographic co-ordinates (Latitude and longitude) of the farms were recorded using a hand held GPS (Global Positioning System) except for a few farms that were not visited personally. Since the Dahanu Thermal Power plant (DTPP) is the most important source of environmental pollution at Dahanu, the radial distance of various farm locations from the chimney of DTPP was also recorded (Appendix 2). The mean geographic location of orchards surveyed from various places and their aerial distances from DTPP are given in Table 1.

Table 1 Major locations in Dahanu taluka surveyed during the study

| Place | Latitude * (degrees °) | Longitude * (degrees °) | Distance from TPP (in km) & Direction |
|---|---|---|---|
| Agwan | 19.94 | 72.79 | 4.81 E, SE |
| Ashagad | 19.94 | 72.88 | 14.10 E |
| Aswali | 20.09 | 72.77 | 15.42 N |
| Bordi | 20.11 | 72.77 | 16.79 N |
| Borigaon | 20.11 | 72.76 | 18.10 N |
| Chikla | 20.07 | 72.71 | 12.90 N |
| Ganjad | 19.95 | 72.84 | 9.94 E |
| Gholvad | 20.09 | 72.74 | 14.68 N |
| Jamshet | 19.99 | 72.82 | 9.21 NE |
| Jhai | 20.09 | 72.73 | 18.70 N |
| Kainad | 20.02 | 72.78 | 8.10 NE |
| Kankradi | 20.00 | 72.75 | 4.90 N |
| Khanoda | 20.08 | 72.78 | 14.05 N |
| Kosbad | 20.05 | 72.74 | 11.00 N |
| Masoli | 20.00 | 72.74 | 6.08 N |
| Pale | 19.90 | 72.78 | 7.00 SE |
| Saravali | 19.99 | 72.77 | 4.32 N, NE |
| Vaki | 20.05 | 72.75 | 10.50 N |
| Vangaon | 19.87 | 72.73 | 9.05 S, SW |

* Based on the mean location of the surveyed farms

## 3. ECOLOGICAL SIGNIFICANCE OF DAHANU TALUKA

Dahanu is one of the 13 talukas coming under the district of Thane in Maharashtra. It consists of 174 villages and the Dahanu Municipal Corporation (DMC) formed in 1985 merging seven villages. Located in the northernmost part of the West Coast of Maharashtra, Dahanu extends over 960 km$^2$ with forests covering more than half of its land area (Dewan and Chawla 1999). The eastern half of Dahanu, otherwise called 'junglepatti', is a tribal dominated hilly area with rich forest cover. The western half is known as 'bandarpatti' and is mainly comprised of low lying coastal zone, dominated by orchards and other agricultural lands.

Dahanu is a crucially important ecological system which still sustain the relict of once continuous Western-Ghat forests existed all along Maharashtra's western boundary. Dahanu has the distinction of majority population being tribals who still depend heavily on the local ecosystem resources and traditional occupations such as agriculture and fishing for their day-to-day needs. Dahanu also an important source of fruits, vegetables, fish, fodder, milk and flowers for the near by urban areas. It is endowed with a beautiful and highly productive coastline, wetlands and significant forest cover and biodiversity. Dahanu is an oasis of greenery amidst a heavily industrialised and altered coastal belt, and can aptly be called as the green lungs of Northern Maharashtra and deserves the utmost conservation priority by virtue. Befittingly, in recognition of the threats to its rich forest cover, bio-diversity, specialised ecosystems, tribal culture, marine and horticultural wealth of the region, Ministry of Environment and Forests declared the Dahanu taluka as an ecologically fragile zone by a special notification in 1991.

## 4. FOREST AND BIODIVERSITY

The forests of Dahanu taluka are rich in biodiversity. In 1999 the Bombay Natural History Society (BNHS) of Mumbai has done a preliminary biodiversity documentation of the area (Rahmani *et al.* 1999). According to their report, there are 420 species of plants, 32 butterflies, 47 reptiles, 210 birds and 30 mammals present this area, which include many ecologically sensitive and protected species. However, this biodiversity documentation was based on a short-term study and is far from complete in many aspects of the biodiversity. Further serious studies on a long-term basis need to be conducted to make a comprehensive document on biodiversity of the area. A list of 50 butterflies from the area based on the opportunistic observations made during the present study is given in Appendix 7, which signals that the area is much richer than the earlier documentation suggests, and emphasise the need for further investigations and documentation.

## 5. CLIMATE

Climate of Dahanu is humid tropical with prominent southwest monsoon showers during the period of June-August. The area receives an annual rainfall of around 1800mm (Figure 1). Although there was slight reduction in the rainfall during the recent past, there was no any drastic change in the rainfall pattern as such (See Appendix 3 for Monthly rainfall pattern over the years). Predominant wind direction during the non-monsoon seasons was from North-east and during monsoon months it was generally from South-west. According to the local farmers, the temperature regime has changed over the recent years with rise in the winter and night temperatures.

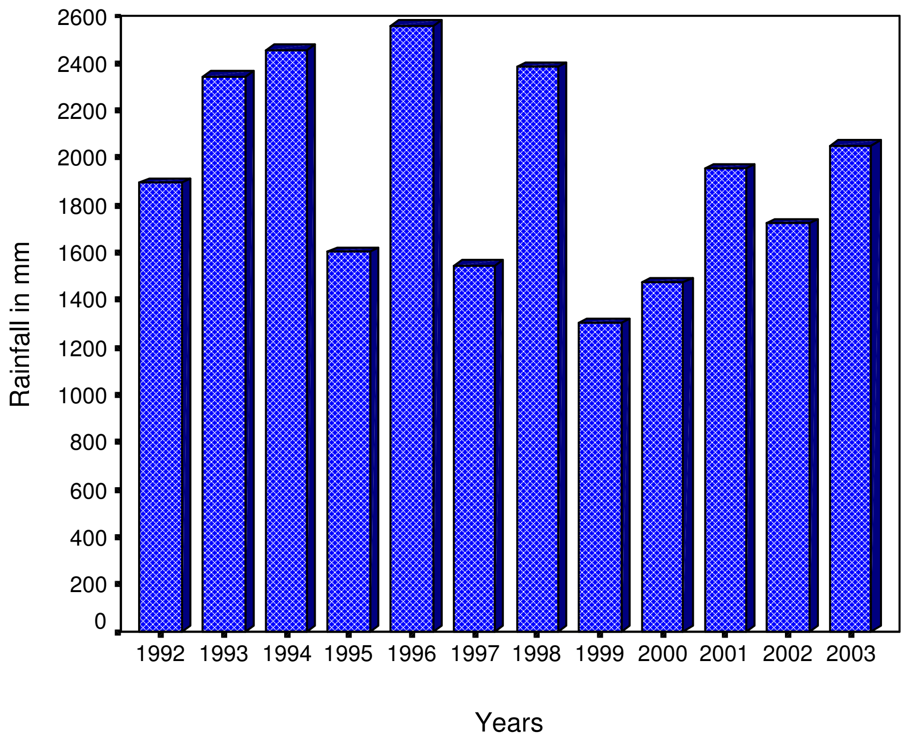


*Figure 1 Annual rainfall of Dahanu during the last twelve years*

## 6. PEOPLE AND ECONOMY

A vast majority of around 3 lakh strong population of Dahanu taluka live in its rural outskirts. Scheduled tribes dominate population (67%) of the taluka. Agriculture and fishery sectors together form the backbone of the economy and livelihoods of the people. A comprehensive account of the socio-economic profile of the region is given in the book by Ritu Dewan and Michelle Chawla (1999). The land use pattern of the Taluka as per the official records is given in Table 2.

109 of the total 254 industrial units operating in Dahanu come under the Red category as per the Notification of 1992 (NEERI 1996). There are many household and small-scale industrial units like jewellery die-making, balloon manufacturing units and buffing units (engaged in polishing of the steel cutlery items). However, most of these small industries are functioning with no proper environmental safeguards and people working in these units as well as those residing in the

immediate neighbourhood are exposed to unhealthy and hazardous working environments. Concerned authorities need to give due attention to such occupational exposure problems in the best interest of the welfare of Dahanu people and environment.

*Table 2 Area under different crops (Dahanu Taluka )*

| Crop | Area in hectars |
|---|---|
| Rice | 16386 |
| Wheat | 99 |
| Moong | 250 |
| Val | 149 |
| Chillies | 150 |
| Other Spices | 170 |
| Coconut | 80 |
| Cashewnut | 22 |
| Mangoes | 290 |
| *Chicku** | 6900 |

*(Source: Dewan and Chawla 1999 & Regional plan) & * Official records*

## 7. ORCHARDS

Orchards are the major employment source for the predominantly tribal work force of Dahanu (Plate 6). Although Sapota is the dominant orchard tree in the farms of Dahanu, several other tree species such as Coconut, Mango, and Litchi are also grown in these orchards. Associated activities such as apiculture, medicinal plant cultivation and vermicomposting are also pursued in many farms (Plate 8-10). Most of the orchard farmers still follow the traditional and environmentally benign organic farming practices. Around 75% of the farms surveyed during the present study were found following biological farming practices without using chemical pesticides and fertilizers. However, of late, forced by the declining yields and the propaganda by agrochemical industry, some of the farmers have deviated from their eco-friendly traditional methods and have gone for expensive and environmentally hazardous chemical practices.

Currently most orchard farms of Dahanu are reeling under multi-faceted problems. Pest menace in the farms has greatly escalated. The African Snails (*Achatina (Lissachatina) fulica* Bowdich) which once devoured the greenery of the orchards of Bordi area few years back has been efficiently controlled by the farmers using just common salt (Plate 11). Eriophyid mites have taken a heavy toll on the coconuts, which earlier had wreck havoc in the coconut farms of southern states, especially Kerala. However, various control agents have been experimented against this pest including a biological control agent *Hirsutella thompsonii* (Gopal and Gupta 2001). However, there are efficient pest management strategies have succeeded in managing this scourge to a great extent. The ICAR centre at Kosabad is conducting the final field tests of a mite management strategy tailor-made for the local environmental conditions of Dahanu. Presently the borer pests (*Trymalitis margarius* and *Anarsia achrasella*) are a severe problem in the *Chicku* orchards (Plate 7)

There was yield decline in Mangoes too in recent years. However unlike Sapota, which yields almost all through the year, the Mangoes are known to yield irregularly and hence, the farmers are not that unhappy with the yield decline from Mango orchards. Since the mango orchards were abundant in flower during early this year (Plate 12) when the field surveys for the present study was under way, and the farmers were looking forward for a bumper yield next season. However their dreams were shattered overnight when the flowers charred out before their eyes due to smoggy weather in last March. From the preliminary observations it appears that the condensation of acidic dew on the flowers has caused this damage.

## 8. SAPOTA (*Manilkara achras* (Mill.) Forberg)

The Sapota (*Manilkara achras* (Mill.) Forberg), known as '*Chicku*' in local language, is a major tropical orchard plant widely cultivated in Dahanu and its neighbourhoods. This tropical American fruit tree is believed to be introduced here by the Portuguese way back in 15$^{th}$ century (Dewan and Chawla 1999). Sapota, cultivated for its edible fruits in India is cultivated in many other tropical countries like Mexico, Guatemala and Venezuela mainly for extraction of the edible gum from the bark (Chicle gum). In India the plant is not known to be used for chicle extraction and is cultivated only for the fruits. Although sapota is only a minor fruit among other Indian fruits, India is the largest producer of Sapota in the world (Bal 1996). The seeds and bark of the Sapota tree have medicinal properties.

Sapota fruits are rich in nutrients (Table 3). It contains poly-phenols and tannin along with sugars in varying concentrations depending mainly on the stage of ripening (deBrito and Narain 2002). Drying is the major processing method used for preservation for Sapota (Ganjyal *et al.* 2003), and many of the enterprising farmers of Dahanu have devised ingenious methods and equipments to hygienically desiccate and preserve the fruits. However attempts to exploit the marketing potentials of the processed fruits appear to be lacking.

*Table 3 Nutritional Composition of ripe Sapota fruit*

| Constituent | Amount (per 100gm of edible portion) |
|---|---|
| Moisture | 73.7 g |
| Carbohydrate | 21.4 g |
| Protein | 00.7 g |
| Fat | 01.1 g |
| Calcium | 28.0 mg |
| Phosphorus | 27.0 mg |
| Iron | 02.0 mg |
| Ascorbic acid | 06.0 mg |

(*Source*: Sulladmath et al 1990)

The first commercial sapota cultivation from Maharashtra was taken up in Gholvad area in 1898 (Sulladmath and Reddy 1990; Bari 2002). Since then the *Chicku* plantations were flourishing well in the warm and humid climate of Dahanu. Unlike many other plant species the Sapota plant has the unique characteristic of flowering and fruiting all through the year, which helped making this plant a hot favourite of many a Horticulturists. Several traditional varieties of Sapota are available for cultivation. Major cultivars include *Kalipatti, Cricket ball, Chhatri, Culcutta round*, and *Pala* varities. Apart from these, superior hybrid varieties are also available which are developed through plant breeding techniques in different parts of the country (Eg:- CO-1, CO-2 and PKM-1 from Tamilnadu Agricultural University, Coimbatore). However these hybrid varieties are not popular among the farmers of Dahanu, and the traditional *Kalipatti* remains the most widely cultivated variety in Dahanu. The Plants grown in the orchards of Dahanu are Kalipatti variety grafted on the rootstock of Rayan or Khirnee (*Manilkara hexandra* or *Mimusops hexandra*). Mahua (*Madhuca latifolia*) is another potential rootstock plant for Sapota. However, *Manilkara hexandra* is the most vigorous and productive rootstock plant widely used in the orchards here.

Traditionally Sapota was considered to be a hardy species that need little attention from the farmers, as there were no serious problems of pests or diseases in the orchards. However presently the scenario has changed and there are increased levels of pest attacks and diseases in the farms. In the young orchards intercrops such as vegetables are grown along with the young Sapota plants, while, older plantations hardly allow any undergrowth due to the thick canopy cover (Plate 4 & 5). Although sapota trees yield all through the year, at Dahanu, it has two major harvesting seasons, winter and summer.

## 9. THE YIELD DECLINE

Of late there had been reports of extensive decline in the yield of Sapota from the orchards of Dahanu (Bari and Bari 2004). According the data obtained during the present study, the annual yields from the farms were found steadily declining over the years (Figure 2). The orchards have experienced around 50% reduction in their annual yields during the past five years. Although, exact time and cause of the decline is unknown, as per the data collected during the present study, earliest record of the decline was in 1995. However, the vast majority of the farms under the present study felt the brunt much later, by around 1999-2000 (Figure 3; Bars indicate cumulative number of orchards that experienced the decline (n=116)). Unfortunately, there had been no attempt in the past to quantify monitor or document this decline. However, few of the farmers in Dahanu have meticulously kept regular long-term record of the yield from their farms. In the present study few of such secondary data were consulted for the purpose of understanding the magnitude and temporal pattern of the decline.

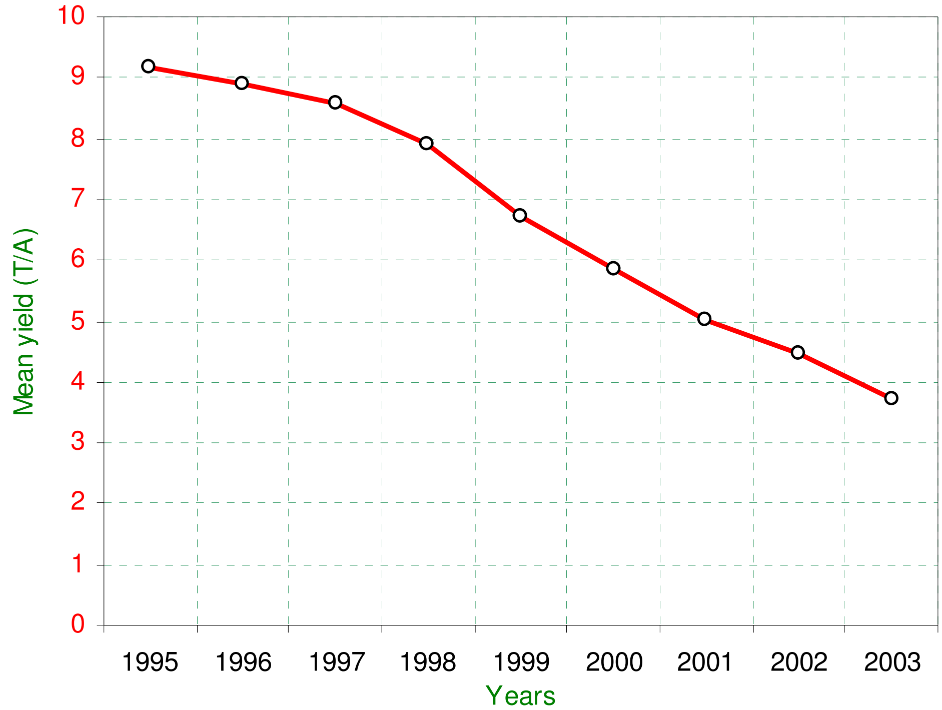


*Figure 2 Mean yield of Sapota (tonnes/acre) during the past nine years*

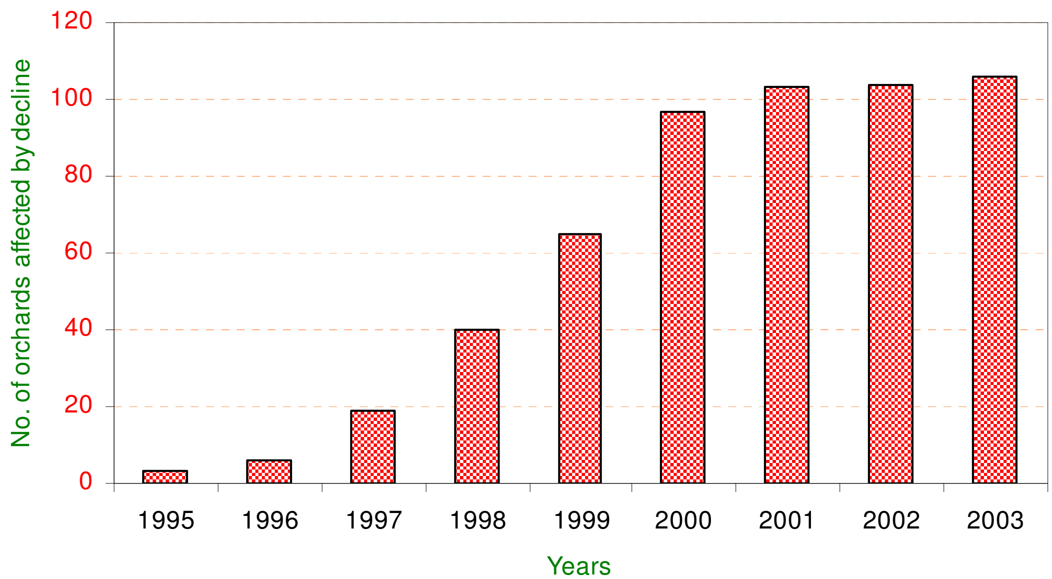


*Figure 3 Temporal pattern in number of farms affected with the yield decline (n =116)*

According to the Wholesale traders, the Sapota pulling from the Dahanu area during the peak seasons has dropped sharply over the past decade (from around 70 truck loads in 1995 to around 20 truck loads in 2003). The magnitude of decline is far more severe in Dahanu (Figure 2) compared to other nearby *Chicku* growing areas such as Amalsad (located north of Dahanu in Gujarat state), where there is hardly any serious decline during the same period (Figure 4; based on the data kindly provided by Hemantbhai B. Naik, Secretary V.V.K.S.K.M Ltd. Amalsad, Appendix 5).


*Figure 4 Sapota production from the orchards of Amalsad (Amalsad VVKSKM Ltd.)*

## 9.1. Seasonal Pattern

Generally the major *Chicku* harvesting season of the area were the winter (post monsoon) and summer. As it could be observed from the detailed month wise data obtained from one of the orchards at Saravli area the yield during the winter season has reduced significantly during 2003 compared to that of 1995. The yield during the summer showed relatively less decline (Figure 5). Presently the yield during summer is far better than the winter. The explanation for this seasonal change in the magnitude of the decline would probably be the seasonal differences in the impact of the unknown '*decline-causing factor*' during the initial fruit setting and retention stages. Further analysis of the results strongly indicated the impact of various factors associated with the environmental pollution on the yield of Sapota.

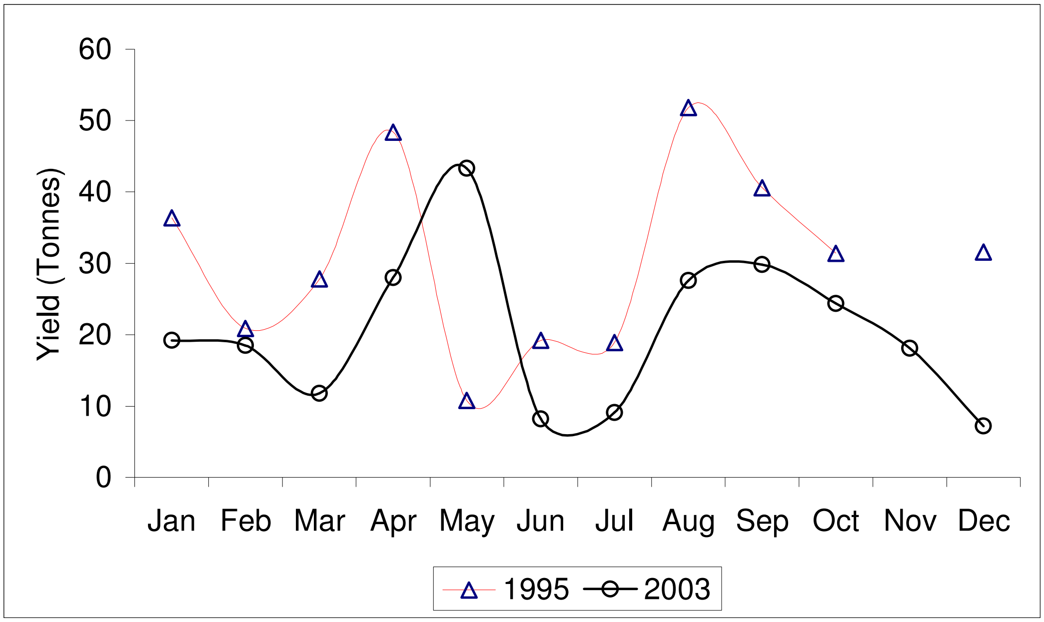


*Figure 5 Change in the Seasonal pattern in the yield of Sapota (at Saravali)*

## 10. FACTORS RESPONSIBLE FOR THE DECLINE

There are many potential factors that could be hypothesised to be responsible for the observed decline in the productivity of plants (such as climate change, erratic rainfall, lack of sunlight penetration, pest incidences, changing water quality, dropping water tables, seawater intrusion, pollinator decline and emissions from the thermal power station). The global climate change has proven to be seriously impacting a variety of ecosystems (Bogya *et al.* 2000; McCarty 2001; Okazaki 2003) and has already been reported to have major impacts on agriculture in Europe (Ito and Oikawa 2002) and America (Peng and Apps 1999; Ni *et al.* 2001) The climate change has also been reported to effect changes in life history patterns of plants by changing the flowering pattern (Fitter and Fitter 2002). However many of these possibilities may could be ruled out in the context of Dahanu (Appendix 6), and some others need to be further investigated in detail using standardised methods before arriving at any comprehensive conclusion regarding their causative relation with the decline in *Chicku* yields. Following major factors important in the context of Dahanu could be identified for examination for the purpose of the present study.

1. Atmospheric pollution
2. Deterioration of soil quality
3. Decline in water quality
4. Decline of Natural enemies of pests
5. Pests and Diseases
6. pH change in soil & water
7. Pollination failure
8. Climatic changes
9. Low intensity of sunlight on plants (foggy weather)
10. Natural senescence of Orchard plants
11. Change in the farming practice
12. Decline in water table and saltwater intrusion
13. Nutrient deficiency

It may be noted that all these factors except a few, could be either directly or indirectly linked to the environmental pollution. However quantitative assessment of the pollution load in the environment and its consequences on the ecological system of the area was not attempted during this study. The impacts of major possible factors and possible mitigatory measures are outlined below.

## 10.1. High incidence of insect pests

The pest incidence in the orchards has gone up significantly during the past few years. Apart from existing pest species crossing the economic threshold limits, new pest species have also emerged to compete with others Presently there are quite a few serious insect pests in the orcards of Dahanu that are causing considerable economic loss (Table 4). According to the observations made by the farmers, earlier the bud borers (*Anarsia achrasella*) was playing a beneficial role in their orchards by effectively pruning the excess flowers off the plants and thus helping in optimal fruit bearing of the plants. In the changed environment, they have changed their roles from a '*farmer friendly insect*' to a 'destructive pest' and are eating away the whole flower bunches, possibly because of the population explosion of the pests because of the ecological stress in the system which has impaired the natural population control mechanisms of these pests probably due to the reduction in their natural enemy populations caused by agro chemicals and air pollution, and also possibly because of the reduced flower/bud availability for the pest populations.

Some of the latest varieties of *Chicku* plants developed by Agriculture universities are resistant to some of these pests (Eg:- The Periyakulam variety (PKM-1) of Tamilnadu Agricultural University, Coimbatore is resistant to bud borer). Farmers may be encouraged to cultivate such superior varieties in future as a long-term pest management strategy for minimising the losses.

*Table 4 Insects pests of Sapota prevalent in Dahanu orchards*

| No | Pest Species | Target of attack | Season |
|---|---|---|---|
| 1 | Bud Borer (*Anarsia achrasella*) | Flowers & buds | March - June |
| 2 | Seed borer (*Trymalitis margarius*) | Young fruits | Oct - Jan |
| 3 | Chicku Moth (*Nephopteryx eugraphella*) | Terminal leaves | Sep - Nov |
| 4 | Fruitfly (*Bactrocera dorsalis*) | Mature fruits | - |
| 5 | Mealy bug (*Pseudococcid sp.*) | Tender plant | - |
| 6 | Stem borer (*Indarbela tetraonis*) | Bark | - |

### 10.2. Age of the plants (Senescence)

Examination of the data from orchards of various age classes indicated that the decline was not dependent on the age of the plants since the decline was reported in plants of all age groups. However the degree of yield reduction showed a significant positive relation with age of the plants (Figure 6) indicating the higher susceptibility of the older plants.

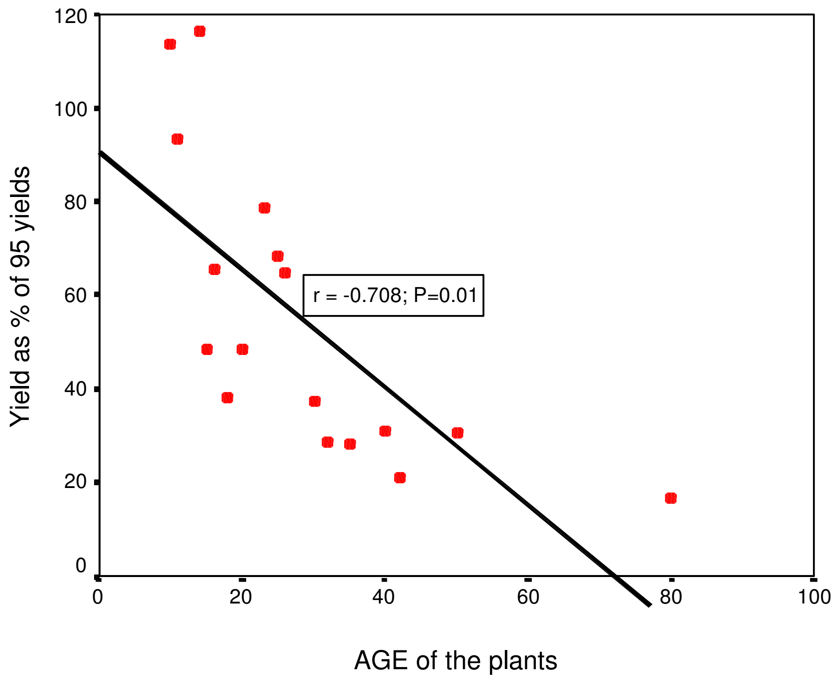


*Figure 6 Age of plants Vs. yield (as % of 1995 yields)*

### 10.3. Indiscriminate pesticide usage

Ever since the declining yields were felt in the farms, the farmers had been trying out various disaster mitigation steps. The timely propaganda by agrochemical industries has been successful in weaning away some of the farmers from the traditional agricultural practices to the 'modern chemical farming', which has only resulted in worsening the situation by shifting towards more and more unsustainable and resource-intensive agricultural practices. Discussions with the farmers have revealed that many of them have resorted to indiscriminate and reckless use of even highly hazardous pesticides, which have resulted in the collapse of natural ecological balance that existed between the pests and their predators and parasites. Pesticides have wiped out more beneficial insects than pests. Widespread decline in the populations of red ants (*Oecophylla smaragdina*), social spiders (Plate 13) and honeybees (Plate 8) in the orchards that have adopted modern chemical farming testify the impact of agrochemicals and other pollutants on the beneficial fauna associated with the orchards.

There is an urgent need of generating awareness among the farmers on the hazards of pesticides and other agrochemicals which would help in guiding them back to the sustainable agricultural practices.

## 10.4. Climatic factors

Natural climatic factors such as temperature, rainfall, humidity and wind can affect the growth and yield of plants. Data on such environmental factors were collected and examined. The detailed day-to-day rainfall data from 1992 to 2003 was collected from the Indian Meteorology Department (IMD) and the patterns in amount and spread of rainfall was examined for any significant fluctuations during the recent years corresponding to the decline in *Chicku* yield using advanced statistical packages. However none of the environmental variables examined could appreciably explain the variability in the yields of *Chicku*, which rules out the possibility of erratic rainfall as a possible cause of the decline.

## 10.5. Role of Rain fall pattern

Although, the initial rains of the season carry down a high dose of atmospheric pollutants, and could prove harmful for the life forms. However, as the season progresses the pollution mitigation effect of the rain gets the upper hand, and it perhaps is the reason behind the better yields during the summer season (Refer Section 9.1 Page 11). During the Monsoon season the impact of atmospheric pollutants on the plants are likely to be minimal compared to other seasons because of two major reasons,

1) Lesser retention time of suspended particulate matter (SPM) and water-soluble gases in the atmosphere reduce the pollution load &
2) The plants surfaces get thorough wash by the rains

Because of low retention times, there is much less chances of direct injury to plants from the pollutants and there is lesser time available for chemical modification of the pollutants into secondary pollutants through atmospheric reactions. The cleaning up the leaf and flower surfaces by the rain greatly mitigates the impacts of SPM and acid depositions and help enhancing photosynthesis and pollination process. The loss of acidic depositions and other toxic pollutants from the soil through runoff also help the plant growth and restore the normal pH. This environmental improved conditions probably helped in better success rates in pollination, fruit setting and fruit retention during this season.

The development of flower into ripe fruit takes 8 to 10 months in Sapota. The monsoon season (June-August) flowers are responsible for the summer season yields of the next season and the summer season flowers are the source of harvest in the following winter. Hence the failure of the summer season flowers and success of the rainy season flowers strongly indicate the possible impact of higher pollution load during summer months on the plants.

### 10.6. Decline in pollinator and predator populations

There is a declining trend in the populations of beneficial insects in the orchards of the area. Bees and ants are becoming increasingly rare in the orchards. Apiculture has been affected severely and deserted bee boxes are a common sight in most of the farms. The predatory red ant (*Oecophylla smaragdina*) population also has been declining gradually from many of the orchards which probably helped producing conducive environment for better survival of insect pests, especially that of lepidopteran caterpillars. Dusting the trees with pesticides during the harvest period is practiced in certain farms and this could well be one of the causes for the red ant decline.

### 10.7. Water - Availability, Quality and Irrigation methods

Sapota requires regular irrigation for better yields. *Chicku* farms of Dahanu area are well irrigated and the majority of farms follows flood irrigation system, followed by drip irrigation and mixed irrigation systems (Figure 7). Although the water table has gone down during the years, there is no scarcity of water experienced in most of the farms. The yield from the flood-irrigated fields appears to be significantly better compared to that of drip irrigated fields (Appendix 4). This suggests the need for customising the drip irrigation to the needs of Sapota plants.

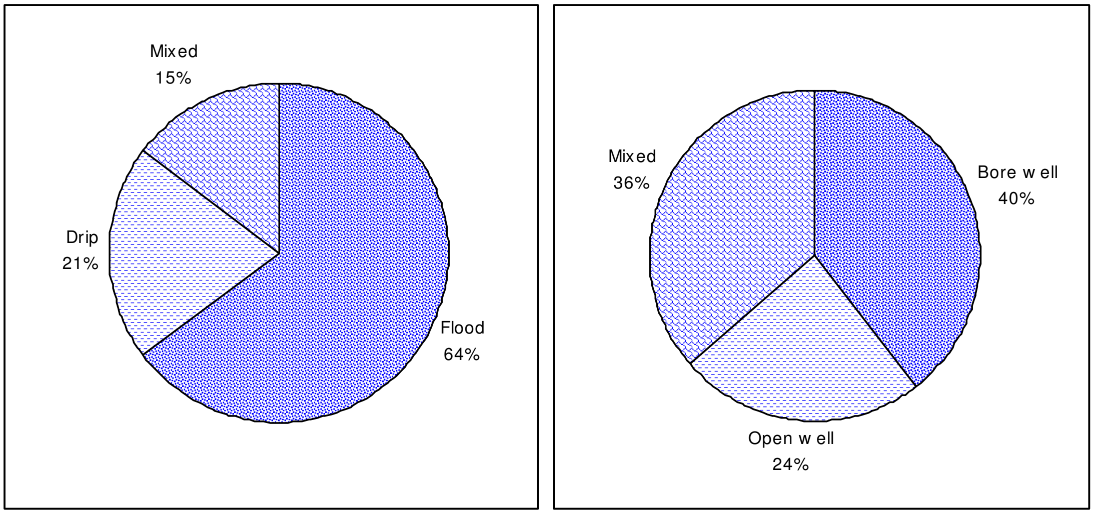


*Figure 7 Irrigation method and Water source of the farms studied*

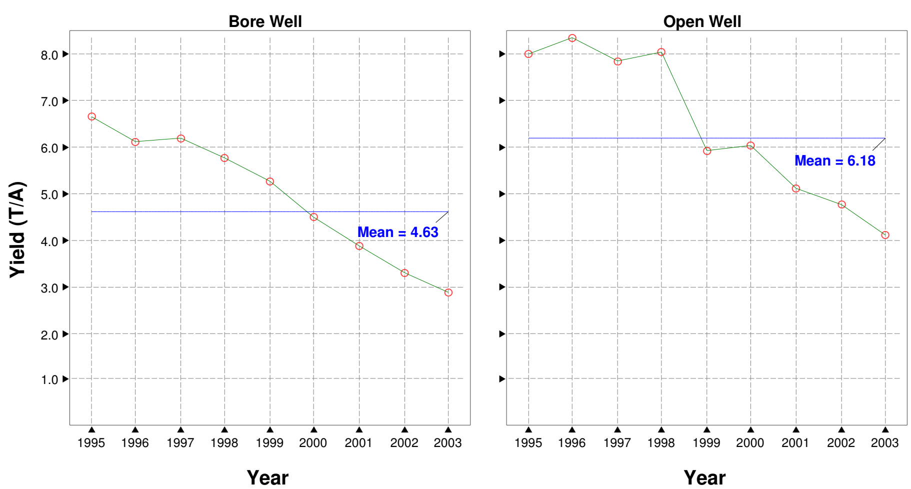


*Figure 8 Comparison of production figures between farms with different water source*

Among the water sources utilized for irrigation, bore wells were the source of water for majority of the farms (39.39%) while about a quarter of all the farms surveyed utilize open wells for irrigation. However the decline in the yield was recorded in all types of farms irrespective of water source and irrigation regimes (Figure 8). The result shows that the insignificance of the role of water sources and irrigation methods in the decline. As none of the farms had reported water scarcity for irrigation, it appears to be a highly unlikely factor to cause the decline. Water quality was not tested during the present study and it need to be tested and monitored regularly for detecting any anomaly in quality.

### 10.8. Nutrient deficiency

Although the assessment of nutrient availability for the plants was beyond the scope of the present study, the field observations did not reveal any of the described deficiency symptoms (Nachegowda *et al.* 1992; Balakrishnan *et al.* 2000) among the plants. Hence the nutrient deficiency factor also appears unlikely.

## 11. ROLE OF INDUSTRIAL POLLUTION

The coal based Thermal Power Plant of Dahanu is the major large scale polluting industry present in Dahanu (Plate 14). Coal; being the most polluting fossil fuel currently in use, the coal powered thermal power plants are '*Pandora's boxes*' of environmental hazards. The serious environmental hazards of coal based thermoelectric plants are well documented (World Bank (1991), Stuczynski *et al.* 1998; Negi and Meenkshi 1998; Mishra and Ramachandran 1998; Agrawal and Singh 2000; Baba *et al.* 2003; Mandal and Sengupta 2003).

However, adopting suitable fuels and pollution control measures it is possible to contain these impacts to a great extent, provided, such measures are implemented and operated meticulously. The negative correlation observed between the radial distance from DTPP and the mean decline at different places indicate a possible link between the yield decline and the pollution from DTPP (Figure 9)

The 500 MW thermal power plant of Dahanu consumes about 8040 metric tonnes of coal each day and releases 76.4 tonnes of $SO_2$, 4.7 tonnes of SPM, and 72.35 tonnes of NOx every day (NEERI 1996) along with even more quantities of $CO_2$ and the ash slurries into the environment. Such emissions and effluents from the Thermal Power Plant contaminate air, soil and water and cause multifaceted impacts on the surrounding environment through multiple routes such as ground water pollution (Davison and Lerner 2000; Adriano *et al.* 2002; Praharaj *et al.* 2002a; Baba *et al.* 2003), soil pollution (Singh and Narayan 1995; Lal 1996; GarciaSanchez *et al.* 1999; Gulec *et al.* 2001), particulate matter pollution (Tucker 1998; Peden 2002; Fernandez *et al.* 2003), acidic depositions (McLeod *et al.* 1992; Mohren *et al.* 1992; Agrawal and Singh 2000; Brigden and Santillo 2002; Taylor and Frost 2004; Biyan and Yu 2004), radio active pollution (Papp *et al.* 2002) and so on. Following is a brief account of major pollutants emitted from the DTPP and their specific impacts.

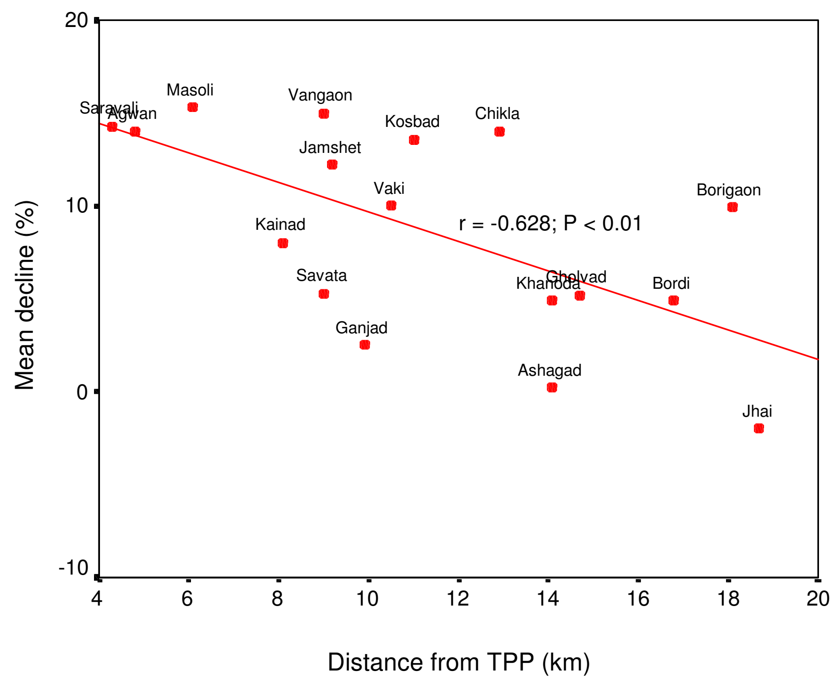


*Figure 9 Yield decline at different places and its relation with distance from TPP*

<u>The Sulphur Dioxide ($SO_2$)</u>. It is one of the major toxic gases released during the combustion of coal and is highly hazardous and cause negative impacts especially in the presence of fly ash -another pollutant produced during the coal combustion- because of their synergistic action (Tung 1995). The Dahanu Thermal power station emits around 76,400 kg of $SO_2$ every day (NEERI 1996), which can potentially cause serious damages to health of animals and plants. $SO_2$ has been reported to have caused 29 to 47% reduction in the agricultural yields at Obra, Renekoot & Singrauli area of Uttar Pradesh adjacent to the Obra Thermal Power plant (Agrawal and Agrawal 2000). The $SO_2$ is also known to promote fungal

diseases on plants (Khan *et al.* 1998). Other impacts of $SO_2$ (along with $NO_2$) include formation of particulates in the atmosphere and causing acid rains. Secondary reactions in the environment may also result in the formation of toxic gases such as ozone, which is beneficial in the upper atmosphere as a UV filter, is hazardous to life at surface and lower elevation zones.

Installation of an appropriate Flue Gas desulphurisation (FGD) plant (Miszcyk and Darowicki 2002) in the thermal power station can greatly reduce the $SO_2$ pollution. Latest alternate FGD technologies such as biological treatment systems are reportedly showing promising results compared traditional flue gas desulphurisation (Philip and Deshusses 2003).

Particulate matter. Of late the particulate matter pollution is being increasingly recognised as more dangerous than many of the gaseous pollutants with serious and irreversible repercussions on life forms, ecosystems and on structures and monuments (Mohanraj 2002). The dispersion and ground level concentrations of these factors are determined by a variety of factors such as physical characteristics of emissions, the stack, meteorological conditions, distance between source and receptors, condition of receptors, and so on.

Particulate matter emitted during the Coal combustion is called the fly ash and is contaminated with various toxic and radio active elements (Negi and Meenkshi 1998; Sahu 1998; Zevenbergen *et al.* 1999; Flanders 1999; Papp *et al.* 2002; Gupta *et al.* 2002; Adriano *et al.* 2002; Praharaj *et al.* 2002b; Baba 2003; Gupta 2004). Apart from fly-ash particles, the SOx and NOx gases also contribute to the load of particulate matter in the atmosphere by chemically transforming itself into acids and later into crystals of salts (sulphates and nitrates) in the environment.

Heavy metals: Heavy metals such as Cd, Cr, Cu, Ni, Pb, Zn and Hg present in the fly ash and bottom ash are toxic to plants, once become bio-available (Ariese *et al.* 2002; Gupta *et al.* 2002; Chaudhuri *et al.* 2003). Many of the heavy metals get enriched during the coal to ash conversion by combustion.

Trace elements. Many of the trace elements present in the Indian coal fly ash have deleterious impacts, often not explicit immediately after exposure. For instance the Selenium (Se), a toxic non-metallic element present in trace quantities in the coal get highly enriched in the fly ash (Sahu 1998). The accumulation of Se in the fish is reported to be creating a ‘time bomb’ situation in United States and elsewhere with substantial impacts on fish populations(Lemly 1999). The cascading impacts would be evident only when the time bomb explodes or the threshold selenium toxicity is exceeded and the lechates from the fly ash dumps and atmospheric fly ash originating from the Thermal power plant are capable of igniting the fuse of the time bomb by increasing waterborne concentrations of selenium and providing conditions favourable for bioaccumulation.

pH changes and bio availability of trace elements: Changes in the hydrogen ion concentration (pH) is another important aspect of pollution from coal emissions. SO2 and NO2 emissions from the Thermal power plant emissions cause the formation of acidic depositions. It reduce the pH of soil and water and promote leaching of trace metals and results in enhanced bio-availability of these elements to the plants (Kanungo and Mohapatra 2000) which may prove toxic to the plants.

Other emissions: Other major emissions include green house gases such as Carbon dioxide ($CO_2$), which cause rise in temperatures and associated impacts. Even the highly toxic and carcinogenic substances such as dioxins are also reported to be present in the exhausts of the coal fired power plants (Lima and Bachmann 2002; Hung and Lin 2003; Hylander *et al.* 2003)

## 12. ADVERSE IMPACTS OF POLLUTION ON THE PLANTS

Ambient atmosphere plays a very important role in the development of plants. Nutrients absorbed from the soil form only a minute fraction of the biomass of plants and most of the biomass is produced photo-synthetically from the atmospheric gases in the presence of water. During this process, a large quantity of atmospheric gases passes through the plant tissues. Any noxious gas present in the atmosphere (such as SOx and NOx) and any obstruction to the gaseous exchange between the plant and its environment (Eg:- stomatal closure by Particulate Matter) can lead to undesirable and deleterious effects (Kayin *et al.* 1999; Agrawal and Singh 2000; Gupta *et al.* 2002). Serious impacts of thermal power plant emissions on the yields has been reported from the wheat fields around Obra thermal power plant (Sing *et al.* 1990).

Unlike many other Orchard trees, Sapota has the characteristic feature of flowering and fruiting continuously all round the year (Singh 1970; Davenport and ONeal 2000; Bari 2002). This makes the yield from Sapota plants more susceptible to stochastic environmental conditions round the year. Major deleterious impacts of by-products of coal combustion on the health of *Chicku* plants involves

- ✍ Impairment of photosynthesis: Caused by fly-ash depositions on the leaves and the presence of fly-ash in the atmosphere in the form of particulate matter; both affecting the sunlight reaching the photosynthetic surface,
- ✍ Interference with gaseous exchange and respiration: Caused by deposition of Fly-ash particles on the leaf surfaces can chock up the stomatal openings of leaves,
- ✍ Radioactive pollution: The fly ash from Indian coal has high amounts of Radioactive elements especially Radon which can cause radioactive pollution and associated damage to the cells and genetic materials of the living organisms on continuous exposure (Papp et al 2002).
- ✍ Various negative impacts associated with pH changes (Table 5). Acids formed by the reaction of SOx and NOx with atmospheric water molecules cause acid rains and affect the health of the plants by causing physical injuries and affecting bio-availability of various nutrients.
- ✍ Pollination disruption: Sapota is generally cross-pollinated and the pollination is effected by wind (Sulladmath and Reddy 1990; Bal 1997). Deposition of particulate matter on the stigma of the flowers cause drying up of stigma and act as a physical barrier for the pollens. Pollution also affects other pollinator populations such as bees, thrips and butterflies, which are also helpful for the pollination of flowers.
- ✍ Withering of flowers and tender shoots: Pollution induced acidic depositions and acid rains may cause charring symptoms on plants.

Enhanced local temperatures caused by the higher levels of greenhouse gases such as $CO_2$ emitted from various contributing sources such especially DTPP.

- Promoting insect pests: Caused by general weakness and lowered immunity levels caused by the environmental stress resulting from the pollution load in the environment. Apart from this, environmental pollution is likely to promote borer pests because of their specialized microhabitat preferences, which insulate them from the direct impact of the acid rains, toxic depositions and particulates to a great extent. Mild exposure to $SO_2$ is known to be conducive for fungal growth (Khan *et al.* 1998).

## 13. EVIDENCES INDICATING THE ROLE OF POLLUTION FACTOR

The emissions and discharges from the thermal power plant appears to be an important factor behind the decline due to the following reasons,

- The onset of yield decline from Sapota orchards coincides with the launching of Dahanu Thermal Power Plant (DTPP).
- The spatial pattern in decline shows a significant negative relationship with distance from DTPP, especially along the major wind directions (Southwest and Northeast). This indicates the role of emissions from the DTPP that are carried in the atmosphere along with the air movements.
- Changes in the pH of dew and rain and resultant loss in agricultural productivity indicate enhanced environmental levels of SOx and NOx which are among the major emissions from the DTPP
- Enhanced atmospheric temperature has made the environment conducive for the proliferation of borer pests. High levels of greenhouse gas emissions from the DTPP would have also contributed to this.
- High rate of failure in the fruit bearing and development despite good anthesis can primarily be due to pollination failure and fungal attacks facilitated by acidic depositions on plant surfaces and other gaseous emissions from TPP.

✍ Higher impact on *Chicku* flowers during non-rainy seasons compared to rainy season also indicates the atmospheric pollution from DTPP. It may be noted here that the development of pollen and subsequent fertilization are highly sensitive to hydrogen ion concentration in the stigma and surroundings of the flowers.

*Table 5 Effect of acidity on plants*

| Effect on | Under Low pH (<5.5) |
|---|---|
| Uptake of Nutrients | Retarded |
| Aluminium Toxicity | Develop due to free Al ion |
| Iron | - |
| Phosphate | Fixed |
| Calcium | Deficient |
| Availability of Anions, Mo & Bo | Reduced |
| Availability of Cations, Cu, Mn, Zn, | Increased even to toxic levels |
| Certain Pathogens | Increased |

*(Source: Wrigley 1981)*

## 14. SPATIO-TEMPOROL PATTERNS IN THE DECLINE AND DTPP

In order to examine the possible impact of pollution on the yield decline pattern, the Chicku yield data was examined with respect to the direction and distance of the farms from the Dahanu Thermal power plant. A comparison of the amount of yield reduction recorded from different directions from the TPP showed that the south-western parts are most affected followed by Northeast (Figure 10). These are the two major wind directions during most time of the year in the area.

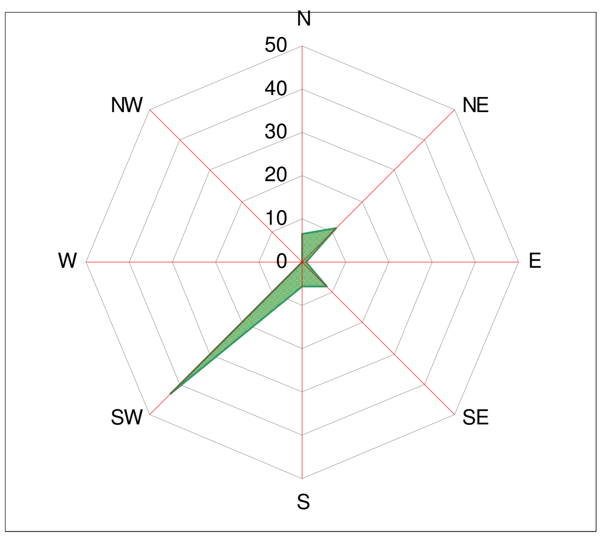


*Figure 10 Directional pattern in the annual decline of Sapota yield from orchards*

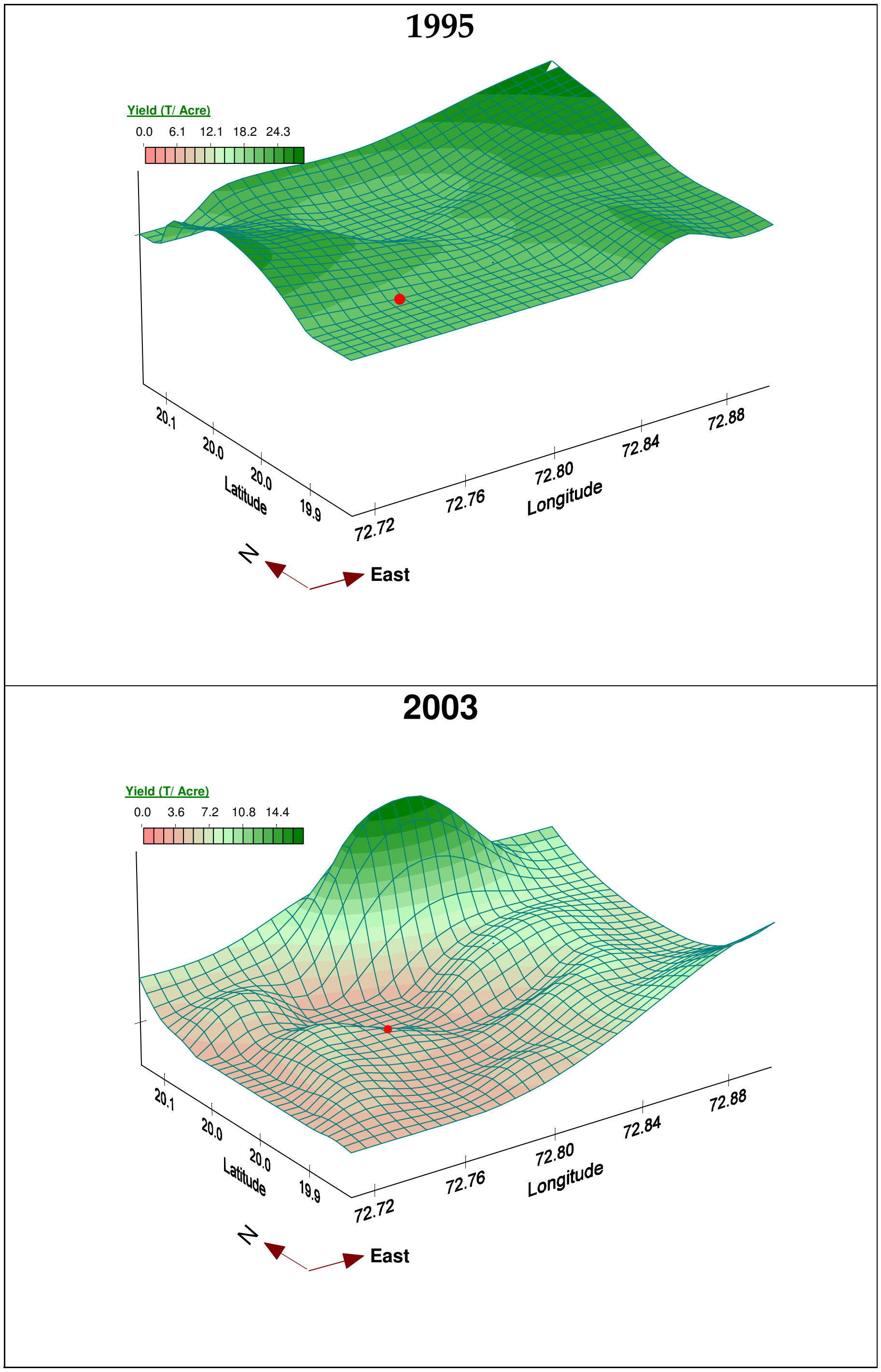


*Figure 11 Spatial pattern in the yield of Sapota in Dahanu (Yield in Southwest parts of the Taluka around Dahanu Thermal Power plant has seriously declined)*

A comparison of the geographical patterns in the *Chicku* yields of 1995 and 2003 (Figure 11) indicates that the yield has drastically reduced in areas around the DTPP. It was further confirmed by the significant positive correlation observed between the present yield in percentage (as percentage of 1995 yields) and the distance from DTPP (Figure 12 & Table 6) indicating that the yield are better in farms further away from the Thermal Power plant. These results decisively indicate that the emission from the Coal fired thermal power plant of Dahanu has a major role in the decline of yields in the orchards.

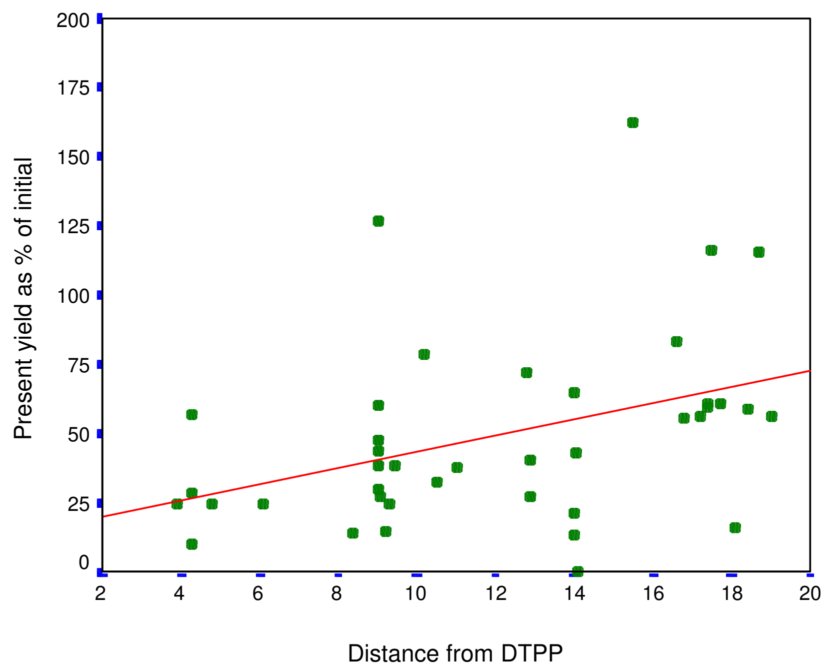


*Figure 12 Relationship between the present sapota yields (as % of 1995 yields) and distance to DTPP in orchards >10 years of age)*

**Correlations**

| | | Distance from TPP | Present yield in % of initial (fron data) |
|---|---|---|---|
| Distance from TPP | Pearson Correlation | 1.000 | .395* |
| | Sig. (2-tailed) | . | .012 |
| | N | 63 | 40 |
| Present yield in % of initial (fron data) | Pearson Correlation | .395* | 1.000 |
| | Sig. (2-tailed) | .012 | . |
| | N | 40 | 42 |

*. Correlation is significant at the 0.05 level (2-tailed).

*Table 6 Correlation of Sapota yield with Distance from DTPP*

## 15. ESTIMATED LOSSES

During the period of 1995 to 2003 the overall yield of Sapota from Dahanu's orchards dropped by around 60%. Alarmingly, the trend in the yield has been taking a steady course of decline over the recent years (Figure 2). In the surveyed *Chicku* orchards the average yield per acre has plummeted to 3.7 tonnes per acre in 2003 from the 9.2 tonnes in 1995. The loss in production during the period (1995- 2003) would amount to nearly one-lakh tonnes if extrapolated to the official records of 6900 ha under *Chicku* cultivation. At an estimated market price of Rs. 6/kg, the monitory loss incurred would amount to a whopping Rs. 60 crores. Considering equally or even more severe decline in the quality and market value of the fruits and increased expenditures at the farms, the actual loss to the farmers is many fold higher.

## 16. DISCUSSION

The present study examined the drastic decline in the yield of Sapota orchards of Dahanu along with various environmental factors. Typically the decline was caused by failure during the fruit setting and later stages of fruit development. The flowering was quite satisfactory in most farms and it was the fruit setting and subsequent stages, which failed miserably. Apparently there are both obvious and unobvious reasons responsible for the decline. While pests and pathogens are the obvious factors, there are non-obvious factors such as pollinator decline, environmental pollution and resultant changes in the various biotic and abiotic factors.

The salient findings of the present study may be summarised as follows:

- The decline is evident among orchard Plantations irrespective of age and variety of plants, water source, irrigation method, farming method (chemical/ biological). Although, the present study was focussed only on the orchards, from opportunistic observations and incidental discussions with fishermen revealed that the fish and prawn yield from Dahanu creek and adjacent coastal areas has also suffered a major decline during the recent years (NEERI 1996).

- A point source of origin of the causative agent responsible for the catastrophic decline was evident from the severe decline in a limited area and a steady rise in the number of orchards experiencing the decline (from 1995 to 2003).
- The cause of decline is unlikely to be the climate change. In that case, the decline should have been felt in all the orchards more or less during the same time period and would have affected the orchards in a much larger spatial scale than the present case.
- Higher survival rate of the flowers and fruits during the time of least pollution load in the atmosphere (rainy season) and during the months of higher number of rainy days indicated the role of atmospheric pollution in the decline.
- Although the older plants are relatively more affected compared to younger plants, the senescence factor could not account for the yield reduction in relatively younger plantations.
- The indiscriminate use of pesticides and agrochemicals have caused serious decline in the natural predators of the pest species and other beneficial pollinator species, which has created conducive environmental conditions for the survival and multiplication of insect pests.

## 17. CONCLUSION

From the results of the present reconnaissance study, it may be stated that the pattern of decline indicates a causative relationship with the environmental pollution, especially atmospheric pollution and the consequent environmental impacts. The Dahanu thermal power plant is the single most likely source of this pollution and hence more stringent pollution control measures in DTTP especially to reduce the $SO_2$ and Ash emissions are imperative for the environmental health and long-term sustainability of Dahanu's orchard farms and other traditional livelihood supports.

The reckless usage of agrochemicals has worsened the situation by affecting the parasites and predators of the pests and thus promoting the pest populations in the orchards already under pollution stress. Appropriate campaigns for training the farmers in ecologically sound pest management strategies, minimising the usage of chemical pesticides and agro chemicals has to be under taken by the concerned authorities. The sustainable benefits of biological farming as opposed to the short-term benefits and environmental hazards from of chemical farming need to be highlighted in such campaigns.

Dahanu notification (1991) prohibits any kind of polluting industry from being set up in Dahanu, in order to conserve the sensitive ecosystem of Dahanu from degradation. However, capitalising on the loopholes in the law, the huge coal-fired thermal power plant consuming large amounts of highly polluting coal continue to operate in the area, spewing out sizeable quantities of pollutants into the environment. Operation of such a massive polluting industry in an ecologically fragile area flouting even the statutory environmental guidelines (NEERI 1996) is ironical and ecologically unreasonable. Moreover, considering the mounting scientific evidences highlighting the grave environmental consequences of coal combustion, it is unjustifiable to have a Coal based thermoelectric station at an ecologically sensitive location, jeopardizing its sustainability. Hence, as an immediate mitigatory measure, the DTPP should drastically reduce the pollution using state of the art pollution controlling devices such as FGD. However in the long run, it should either have to switch over from coal to other environmentally safer and less polluting fuels such as Natural gas or be translocated to any other safer and ecologically less sensitive location elsewhere.

The present results are only indicative and further detailed and long-term studies need to be undertaken to monitor the air, water and soil quality parameters of the area in a regular 24-hour basis, in order to zero in on the exact nature source and environmental fate of the pollutants responsible for the catastrophe. Such a study is imperative to device long-term solutions and management strategies for the area as well. Only environmentally sound and comprehensive risk assessments based on scientific research followed up by prudent management actions can avert further disasters before it would be too late.

## 18. ACKNOWLEDGEMENTS

We gratefully acknowledge Dr. V S Vijayan, Director, Sálim Ali Centre for Ornithology and Natural History (SACON) for all the facilities, support and encouragement provided.

This study would not have been materialised without the wholehearted help and co-operation from hundreds of farmers and farm labourers of Dahanu. Our sincere thanks are due to each and every farmer of Dahanu, who greatly helped us by meticulously providing the required data.

We gratefully acknowledge the generous help and cooperation rendered to us by various people during the study period; Satish Barve, Prabhakar Save, Vijay Mahtre, Noshir Irani, Suhas Patil, Ajay Bafna, Bhaskar Save, Sidney Aiman, the list is far from complete.

We are thankful to Mr. Ajay Bafna and Suhas Patil for their help by providing detailed long-term monthly data on the yield of *Chicku* orchards. Our sincere thanks are also due to Mr. H B. Naik of Amalsad who kindly provided the year-wise Chicku pulling data of Amalsad fruit Market.

Mr Berde and Mr. Gogte of Reliance Energy Ltd. has been very cooperative and helpful during our visit to the Dahanu Thermal Power plant (although the visit was not in connection with the study) and explained in detail about the functioning of DTPP and its environmental performance. We are greatly Indebted to Dr Maya Mahajan and Mr. Ketan Dulvi for extending their wholehearted support and cooperation during the field surveys.

The Dahanu Taluka Environmental Welfare Association (DTEWA) was very helpful and cooperative with us. We are thankful to all members of DTEWA for the warm hospitality extended to us during our stay at Dahanu. Mrs. Phiroza Tafti and Mr. Noushir Irani are gratefully acknowledged for their active support and assistance provided for the study. Mr. Jagannath Save of Kosbad Agriculture College has been very helpful and we are indebted to him for valuable information on the *Chicku* plant and their insect pests. The photographs of the pests (Plate 7) were also kindly provided by Mr. Save

## 19. LITERATURE CITED

Adriano, D. C., Weber, J., Bolan, N. S., Paramasivam, S., Koo, B. J. and Sajwan, K. S. (2002) Effects of high rates of coal fly ash on soil, turfgrass, and groundwater quality. *Water Air and Soil Pollution*. **139** (1-4); 365-385

Agrawal, M. and Singh, J. (2000) Impact of coal power plant emission on the foliar elemental concentrations in plants in a low rainfall tropical region. *Environ. Monit. Assess.* **60** (3); 261-282

Agrawal, S. B. and Agrawal, M. (2000). Environmental pollution and plant responses. (Lewis Publishers:

Ariese, F., Swart, K., Morabito, R., Brunori, C., Balzamo, S., Slobodnik, J., Korenkova, E., Janos, P., Wildnerova, M., Hlavay, J., Polyak, K., Fodor, P. and Muntau, H. (2002) Leaching studies of inorganic and organic compounds from fly ash. *Int. J Environ. Anal. Chem*. **82** (11-12); 751-770

Baba, A. (2003) Geochemical assessment of environmental effects of ash from Yatagan (Mugla-Turkey) Thermal Power Plant. *Water Air and Soil Pollution*. **144** (1); 3-18

Baba, A., Kaya, A. and Birsoy, Y. K. (2003) The effect of Yatagan thermal power plant (Mugla, Turkey) on the quality of surface and groundwaters. *Water Air and Soil Pollution*. **149** (1-4); 93-111

Bal, J. S. (1997). Sapota. In 'Fruit Growing'. Ed. J. S. Bal. pp. 115-124. (Kalyani Publishers: New Delhi.)

Balakrishnan, K., Rajendran, C. and Kulandaivelu, G. (2000) Differential responses of iron, magnesium, and zinc deficiency on pigment composition, nutrient content, and photosynthetic activity in tropical fruit crops. *Photosynthetica.* **38** (3); 477-479

Bari, M. (2002). Chicku. -115 p.

Bari, M. and Bari, S. A. (2004). Enironmental study on declination of chicku production in coastal parts of Thane and Navasari Districts. -13 p.

Biyan, Y. M. and Yu, S. W. (2004) Forest decline in Nanshan, China. *Forest Ecology and Management*. **51** (1-3)

Bogya, S., Marko, V. and Szinetar, C. (2000) Effect of pest management systems on foliage- and grass-dwelling spider communities in an apple orchard in Hungary. *Int. J. Pest. Manage.* **46** (4); 241-250

Brigden, K. and Santillo, D. (2002). Hazardous emissions from Philippine Coal-fired Power plants.

Chaudhuri, D., Tripathy, S., Veeresh, H., Powell, M. A. and Hart, B. R. (2003) Mobility and bioavailability of selected heavy metals in coal ash- and sewage sludge-amended acid soil. *Environ. Geol.* **44** (4); 419-432

Davenport, T. L. and ONeal, J. T. (2000) Flowering and fruit set of mamey sapote [Calocarpum sapota (Jacq.) Merr.] cv. Magana in South Florida. *Sci. Hort. Amsterdam*. **83** (1); 61-70

Davison, R. M. and Lerner, D. N. (2000) Evaluating natural attenuation of groundwater pollution from a coal- carbonisation plant: Developing a local-scale model using MODFLOW, MODTMR and MT3D. *J Chart. Inst. Water Env. Manage.* **14** (6); 419-426

deBrito, E. S. and Narain, N. (2002) Physical and chemical characteristics of sapota fruit at different stages of maturation. *Pesquisa Agropecuaria Brasileira*. **37** (4); 567-572

Dewan, R. and Chawla, M. (1999). Of Development Amidst Fragility: A societal and Environmental perspective on Vadhavan port. (Popular Prakashan: Mumbai.)

Fernandez, A., Wendt, J. O. L., Wolski, N., Hein, K. R. G., Wang, S. J. and Witten, M. L. (2003) Inhalation health effects of fine particles from the co-combustion of coal and refuse derived fuel. *Chemosphere*. **51** (10); 1129-1137

Fitter, A. H. and Fitter, R. S. R. (2002) Rapid changes in flowering time in British plants. *Science*. **296** (5573); 1689-1691

Flanders, P. J. (1999) Identifying fly ash at a distance from fossil fuel power stations. *Environ. Sci Technol.* **33** (4); 528-532

Ganjyal, G. M., Hanna, M. A. and Devadattam, D. S. K. (2003) Processing of sapota (Sapodilla): Drying. *Journal of Food Science*. **68** (2); 517-520

GarciaSanchez, A., Alastuey, A. and Querol, X. (1999) Heavy metal adsorption by different minerals: application to the remediation of polluted soils. *Sci Total Envir.* **242** (1-3); 179-188

Gopal, M. and Gupta, A. (2001). Has *Hirsutella thompsonii* the wherewithal to counter coconut eriophyid mite scourge? *Current Science* **80**, 831-836.

Gulec, N., Gunal, B. and Erler, A. (2001) Assessment of soil and water contamination around an ash-disposal site: A case study from the Seyitomer coal-fired power plant in western Turkey. *Environ. Geol.* **40** (3); 331-344

Gupta, D. K., Rai, U. N., Tripathi, R. D. and Inouhe, M. (2002) Impacts of fly-ash on soil and plant responses. *J Plant Res*. **115** (1122); 401-409

Gupta, J. S. (1998). Characteristics of Indian Coal Fly Ash and its Utilization as Building Material. In 'Enironmental Impact of Coal Utilization'. pp. 165-183.

Horvitz, C. C. and Schemske, D. W. (2002) Effects of plant size, leaf herbivory, local competition and fruit production on survival, growth and future reproduction of a neotropical herb. *J. Ecol.* **90** (2); 279-290

Hung, W. T. and Lin, C. F. (2003) Use of regenerated ferric oxide for CO destruction and suppressing dioxin formation in flue gas in a pilot-scale incinerator. *Chemosphere*. **53** (7); 727-735

Hylander, L. D., Sollenberg, H. and Westas, H. (2003) A three-stage system to remove mercury and dioxins in flue gases. *Sci Total Envir.* **304** (1-3); 137-144

Ito, A. and Oikawa, T. (2002) A simulation model of the carbon cycle in land ecosystems (Sim-CYCLE): a description based on dry-matter production theory and plot- scale validation. *Ecol. Model.* **151** (2-3); 143-176

Kanungo, S. B. and Mohapatra, R. (2000) Leaching behavior of various trace metals in aqueous medium from two fly ash samples. *J Environ. Qual.* **29** (1); 188-196

Kayin, S., Tuncel, G. and Yurteri, C. (1999) Local air quality impacts due to downwash around thermal power plants: Numerical simulations of the effect of building orientation. *Environ. Monit. Assess.* **58** (1); 61-77

Khan, M. R., Khan, M. W. and Pasha, M. J. (1998) Effects of sulfur dioxide on the development of powdery mildew of cucumber. *Environ. Exp. Bot.* **40** (3); 265-273

Lal, S. (1996). Rehabilitation of fly ash dump yard of Shaktinagar super thermal power station through afforestation. *Indian Forester* **122**, 777-782.

Lemly, A. D. (1999) Selenium impacts on fish: An insidious time bomb. *Hum. Ecol. Risk Assessment.* **5** (6); 1139-1151

Lima, R. and Bachmann, R. T. (2002) Pollutant emissions from modern incinerators. *Int. J Environ. Pollution.* **18** (4); 336-345

Mandal, A. and Sengupta, D. (2003) Radioelemental study of Kolaghat, thermal power plant, West Bengal, India: possible environmental hazards. *Environ. Geol.* **44** (2); 180-186

McCarty, J. P. (2001) Ecological consequences of recent climate change. *Conservation Biology*. **15** (2); 320-331

McLeod, A. R., Shaw, P. J. A. and Holland, M. R. (1992) The Liphook forest Fumigation project. Studies of sulphur dioxide and ozone effects on coniferous trees. *Forest Ecology and Management*. **51** (1-3); 121-127

Mishra, U. C. and Ramachandran, T. V. (1998). Environmental Impact of Coal Utilization for Electricity Generation. In 'Enironmental Impact of Coal Utilization'. pp. 117-125.

Miszcyk, A. and Darowicki, K. (2002) Reliability of flue gas desulphurisation installations - the essential condition of efficient air pollution control. *Pol. J Environ. Stud.* **11** (3); 205-209

Mohanraj, R (2002) Air quality od Coimbatore with emphasis on Respirable particulate matter. Ph.D Thesis, Bharathiar Unievrsity Coimbatore.

Mohren, G. M. J., Jorritsma, I. T. M., Vermetten, A. W. M., Kropff, M. J., Smeets, W. L. M. and Tiktak, A. (1992) Quantifying the direct effects of $SO_2$ and $O_3$ on forest growth. *Forest Ecology and Management*. **51** (1-3); 137-150

Nachegowda, V., Sulladmath, U. V. and Vijayakumar, N. (1992) Visual Nutrient Deficiency Symptoms In Sapota (*Manilkara Achras* Forsberg). *Acta Hort.* **321**; 566-573

NEERI (1996). Examination of Regional Plan for Ecologically Fragile Dahanu Region and its Environmental Viability.

Negi, B. S. and Meenkshi, V. (1998). Characterisation of Coal Fly Ash from Thermal Power Plants in India. In 'Enironmental Impact of Coal Utilization'. pp. 143-164.

Ni, J., Zhang, X. S. and Scurlock, J. M. O. (2001) Synthesis and analysis of biomass and net primary productivity in Chinese forests. *Ann. For. Sci.* **58** (4); 351-384

Okazaki, K. (2003) Various combinations of biological pesticides and agrochemicals - For efficient insect pest management in apple orchards. *J. Pestic. Sci.* **28** (2); 251-256

Papp, Z., Dezso, Z. and Daroczy, S. (2002) Significant radioactive contamination of soil around a coal-fired thermal power plant. *J. Environ. Radioact.* **59** (2); 191-205

Parrotta, J. A., Francis, J. K. and Knowles, O. H. (2002) Harvesting intensity affects forest structure and composition in an upland Amazonian forest. *Forest. Ecol. Manage.* **169** (3); 243-255

Peden, D. B. (2002) Pollutants and asthma: Role of air toxics. *Environ. Health Perspect.* **110**; 565-568

Peng, C. H. and Apps, M. J. (1999) Modelling the response of net primary productivity (NPP) of boreal forest ecosystems to changes in climate and fire disturbance regimes. *Ecol. Model.* **122** (3); 175-193

Philip, L. and Deshusses, M. A. (2003) Sulfur dioxide treatment from flue gases using a biotrickling filter - Bioreactor system. *Environ. Sci Technol.* **37** (9); 1978-1982

Praharaj, I., Swain, S. P., Powell, M. A., Hart, B. R. and Tripathy, S. (2002a) Delineation of groundwater contamination around an ash pond - Geochemical and GIS approach. *Environ. Int.* **27** (8); 631-638

Praharaj, T., Powell, M. A., Hart, B. R. and Tripathy, S. (2002b) Leachability of elements from sub-bituminous coal fly ash from India. *Environ. Int.* **27** (8); 609-615

Rahmani, A. R., Muni, M, Ahmed, K, and Potia, U (1999). Biodiversity documentation of Dahanu Taluka. 1-108 pp.

Sahu, K. C. (1998). Coal and Fly ash problem. In 'Eironmental Impact of Coal Utilization'.

Singh, J. and Narayan, D. (1995) Changes in soil characteristics around coal-fired power plants. *Environment International*. **21** (1); 93-102

Sing, J.S., Singh, K.P.and Agrawal, M., Environmental Degradation of Obra-Renekoot-Singrauli Area and its Impact on Natural and Derived Ecosystems, Project Report Submitted to the Ministry Environment and Forests, Government of India, 14/167/84MAB/EN-2 RE 1990

Singh, R. D. (1970). Studies on flowering and pollination in sapota (*Achras sapota* L.). *Indian J.Sci.& Indus.* **4**, 65-72.

Stuczynski, T. I., McCarty, G. W. and Wright, R. J. (1998) Impact of coal combustion product amendments on soil quality: I. Mobilization of soil organic nitrogen. *Soil Sci*. **163** (12); 952-959

Sulladmath, U. V. and Reddy, M. A. (1990). Sapota. In 'Fruits: Tropical and Subtropical'. T. K. Bose and S. K. Mitra (Eds.). pp. 565-591. (Naya Prokash: Culcutta.)

Taylor, G. and Frost, D. L. (2004) Impact of gaseous air pollution on leaf growth of hybrid poplar. *Forest Ecology and Management*. **51** (1-3); 151-162

Tucker, W. G. (1998). Particulate matter sources, emissions, and control options - USA. In 'Air Pollution in the 21St Century: Priority Issues and Policy'. pp. 149-164. (Elsevier Science Pub: 1000 AE Amsterdam.)

Tung, G. (1995) Synergistic effect of fly ash and SO2 on development of Cucumber (Cucumis sativus L.) leaf injury. *Enironmental Toxicology and Chemistry*. **14** (10); 1701-1710

World Bank technical paper number 154 (1991) Environmental Assessment source book Volume III, Guidelines for environmental assessment of energy and industry projects

Zevenbergen, C., Bradley, J. P., VanReeuwijk, L. P., Shyam, A. K., Hjelmar, O. and Comans, R. N. J. (1999) Clay formation and metal fixation during weathering of coal fly ash. *Environ. Sci Technol.* **33** (19); 3405-3409

*Appendix 1 Questionnaire used for the Survey*

**QUESTIONNAIRE (PAGE 1)**

We are conducting a study on the horticultural practices of Dahanu.
Kindly help us by sparing a few minutes for filling up this questionnaire sincerely.

| | | | |
|---|---|---|---|
| | Name: | | |
| | Age | Sex: M / F | Education: Nil / <10th / 10th / Grad./ PG/ |
| | Place: | | Panchayat: |
| | Acreage of farm/field: ……………….. ha | | Sapota: ………………..ha |
| | Major Crops | | |
| | Irrigation facility: | | Yes / No |
| | Water Source | | Open Well / Bore well/ River/ |
| | Irrigation Method | | Open / Drip |
| | Is their any change in flowering/ fruiting patterns of your crops | | |
| | Is there any pest problem?<br>If yes Since when? | | |
| | Any major change you adopted in your farming practice during the recent past? | | |
| | Of late is there any significant drop in production?. If so since when? | | Yes/ No<br>Since ………….. |
| | Employment reduction | | Mandays/ year |
| | What caused the decline? | | Climate/ Pest/ Water/ ………….. |
| | Flowering/ fruiting pattern | | Flower normal & Fruit failed<br>Flower and fruit failed |
| | Any suggestion to improve yields? | | |
| | Have you noticed any dust deposition on your plants? | | Yes / No |
| | Do you use any bio pesticide/ fertilizers | | |
| | Are You a member of Krishak Samaj ? | | Yes / No |
| | If not, Why ? | | |
| | Would you like to get training on Organic Farming, fruit preservation technology etc? | | |

Any other Information:

## FARM DETAILS (PAGE 2)

Name of the Farm :

Number of Bore wells :

Number of live stock : ………….Cows; …………..Goats; …………………

Inter Cropping : Yes / No Bee keeping ……………………….

| Crop | Variety | Age of farm | Employees | | Fertilizer / Pesticides Used | Irrigation type (Open/ Drip) | % Decline in yield | Any Other Remarks. |
|---|---|---|---|---|---|---|---|---|
| | | | Regular | Harvest time | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|---|---|---|---|---|
| *Chicku* Production from your farm in ………… | | | | | | | | | |

Name & Address of Farm Owner

……………………………………………………

……………………………………………………

……………………………………………………

Phone No: Place: Date

*Appendix 2 Location of farms surveyed*

| Farm Code # | Latitude (Degrees) | Longitude (Degrees) | Distance from TPP (km) | Angle to TPP (Degrees) |
|---|---|---|---|---|
| 1 | 20.00 | 72.74 | 4.9 | 170 |
| *2 | . | . | 15.5 | 184 |
| 3 | 20.11 | 72.76 | 17.2 | 186 |
| 4 | 20.11 | 72.77 | 17.4 | 187 |
| 5 | 20.00 | 72.74 | 4.9 | 172 |
| 7 | 20.11 | 72.76 | 17.5 | 187 |
| 11 | 19.99 | 72.76 | 4.3 | 208 |
| 13 | 19.95 | 72.83 | 8.3 | 272 |
| 15 | 19.99 | 72.75 | 3.9 | 190 |
| 18 | 20.06 | 72.74 | 11.3 | 178 |
| *19 | . | . | 4.9 | 172 |
| 20 | 20.05 | 72.74 | 11.0 | 178 |
| 21 | 20.08 | 72.78 | 14.1 | 197 |
| 22 | 20.08 | 72.77 | 14.0 | 192 |
| 23 | 20.08 | 72.78 | 14.1 | 197 |
| 24 | 20.08 | 72.77 | 14.0 | 192 |
| 27 | 19.95 | 72.83 | 8.7 | 273 |
| 31 | 19.99 | 72.82 | 9.0 | 245 |
| 32 | 19.99 | 72.82 | 8.4 | 246 |
| 33 | 19.99 | 72.83 | 9.4 | 244 |
| 34 | 19.99 | 72.82 | 9.0 | 245 |
| 36 | 19.87 | 72.74 | 9.0 | 7 |
| 37 | 19.87 | 72.74 | 9.0 | 7 |
| 38 | 19.87 | 72.73 | 9.1 | 9 |
| 39 | 19.87 | 72.71 | 9.9 | 24 |
| 40 | 19.88 | 72.72 | 9.0 | 18 |
| 41 | 19.87 | 72.73 | 9.1 | 10 |
| 42 | 19.87 | 72.73 | 9.1 | 10 |
| 44 | 20.12 | 72.76 | 18.9 | 194 |
| 45 | 20.13 | 72.75 | 19.0 | 183 |
| 46 | 20.11 | 72.78 | 17.7 | 192 |
| 47 | 20.09 | 72.77 | 15.4 | 191 |
| 48 | 20.09 | 72.77 | 15.4 | 191 |
| 49 | 19.90 | 72.78 | 7.0 | 326 |
| 51 | 19.87 | 72.71 | 9.8 | 22 |
| 52 | 20.00 | 72.83 | 10.2 | 244 |
| 54 | 20.08 | 72.74 | 14.4 | 178 |
| 55 | 19.94 | 72.88 | 14.2 | 277 |
| 58 | 20.00 | 72.75 | 5.0 | 187 |
| 59 | 19.94 | 72.87 | 12.8 | 277 |
| 62 | 19.99 | 72.79 | 6.1 | 227 |
| 63 | 19.94 | 72.79 | 5.1 | . |
| 64 | 19.94 | 72.78 | 4.1 | 291 |
| 65 | 20.04 | 72.75 | . | 185 |
| 66 | 19.87 | 72.74 | . | 0 |
| 67 | 20.00 | 72.74 | 4.8 | 180 |
| 68 | 20.09 | 72.74 | 14.7 | 179 |

| Farm Code # | Latitude (Degrees) | Longitude (Degrees) | Distance from TPP (km) | Angle to TPP (Degrees) |
|---|---|---|---|---|
| 70 | 20.09 | 72.74 | 15.2 | 178 |
| *81 | . | . | 3.1 | 293 |
| 82 | 20.00 | 72.75 | 5.2 | 188 |
| *84 | . | . | 9.7 | . |
| 85 | 20.09 | 72.73 | 18.7 | 181 |
| 86 | 20.10 | 72.75 | 16.6 | 181 |
| 87 | 20.11 | 72.74 | 16.6 | 181 |
| *88 | . | . | 16.8 | 180 |
| *89 | . | . | 16.6 | 181 |
| 90 | 19.94 | 72.79 | 5.2 | 294 |
| 93 | 20.02 | 72.78 | 8.1 | 204 |
| 96 | 20.12 | 72.76 | 18.4 | 185 |
| *97 | . | . | 18.3 | . |
| *99 | . | . | 17.4 | 174 |
| 100 | 20.09 | 72.74 | 14.8 | 177 |
| 109 | 20.10 | 72.76 | 16.3 | 186 |
| 110 | 20.00 | 72.75 | 4.6 | 185 |
| 113 | 20.10 | 72.75 | 16.5 | 182 |
| 114 | . | . | 9.6 | . |
| *115 | 20.08 | 72.74 | 14.2 | 177 |
| 116 | 20.10 | 72.90 | 16.2 | 182 |

*Geographic position not recorded*

*Appendix 3 Patten of monthly rainfall at Dahanu during the last 12 years*

**Monthly rainfall**

| *Year* | *Jan* | *Feb* | *Mar* | *Apr* | *May* | *Jun* | *Jul* | *Aug* | *Sep* | *Oct* | *Nov* | *Dec* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1992 | - | - | - | - | - | 414.8 | 349.9 | 703.0 | 405.4 | 19.6 | - | - |
| 1993 | - | - | 7.0 | - | 0.4 | 610.8 | 721.1 | 226.3 | 702.0 | 75.5 | - | - |
| 1994 | 26.2 | - | - | - | - | 845.9 | 780.6 | 632.8 | 161.1 | 7.9 | 0.3 | - |
| 1995 | 301.0 | - | - | - | - | 28.8 | 880.0 | 177.7 | 209.5 | 4.6 | - | - |
| 1996 | 1.4 | - | - | - | - | 213.5 | 1,062.4 | 271.6 | 137.7 | 871.0 | 1.4 | - |
| 1997 | 7.5 | - | - | 4.6 | 2.7 | 437.9 | 526.8 | 235.4 | 243.8 | 23.2 | 59.0 | 6.0 |
| 1998 | - | 0.2 | - | - | - | 504.3 | 504.0 | 419.4 | 677.4 | 278.4 | 0.7 | - |
| 1999 | - | - | - | - | 33.0 | 439.4 | 393.2 | 171.9 | 185.4 | 78.0 | - | - |
| 2000 | - | - | - | - | 94.9 | 81.3 | 843.9 | 404.9 | 28.2 | 20.2 | - | 1.2 |
| 2001 | 2.1 | - | - | - | 12.2 | 632.7 | 500.6 | 668.2 | 131.3 | 6.3 | - | - |
| 2002 | - | - | 3.5 | - | 3.8 | 1,020.7 | 85.2 | 578.4 | 31.0 | 0.2 | 0.2 | - |
| 2003 | - | - | - | - | - | 569.3 | 815.6 | 463.2 | 205.0 | - | - | - |

**Number of Rainy days**

| *Year* | *Jan* | *Feb* | *Mar* | *Apr* | *May* | *Jun* | *Jul* | *Aug* | *Sep* | *Oct* | *Nov* | *Dec* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1992 | - | - | - | - | - | 15 | 27 | 27 | 15 | 2 | - | - |
| 1993 | 1 | - | 1 | - | 1 | 15 | 27 | 23 | 20 | 8 | - | - |
| 1994 | 1 | - | - | - | - | 21 | 30 | 26 | 16 | 3 | 1 | - |
| 1995 | 1 | - | - | - | - | 8 | 27 | 21 | 11 | 5 | - | - |
| 1996 | 1 | - | - | - | - | 21 | 28 | 29 | 20 | 8 | 1 | - |
| 1997 | 2 | - | - | 1 | 1 | 21 | 26 | 29 | 19 | - | 5 | 2 |
| 1998 | - | 1 | - | - | - | 16 | 30 | 29 | 24 | 14 | 2 | - |
| 1999 | - | 1 | - | - | 6 | 15 | 20 | 26 | 19 | 7 | - | - |
| 2000 | - | - | - | - | 9 | 17 | 30 | 24 | 12 | 2 | - | 1 |
| 2001 | 1 | - | - | - | 6 | 23 | 31 | 29 | 14 | 5 | - | - |
| 2002 | - | - | 2 | - | 4 | 19 | 24 | 27 | 5 | 1 | 1 | - |
| 2003 | - | - | - | - | - | 20 | 30 | 29 | 26 | - | - | - |

Source: Indian meteorology Department, Mumbai

*Appendix 4 Analysis of variance results showing significant variation in the yields between flood and drip irrigated fields*

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Mean yield (Tonnes /Acre) | Between Groups | 436.009 | 2 | 218.004 | 11.785 | .000 |
| | Within Groups | 684.463 | 37 | 18.499 | | |
| | Total | 1120.471 | 39 | | | |

*Appendix 5 Yearly detail of chicku pulling at Amalsad**

| Year | Members | Mound | Amount | Average |
|---|---|---|---|---|
| 1977/78 | 503 | 138328 | 5304405 | 29.74 |
| 1978/79 | 524 | 215137 | 5561285 | 25.85 |
| 1979/80 | 550 | 213759 | 6016168 | 28.31 |
| 1980/81 | 587 | 245989 | 8693711 | 35.34 |
| 1981/82 | 620 | 267373 | 9716253 | 36.34 |
| 1982/83 | 649 | 296705 | 11802914 | 39.78 |
| 1983/84 | 697 | 360110 | 11159808 | 30.99 |
| 1984/85 | 717 | 257272 | 11785914 | 45.81 |
| 1985/86 | 825 | 313501 | 14874120 | 47.44 |
| 1986/87 | 820 | 372925 | 19667959 | 52.74 |
| 1987/88 | 876 | 346190 | 25013149 | 72.25 |
| 1988/89 | 926 | 447963 | 24868456 | 55.51 |
| 1989/90 | 990 | 398831 | 25953304 | 65.07 |
| 1990/91 | 1037 | 536416 | 34366080 | 64.07 |
| 1991/92 | 1075 | 568269 | 43790030 | 77.06 |
| 1992/93 | 1136 | 619589 | 42525513 | 68.64 |
| 1993/94 | 1157 | 542956 | 40406785 | 74.42 |
| 1994/95 | 1321 | 656680 | 47359761 | 72.12 |
| 1995/96 | 1203 | 494523 | 49624133 | 100.35 |
| 1996/97 | 1339 | 626232 | 54519673 | 87.06 |
| 1997/98 | 1248 | 576874 | 64846844 | 112.41 |
| 1998/99 | 1224 | 537135 | 71320971 | 132.78 |
| 1999/00 | 1256 | 631841 | 61535858 | 97.39 |
| 2000/01 | 1244 | 587878 | 73361617 | 124.79 |
| 2001/02 | 1446 | 614642 | 67958557 | 110.55 |
| 2002/03 | 1459 | 539760 | 69820650 | 129.35 |

* Data kindly provided by Hemantbhai B. Naik, Secretary, V.V.K.S.K.M Ltd. Amalsad

*Appendix 6 Role of various factors in the declining yields*

| | Factors Examined | Results |
|---|---|---|
| 1 | Pollution from the Thermal power plant | As the emissions from TPP contribute greatly to many of the possible problems examined. TPP is a grave concern and further studies should focus more on the issue. |
| 2 | Soil quality | According to farmers, soil testing did not reveal any quality deterioration. May need further investigation. |
| 3 | Water quality | Although the water table has gone down,. However, water quality need to be monitored. |
| 4 | Pollinators and Predators | Pollinator population is found to be greatly declined. Possibly by multiple factors such as acid rains and chemical pesticides. Beneficial insects such as Weaver ants (*Oecophylla smaragdina*), which were helping to keep the insect pests under check, have also reduced. |
| 5 | Pests and diseases | This is a major problem. Borer pests and fungal diseases are prevalent. The deteriorating health and immunity of the plants has aggravated the problem. Mild Sulphur dioxide (SO2) pollution is known to promote fungal growth. |
| 6 | pH change | There are reports of acidic dew formations on the plants. Water and soil samples need to be monitored for pH fluctuations. |
| 7 | Pollination barriers | Dust & Ash particle deposited on the leaves and flowers cause decreased photosynthesis and such depositions on the stigma of flowers act as an effective barrier for pollination, and thus result in reduction of yield from plants. |
| 8 | Climate | Decline did not show any significant relation with the climatic factors Such as Rainfall. Higher number of rainy days favour |
| 9 | Changes in light regime | Because of the increased load of suspended particles in the atmosphere the light penetration through the atmosphere is hampered and it negatively affect the plants and other photosynthetic organisms. |
| 10 | Senescence of plants | It is found to be not a factor, since farms in a wide range of age group has shown the decline. However the older plants are affected more (>50 years) |
| 11 | Farming practice | No major change in the farming practice in the recent past. Some farmers have started using pesticides and chemicals, |

| | Factors Examined | Results |
|---|---|---|
| | | but this was mostly adopted only after the decline was felt in their farms as a corrective measure. |
| 12 | Water scarcity, decline in water table and saltwater intrusion | Although the water table has gone down slightly, presently there is no water scarcity in the Sapota farms of Dahanu and are mostly well irrigated. Hence, it is unlikely to be a factor. Saltwater intrusion is also not a major factor as many farms are located far from the coastline and the Sapota is known to be tolerant to salts in the soil (Sulladmath and Reddy 1990). |

*Appendix 7 List of butterflies recorded from Dahanu during the survey*

| No. | Common Name | Scientific Name | Family |
|---|---|---|---|
| 1 | Brown Awl | *Badamia exclamationis* Fabricius | Hesperiidae |
| 2 | Common Redeye | *Matapa aria* (Moore) | Hesperiidae |
| 3 | Water Snow Flat | *Tagiades litigiosa* (Moschler) | Hesperiidae |
| 4 | Angled Pierrot | *Caleta caleta* Hewitson | Lycaenidae |
| 5 | Common Cerulean | *Jamides celeno* Cramer | Lycaenidae |
| 6 | Common Pierrot | *Castalius rosimon* (Fabricius) | Lycaenidae |
| 7 | Common Silverline | *Spindasis vulcans* Moore | Lycaenidae |
| 8 | Dark Cerulean | *Jamides bochus* Cramer | Lycaenidae |
| 9 | Pale Grass Blue | *Pseudozizeeria maha* (Kiollar) | Lycaenidae |
| 10 | Pea Blue | *Lampides boeticus* (Lin.) | Lycaenidae |
| 11 | Angled Castor | *Ariadne ariadne* Fruhstorfer | Nymphalidae |
| 12 | Blue Pansy | *Precis orithya* Hubener | Nymphalidae |
| 13 | Blue Tiger | *Tirumala limniace* Butler | Nymphalidae |
| 14 | Chocolate Pansy | *Precis iphita* Cramer | Nymphalidae |
| 15 | Common Baron | *Euthalia aconthea* Fruhtorfer | Nymphalidae |
| 16 | Common Bushbrown | *Mycalesis perseus* Fabricius | Nymphalidae |
| 17 | Common Crow | *Euploea core* Cramer | Nymphalidae |
| 18 | Common Eveningbrown | *Melanitis leda* Cramer | Nymphalidae |
| 19 | Common Fivering | *Ypthima baldus* Fabricius | Nymphalidae |
| 20 | Common Fourring | *Ypthima hubneri* Kirby | Nymphalidae |
| 21 | Common Leopard | *Phalanta phalantha* Drury | Nymphalidae |
| 22 | Common Map | *Cyrestis thyodamas* (Boisduval) | Nymphalidae |
| 23 | Common Sailor | *Neptis hylas* Moore | Nymphalidae |
| 24 | Danaid Eggfly | *Hypolimnas misippus* Linnaeus | Nymphalidae |
| 25 | Great Eggfly | *Hypolimnas bolina* Linnaeus | Nymphalidae |
| 26 | Grey Pansy | *Precis atlites* (Johanssen) | Nymphalidae |
| 27 | Lemon Pansy | *Precis lemonias* Linnaeus | Nymphalidae |
| 28 | Painted Lady | *Cynthia cardui* (Linn.) | Nymphalidae |
| 29 | Peacock Pansy | *Precis almana* Linnaeus | Nymphalidae |
| 30 | Plain Tiger | *Danaus chrysippus* Linnaeus | Nymphalidae |
| 31 | Striped Tiger | *Danaus genutia* Cramer | Nymphalidae |
| 32 | Tawny Coster | *Acraea violae* Horsfield | Nymphalidae |
| 33 | Yellow Pansy | *Precis hierta* Evans | Nymphalidae |

| No. | Common Name | Scientific Name | Family |
|---|---|---|---|
| 34 | Blue Mormon | *Papilio polymnestor* Cramer | Papilionidae |
| 35 | Common Mormon | *Princeps polytes* Cramer | Papilionidae |
| 36 | Common Rose | *Pachliopta aristolochiae* Fabricius | Papilionidae |
| 37 | Crimson Rose | *Pachliopta hector* Linnaeus | Papilionidae |
| 38 | Lime Butterfly | *Princeps demoleus* Linnaeus | Papilionidae |
| 39 | Red Helen | *Princeps helenus* Linnaeus | Papilionidae |
| 40 | Common Albatross | *Appias albina* (C.&R.Fielder) | Pieridae |
| 41 | Common Grass Yellow | *Eurema hecabe* Moore | Pieridae |
| 42 | Common Jezebel | *Delias eucharis* Drury | Pieridae |
| 43 | Common Wanderer | *Pareronia valeria* Fabricius | Pieridae |
| 44 | Indian Cabbage White | *Pieris canidia* (Evans) | Pieridae |
| 45 | Lemon Emigrant | *Catopsilia pomona* Fabricius | Pieridae |
| 46 | Mottled Emigrant | *Catopsilia pyranthe* Linnaeus | Pieridae |
| 47 | Pioneer | *Anaphaeis aurota* Fabricius | Pieridae |
| 48 | Psyche | *Leptosia nina* Fabricius | Pieridae |
| 49 | Small Salmon Arab | *Colotis calais* (Cramer) | Pieridae |
| 50 | Yellow Orangetip | *Ixias pyrene* Butler | Pieridae |

## ABOUT THE AUTHORS

**Dr PR Arun** has a doctorate from the Bharathiar University of Coimbatore and has got over ten years of research experience in various fields such as Ecology and Environmental Impact Assessment (EIA). Apart from EIA he has wide ranging research interests in various fields such as Ecological entomology, insect seasonality, butterfly ecology and pharmaceutical pollution. He is presently associated with Dr. P A Azeez in the Environmental Impact Assessment Division of Sálim Ali Centre for Ornithology and Natural History, Coimbatore and has published scientific papers in various national and international journals. He had been involved in around fifteen Environmental Impact assessment projects, on various developmental projects such as hydroelectric dams, long distance gas/ petroleum pipelines, bauxite mines, Thermal power plants, etc. from various parts of the country.

**Dr P A Azeez** is presently the Senior Principal Scientist and Head of the Environmental Impact Assessment Division at SACON, Coimbatore. He is basically an Environmental Chemist with research interest in related fields such as environmental Management, sustainable development and environmental economics. He has published a number of scientific papers and reports on various Environmental Issues and has guided doctoral and postdoctoral researches.