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POPULATION AND NATURAL RESOURCES

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INTRODUCTION

India ranks as an overpopulated country in the world. Its large and ever growing population has led to environmental destruction. It is well-known that the population pressure has outstripped the country's capacity to cope. The government statistical hoax presents a confusing picture as there is no rigorous scientific study on the production potential of the country's lands. The UN study (most rigorous) has revealed that *India can feed three times its population (current) provided that the government and people seriously manage their soil and water resources*. The present status of poverty and hunger in the country today is only because our scientists, politicians and planners have not learnt how to use the environment at a high level of sustainable productivity.

Human population and Distribution

Population is intimately related to environment. The human population has grown faster in the 20th Century than ever before. World population doubled in 40 years between 1950 and 1990 to cross 5 billion. The developed countries account for 1.5 billion while the developing countries 3.5 billion population. By 2000 the population has touched 6.3 billion and by 2010 it has grown to 7 billion (one in every seven will be an Indian). World population is growing by 92 million every year adding roughly population of Mexico.

It is interesting to note that it took about 2 million years for the world population to become 1 billion (1830), 100 years for 2 billion (1930), 30 years for 3 billion (1960), 25 years for 4 billion (1985) and 12 years for 5 billion (1997). The population stands at 6.3 billion (2000) and estimated to be about four times around 22.5 billion in 2100. In developed countries the population is likely to be less than double while in developing countries like India about four times (2100).

The statistics for India is of serious concern (though if may be a bit hoax). Between 1901 and 1951 India's population grew from 238 million to 361 million, an increase of 52 percent in 50 years; between 1951 and 1981 expanded from 361 to 685 million. In other words, post Independent India in 35 years literally added a second India i.e. doubled its population. At present (2011), it has touched 1.25 billion, close to China. We are in the grip of population explosion since 1980.

Distribution

For historical and other reasons, world population is not uniformly distributed. USA and Canada have a population of 250 million. South America and the Soviet Union (CIS) have the same population. Africa and Western Europe have about 500 million people. East Asia – China, Japan and Korea have more than 1 billion while South Asia is the most populous region (India, Bangladesh, Pakistan) with 1.5 billion population. Every year India is adding the population of Australia (16 million).

Table 1.
World population and distribution

Developed Countries (North Block, Australia)	–	7.5 billion
Developing Countries (South Block)	–	3.5 billion
USA, Canada	–	250 million
S. America, CIS	–	250 million
W. Europe, Africa	–	500 million
East Asia	–	1 billion
South Asia	–	1.5 billion

Population Density

The density of population within a country gives a rough idea of the effect of population on natural resources. Population density is defined as the number of persons per sq. km. In general, less populated countries retain more of their natural resources-vegetations and wild animal population than those with dense human population. Thus Australia (4 people/sq. km.) is not likely to face wood or water shortage compared to Bangladesh (1800 people/sq. km.). However, population density cannot accurately predict

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the impact of environmental damage on the economy of a country. Some of the crowded countries in the East and South Asia are prosperous. Examples are : Taiwan, South Korea, Hong Kong and Singapore where population density is 1000 people/sq. km.

Some crowded countries with stable population can manage to be self-sufficient in food. Thus U.K. (600 people/Sq. km.) exports food while Brazil (44 people/sq. km.) faces acute shortage of food and has to import it. Europe has all the timber and water it needs while Africa (95 people/sq. km.) has acute shortage of these items. Such inequalities among countries are attributed to differences in their economic status – sustainable and non-sustainable. The countries with stable population such as U.K. have sustainable economy and are prosperous. But those with fast population growth suffer from non-sustainable economy and consequent problems of poverty, diseases etc.

Age Structure

In contrast to the developed countries, India shows a pyramidal distribution of age-wise population. Children constitute 40 per cent, youth 33 per cent (upto 34 years), middle aged 21.5 per cent and 6.2 per cent old. This India has a reproductive youthful age group while the western countries have a less youthful age structure with slow population growth (almost stable).

The ratio of people over 65 and under 15 to the rest of the population is known as *dependency ratio*. This is a measure of the economic impact of the age structure. People over 65 and under 15 contribute little to the economy and need support from the working population. India with high dependency ratio has adverse impact on economy with the result that the working class have lower standard of living. The developed countries e.g. USA, U.K. face another type of crisis. Their aging population is increasing due to increased life span (better medical facilities and life style) and has to encourage immigration from overseas to make up the working class.

Fertility Rate

The general fertility rate of a population is defined as the number of babies born to 1000 women of the reproductive age. The rate of population growth is based on the average age of reproduction. The fertility rate for India and other developing countries is 3.0 while that for the western countries the rate is below 1.0

Doubling Time

This is the period within which the population of a country becomes double. It gives a measure of the population growth rate. Most developed countries have doubling times of more than 100 years where as in case of developing countries the doubling time is less than 25 years. We cannot double our resource (water, food and energy) within this period and thereby we fail to tackle the pressure on schools, hospitals (education, health care), police protection (security), food production etc.

Tribes of India

Tribal population of India falls under three main geographical clusters. The larger cluster consists of the central Indian group – Bhils, Gonds and others spread over extensive areas of deciduous forests. The eastern Indian group includes the Munda – speaking populations – Munda, Ho Savaras, Santals – of Orissa and Chotanagpur area, located within the evergreen sal forest area. The third and smallest cluster consists of populations belonging to south India located in the Eastern and Western Ghats, South of the river Krishna.

The main occupation of the tribals are food gathering, shifting cultivation and settled cultivation. For food gathering they collect forest products – wild fruit, roots, and hunt wild animals for meat. They live in S. India. Tribals engaged in shifting cultivation live in North East India. This practice of jhum cultivation (slash and burn) destroys forests as they move from one place to another involving loss of soil fertility and soil erosion. Settled cultivators are among economically better off tribals – Bhils and Gondas in Central India, Santals and Oraons in Eastern India. They are, however, facing threat of loss of land from rich non-tribal people in the name of development.

Non-accountable Tribals

Some tribal groups remain unaccountable as they have not been registered under two successive censuses (1991, 2001) due to negligence of the Central and State Ministers of Tribal welfare. These belong to West Bengal, Orissa, Andhra Pradesh, Maharastra and Madhya Pradesh. They are deprived of their fundamental rights to be Indian citizens and benefits (food, education, health care, housing, security) to which they are entitled.

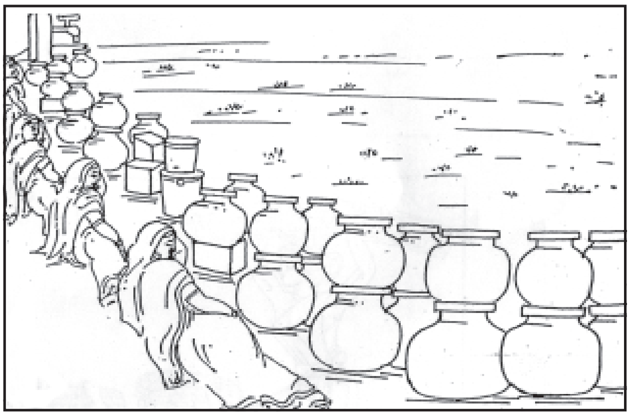
Women and Natural Resources

The poor village women are worst victims of environmental destruction. Their day starts from early dawn when they go on their *long march* in quest of fuel, fodder and water, irrespective of whether they are old, young and pregnant to meet their household requirements. Deforestation and devegetation aggravate their woes and push them to the brink of survival.

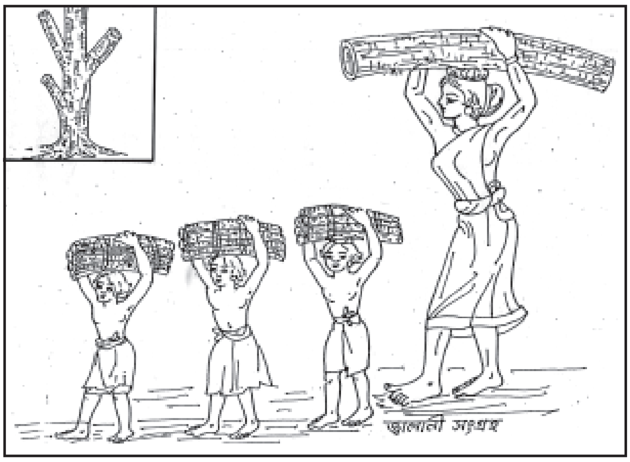
A typical poor rural woman even in her seventh month of pregnancy is the only adult in the household to take care of children, buffaloes and calf. Her husband is a petty trader in a nearby town. Her responsibility is to cook, fetch water and collect fodder for animals. In the evening she has to take them for grazing and collect green fodder. She spends about 14 to 16 hour working day and has no time to rest.

The fates of head loaders in Ranchi (sale of fire wood) and Tamil Nadu women for collection of water highlight the miseries of poor rural women. The Ranchi firewood sellers start their day at 2 AM, complete their household chores and then set out on 8-10 km walk to the surrounding forests to collect wood. To reach the market early, the women leave their village the previous evening by train or bus and spend the night at the railway station or some public place. Each woman carries about 20 kg head load which sells for Rs. 8.00 to Rs. 10.00. Part of this money has to be paid to forest guards and train/bus conductors. After their return home, they have to cook meal for the day. This back-breaking routine goes on till they collapse.

Ironically enough, Tamil Nadu suffers from shortage of fresh water inspite of its proximity to the East coast. Women from slum areas shuttle from one part of the city to another by trains for collecting water. They sleep in queue at previous night beside roadside taps for collecting water early morning next day.



Tamil Nadu women (Slumdweller) sleep in queue at night for collection of water from roadside tap next day early morning



Head loaders collect firewood from forest

In general, tribals and nomads i.e. forest dwellers who wander from place to place and no fixed location face total social destruction and swell the rank of uprooted "*environmental refugees*".

Woman Power

In the 18th Century some 350 Bishnoi men and women from the Bishnoi community in Rajasthan were determined to protect their forest from the tyranny of Maharaja of Marwar. The Maharaja had plan to make marble slab for his palace for which it was necessary to build a brick kiln (furnace). The latter needed firewood which was collected from nearby forest. As soon as the wood cutters along with Maharaja's soldiers arrived, the Bishnoi men and women clasped the trees. At last these people were hacked to death. This was the fore-runner of the Chipko movement two centuries later.

The women of the Garhwal region of Uttarakhand were at the vanguard of the Chipko movement. The term "**Chipko**" means "hugging". The fragile hill ecosystem was victim of reckless deforestation by timber contractors. Whenever the axe men arrived, the hill women hugged the trees and prevented the axemen from cutting the trees. The movement, spearheaded by Sunder Lal Bahuguna was recognized by the UN conference of Stockholm (1972) as a mighty Environment Protection Movement. The hill women were at the frontline of the battle. In course of time the Chipko Movement spread the message all along the hill region and also move to the South in Karnataka in 1983 where it was termed "Appico" Movement. Soon it crossed geographical boundaries and was observed as a Chipko day at New York, USA in 1983.

An important bioreserve Silent Vally in Kerala was saved by **Silent Valley Movement** led by Kerala-based NGO. The government hydel project at the spot at the cost of the bioreserve was stalled and finally given up.

The Madhya Pradesh Government undertook a gigantic project of Narmada River Basin Development by construction of large dams for Narmada and its tributaries. It would provide irrigation for million hectares of land, water supply to many industries and thousands of mega watts of power. But the damage to the ecosystem – destruction of forests and displacement of people would for outweigh the projected benefits. The environmental activists, led by Medha Patkar stalled the project.

Infant Mortality/Life Expectancy

The death rate is generally expressed as the number of deaths per year for every 100 people. Advanced medical science has helped to reduce the death rate but not the birth rate. Death control without birth control has led to population explosion.

Infant mortality is one of the most tragic index of poverty of a country. It also sets the parameter of life expectancy i.e. the average number of years that a new born baby is expected to survive. Progress in medical science has in general increased the life expectancy. In 1900 life expectancy was 46 years in the developed countries since infant mortality was high i.e. 40 per 1000. The situation improved much in 1984 in these countries and the life expectancy rose to above 70 years as the infant mortality dropped to about 10 per 1000. The world's highest life expectancy is in Japan (79) which enjoys high literacy and high standard of living. In the developing countries high infant mortality is associated with low life expectancy.

In developing countries 1 in 3 children is malnourished and about 3 million children die annually from diseases that could be avoided by immunisation. Moreover, 1 million women die each year from preventable reproductive health problems.

Carrying Capacity

The maximum population size that an ecosystem can support under particular environmental conditions is known as the *carrying capacity.* In natural ecosystem with unlimited resources and ideal environment, species can multiply at a maximum rate, However, in actual practice, the population of a species remains in check due to interaction of the inhabiting species as also finite nature of resources.

It is an established fact that while foodgrain production can under optimum conditions increase arithmetically (1, 2, 3, 4,...), population increases geometrically (2^2, 3^2, 4^2,...).

Rate of population growth, $$\frac{dN}{dt} = rN$$

where N = popualtion size

and r = specific growth rate

With doubling of population, resources do not double and hence set in a critical situation. If the population size far exceeds the carrying capacity by a wide margin, it leads to *population crash* or *explosion* when environmental conditions get degraded and lowers the carrying capacity.

The earth weighs about 5.97 x 10^{24} kg. If the present population growth continues for the next 5000 years, then the weight of human population itself will match the earth's weight. In other words, another earth will have to be accommodated within this earth, which is totally absurd. This implies man will run out of space and resources. Thus the present population growth will get more and more unfavourable for human survival as it will destroy the carrying capacity in the long run.

The concept of carrying capacity, as stated above, implies that only a limited number of people can be supported by the resource base of a country. The population growth must be linked to the resource base in order to have sustainable development. The developed countries follow the policy *of Population Stabilisation* i.e., keep the population growth level below 0.5 per cent and thereby hold the key to economic development and resource management. This is the success story of all developed countries.

For India, population explosion is a time bomb, which must he diffused sooner the better. It is the major crisis facing the country. *We have to break the vicious P-triangle: Population-Poverty-Pollution on an emergency basis for our own survival.*

Population growth pattern (Indian Context)

During the British rule in India the population growth rate was insignificant. Agriculture was neglected and peasants were tortured as a matter of the colonial policy which led to poverty, malnutrition, famine, epidemics and death. The birth rate and death rate were almost balanced and this caused population drop by 1.1 per cent during 1911-1921. Slow increase in population was noticed from 1931 onwards which got a boost after Independence in 1947.

At present, India has been adding a population of 18 million every year roughly equal to the population of Australia. At this rate it is expected to overtake China by 2025 A.D. and earn the distinction of becoming the most populous country in the world.

The population growth rate in India is shown in Table 2.

Such fast growth rate of population (2.4%) has led to population explosion. This is responsible for rapid environmental degradation and poor economy of the country.

Urbanisation

Industrial progress along with job opportunities led to growth and mushrooming of cities all over the world as centres of commerce and production and of art and culture. These also encouraged migration of rural

Table 2.
Population Growth in India (1901-2000)

Year	Population (in million)	Decade growth rate (%)
1901	238.1	–
1911	252.1	+ 5.75
1921	251.3	– 0.31
1931	279.0	+ 11.00
1941	318.9	+ 14.22
1951	361.1	+ 13.31
1961	439.2	+ 21.51
1971	548.2	+ 24.80
1981	683.8	+ 24.75
1991	846.3	+ 23.51
2000 (May 11)	1000 (1 billion)	

population to cities, At the time of Independence the share of urban population did not exceed 8 per cent of total population but by 1991 it rose to 36.2 per cent (217 million). The number of million-plus cities increased from 3 (pre-1947) to 23 by 1991. The top ten such cities are listed in Table 3.

Unplanned growth of urbanisation has led to collapse of infrastructure particularly in the metropolitan cities and also miserable living conditions in slums with the net result that the citizens have poor quality of life.

The world scenario of megacities (population exceeding 10 million) is presented in Table 4.

It is intriguing that whereas London, once a megacity till 1950s, moved out of the list with its stabilised population, Kolkata moved in since the 1980s. Originally built for a population of 1 million, the infrastructure of Kolkata is on the point of collapsing under the pressure of the megacity population for their basic civic amenities viz. housing, transport, roads, water supply, sanitation etc.

Table 3.
Top Ten Cities (1-Million-plus) of India (1991)

Cities	Population (in million)
1. Greater Mumbai	12.57
2. Kolkata	10.92
3. Delhi	8.38
4. Chennai	5.36
5. Hyderabad	4.28
6. Bangalore	4.09
7. Ahmedabad	3.30
8. Pune	2.49
9. Kanpur	2.11
10. Nagpur	1.66

Table 4.
World's Megacities (2000)

Cities	Population (in million)
Tokyo	28.0
Sao Paulo	22.6
New York	16.6
Mexico	16.2
Sanghai	17.4
Mumbai	14.2
Los Angeles	13.2
Buenos Aiyres	13.8
Seuol	13.0
Beijing	14.4
Kolkata	10.9

Impact of population pressure on India's environment – Food and natural resources

India occupies 2.4% of world's land area but it accounts for 16% of world population. Also the hard fact remains that among 1-billion plus population; about 400 million are illiterate and an equal number live below poverty line. Such huge population has enormous demands for food, shelter, *water,* fuel, sanitation etc. which in turn have impact on the natural resources.

Land

With just about a fortieth of the world's land, India supports over 50 per cent of its buffaloes and over 14 per cent of its cattle and goats. As more and more of its grazing lands are brought under the plough, often as a result of government programmes, leading to ecodisaster.

As grazing lands degenerate, people keep more goats, which survive better in hostile environment. Also as fodder becomes scarce, people and animals turn to forests and the result is reckless deforestation. The worst affected are millions of nomads. Their cattle starve and they travel ever-increasing distances. Finally they give up their traditional life styles to become landless labourers.

As lands continue to degenerate we are losing every year in India 600 tons of top soil resulting in soil erosion, loss in soil fertility, drought and flood.

In India rice is the principal crop which mainly grows in the monsoon–dominated regions of West Bengal, Assam, Bihar, Orissa, eastern U.P. and Southern states of Tamil Nadu, Kerala and Karnataka. The second and most important crop is wheat which grows in Punjab, Haryana, U.P., M.P. and in the plains of Gujrat and Rajasthan.

The Green Revolution of the sixties boosted wheat production in Punjab and Haryana which are known as the bread baskets of India. Use of high input-high output technology viz. high yielding variety of wheat (Mexican) intensive irrigation, chemical fertilizers and pesticides showed record production of wheat in Punjab and Haryana. This increased overall food production. Food grain production jumped from 50 million tons (1946) to 100 million tons in 1970, 180 million tons in 1983 and 250 million tons in 1990. But since the nineties they reached the saturation plateau. It could not keep pace with population explosion. It is well known that while agricultural production increases arithmetically, population increases geometrically. The cultivated land (about 143 million hectares) has already reached the saturation carrying capacity due to loss of fertility of soil as a result of intensive irrigation, soil erosion, excessive use of fertilizers, pesticides etc. water tables have gone down and ecological crisis has overshadowed the Green Revolution which has crossed its life time of 30 years as postulated by the Father of Green Revolution, Normal Borlaug. In his famous Nobel Prize address (1970) he said : "Green Revolution is like a tiger. Once you are on it, you have to keep going with more and more improved technology".

Water

India is one of the wettest countries of the world – its average rainfall is 120 cm. while Cherapunji in the North East has world record of 1200 cm and Jaisalmer in Rajasthan 21 cm. Elsewhere in the mid-western USA – the breadbasket of the world gets an average of 20 cm. a year. In this respect India should consider itself singularly blessed.

Modern India uses hardly 10 per cent of the rainfall it receives annually which may grow to 25 per cent by 2050 A.D. – the rest is wasted in absence of storing facilities. Ancient India stored rain water in tanks and ponds which irrigated 50 per cent cropland. But the British and independent India neglected the practice.

The water front presents a gloomy scenario which may end up in "**Water War**" among neighbouring states and countries via their rivers which have no geographical boundaries. Heavy withdrawal of groundwater for the purpose of intensive cultivation has caused water tables to sink threatening food production in the country. According to an estimate of the International Water Management Institute (IWMI) withdrawals of ground water are double the rate of aquifier recharge from rainfall. As a result, water tables are falling all over the country. This may reduce grain production by 25 percent.

On the other hand, population pressure has tremendous impact on water resources. Our available water resource is 700 cubic km (Km^3) surface water and 460 Km^3 ground water. This is inadequate to meet the growing need for water.

Our policy makers (water and energy) are obsessed with hydroelectric power and large dams. But these are the core environmental issues – they do not bother about displacement of thousands of people, loss of forest and agricultural lands. The victims are the poorest and powerless tribals. Environmental activists have stalled Silent Valley Project and Narmada Basin Project through their sustained movement. Small earthen dams for water harvesting are both ecologically sound and economically viable. A village near Chandigarh has set the example. In cities in high rise buildings roofs are being planned for rainwater harvesting to meet the water supply requirements of the residents.

Forests

Satellite data reveal that India is losing 1.3 million hectares of forests per year. Under social forestry programmes of the government, priority is given to commercial investments and not to fulfill the basic survival needs of fuel and fodder of poor villagers. Tribal heartlands in Madhya Pradesh are exploited for construction of dams and extraction of mines turning the tribals into refugees in their homeland. Few attempts are made to involve the landless in afforestation. Some 5 to 10 million landless families could be settled on degraded forest lands, making it the country's largest land reform program.

Deforestation has brought in its trail extinction of valuable species of plants and animals, loss of biodiversity and national calamity.

Fuel

Population pressure puts tremendous stress on our energy resources, both renewable and conventional (non-renewable). Convention energy resources such as coal, petroleum natural gas are getting exhausted which may last barely a century. Consumption of fossil fuel generates air pollution and associated health hazards.

Epilogue

Population, food, natural resources and environment are interlinked. Notwithstanding the statistical hoax presented by policy makers and government, India has the largest illiterate and hungry population. Chinese pride of one-child family and Indian poor population statistics have proved to be hoax again and again in the context of UN yardstick of income $1.00 per day. The nation cannot be fooled by statistical hoax with the prospect of Second Green revolution and food security. The warning sounded by Norman Borlaug (1970) that the Second Green Revolution is due by 1990s has not been followed with improved technology. Genetically modified crop (GM crops) is one such option which has succeeded in case of cotton but not food crops where more vigilance and experimentation is needed. Moreover we have failed to tame the population monster, the crucial suggestion of Borlaug. Our population annual growth has to be cut down from 2.4 to 1.5 per cent (Western countries 0.5 per cent) so that we can pull the country out of the vicious trap of the **P-Triangle** – Population, Poverty, Pollution.

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POPULATION : A RESOURCE OR A BURDEN

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When we confront a question like 'population : a resource or a burden?' an immediate answer that comes in our mind : the population is of course a resource of a species, on which the stability and evolutionary progresses are depended. In the case of human population, from the prehistoric age, the progress of the society has always been achieved by manpower with their creative activities. People are actually the creative resource of a society, but when a population exceeds the carrying capacity of an environment it turns out to be a burden of the society. In our country the population has become the primary problem and other important problems like food, health, education, pollution, space, employment, law and order, etc., have become the secondary ones, because in most cases these are generated from this primary problem. It gradually becomes prominent as an undeniable fact that whatever spectacular achievement we made in the field of agriculture or industry we are bound to embrace a catastrophic disaster unless this abnormal population growth rate is properly subdued. But why this growth rate is called abnormal?

A steady growth rate of population is unknown in nature

Experts consider that it is not the human population size but its steady, exponential growth rate maintained since the last century poses a serious threat against the economic growth through rapid expenditure of limited non-renewable resources of the country. At present, the annual growth rate of population in India is about 1.7%. In Asia it is 1.6%, in Africa it is 3.1%, in Latin America it is 2.0%, in North America (USA plus Canada) it is 0.8%, in Europe it is only 0.3%, and the World's average is 0.7%, According to Brody (1969) even 1% annual growth of population, if it is maintained steadily for a long time, should be considered as abnormally high one and cannot be balanced with the carrying capacity of the world. He explained : 'let us assume that Adam and Eve set up housekeeping 5300 years ago, and that the population increased following a steady growth rate of only 1 per cent per year. In 5300 years, the population P, would number $P = 2e^{0.01 \times 5300} = 1.0 \times 10^{23}$ individuals, weighing (at 100 lbs per person) 1.0×10^{25} lbs, equal to the weight of the entire Earth. The Earth's surface would then be covered miles thick with human beings. This is a good arithmetical proof that the present steady growth rate of population is something really new under the sun; and if allowed to continue without planned control, must be checked by the harsh natural methods that operate to maintain constant subhuman populations : starvation, disease, violence and premature death. Which method shall we humans choose?' Then an obvious question arises, how does the population is stabilized in the nature?

The strategy for survival in nature

When I face a serious social problem I often look at the nature and try to find out how such problem is being tackled in nature and solved through her time tested strategy stabilized through innumerable trials and errors of many millenniums.

Life is not new in this world, it was evolved more than 3.5 billion years (3500 million or 350 crores) ago and evolved into several millions species of plants and animals. The life is stabilized in the world through developing a strategy for survival on an infinite time scale. Controlling of population of species is one of the foremost Principle of the strategy for survival. All the species of plants and animals posses an infinite capacity to multiply, but their populations are not increasingly by leaps and bounds following a steady growth rate, a very significant fact observed by Charles Darwin about one and half century ago. There are numerous natural constrains for controlling population effectively. In fact, the population growth rate of many species of plants and animals is much higher than that of man. Bacteria can double their population just within 20 minutes. Theoretically it is possible for a single bacterium to build up 2 thousand tons of bacterial mass just within 24 hours, but it never happens in nature, before long the growth rate is halted by a series of natural constrains, foremost one is, of course, the depletion of substrate or food material.

As a rule, a perpetual, steady growth rate, irrespective of high or low, is not possible to be sustained in nature.

In many plants and animals, like microbes, insects, locusts and plant groups in changing succession, etc., a steady growth rate is sustained only for a limited period then followed by a population crash and coming back to the square one. Such ups and downs of population also found among large number species of higher animals, e.g., lemmings, snowshoe hares, lynxs, even human beings of early ages as well as tribals of more recent era. It appears from this growth pattern that population growth curve in nature is just like a series of waves arranged on a line of time scale. When population is stabilized it reaches the replacement level where the birth rate and death rate are almost equal and approximately a zero population growth is maintained.

In nature, the population is controlled by two sets of factors. One is external, like activity of predators or depletion of food, water, oxygen, light of the habitat or spreading of epidemic diseases or accumulation of toxic substances in the habitat. Mass migrations are also quite common for reducing the population pressure. Apart from these external factors, there is also set of internal factors, that is hormonal imbalance. Psychic tension, resulting from overcrowding, disturbs the pituitary-adrenal system and diverts or suppresses the hormones governing birth rate and parental care. Most of the evidence comes from somewhat artificial experiments with caged rodents. It is possible that the lemmings' famous mechanism for restoring equilibrium through mass suicide is the product of psychic stress. In experimental populations of rats and mice, at least, anxiety has been observed to increase the death rate through fighting or merely from shock. The growth rate of population also is thus reduced under such condition.

Proportionate distribution of population in food-chain

Plants and animals are not only controlling their own number but also maintaining a definite ratio between themselves in the food-chain. Green plants are the primary producers, and the whole animal-world including humans lead a parasitic life upon green plants, hence, in nature, the total green population is much higher than that of animals. The survival ratio of green plants to animals is found to be 99 : 1, i.e., in any particular environment, in order to maintain the existence of one part of animal population, there should be, at least, 99 parts of green plants; because of the fact, that every 100 parts of solar energy trapped by the green plants, about 80-88 parts are consumed by the green plants themselves and very meager amount of energy is available to the herbivorous animals, the consumers of the 1st order in the food-chain. The available amount of energy is further stepwise reduced to the animals of the successive orders in the food-chain. Man himself is very selective in food habit, he consumes only a few plant species for his food and he never consumes entire plant but only the grains or fruits. Hence, in comparison with other herbivores much more green area would be needed for his survival. But the most paradoxical situation is that every day the number of people is increasing by 3,00,000, which requires corresponding daily increase of green mass amounting to 99 times of the newly incorporated human mass, but in reality, the green area of the world has been reducing every day. We are, therefore, fighting a losing battle.

The genesis of a manmade problem

Human species was evolved about two million years ago. For more than 99 per cent of this time span on Earth, humans have lived in small families or tribes and survived by hunting and gathering. In this capacity, the ecological impact of humans was small, and human population was stable over long period of time. Demographers have concluded that primitive cultures experienced a low birth rate. About 10 to 12 thousand years' ago humans slowly learned how to grow plants and domesticate other animals including discovery of herbal medicines and other natural resources for betterment of health and housekeeping. As agriculture became increasingly efficient, people used to get more food, more leisure and women began to bear more children, and human population started to increase very slowly. The population growth in between 10,000 BC and 1,800 AD was largely a result of the increasing birth rate that coincided with the progress in agriculture. But even during this period the population did not increase steadily, periodic decline of population occurred due to recurrence of famine, epidemic disease, natural disaster, human warfare, etc. We must not forget that as many as 17 human civilizations were totally crashed and obliterated during this period. Hence, in the ancient period, the human population did follow a wavy pattern of growth curve comparable to that of plants and animals of the nature.

With the effect of practicing agriculture and using ancient medicine the total population slowly reached one billion sometime in the first half of the last century, most possibly in 1830s. After that a dramatic change occurred, just within 100 years the second billion of people came and world population reached 2 billion in 1930, and within next 30 years 3rd billion was added and world population reached 3 billion in 1960, the 4th billion was added within 15 years in 1975. At present the world population well exceeds 6 billion. The latest UN medium projection, which assume major continuing progress in fertility reduction over the decades ahead, show the world population may stabilize only after reaching 10.5 billion in the early twenty-second century. Within the span of only 165 years such abnormal change of growth rate pattern has been occurred mostly due to the gross misuse and eccentric application of modern scientific knowledge. If I am allowed to name a single person responsible for such change, his name is Louis Pasteur, following his discovery the infantile mortality has been controlled all over the world very effectively, but not the birth rate, this partial and eccentric application of scientific knowledge has been acting as a major factor for the population boom. The forgoing statement implicating the name of Louis Pasteur is, however, a fallacy. Not Louis Pasteur, actually the policy makers of the world and the common people who are consuming the fruits of science without acquiring scientific temper are solely responsible for such pre-determined disaster, they did not pay any heed to the doctrine of Malthus available at hand and allowed to grow the population without any check. These policy makers suffer from myopic attitudes they are always ready to welcome the short-term immediate gains overlooking the consequential long-term disasters. From the very beginning, controlling of birth rate should be adopted as a complementary measure. This is a wholesome and holistic view of science which basically differs from the exploitation of science for ulterior gains. Such holistic view normally develops through acquiring scientific temper, which is awfully laking in human society. The problem of population is, therefore, a full-fledged manmade problem. The science itself is an extremely powerful tool man ever discovers, using of science without acquiring scientific temper breeds ultimate disaster.

Problems of population in India

In 1952, India became the first developing country to adopt an official population policy and initiated a government-sponsored family planning programme. Though the birth rate in India is considerably lower than that in order neighboring countries like Pakistan and Bangladesh, the census reports, however, do not reflect any spectacular success on reducing the growth of population. In 1951 census, the population of India was 361.08 million and in 1991 census, it is now 843.93 million, the growth of population during the last 40 years is more than double. The decennial growth rate of population is 23.50 per cent during 1981-91. The decennial growth rate in the decade 1971-81 was 24.66 per cent. There has been, therefore, a decrease by 1.16 percent in growth rate during 1981-91 compared to 1971-81. The average annual growth rate has slightly decreased from 2.22 per cent during 1971-81 to 2.11 per cent during 1981-91. According to last census (2001-2011) the growth rate of population further slightly decreased to 1.7% per year. The density of population in the country according to 1991 census is 267 persons per square kilometer as against 216 persons at the 1981 census. There has, therefore, been an increase of 51 persons per square kilometer in the country during the decade 1981-91. In 1951 such density was 117 persons and in 1901 was only 77 persons per square kilometer. It is curious to note that the growth rate of population is not uniform, it is different in different classes of people. The growth rate is significantly higher among weaker and illiterate people as compared to that of elites and literates. It shows that the family planning programme neither is reached nor is working properly where it should be. It also bears a high probability for dilution of quality of the population. Among the Indian States, in our West Bengal the density of population is the highest, the figures is 766 persons per square kilometer. The annual population growth in our State is 13 lakh, which needs each year 4 lakh new jobs, 2.5 lakh new houses, 1300 new schools and 13 new colleges, the demand almost exceeds the bearing capacity of the resources of our State.

Conversion of burden to resources - the ideal aim

The period of the steady growth rate of population is necessarily be a short one. Exponential growth cannot long be sustained without producing unsupportable number of people. According to many experts the adjustment towards a new era of roughly stable population size has already begun. In 1960s, the annual growth rate of global population reached the peak of the wave at somewhere near 2 per cent and has declined somewhat since then. In 1970s the rate was declined to about 1.9 per cent, in 1980s it was 1.8 percent and in 1990s it is further dropped to 1.7 per cent. The rate of decline, however, is very slow and when it will reach the base line of the wave (zero population growth) the total population of developing countries like India, Pakistan and Bangladesh would, much earlier, exceed the carrying capacities of those countries. So, every possible means should be adopted on a top priority basis to reach the zero population growth within a much shorter span of time. Only campaigns for spreading literacy and the half-hearted family planning programmes may not be sufficient to accomplish the goal. Well planned legislative measures also to be incorporated to curb the population growth where it is needed most.

The people is the unit of a population. Whether a population becomes a burden or a resource, that depends on the creative activity and net productivity of the people. The availability of food, space, education, health care, job satisfaction and plentiful natural resources, etc. are the prerequisite for the creative productivity of the people. These prerequisites are only possible to be distributed to the people to a significant amount if their total number remains well within the carrying capacity of the country. The carrying capacity also can be increased to a certain extent with application of modern scientific knowledge and technological skill especially in the fields of agriculture, engineering, medicine, etc. With our almost one billion of population, less than one-third as much land as that of China or the United States and extraordinary poverty to overcome, we the common people of our country should recognize the gravity of the situation and the lateness of the hour and must act to salvage the country's prospects for future prosperity through converting this burden of population to a rising resource.

Since the Independence a small section of well educated, practical minded and scientific tempered people irrespective of caste, creed and religion have been sincerely and successfully controlling their population, but vastly larger weaker sections of people are not. Such unequal growth dilutes the quality of population creating more problems. It is, therefore, apparent that spreading of proper education, specially women education among weaker sections within a shortest possible time is obligatory.

Wide spreading of scientific temper is equally obligatory among the people at large and people who matter. Otherwise, they would not be able to face the imminent, self-inflicted serious disaster developed from derailing of economy and environment.

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PRE-STORAGE SEED TREATMENT FOR IMPROVED STORABILITY AND FIELD PERFORMANCE OF HIGH-VIGOUR SUNFLOWER (*Helianthus annuus* L.) SEEDS

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ABSTRACT

Pre-storage dry treatment of freshly-harvested (high-vigour) sunflower (*Helianthus annuus* L.) seeds with red chilli powder (@ 1g/kg of seed) showed significant improvement in post-storage germinability as well as field performance of the resultant crop over untreated control. High-vigour seeds were also dry dressed with aspirin @ 50 mg/kg of seed; bleaching powder @ 2 g/kg of seed; *para*-amino-benzoic acid @ 500 mg/kg of seed and neem leaf powder @ 2g/kg of seed under ambient conditions. Beside red chilli powder, bleaching powder and aspirin treated seeds showed some beneficial improvement on storability and productivity but did not surpass the values of red chilli powder. Pre-storage soaking-drying (wet) treatment showed adverse effect on improving germinability as well as field performance over untreated control due to soaking injury. Biochemical studies revealed that treated seeds showed significantly reduced leakage of sugar and electrolyte, higher dehydrogenase enzyme activity and lower volatile aldehyde production than the untreated control**.** On the the basis of present investigation, pre-storage dry treatment with red chilli powder may be suggested for the improvement of germinability and yield potential of stored high-vigour sunflower seeds.

INTRODUCTION

Several orthodox agricultural and horticultural crop seeds specially oil seeds face a serious problem in maintaining high germinability during storage due to prevailing high temperature and high humidity in the tropical and subtropical countries like India. Moreover in India prolonged monsoon season makes it more difficult. In eastern parts of India, sunflower seeds are generally grown in the *rabi* (December-March) season and then stored in moisture pervasive containers, germinability of seeds falls very rapidly in the monsoon months due to absorption of moisture from the humid atmosphere. So, maintenance of vigour and viability of the high-vigour (freshly harvested) seeds for planting in the next season is very difficult.

Pre-storage dry dressing treatments of freshly harvested high-vigour seed of several crop plants are effective in slowing down seed deterioration under subsequent storage conditions (Mandal *et al.,* 1999; Kapri and Mandal, 2005). Hydration-dehydration treatments are not effective in freshly harvested high-vigour seeds and thorough drying of a large seed stock to its safe moisture content after hydration is problematic especially during monsoon month (June-August) due to non-availability of costly artificial drying facilities by poor farmers. Therefore, dry-dressing treatment in high-vigour seed with finely powdered halogenated compounds (bleaching powder), non-toxic chemicals (*para*-amino-benzoic acid), pharmaceutical formulations (aspirin) and crude plant materials (red chilli powder and neem leaf powder) were effective in controlling seed deterioration of wheat and okra (De *et al*., 2003; and Guha *et al.,* 2012). In the present study, major emphasis has been given towards standardization of suitable method of seed invigoration treatments for the improvement of germinability and field performance of high-vigour sunflower seeds.

MATERIALS AND METHODS

Freshly harvested sunflower (cv. Morden) seeds were cleaned and sun dried to a safe moisture content of 8 % for safe storage in rubber stoppered air-tight glass bottles under ambient conditions in the laboratory till they were used for treatments.

Dry treatments were given to freshly harvested (high-vigour) seeds with finely powdered aspirin (active

Table 1

Effect of seed invigoration treatments for the maintenance of vigour and viability of high-vigour sunflower (cv. Morden) seeds immediately after treatment (before ageing) and after natural ageing at $76\pm3.2\%$ RH and 30 ± 1.6^{o}C temperature for 6 months

Treatments	Before ageing					Natural ageing				
	Germination		Mean root length (mm)	Mean shoot length (mm)	Vigour index*	Germination		Mean root length (mm)	Mean shoot length (mm)	Vigour index*
	(%)	Arc-sin value				(%)	Arc-sin value			
Control	100	90.00	121.96	56.13	17809.00	48	43.85	57.24	23.38	3864.96
Aspirin	95	77.08	123.73	51.74	16669.65	58	49.60	63.74	25.93	5200.86
Bleaching powder	98	81.87	119.40	48.68	16471.84	60	50.77	73.76	27.22	6058.80
para-amino-benzoic acid	93	74.66	134.63	56.26	17752.77	50	45.00	57.79	20.57	3918.00
Red chilli powder	88	69.73	112.78	50.67	14383.60	70	56.79	78.41	32.16	7739.90
Neem leaf powder	100	90.00	133.45	53.42	18687.00	45	42.13	39.96	19.25	2664.45
Soaking-drying	95	77.08	116.86	49.54	15808.00	40	39.23	37.26	16.46	2148.80
L.S.D. at 0.05P	**–**	**NS**	**NS**	**NS**	**–**	**–**	**9.83**	**7.98**	**7.88**	**–**

Dry and wet treatments were given to freshly harvested seeds which were stored in the refrigerator at -20 ºC.

Concentrations : Aspirin @ 50 mg/kg of seed; Bleaching powder @ 2 g/kg of seed; *para*-amino-benzoic acid @ 500 mg/kg of seed; Red chilli powder @ 1 g/kg of seed and Neem leaf powder @ 2 g/kg of seed.

Abbreviation : NS **:** Non-significant

Data were recorded after 5 days of germination at 23 ± 1^{o}C.

***Vigour index =** G % × Seedling length ingredient, *ortho*-acetyl salicylic acid) @ 50 mg/kg of seed, *para*-amino benzoic acid @ 500 mg/kg of seed, bleaching powder (active ingredient, chlorine of calcium hypochlorite) @ 2 g/kg of seed, red chilli powder (active ingredient, capsaicin) @ 1g/kg of seed and neem leaf powder (active ingredient, azadirachtin) @ 2 g/kg of seed in rubber stoppered glass bottles at room temperature (28±1°C) under ambient conditions, which were shaken once daily for seven days to mix thoroughly with the powdered ingredients and seeds. In case of soaking-drying (wet) treatment, seeds were soaked in double volume of water for 2 hours at room temperature (28±1°C) followed by drying back to its original moisture content in the artificial drying cabinet under a current of hot air (35±1°C) for 4-5 days. After drying, seeds were transformed to a desiccators containing over-fused calcium chloride for 7 days for uniform moisture stabilization.

After fifteen days of treatment, treated and untreated seeds were taken separately in perforated paper packets (containing same amount of seed with equal number of holes) and then all the packets containing seeds were subjected to natural ageing in a cloth bag under ambient conditions (RH 76±3.2% 30±1.6°C) for 180 days. The packets were shaken at a regular interval for uniform ageing. Germination test of treated and untreated seeds (more than 400 seeds for each treatment as specified by ISTA, 1996) were done immediately after treatment (before ageing) and six months' natural ageing following the method of Punjabi and Basu (1982) with minor modifications. Data on germination percentage and seedling length were recorded after 5 days of germination at 23±1°C temperature.

Field experiment

Field experiment of treated and untreated sunflower seeds were studied at the Agricultural Experimental Farm of Calcutta University at Baruipur, 24-parganas (South), West Bengal during *rabi* (December-February) season using randomized block design (RBD) with three replications for each treatment. After final land preparation, seeds were sown in the pit @ 10 kg/ha giving a space of 40 cm between the pits and 40 cm between the rows. The plot size was 10 m^2 (4 m×2.5 m) for each replication. A fertilizer dose of N: P_2O_5: K_2O was given @ 80: 40: 40 kg/ha respectively. The entire amount of phosphate and potash and 50 % of nitrogen was added at the time of sowing along with an immediate irrigation for proper field establishment. The rest of nitrogen was top dressed in two equal split doses; one at one month after sowing and another at the flower initiation stage. The crop has received a total of four irrigations. Besides, intercultural practices were made periodically during the cultivation period.

Data on plant population/m^2 was taken after 15 days of sowing. The plant height, number of heads per m^2, head diameter, number of seeds per head, yield per m^2 and 1000-seed weight was recorded replication-wise for each treatment after harvest.

Table 2

Effect of seed invigoration treatments on field performance and productivity of high-vigour stored sunflower (cv. Morden) seeds

Treatments	Plant population/m^2	Plant height (cm)	Head diameter (mm)	No. of seeds/head	Yield/m^2 (g)	1000-seed weight (g)
Control	26	120.20	135.13	456	62.13	27.25
Aspirin	26	124.27	148.33	487	77.80	31.95
Bleaching powder	29	125.80	149.27	493	79.69	32.33
para-amino-benzoic acid	24	121.80	145.17	483	65.59	27.16
Red chilli powder	32	129.93	161.53	590	99.80	33.83
Neam leaf powder	24	119.67	132.67	428	51.30	23.97
Soaking-drying	13	117.47	131.00	411	43.07	20.96
L.S.D. at 0.05P	**NS**	**NS**	**9.8**	**20.1**	**16.90**	**3.60**

After treatment, seeds were restored in rubber-stoppered glass bottles and kept in the laboratory under ambient conditions till sowing in the field.

After thinning, plant population was fixed at 5 per square meter.

Other details are same as in Table : 1

Biochemical studies

Biochemical studies of treated and untreated seeds were conducted immediately after treatment (before ageing) and six months' natural ageing. The membrane permeability of treated and untreated high-vigour sunflower seeds as measured by leakage of electrolytes and leaching of sugar were studied following the method of Anderson *et al.* (1964) and McCready *et al.* (1950) with minor modifications. Dehydrogenase enzyme activity of treated and untreated sunflower seeds were measured following the method of Kittock and Law (1968) with minor modifications. The chemical assay of volatile aldehyde production by the treated and untreated seeds was studied following the method of Wilson and McDonald (1986a) and Sur and Basu (1990) with minor modifications.

Statistical analysis

Data collected on various parameters were statistically analyzed (Fisher, 1948) to evaluate the treatment effects on germinability and field performance of sunflower seed. Germination percentage data were transformed to their respective angles (arc-sin) before analysis.

RESULTS AND DISCUSSION

Germination tests conducted immediately after treatment did not show any beneficial effect on germinability over untreated control (Table 1). However, after natural ageing at 76$\pm$3.2% RH and 30$\pm$1.6°C temperature for 180 days, all the dry treated seeds except neem leaf powder showed improvement on germinability over untreated control (Table 1). But among the dry treatments, red chilli powder showed significantly better result in improving storability followed by marginal improvement of bleaching powder and aspirin (Table 1). Pre-storage wet treatment (soaking-drying or hydration-dehydration) did not show any improvement on germinability over untreated control (Table 1) probably due to soaking injury in harvest fresh seed.

The crop raised from the treated and untreated seeds showed that most of the dry treatments viz. red chilli powder, bleaching powder and aspirin improved field performance and productivity, especially yield per m^2 and 1000 seed weight over untreated control (Table 2). But, red chilli powder treated seeds have shown better results in increasing yield per m^2 and 1000-seed weight. The pre-storage wet (soaking-drying) treatment showed adverse effect on field performance and productivity due to soaking injury as it was also observed in laboratory experiment (Table 2).

Physiological and biochemical studies reveal that there was not any significant difference on leaching of electrolytes and sugar and dehydrogenase enzyme activity and volatile aldehyde production between the treated and untreated seeds when tested immediately after treatment i.e. before ageing (Table 3). But, after natural ageing at 76$\pm$3.2 % RH and 30$\pm$1.6°C temperature for 180 days, most of the dry physiological treatments viz. red chilli powder, bleaching powder and aspirin showed lesser leaching of sugar and electrolytes, higher dehydrogenase enzyme activity as well as lower volatile aldehyde production over untreated control (Table 3). Among the dry treatments, red chilli powder was the best treatment with significantly better result in maintaining membrane permeability and dehydrogenase enzyme activity. Pre-storage soaking-drying treatment showed adverse effect on membrane integrity and enzyme activity due to soaking injury.

Regarding the mode of action of dry treatments, Rudrapal and Basu (1981) suggested the role of iodine (and other halogenated compounds) in the stabilization of double bonds of unsaturated fatty acid moieties of lipo-protein bio-membranes might be the possible reason of viability maintenance, besides the possibility of iodine acting as a free radical controlling agent (Pryor and Lasswell, 1975). The role of chlorine (bleaching powder, a source of chlorine) would be more or less similar (Mandal and Basu, 1986).

The protein protective role of acetyl salicylic acid (aspirin) at much lower concentration (20-100 mg/kg of seeds) might be responsible for viability maintenance of stored seeds (De *et al.*, 2003; Guha *et al.,* 2012; Layek *et al.,* 2012). Aspirin, a non-steroidal anti-inflammatory drug and chemically is a weak organic acid. They may also decrease the production of free radicals and superoxide and may interact with adenyl cyclase to alter the cellular concentration of cAMP (Bertram, 1998). Further, Takaki and Rosim (2000) have reported that aspirin application to *Raphunus sativus* L. seeds would increase the tolerance to high temperature and synchronize seed germination.

Capsaicin, an active ingredient of red chilli (*Capsicum frutescens* L.) is an acknowledged inhibitor of lipid peroxidation (Brand *et al*., 1990; Dey and Ghosh, 1993). Wilson and McDonald (1986b) suggested that seed deterioration would take place during ageing via lipid peroxidation of bio-membrane resulting in increased membrane permeability. Sung and Chiu (2001) have given strong support to the concept of free radical induced lipid peroxidation as a causative factor of seed deterioration in sweet corn (*Zea mays* L.) thereby confirming similar findings of this laboratory.

Table 3

Effect of pre-storage seed invigoration treatments on membrane permeability, dehydrogenase enzyme activity and volatile aldehyde production of sunflower (cv. Morden) seeds immediately after treatment (before ageing) and after natural ageing at 76±3.2 % RH and 30±1.6°C temperature for 6 months

Treatments	Before ageing					Natural ageing				
	Germination (%)	Elactrical conductance (dsm^{-1})	Leaching of sugar (µg/ml)	Dehydrogenase activity (nmole/hr/ embryo)	Volatile aldehyde production (O.D.)	Germination (%)	Electrical conductance (dsm^{-1})	Leaching of sugar (µg/ml)	Dehydrogenase activity (nmole/hr/ embryo)	Volatile aldehyde production (O.D.)
Control	100	0.034	11.60	11.60	0.517	48	0.072	34.20	9.31	0.605
Aspirin	95	0.038	11.28	11.28	0.520	58	0.048	25.60	10.84	0.587
Bleaching powder	98	0.038	11.31	11.31	0.516	60	0.044	23.40	10.98	0.579
para-amino-benzoic acid	93	0.042	11.22	11.22	0.526	50	0.061	30.40	9.17	0.598
Red chilli powder	88	0.035	11.10	11.10	0.542	70	0.037	18.20	11.28	0.564
Neem leaf powder	100	0.033	11.63	11.63	0.512	45	0.068	41.50	9.38	0.689
Soaking-drying	95	0.040	11.28	11.28	0.521	40	0.097	62.60	7.36	0.716
L.S.D. at 0.05P	**–**	**NS**	**NS**	**NS**	**NS**	**–**	**0.002**	**9.60**	**1.15**	**0.03**

Other details are same as in Table : 1

The present findings confirm the entry of active ingredients into stored seeds but the mechanism of their entry requires a critical elucidation. However, the cracks and crevices in the seed coat may possibly serve as entry point of exogenously applied substances. Channel proteins present in the membrane (permits entry of water soluble substances across the hydrophobic lipid bi-layer) possibly act as passage for the entry of the dry active ingredients inside cell.

On the basis of the results, pre-storage dry seed treatment with red chilli powder may be suggested for extended storability and improved field performance and productivity of high-vigour sunflower seeds.

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PRELIMINARY ESTIMATION OF THERMAL TIME REQUIREMENT FOR GROWTH OF SILKWORM BREEDS

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ABSTRACT

Labor-intensive sericulture industry in India provides gainful employment to 7.628 million people producing around 18,755 MT of mulberry silk and fetching export earning of Rs 22.3108 billion during 2012-13. The success of sericulture industry depends sizably upon environmental conditions and temperature plays a major role on growth and productivity of silkworm. Often rearers are at a loss while failing to harvest the estimated cocoon crop. Their predicament leads to studies on identification of climate-ready technology innovations in crop management and pinpointing areas where policy interventions may help accelerating adaptation of revised cropping systems. The speed at which the metabolism occurs is thermally controlled because the enzymes, that drive the reactions, are mostly thermo-sensitive. Therefore, measuring the amount of heat accumulated over time provided a physiological time scale that is biologically more accurate than calendar days. Growing degree days (GDD) is a weather-based indicator for assessing crop development. It is a measure of heat accumulation used to predict development rates such as the date that a silkworm crop reaches instar-wise maturity. The present study was conducted to estimate the thermal requirement of mulberry silkworm in terms of accumulation of GDD along the phenology and its association with the growth of larvae for better crop management.

INTRODUCTION

India, the second largest producer of silk having current (2012-13) yield output to the tune of 23,679 MT is also the largest silk consumer in the world. Labor-intensive sericulture industry provides employment to approximately 7.628 million people along the value chain. Mulberry sector of this industry has captured the most significant place in the world silk scenario for its popularity, quality, demand, supply and consumption. India occupies the global pride position by producing around 18,755 MT of mulberry silk and fetching export earning of Rs 22.31.08 billion during the current financial year.

The success of sericulture industry depends upon several factors of which the impact of the environmental factors -both biotic and abiotic are of vital importance. Among the abiotic factors, temperature plays a major role on growth and productivity of silkworm,.

Silkworm, *Bombyx mori* L., is a highly specialized monophagous, domesticated insect which is reared exclusively on the feed of mulberry (*Morus* sp.) foliage. Though silkworm larvae are reared indoor, the Indian rearers still remain at the mercy of nature's vagary with special respect to temperature. As a consequence rearers fail to harvest the estimated cocoon crop. Their predicament leads to studies on identification of climate-ready technology innovations in crop management and pinpointing areas where policy interventions may help accelerate adaptation of cropping systems (Xu and Wu, 1992).

Unless stressed by other environmental factors like feed and moisture, the development rate from emergence to maturity of most of the insects depends upon the daily air temperature. Because many developmental events of insects depend on the accumulation of specific quantities of heat, it is possible to predict when these events should occur during a rearing season regardless of differences in temperatures from year to year (Davidson,1944).

Growing degree days (GDD) is a weather-based indicator for assessing crop development. It is a measure of heat accumulation used to predict development rates such as the date that a silkworm crop reaches instar-wise maturity (Forister and Shapiro, 2003).

In the absence of extreme weather conditions or disease, insects grow in a cumulative stepwise manner which is strongly influenced by the ambient temperature. The Growing Degree Days calculation allows producers to predict the insects' pace towards maturity. Daily growing degree day values are added together from the beginning of the season at the onset of hatching, providing an indication of the energy available for insect growth. Growing degree day totals are used for comparing the progress of a growing season to the long-term average and are useful for estimating crop development stages and maturity dates (Forkner *et al.* 2008).

Metabolism of any insect is governed by a set of genetically pre-determined chemical reactions which include physiological life cycle processes and phenotypic expressions of all genetic traits. The speed at which the metabolism occurs is thermally controlled because the enzymes that drive the reactions are mostly thermo-sensitive. Therefore, measuring the amount of heat accumulated over time provided a physiological time scale that was biologically more accurate than calendar days (Gordon and Sanz, 2006).

The basic concept of growing degree days is that insect development occurs when temperatures exceed a base temperature. In mulberry silkworm the base temperature was reported to be as 10°C as most other insects (Menzel *et al.* 2006).

There are ample literatures stating that good quality cocoons are produced within a temperature range of 22-27°C and temperature above these levels makes the cocoon quality poorer (Krishnaswami *et al*., 1973; Rangaswami *et al.,* 1976; Benchamin & Jolly 1986). With the increase of temperature (20° – 30°) leaf to silk conversion rate decreases too (Ueda and Suzuki 1976).

Zhou *et al.* (1995) described that the growth or development of trees and insects are dependent on several environmental factors including temperature (heat), light and humidity. Growing degree days are therefore used to predict the maturity stage of a plant and also even the life stages of an insect, for better management whether in terms of growth and development for harvesting the plant or for herbivore management.

The alfalfa weevil, *Hypera postica* (Gyllenhal), is a serious, yet sporadic defoliator of alfalfa, *Medicago sativa* L., in Nebraska and Stilwell *et al.* (2010) studied the variation in degree-day requirements by location in eastern Nebraska.

Of late development of biological calendars based on GDD and growth of insect pests has found wide application in insect-herbivory management (Bale *et al.*, 2002).

The present study was designed to estimate the thermal requirement of mulberry silkworm in terms of accumulation of GDD along the phenology and its association with the growth of larvae for better crop management with respect to silkworm as well as mulberry.

MATERIALS AND METHODS

The study was carried out with rearing of two popular breeds of silkworm namely B.Con4 and M.Con4 fed on leaves of S1 and S1635, two improved varieties of mulberry. Rearing was conducted as per standard procedure.

Two disease free layings (dfls) each of the breeds were brushed on 3rd August, 2013 and rearing was conducted at ambient room temperature with leaves of S1 and S1635 in 3 replications each. After the chawki stage (young age: 1st to 3rd instar), rearing was carried forward with 300 worms per treatment. Biofixing of temperature was done with the hatching of the larvae.

The GDD for each day was calculated considering the base temperature for the silkworm as 10°C, below which the growth of these biological entity is virtually zero. The GDD index or the accumulated GDD was calculated using the following formula (Baskerville and Emin. 1969).

$$\Sigma GDD = \{[T_{max} + T_{min}]/2 - T_b\}$$

Where,

T_{max} = Maximum daily temperature in

T_{min} = Minimum temperature in ÚC

T_b = Base temperature for mulberry.

RESULT AND DISCUSSION

During the experiment the temporal data on temperature were recorded and analyzed. Air temperature in the open ranged between 34.8°C and 25.2°C with average of daily mean of 29.12°C. The range of ambient temperature of the rearing room was from 32°C to 27°C while the daily mean averaged as 28.85°C. (Table 1)

Table 1.

Summary of temperature in regime °C during the experiment

Particulars	Range	Mean
Open air Temp.	34.80-25.20	29.12
Rearing room Temp.	32-27	28.85

While rearing silkworm breeds B.Con4 and M.Con4, it was observed that the same amount of GDD was required for the growth during each of the five instars of larva irrespective of dietary difference. Both the silkworm breeds required 413.5ºC days to complete the larval duration (Table 2)

Table 2.

Instar-wise GDD requirement in ºC Day for growth of Larvae

GDD requirement (ºC Day)			
Silkworm breed		Diet	
	Instar	S1	S1635
B. Con4	I	60.5	60.5
	II	117.5	117.5
	III	191.5	191.5
	IV	191.5	191.5
	V	285.5	285.5
	Matured Larva	413.5	413.5
M.Con4	I	60.5	60.5
	II	117.5	117.5
	III	191.5	191.5
	IV	191.5	191.5
	V	285.5	285.5
	Matured Larva	413.5	413.5

Thermal time requirement for ecdysis of B.Con4 and M.Con4 larvae was confined to 18ºC Day -19.5ºC Day. (Table 3 and Chat 1).

Table 3.

Moult -wise thermal requirement in ºC Day for Ecdysis

Silkworm breed	Moult	GDD
B. Con4	I	19.5
	II	18.5
	III	19
	IV	19.5
	V	19.5
M.Con4	I	19.5
	II	18.5
	III	19
	IV	19.5
	V	19.5

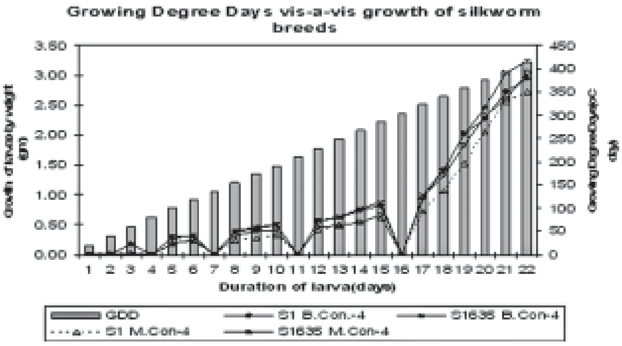

Chart 1

Both the silkworm breeds B.Con4 and M.Con4 reached maturity within 22 days after hatching and showed the similar trend before and after ecdysis in terms of daily weight gain. As expected, daily weight gain of bivoltine breed B.Con4 surpassed that of multivoltine breed M.Con4. But dietary difference did make a difference in daily weight gain. In case of both the silkworm breeds, daily weight gain was consistently more when fed on leaves of mulberry variety S1635 than the feed of mulberry variety S1 (chart 1).

Correlation study between growth by daily weight and accumulated GDD indicated that the growth of both B.Con4 and M.Con4 had highly significant and positive association with respective GDD irrespective of dietary difference. This is in agreement with the findings of Sparks and Yates (1997); Walther *et al.* (2002) and Stefanescu *et al.* (2003) in other herbivorous insects of interest.

Table 4.

Correlation coefficients between growth by weight increment and accumulated GDD in silkworm

Silkworm breed	B.Con4		M.Con4	
Diet	S1	S1635	S1	S1635
Correlation coefficient	0.823**	0.816**	0.807**	0.817**

*Significant at 1% level of significance

The findings formed the base work towards making an environment-mediated crop calendar for better silkworm crop as well as mulberry farm management. Further, this paper develops an approach to thermal time lag combining temperature and body mass into a general process of growth functions. The resulting differential outputs may then be solved to yield the time for development through phases of life cycle.

Nevertheless, similar experiments are required to be conducted for precision results.

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EVALUATION OF IMPACT OF WEATHER ON MULBERRY LEAF YIELD

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ABSTRACT

A synthetic yield-weather model on mulberry was developed through mining of archived yield and spatio temporal weather data for the period from Oct, 2002 to Sept, 2013. The data sets were finally re-analyzed crop-wise into 16 agro-meteorological variables vis-à-vis yield data of ruling mulberry variety S1635. Data were subjected to regression analysis. The ensuing equation led to construction of the final synthetic yield-weather model of mulberry foliage under standard package of practices(irrigated) at 24°06′ North Latitude and 88°15′ East Longitude geo-referencing the institute farm. Retrospective model validation for the regression equation developed with data from 2002-03 to 2009-10 vis-à-vis the rest of the period under study i.e. from 2010-11 to 2012-13 confirmed that there had been no significant deviation of mulberry foliage yield from the prediction.

INTRODUCTION

Mulberry sericulture is a traditional vocation in the Eastern, including the North-Eastern India and bears the brunt of diverse agro climate. Of late the erratic climate has started taking toll on mulberry and the resultant cocoon crops. Many times foliage abundance does not complement silkworm rearing environment or congenial rearing environments are not met with silkworm instar-specific sufficient harvestable foliage, thus resources and efforts are wasted at different scales. But now agro meteorology took a pragmatic approach to the goal of improving prediction of crop yields. (French and Geldermann, 2005). Monitoring weather and estimating production have been essential components of the Decision Support System, with a direct and active involvement of Meteorological Services. Over the years, the methodology has kept evolving, but crop monitoring and forecasting remain central activities (Lobell *et al.*, 2011). Operational forecasts are now mostly based on readily available agro meteorological or satellite data, sometimes a combination of both. They do not depend on expensive and labour intensive ground surveys and are easily revisable as new data become available (Gommes, 1996). Harwood *et al.* (2010) developed an uncertainty model in field grown iceberg lettuce for decision support. Comprehensive mulberry crop-yield weather models projecting the impact of agro climate on yield were not available till currently. The treasure-troves of historical spatio- temporal databases available at open source were mined at advantage for the first time herein vis-a vis mulberry yield data. Historical climate data that are geo-spatially explicit is a necessity for any crop modeling process, especially on a regional scale. Crop simulation models typically require large amounts of climatic input data, including maximum and minimum temperature and solar radiation at a daily time step. The relationship between outdoor-reared muga cocoon crop yield and prevailing agro climate was investigated and comprehensive deterministic models with real time data were reported by Chaudhuri *et al.*, 1999; Chaudhuri, 2003; Chaudhuri, 2004; Chaudhuri, 2008. But in mulberry, the present study is first ever attempt towards development of a crop- weather model. Presently a vast wealth of ground-truth and remotely sensed historical data are available at varied sources, even a synthetic model for the foundation of a comprehensive model deciphering the impact of agro meteorology on foliage yield of mulberry was lacking so far. Assimilation of remotely sensed data into biophysical process models is a very promising approach (Reilly, *et al.*, 2003; Hundal, 2004; Xiong *et al.*, 2007). These databases were integrated, analyzed and worked out in the present study towards development of a deterministic model helping in effective crop management and resource utilization-a step to pave precision in sericulture.

Objective:

i) Historical data mining and retrospective analysis of weather variables over mulberry crop schedule for the period from October 2002 to September 2013 from archive of remotely sensed spatio-temporal data

ii) Data retrieval on mulberry foliage yield from this Institute record for the aforementioned period

iii) Development of a synthetic yield-weather model with re-analyzed weather during the mulberry crops and crop yield

MATERIALS AND METHODS

Foliage yield of ruling mulberry variety S1635 and corresponding agro meteorology along the growth of mulberry.

Temporal historical weather data were mined on location of CSR&TI, Berhampore mulberry farm geo-referenced at 24º06′ North Latitude and 88º15′ East Longitude from ASDC, NASA, Langley, USA (courtesy: Responsible NASA Official: John M. Kusterer) for the period from Oct. 2002 to Sept. 2012 on daily basis. Foliage yield data of ruling mulberry variety S1635 raised under irrigation and standard package of practices in separate blocks of 90 cm X 90 cm and 60 cm X 60 cm spacing respectively were retrieved on per plant basis for five crops in a year from CSR&TI, Berhampore record over the same period. The data sets were analyzed retrospectively (re-analysis) crop-wise into 16 agro-meteorological variables vis-à-vis mulberry foliage yield (Table 1). During the entire period of each crop growing season i.e. from the day after foliage harvest till the day before next harvest, daily agro meteorological data on 16 parameters corresponding a total of 52 foliage yield harvests were re-analyzed for impact assessment (Table 2). All the aforementioned 16 agro meteorological variables were used as independent predictors in a stepwise backward multiple regression over crop wise foliage yield as dependent variable using SPSS 20 software. Chi square (χ^2) test was conducted for retrospective model validation by ascertaining the relative deviation of the calculated impact by putting values of actual historical data in regression equation vis-a-vis that of respective predictors.

RESULTS

Average of the crop yield and prevailing agro climate during the period from September 2002 to September 2012 covering a total of 52 crops are summarized in Table 3.

Mulberry thrives and endures a wide range of temperatures within the threshold of 13ºC and 37ºC, beyond which growth processes are arrested (Rangaswami *et al.,* 1976, Sarkar *et al.*, 2005; Ganga and Chetty, 2008). It was observed that climate change in terms of warming had been pronounced since 2008 and kept fluctuating persistently then onward. Mulberry

Table 1.

Details of crop growing seasons studied

Crop no	Crop Season	Duration of study
1	Feb 26 to May 9	
2	May 10 to July 23	
3	July 24 to Sept 13	From crop 3, 2002 to crop 4, 2012
4	Sept 14 to Nov 28	
5	Nov 29 to Feb 25	

Table 2.

Details of parameters included in the study

Sl no	Parameters	Abbrvn	Unit
1	Crop growing season: 1 to 5	CROP	No
2	Heat stress day: total no. of days above 37ºC	HSD	Day
3	Heat stress load: total amount of temp. accumulation above 37ºC	HSL	ºC
4	Cold stress day: total no. of days below 13ºC	CSD	Day
5	Cold stress load: total amount of temp. accumulation below 13ºC	CSL	ºC
6	Mean day time temp	MDTT	ºC
7	Mean night time temp	MNTT	ºC
8	Mean diurnal temp.variation	MDUV	ºC
9	Daily insolation incident on a horizontal surface	SRAD	MJ/m^2/day
10	Maximum air temp. at 2m above the earth surface	TMAX	ºC
11	Minimum air temp. at 2m above the earth surface	TMIN	ºC
12	Wind speed at 10m above the surface of the earth	WIND	m/s
13	Dew/frost point temperature at 2m	TDEW	ºC
14	Av. air temperature at 2m above the surface of the earth	T2M	ºC
15	Relative humidity at 2m	RH2M	%
16	Diurnal temp. range	DTR	ºC
	Mulberry foliage yield harvested at the end of each crop season	YLD	gm/plant

Table 3.

Descriptive Statistics

Parameters	Mean	Std. Deviation
YLD	0.327	0.143
CROP	3.019	1.407
HSD	4.865	11.757
HSL	16.081	43.525
CSD	4.673	10.369
CSL	6.898	17.179
MDTT	26.972	3.335
MNTT	25.338	3.513
MDUV	1.634	0.614
SRAD	17.803	2.475
TMAX	30.267	3.282
TMIN	22.1057	4.124
WIND	2.510	0.760
TDEW	19.736	5.712
T2M	25.937	3.432
RH2M	71.589	14.382
DTR	8.162	3.087

experienced heat stress days (HSD) above the upper threshold temperature of 37^{o}C during two growing seasons (HSD 1 and HSD 2) acumulating 63 (48+15) days and 50 (37+13) days in 2008 and 2012 respectively (Chart 1). But cold stressed days (CSD) increased from mere five days to 31 days drastically in 2004 and the trend continued till 2012 during crop growing season-5 (CSD 5) in which the winter season falls (Chart 2). Correlation study (Table 4) revealed that crop seasons, cold stress days, mean diurnal temperature variation,

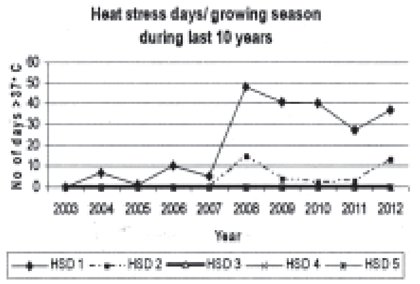

Chart 1

Chart 2

minimum temperature, dew temperature, mean relative humidity and diurnal temperature range were significantly correlated with yield. While crop seasons, cold stress days, mean diurnal temperature variation and diurnal temperature range had negative association, minimum temperature, dew temperature and mean relative humidity had positive association with yield. As expected all the weather variables were significantly correlated amongst themselves in most cases. Stepwise backward multiple regression analyses were carried out next to enumerate the impact of agro meteorology on the mulberry yield by running SPSS 20 multiple regression>stepwise>backward. The regression output terminated through ten steps putting forth ten models (Table 5). It was evident that with inclusion of all the 16 weather parameters as independent predictors versus foliage yield as dependent variable resulted in the most explicit model (model 1) having the greatest strength of both the multiple correlation co-efficient (0.82) as well as co-efficient of determination (0.67). The subsequent backward steps of the multiple regression eliminated the predictors having weaker influence on the yield deciphered by the value of the coefficients (Table 6). Though such elimination did not improve the strength of multiple correlation co-efficient as well as co-efficient of determination of the models 2 to 10, the tenth and final model came out as the most workable and accepted one. Nonetheless, the fitness of all the models were confirmed by the generally high output of multiple correlation co-efficients and co-efficients of determination ranging from 0.82 to 0.78 and 0.67 to 0.61 respectively as well as very low residual output coupled with highly significant F value for each model as was explicated by regression ANOVA (Table 6). The initial model accounted for 67% of the foliage yield output by including 14 agro meteorological variables. But, for more comprehensible practical application the final model stood more suitable wherein independent variables such as the crop growing seasons, heat stress load, solar insolation, maximum temperature and daily mean temperature contributed at least 61% towards the foliage yield. The tenability of the model was verified by the great extent the histogram of regression standardized residuals matched the normal distribution, indicative of our sample can very well predict a normal distribution in the population as is evident by Chart 3. Further acceptability of the model was ensured through a PP Plot. Since the distribution was also normal here (Chart 4) to the extent that the plotted points match the diagonal line, our model is deemed to be fit. The initial (Model 1) equation developed thereof is as hereunder:

Table 4.

Correlation between yield and agro meteorology

	CROP	YLD	HSD	HSL	CSD	CSL	MDTT	MNTT	MDUV	SRAD	TMAX	TMIN	TDEW	T2M	RH2M	DTR
CROP	1	-.447**	-.501**	-.448**	.659**	.607**	-.810**	-.789**	.126	-.854**	-.792**	-.727**	-.402*	-.835**	-.065	.149
YLD		1	-.073	-.081	-.341*	-.272	.217	.278	-.422**	.182	.074	.383*	.324*	.301	.361*	-.442**
HSD			1	.988**	-.176	-.162	.555**	.420**	.618**	.688**	.798**	.173	-.158	.466**	-.558**	.610**
HSL				1	-.155	-.142	.526**	.393*	.623**	.647**	.771**	.149	-.144	.437**	-.535**	.614**
CSD	.				1	.938**	-.750**	-.792**	.473**	-.370*	-.560**	-.811**	-.725**	-.768**	-.540**	.509**
CSL						1	-.714**	-.748**	.417**	-.333*	-.537**	-.759**	-.669**	-.725**	-.488**	.463**
MDTT							1	.986**	-.226	.630**	.919**	.890**	.626**	.977**	.237	-.236
MNTT				.				1	-.385*	.547**	.848**	.951**	.732**	.985**	.386*	-.393*
MDUV	.								1	.291	.131	-.629**	-.814**	-.346*	-.943**	.993**
SRAD										1	.762**	.393*	.017	.607**	-.341*	.274
TMAX			.	.				.	.	.	1	.684**	.341*	.881**	-.113	.130
TMIN		.				.						1	.870**	.945**	.613**	-.634**
TDEW												.	1	.701**	.872**	-.821**
T2M							.							1	.333*	-.350*
RH2M															1	-.952**
DTR															1	.000

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Mulberry Foliage yield =2.26 -0.168*CROP + 0.004*HSD + 0.003*HSL + 0.009*CSD - 0.003*CSL + 0.026*MDTT - 0.375*MDUV - 0.021*SRAD - 0.157*TMAX - 0.073*WIND - 0.021*TDEW + 0.095*T2M + 0.011*RH2M + 0.105*DTR

The initial equation predicted that with increased number of days hotter than 37°C and colder than 13°C coupled with higher accumulation temperature up to 16.9°C beyond 37°C, higher mean temperature, relative humidity and diurnal temperature range; but with fewer temperature accumulation below 13°C as well as lower mean diurnal variation, solar insolation, maximum temperature, wind speed and dew point temperature during earlier crop seasons foliage yield was expected to increase proportionately. Nevertheless, the final model output by the software deciphered the most comprehensive impact of agro meteorology on mulberry yield goes by the equation developed using the regression coefficients was :

Mulberry Foliage yield = 3.244 -0.153*CROP + 0.003*HSL - 0.03*SRAD -0.101*TMAX + 0.042*T2M

This final model interpreted that mild heat stress load i.e. temperature accumulation beyond 37°C within a mean load of 16.9°C and higher mean temperature were directly proportional to yield but crop seasons, solar radiation and maximum temperature had inverse relationship with the foliage yield. So, with slight increase of heat stress load but lower solar insolation, maximum temperature as well as mean temperature respectively and harvest during early crop seasons, greater yield could be expected**.** The impact of each of the final predictors with the yield are portrayed by the scatter plots on Charts 5, 6, 7, 8 and 9 wherein homoscedasticity was observed. Retrospective model validation with regression equation developed with data from 3rd crop of 2002-03 to 2nd crop of 2010 on the rest of the period under study i.e. from the 3rd crop of 2010 to 4th crop of 2012 confirmed that there had been no significant deviation of mulberry foliage yield from the prediction through Chi^2 (χ^2) test (Table 8)

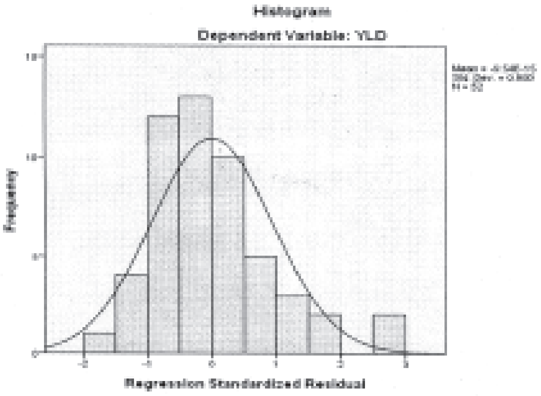

Chart 3

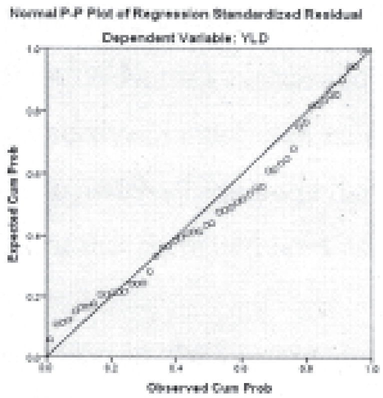

Chart 4

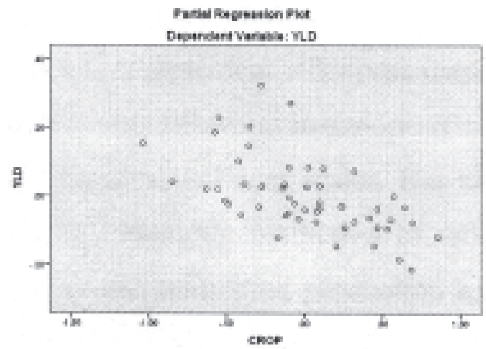

Chart 5

Table 5.

Regression output

Model	Multiple correlation (R)	Co-efficient of determination (R^2)
1	0.82[a]	0.67
2	0.82[b]	0.66
3	0.81[c]	0.66
4	0.81[d]	0.66
5	0.81[e]	0.65
6	0.81[f]	0.65
7	0.80[g]	0.64
8	0.80[h]	0.63
9	0.79[i]	0.63
10	0.78[j]	0.61

Table 6. ANOVA

Model	Mean	Square	F	Sig.
Initial	Regression	.050	5.263**	.000
	Residual	.009		
Final	Regression	.127	14.100**	.000
	Residual	.009		

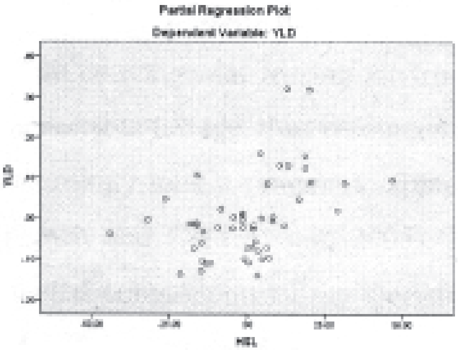

Chart 6

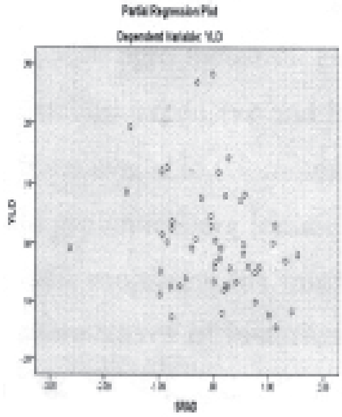

Chart 7

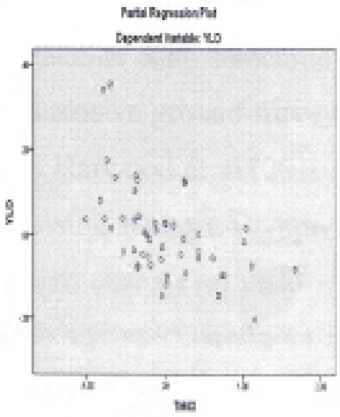

Chart 8

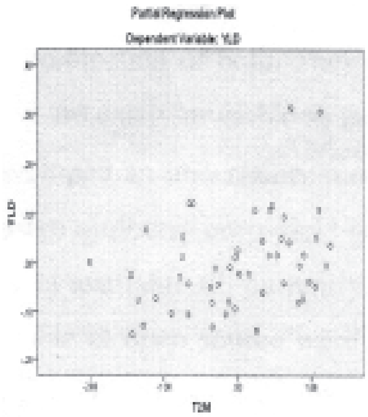

Chart 9

DISCUSSION

Analyses of meteorological and climatic data allow to provide near real time information about the crop state in qualities and quantities. With the possibility of early warning as alarm/alert situations timely interventions can be planned and undertaken The agro meteorological impact on yield over as a long period as 10+ years in the form of the synthetic final model we arrived at provided an insight on crop management intervention towards reaping the maximum harvest. Silkworm rearing

Table 7.

Assessment of relative deviation of predicted impact from observed impact

Year	Crop	yld predicted (e)	yld observed (o)	sq(o-e)/e
2010	3	0.36	0.301	0.009
	4	0.28	0.262	0.001
	5	0.24	0.165	0.023
2011	1	0.10	0.243	0.186
	2	0.34	0.291	0.007
	3	0.39	0.254	0.049
	4	0.28	0.235	0.007
	5	0.27	0.236	0.005
2012	1	0.19	0.247	0.020
	2	0.32	0.360	0.005
	3	0.39	0.331	0.010
	4	0.28	0.255	0.003
			(χ^2) =	0.314 (ns)

schedule and size of the rearing of any particular crop could be supported by packages of pruning and other intercultural operations which could be organized on the basis of model prediction for optimum leaf harvests instead of following packages on a fixed calendar day basis. Moreover, human and financial resource loss could be mitigated well in advance by reducing the silkworm crop size and sectorizing mulberry plots with specific requirement of agronomic intervention when advent of inclement weather during growth phases of mulberry is predicted. In this context the results are in conformity with the studies by Hundal (2004) and Bazgeer *et al.* (2008). The results produced by the models can be used to make appropriate management dimensions and facilitate sericulture farmers and other stake-holders with alternate options for their farming systems. It is expected that with the increased availability of computers the use of crop models by farmers as well as policy and decision makers will increase. Short, medium and long term yield forecasts derived from weather and yield data in the form of archived data or observations made on real time growing seasons will play a critical role in these applications.

ACKNOWLEDGEMENT

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EFFICACY OF DIFFERENT INSECTICIDES ON LEAFHOPPER (*Amrasca biguttula biguttula*.) POPULATION IN EGGPLANT (*Solanum melongena* L.) VIS-À-VIS REPEATED AND SEQUENTIAL APPLICATION

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ABSTRACT

The present study focuses on the efficacy of repeated and sequential application of four different insecticides at their recommended doses in control of leafhopper in eggplant. The study was conducted in two consecutive *Kharif* and *Rabi* seasons of 2009-10. Four different insecticides namely Triazophos 40% E.C, Carbaryl 50% W.D.P, Cypermethrin 10 % E.C and Azadiractin 10000 ppm were used in the study. Four consecutive sprays of each insecticide at their recommended dose were applied in both the seasons at an interval of 15 days starting after one month of transplanting. Parallely, these four insecticides were applied sequentially at an interval of 15 days in two different spraying sequence of insecticide i.e., Triazophos-Carbaryl-Cypermethrin-Azadiractin **(S1)** and Azadiractin-Cypermethrin-Carbaryl-Triazophos **(S2)**. The results reveal that the mean population of leafhopper was significantly ($p<0.05$) reduced in all the treated plots in comparison to the control plot in both the seasons. However, more effective control of the pest was obtained by sequential application of insecticides in comparison to repeated application of the same insecticides.

INTRODUCTION

Eggplant or Brinjal (*Solanum melongena* L.) is a globally grown vegetable crop. The cultivation practice of eggplant is very common and popular in sub-tropical and tropical areas of Asia**.** The Indian scenario of cultivation of eggplants depicts that eggplant is cultivated over an area of more than 5,00,000 ha (hectares) (Elanchezhyan *et al*., 2008) and henceforth is a key source of cash for many farmers (Miller, 2007). Within India, West Bengal, Orissa, Bihar and Gujrat are considered as major Brinjal producing States with maximum productivity of 27, 35,000 MT (metric tons)in West Bengal (Shah *et al*., 2012). The long cropping season and commercial cultivation of eggplant crop throughout the year made it exposed to the attack by a number of insect pests right from nursery stage till harvesting (Regupathy *et. al.,* 1997). Among the insect pests infesting eggplant, the major ones are eggplant shoot and fruit borer (EFSB), *Leucinodes orbonalis*, Whitefly, *Bemicia tabaci*, Leafhopper, *Amrasca biguttula biguttula*, Epilachna beetle, *Henosepilachna vigintioctopunctata* and non insect pest such as red spider mite, *Tetranychus macfurlanei* is reported from all brinjal growing areas of the World (Eswara and Srinivasa, 2001).

Leafhopper, *Amrasca biguttula biguttula* is considered as one of the sucking pests and has been reported to cause several damage of the crop including yellowing, curling and drying of leaves (Nayar *et al.* 1979). The control of the pest depends primarily on extensive use of insecticides. This practice has resulted in a multitude of consequences like insect resistance development, resurgence of secondary pests, adverse effect on beneficial insects, accumulation of residues in the environment and food grains finally leading to environmental contamination (Balasubramani and

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Swamiappan, 1993). Insecticide resistance due to repeated spraying has been reported earlier (Tattersfield and Kerridge, 1953). Also repeated use of a single insecticide results in environmental contamination, bioaccumulation and biomagnification of toxic insecticide residues and disturbance in ecological balance (Dadmal *et al.*, 2004). The alternative approach to repeated application of pesticide is the sequential application. In this system more than one type of insecticide are used in field in sequential pattern i.e. application of one insecticide follows the other and so on.

The current study was therefore undertaken to evaluate the efficacy of repeated and sequential application of four different insecticides applied at their recommended doses in control of leaf hopper infestation in eggplant.

MATERIALS AND METHODS

Sites, design, and crop husbandry

Field experiments were conducted in two consecutive cropping seasons i,e. the *Kharif* season (May to September, 2009) and *Rabi* season (October to February, 2009-10) at the Agricultural Experimental Farm, University of Calcutta, Baruipur, (22º22′44.20″ N 86º26′ 08.55″ E) South 24 Parganas, West Bengal, India with a high yielding variety of Eggplant (var. Muktakeshi). The experiment was conducted in a Randomized Block Design (RBD) with 28 plots (measuring 4 x 3 Sq m.), involving seven treatments having four replications. Eggplant seedlings were first raised in seed bed and then healthy seedling of about one month old (3-4 leaf stage) were transferred to field. Each plot consisted of three rows and eggplant seedlings were transplanted in each plot with a spacing of 75 cm. Two buffer rows were placed in between each plot. All the plots received a recommended dose of fertilizers in the form of urea, single super phosphate and murate of potash.

Insecticides application

Four different insecticides namely Triazophos 40% E.C, Cypermethrin 10% E.C, Carbaryl 50% W.D.P and Azadiractin 10000 ppm were purchased from local agro market. The insecticides were applied at their field recommended dose of application i.e., Triazophos (300 g.a.i/ha), Cypermethrin (60 g.a.i/ha), Carbary W.D.P (1875 g.a.i/ha) and Azadiractin (5g.a.i/ha). Insecticide sprays were applied using a small knapsack sprayer at the rate of 500L/ha. Four consecutive sprays of each insecticide were given in both the seasons at an interval of 15 days. Parallely, these four insecticides were also applied sequentially at an interval of 15 days. The sequential application of insecticide include two different spraying sequence of insecticide i.e., Triazophos-Carbaryl-Cypermethrin-Azadiractin **(S1)** and Azadiractin-Cypermethrin-Carbaryl-Triazophos **(S2)** where each of insecticides were applied one after another at 15 days interval. The control plants were sprayed with water only. Precautions were taken to avoid drift of insecticides to the adjacent plots during spraying.

Data collection

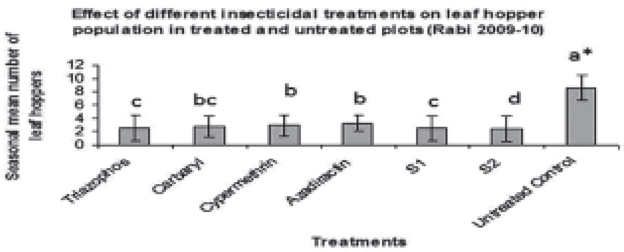
Periodic observations were made at weekly interval. Five plants were selected from each plot randomly and labeled for recording observations. Three randomly selected leaves from each plant along with stem were scouted for the incidence of the pest. The mean population number of leafhopper in treated and untreated plots after all the sprays were calculated from the above data for each season respectively.

Statistical Analysis

Assigning different insecticide application either alone or in sequence as treatment factor, analysis of variance (ANOVA) was carried out by Randomized Block Design (RBD) using SPSS version 10. The factor insecticide application had seven levels and the replicate had four levels. The least significance difference (LSD) test was applied to evaluate the significance of differences between the individual treatment factors. The treatment means were compared by Duncan's multiple range test at 0.05P.

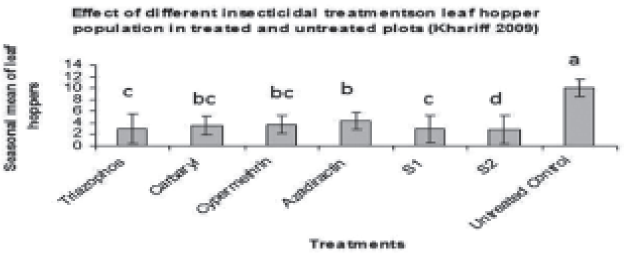
RESULTS AND DISCUSSION

The results obtained in the present study are represented graphically in (Fig 1 and 2). The results reveal that the population of leafhopper was significantly ($p<0.05$) reduced in all the insecticide treated plots in comparison to the control in both the seasons. However in *Rabi* season the mean reduction in population of leafhopper was found to be higher than that of *Kharif* season. This may be due to more run off of insecticide from the plant during the *Kharif* season by rainfall. Maximum reduction of leaf hopper population i.e. 72.0% over control was found in plots where sequential application of insecticide were done in the order from S2 in *Rabi* season while minimum reduction i.e., 56.9% over control was found in Azadiractin treated plot in *Kharif* season respectively. The order of efficacy of the four insecticide application in repeated and sequential manner in both the season was found to be S2 >S1 >Triazophos> Cypermethrin> Carbaryl> Azadiractin. The more effective control of the leaf hopper population by sequential application of insecticide than repeated application of the same insecticide may be due to the development of insecticide resistance as insecticide resistance development due to repeated spraying has been reported earlier (Tattersfield and Kerridge, 1953) or better adaptatibililty of pest towards the individual insecticides due to its frequent application.



*Figures denoted by same alphabets are statistically similar at 5% probability level by DMRT

Fig. 1. Effect of different insecticidal application on leaf hopper population in treated and untreated plots during *Rabi* season (2009-10).



*Figures denoted by same alphabets are statistically similar at 5% probability level by DMRT

Fig. 2. Effect of different insecticidal application on leaf hopper population in treated and untreated plots during *Kharif* season (2009).

CONCLUSION

From the present study it can be concluded that infestation of leafhopper on Eggplant can be more effectively controlled by sequential application of insecticides in comparison to repeated application of the same insecticide. However more field trials are required to have a more realistic approach for the above fact.

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PERFORMANCE AND HETEROSIS OF HYBRID JUTE UNDER TWO AGRO-ECOSYSTEMS

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ABSTRACT

To investigate commercial possibility of heterosis utilization in jute (*Corchorus olitorius* L.), five high heterotic crosses identified from a 8 x 8 diallel cross experiment were evaluated against three inbred checks under both high-fertility irrigated and low- fertility rain fed agro-ecosystems. Presence of significant positive heterosis was observed for two test hybrids viz. Tanganyika1 x O50-4963 and Tanganyika1 x Russian Green against the dominant inbred check, JRO 524. Significant high yield advantage of the first hybrid was found in the low input while, that for the later one in the high input management. Nevertheless, it was observed that realized level of heterosis was far behind the desired level. A dynamic breeding scheme to elevate yield heterosis, taking example from cotton, was suggested.

INTRODUCTION

Jute is mainly grown under less favourable i.e. low-fertility rain fed ecosystem. But there are farmers who can resist immediate distress sale and sell jute (fibres) in the month of November - December even in January, when sale-price goes up to the maximum. These farmers actually make a substantial profit out of jute farming. They are the target farmers for hybrid that would respond favourably to the high input management.

It may not always be easy to identify precisely from the multilocation, over years test that whether a hybrid would perform equally good and show high heterosis in both high as well as low-fertility environments or a separate hybrid would be required for each of the two different agro ecosystems. In fact, whatever information on heterosis in jute are available, that were mostly assessed against mid- and / or better parent under standard fertility level and from small number of plant samples. There is limited information, if any, on the evaluation of heterosis at population level in the large plot test. Regarding assessment of genotypes, Perkins and Jinks (1968) suggested that particular attention should be paid to those environmental factors, whether natural or deliberately imposed, that are likely to determine the response of the material to those conditions under which it will be grown.

Hence, the present experiment was designed to study the relative performance and magnitude of standard heterosis of hybrids in population level under both high fertility irrigated and low-fertility rain fed ecosystems.

MATERIALS AND METHODS

Five combinations that were identified as high heterotic from a 8-parent diallel cross study in the Central Research Institute for Jute and Allied Fibres (ICAR), Barrackpore, W. Bengal (Basak *et al.*, 1975) were included in the present investigation along with three inbred checks. Hybrids included were Russian Green x JRO 620, Russian Green x Sallyout, JRO 632 x Russian1, Tanganyika1 x 050-4963, and Tangamyika1 x Russian Green.Three checks were JRO 632, JRO 36E and JRO 524. All eight genotypes were grown over three years in a randomized block design with four replications at the Experimental Farm, Institute of Agricultural Science, University of Calcutta, Baruipur, South 24-Paraganas. For each treatment in each replication, a 4.8m x 5.0 m plot was allotted. Sowing was done within 3rd week of April in each of three years. Spacing between rows and between plants within a row were 30 cm and 5-6 cm respectively. For high fertility-irrigated ecosystem, fertilizers: N (urea), P_2O_5 (single super phosphate) and K_2O (muriate of potash) @ 60:30:30 kg ha^{-1}

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were applied in each year. Half of urea and whole of super phosphate and potash were applied as basal dose before final land preparation. Other half of urea was applied as topdressing in two equal doses, the first at 3 weeks and the second at 6 weeks after sowing as recommended. While, for low-fertility rain fed ecosystem, only basal dose of fertilizers, N (urea), P_2O_5 (single super phosphate) and K_2O (muriate of potash) @ 30:30:30 kg ha^{-1} were applied before final land preparation in each year. In irrigated experiment, need based 3 irrigations, as recommended, was applied. Rain fed experiment depended solely on rain water. Other recommended intercultural operations were also followed to raise a healthy crop. In each year, at about 120 days crop age, replication and treatment-wise whole plot was harvested leaving 0.25 m along the length and 0.30 m along the breadth as boarder. Fibres were extracted by retting green stems under a pool of water, then washed thoroughly, sun-dried and finally weighed in kilograms to estimate fibre yield (g kg plot $^{-1}$). Data thus obtained, were converted to quintal ha^{-1} for further use.

Standard parent (SP) heterosis was calculated as : F_1 - SP x 100 / SP. Significance test of heterosis was performed using Least Significance Difference (LSD).

RESULTS AND DISCUSSION

Only one hybrid, Tanganyika 1 x Russian Green (Table 1) registered significant higher yield (34.6 q ha^{-1}) than that of the dominant inbred commercial check, JRO 524 (28.9 q ha^{-1}) in high fertility-irrigated ecosystem. While, a different hybrid viz. Tanganyika 1 x 050-4963 exhibited significant high yield (28.8 q ha^{-1}) under low-fertility rain fed management over the same check (27.1 q ha $^{-1}$). Further, both these hybrids were significantly superior to each other in their respective best performing environment. It appears from these results that same hybrid would not perform the best in both high and low input management, rather, a separate hybrid would be required for each of two different ecosystem.

From the analysis of variance (Table 2), it was observed that there was large difference, as expected, between two deliberately created environments. This aside, large difference in seasonal environment associated with years was also evident. Genotypes were significantly different for their yielding ability. Large entries by ecosystem interaction variance can be attributed to the combined analysis including two almost contrasting deliberately created environments together. Such type of interactions, what ever large, can be reduced substantially with the reduction in wide management difference used. However, considering farmers' demand, practical feasibility, and resource management etc., in a breeding experiment, this type of widely different environments, some times, though not often, requires to be accommodated under the same umbrella. Since seasonal variation is uncontrollable environments, its significant interaction variance can only be reduced by imparting heterogeneity within the hybrid population (Allard, 1961, Finlay, 1963 and Becker *et al.*, 1982).

Swaminathan, Siddiq and Sharma (1972) reported from different estimates that for hybrid vigour in a self-pollinated crop to be economically advantageous, it must give 25 percent more yield than the best inbred

Table 1.

Mean fibre yield (q ha $^{-1}$) of 5 selected hybrids and 3 checks over high fertility- irrigated and low fertility-rain fed ecosystems (years pooled)

Hybrid	Ecosystem-wise yield (q ha $^{-1}$)	
	High fertility - Irrigated	Low fertility - Rain fed
Russian Green x JRO 620	28.7	20.9
Russian Green x Sallyout	30.0	23.5
JRO 632 x Russian 1	28.4	23.0
Tanganyika 1 x O50-4963	29.4	28.8
Tanganyika 1 x Russian Green	34.6	26.8
Check		
JRO 632	27.2	26.7
JRO 36 E	31.8	25.8
JRO 524	28.9	27.1
$LSD_{(0.05)}$	1.2 (q ha $^{-1}$)	1.6 (q ha $^{-1}$)

Table 2.

Mean squares from General Analysis of Variance for fibre yield of 5 selected F_1 hybrids and 3 checks over 6 environments (2 ecosystems x 3 years)

Source	df	Mean Squares
Replication within ecosystem and years	18	20.498 **
Ecosystem	1	2052.116 **
Year	2	1633.374 **
Entry	7	96.721 ** ∫∫ ●● ++
Check	2	21.258 **
Hybrid	4	157.003 **
Hybrid vs. check	1	6.521 **
Entry x ecosystem	7	11.916 **
Entry x year	14	14.786 **
Ecosystem x year	2	132 .889 **
Entry x ecosystem x year	14	10.099 **
Error	126	0.32204

** Significantly different (P < 0.01) against error.

++ ∫∫ , ●● , ++ Significantly different (P < 0.01) against entry x ecosystem entry x year and entry x ecosystem x year interactions respectively.

commercial variety. In rice, 35 percent higher magnitude of heterosis against the check variety is normally considered for recommendation (Yuan, 2003). Although 3 inbred checks were used in this study, according to the former report, heterosis expression was finally assessed over the dominant commercial variety, JRO 524. Moreover, from the above two estimates of desirable level of heterosis, it appears that for hybrid vigour in jute crop to be economically viable, it should show 25-30 percent more yield advantage over the dominant inbred commercial variety.

Under both the agro-ecosystem, hybrids exhibited differential expression of heterosis (Table 3) both in positive and negative directions against the 3 inbred checks. In high input management, only one hybrid i.e. Tanganyika 1 x Russian Green showed significant positive heterosis (19.7%) against the dominant check variety, JRO 524. Whereas, under the low-fertility rain fed agronomic management, none of the hybrid other than Tanganyika 1 x 050-4963 exhibited significant positive heterosis (6.3%) against the same check, while that for the former hybrid was a negative value (-1.1%). The later hybrid and JRO 524 did not respond so high as Tanganyika1 x Russian Green with the improvement of environment. Again Tanganyika1 x Russian Green suffered from yield loss under low input management. This suggests that heterosis expression of different hybrids vary with the agro-management conditions. This also pins to the necessity for deploying different hybrid under high and low input management.

Results of this experiment, further suggests that, high heterotic hybrids identified in respect of better parent based on small number of sample plants in a diallel experiment demand retesting its status in the population level over environments against the commercial variety before recommending for large scale adoption.

It is observed from this experiment that realized level of standard heterosis is far behind the desired level of 25-30% for jute crop. Hence, for commercial use of hybrid vigour in this species of jute, heterosis is to be elevated from the realized level to the desired level.

In most of the earlier studies by Jana (1972), Basu (1985) Saha *et al*. (1996).) it was reported that additive genetic control for fibre yield was either equal to or greater than the non-additive part. In majority of the reports in autogamous crops including jute, where additive genetic variance was observed predominant, instead of heterosis breeding, inbred development was advocated. Heterosis breeding was advocated only for the crops where major control of character to be altered was due to non-additive genetic variance. Mann *et al.* (1962) observing major control of additive genetic effects in flue-cured tobacco suggested that breeding methods designed to accumulate favourable genetic factors in homozygous genotypes appear to remain a more appropriate procedure for tobacco improvement than the commercial production of hybrids. Venkateswarlu and Singh (1981) on the basis of their experiment in peas, viewed that although the significant

Table 3.

Percent standard heterosis for fibre yield of 5 selected hybrids against 3 checks over 2 ecosystems (years pooled)

Hybrid / Check	Ecosystem-wise heterosis (%) (years pooled)					
	High fertility - Irrigated			Low fertility - Rainfed		
	JRO 632	JRO 36 E	JRO 524	JRO 632	JRO 36 E	JRO 524
Russian Green x JRO 620	5.5 *	- 9.7 *	- 0.7	- 21.7 *	- 19.0 *	- 22.9 *
Russian Green x Sallyout	10.3 *	- 5.7 *	3.8	- 12.0 *	- 8.9 *	- 13.3 *
JRO 632 X Russian 1	4.4	- 10.7 *	- 1.7	- 13.9 *	- 10.8 *	- 15.1 *
Tanganyika 1 x O50-4963	8.1 *	- 7.5 *	1.7	7.9 *	11.6 *	6.3 *
Tanganyika 1 x Russian Green	27,2 *	8.8 *	19.7 *	0.4	3.9	- 1.1
LSD $_{(0.05)}$	1.2 q ha $^{-1}$			1.6 q ha $^{-1}$		

* Significant at 5 percent level.

estimates of additive genetic variance suggest that it should be possible to make considerable progress in breeding higher yielding pure lines, it might be difficult to develop pure lines with yielding ability equal to F_1 s, for much of the yielding ability of F_1s appear to be due to non-additive type of genetic variance.

But Arunachlam (1977), reported that heterosis for characters governed by one gene are attributable to dominance. Whereas, it is possible to realize heterosis on the basis of additive genetic effects and its interactions alone for the characters, that are govern by more than one gene. In support of this, Reddy and Arunachalam (1981) presented experimental evidence for the expression of high heterosis without dominance or their interactions in pearl millet. They further suggested that more than genetic and geographic divergence, general combining ability (*gca*) divergence would be needed for bringing about high heterosis. While reviewing 'Genetics and Breeding of Jute', Basak (1993) suggested that additive genetic variance acted as the 'bench mark value' for heterosis and if it is raised, total heterosis would be increased. So it is felt that emphasis is to be paid for increasing variability for general combining ability along with maintaining genetic diversity. So presence of high *gca* for yield should not be considered as deterrent for heterosis breeding, rather, this advantage is to be capitalized for realizing high heterosis.

Patil and Patil (2003) suggested two population improvement schemes viz. reciprocal and triangular approach to create variability for combing ability and exploit the same through selection for combining ability using appropriate tester in autogamous crops taking example from cotton. Of these, later scheme would be more applicable for jute since, in this crop high level of residual F_2 heterosis which depends on improvement of *gca* variance is desirable for the commercial use. Singh and Jain (1970) reported on mung bean that the hybrid vigour present in F_1 generation over better parent was retained in the F_2 generation in large number of crosses. They also stated that this phenomenon of F_1 hybrid vigour retention in F_2 generation can be ascribed to additive genetic control of heterosis for those F_1 crosses. Matzinger *et al.* (1971) from their results on burley tobacco reported that evidence of limited dominance variance is the general lack of inbreeding depression from the F_1 to the F_2 generation for most characters. Nanda *et al*. (1981), from their results on wheat repoted that the mean of F_2 was considerably larger than the mean of parents and F_1 for tiller number, seed size and grain yield.

Studies of Walton (1971) on spring wheat and Gyawali *et al.* (1968) on winter wheat showed that for guaranteed better expression of heterosis genotype-environment interaction is to be reduced.

Becker *et al*. (1982) observed in their experiment on rye that a more heterogeneous hybrid was more stable than a less heterogeneous one, due to its better population buffering capacity. Meredith and Brown (1998) cited that due to the genetic variation within an F_2 hybrid in cotton, the possibility exists that F_2 s might have a broader range of adaptation than conventional varieties. This suggests that introduction of genetic variability in the hybrid population like F_2 would reduce the negative influence of unpredictable environments in jute also. If so, potential heterosis to its maximum level will be expressed.

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HYDRATION-DEHYDRATION TREATMENTS FOR THE MAINTENANCE OF GERMINABILITY AND BETTER SEEDLING EMERGENCE OF BASIL (*Ocimum basilicum* L.) SEED

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ABSTRACT

Basil (*Ocimum basilicum* L.) is very important medicinal plants in perspective of Ayurveda. Maintenance of basil seed vigour and viability is essential for better crop stand. Hydration-dehydration treatments in two months (medium vigour) old basil (*Ocimum basilicum* L.) seeds were given for the improvement of storability and field emergence after subsequent storage. Hydration-dehydration treatments were given with distilled water and different solutions of KNO_3 (10^{-2} and 10^{-4} M), acetyl salicylic acid (10^{-2} and 10^{-4} M) and *para*-amino benzoic acid (PABA, 10^{-2} and 10^{-4} M) for 2 hours at room temperature. Few treatments (KNO_3 10^{-2}M and PABA, 10^{-2} M) were significantly effective over control for the maintenance of seed germinability and field emergence.

INTRODUCTION

The Indian System of Medicine like Ayurveda, Siddha and Unani are flourishing day by day as a part of curing many ailments. Genus *Ocimum,* member of Lamiaceae family comprised of almost 200 species of herbs and shrubs and distributed over Asia, Africa, Central and Southern America. *Ocimum* is cultivated for its essential oil which displays many potent pharmacological applications. Basil (*Ocimum basilicum* L.) is very important medicinal plants in perspective of Ayurveda. Maintenance of basil seed vigour and viability is essential for better crop stand.

Seeds being hygroscopic in nature, absorbs a lot of moisture from the humid atmosphere and coupled with high temperature accelerates the physiological ageing of seed with a consequent loss of vigour, viability and yield potential of the crop (Teckrony and Egli, 1991) specially during the monsoon months. Mid-storage hydration-dehydration treatments of stored seed (medium vigour) of agriculturally important crop plants would greatly minimize their physiological deterioration during subsequent storage under uncontrolled warm humid conditions (Mandal and Basu, 1986).

Hydration-dehydration treatments in two months (medium vigour) old basil (*Ocimum basilicum* L.) seeds were given for the improvement of storability and field emergence after subsequent storage. Hydration-dehydration treatments were given with distilled water and different solutions of KNO_3 (10^{-2} and 10^{-4} M), Acetyl salicylic acid (10^{-2} and 10^{-4} M) and *para*-Amino benzoic acid (PABA, 10^{-2} and 10^{-4} M) for 2 hours at room temperature. Few treatments (KNO_3 10^{-2}M and PABA, 10^{-2} M) were significantly effective over control for the maintenance of seed germinability and field emergence.

MATERIALS AND METHODS

Basil (*Ocimum basilicum*) seeds were collected from the nursery of State Medicinal Plant Board, Govt. of West Bengal, Kalyani, Nadia. At first, seeds were cleaned and sun dried to a safe moisture content of 8% for storage under ambient condition in the laboratory. After drying, seeds were stored in different rubber stoppered 50 ml capacity air-tight glass bottles.

Method of seed treatment

Soaking-drying treatment was done according to the methods described earlier by Basu and Dasgupta (1974). Soaking – drying treatments were given to medium vigour basil seeds which were stored in rubber stoppered glass bottle after cleaning and drying. The seeds were soaked in double volume of water and solutions of KNO_3

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(10^{-2} and 10^{-4} M), Acetyl salicylic acid (10^{-2} and 10^{-4} M) and *para*-Amino benzoic acid (PABA, 10^{-2} and 10^{-4} M) for 2 hours at room temperature (28±1°C) followed by drying back to the original weight in a current of hot air in a drying cabinet at 35±1°C. Control seeds were not soaked but dried along with the other treatments to maintain uniform moisture level prior to restore.

After 7 days of treatment, treated and untreated seeds were taken separately in perforated paper packets (containing same amount of seed with equal number of holes) and then all packets were kept in a desiccator at 98% RH and 40°C temperature for 5days accelerated ageing. Treated and untreated seeds containing perforated packets were also kept in cloth bag under ambient conditions for two months natural ageing in the laboratory (average RH 86 ± 1.22% and temperature 29.5 ± 1.4°C). The packets were shaken at a regular interval for uniform ageing. Germination test of treated and untreated seeds (more than 400 seeds for each treatment as specified by ISTA, 1996) were done following the method of Punjabi and Basu (1982) with minor modifications. Germination test were carried out just after treatment, after accelerated ageing and natural ageing. Data on germination percentage, percentage of abnormal seedling, seedling length and seedling weight were recorded after 7 days of germination at room temperature.

Pot culture were conducted at the nursery of SPLPIM, Kalyani, Nadia with three replications for each treatments. The earthen pot was filled with the mixture of vermicompost , sand, soil etc. After that one hundred seeds were sown in each pot after two months of treatment. Seedling emergence percentage was recorded after 20 days of sowing.

The dehydrogenase enzyme activity of treated and untreated seeds were estimated following the methods of Kittock and Law (1968) .

The data obtained from laboratory germination test were analyzed statistically following the method of analysis of variance (Fisher, 1948). Data on germination percentage were transformed to their respective arc-sin angle prior to statistical analysis and seedling length data were analyzed as such.

RESULTS AND DISCUSSION

Germination tests were conducted immediately after treatments showed some improvement on germination percentage, seedling length and vigour index over control (Table 1). Fresh weights per seedling were also increased by different hydration – dehydration treatments (Table 1). But after accelerated ageing (at 98% RH and 40°C temperature for 5 days) and natural ageing (for two months), hydration – dehydration treatments especially with KNO_3 (10^{-2}M) showed significant improvement on germination percentage, seedling length, fresh weight per seedling and vigour index over control (Table 2 & 3).

But other treatments did not show remarkable results in improving basil seed germinability over control. Hydration – dehydration treatments with water and PABA$^{10-2}$ M showed some positive result in improving germinability of basil seed after subsequent ageing

Table 1.

Effect of hydration-dehydration treatments on germinability of basil (*Ocimum basilicum* L.) seed just after treatment.

Treatments	Germination		Mean Root Length (mm)	Mean shoot Length (mm)	Vigor index*	Fresh weight / seedling (mg)
	%	Arc-Sin Value				
Control	88	69.7	32	29	5368	17.32
S-D (Water)	92	73.6	34	30	5888	17.56
S-D ($KNO_3 10^{-2}$ M)	94	75.8	35	33	6392	18.01
S-D ($KNO_3 10^{-4}$ M)	90	71.6	33	27	5400	17.92
S-D (PABA 10^{-2} M)	94	75.8	32	31	5922	17.23
S-D (PABA 10^{-4} M)	92	73.6	30	30	5520	16.94
S-D (Salicylic acid $^{-2}$ M)	96	78.5	32	32	6144	17.59
S-D (Salicylic acid $^{-4}$ M)	88	69.7	31	28	5704	17.95
L.S.D. at 0.05P	–	6.2	3	4	–	0.46
L.S.D. at 0.01P	–	NS	NS	NS	–	NS

Abbreviation : S-D : Soaking-drying, PABA- *para* amino benzoic acid , NS- Not significant.

*Vigor index=Germination % × Seedling length

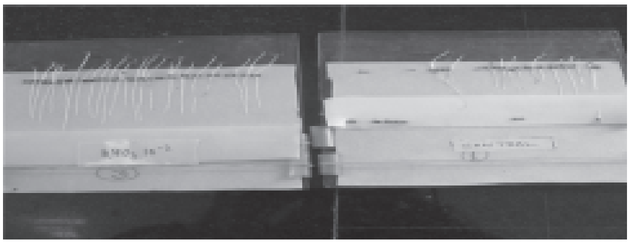

Plate-1: Germinated seedlings from control and hydration-dehydration treatment with KNO_3 (10^{-2}M) solution

(Plate-1 & Table 2, 3). Hydration – dehydration treatments with solution of acetylsalicylic acid (10^{-2}M & 10^{-4}M) showed adverse effect on germinability and seedling emergence (Table 1,2,3,4 & Fig. 1). Besides germinability, hydration – dehydration treatments with $KNO_3 10^{-2}$M, water and PABA 10^{-2}M solutions showed significantly higher dehydrogenase enzyme activity over control (Table-4). Percentage of seedling emergence in soil was also increase by the seeds treated with $KNO_3 10^{-2}$ M solution (Fig. 1) and percentage of abnormal seedling was 13% in control which is higher than other treatments (Fig. 2).

Regarding the mode of action of the hydration-dehydration treatments, several postulalion have been examined (Basu 1976, 1994, Basu and Rudrapal, 1980, Mandal *et al.* 1987); the exact mechanism of action of mid-term seed treatments is still not clear. Two possibilities, viz. the involvement of the cellular repair system in correcting age induced biochemical lesions during seed hydration (Villiers and Edgcumbe, 1975, Burgass and Powell, 1984) and control of free radical and lipid peroxidation reactions by hydration treatments (Basu 1976; 1994; Berjak,1978; Buchvarov and Gantcheff, 1984). Wilson and Me.Donald (1986b) suggested that seed deterioration would take place during ageing via lipid peroxidation. The free radicals and lipid peroxidation reactions in the stored seed (Wilson and McDonald, 1986b; McDonald, 1999) that could be reduced by hydration-dehydration treatments (Basu, 1994). The role of iodine in the stabilization of double bonds of unsaturated fatty acid moieties of lipoprotein biomembranes as a possible reason for viability extension was suggested by Basu and Rudrapal (1980), besides the possibility of iodine acting as a free radical controlling agent (Pryor and Lasswell. 1975).

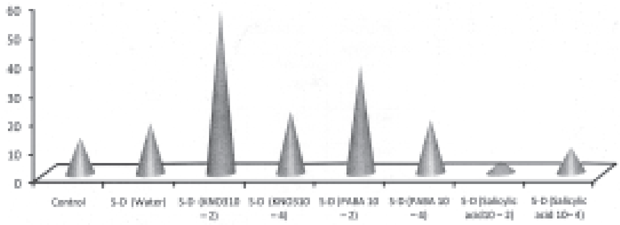

Fig. 1. Effect if hydration-dehydration treatments on field emergence from basil (*Ocimum basilicum* L.) after two month storage.

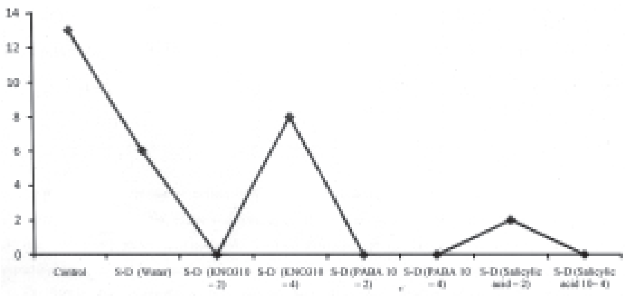

Fig. 2. Effect if hydration-dehydration treatments on abnormal seedling development percentage from basil (*Ocimum basilicum* L.) after two month storage.

Table 2.

Effect of hydration-dehydration treatments on germinability of basil (*Ocimum basilicum* L.) seed after accelerated ageing at 98 % RH and 40^0C temperature for 5 days

Treatments	Germination		Mean Root Length (mm)	Mean shoot Length (mm)	Vigor index*	Fresh weight / seedling (mg)
	%	Arc-Sin Value				
Control	37	37.4	17	9	962	6.42
S-D (Water)	42	40.4	33	19	2184	12.12
S-D ($KNO_3 10^{-2}$ M)	60	50.7	34	19	3180	16.58
S-D ($KNO_3 10^{-4}$ M)	35	36.2	23	14	1295	8.22
S-D (PABA 10^{-2} M)	35	36.2	28	13	1107	10.26
S-D (PABA 10^{-4} M)	30	33.2	27	13	1200	10.67
S-D (Salicylic acid $^{-2}$ M)	30	33.2	23	12	1050	8.45
S-D (Salicylic acid $^{-4}$ M)	30	33.2	29	15	1320	11.84
L.S.D. at 0.05P	–	12.3	3	4	–	3.9
L.S.D. at 0.01P	–	16.8	5	7	–	5.7

Table 3.

Effect of hydration-dehydration treatments on germinability of basil (*Ocimum basilicum* L.) seed after natural ageing under ambient conditions for 2 months (average RH 86±1.22 % and temperature 29.5 ± 1.4ºC).

Treatments	Germination		Mean Root Length (mm)	Mean shoot Length (mm)	Vigor index*	Fresh weight / seedling (mg)
	%	Arc-Sin Value				
Control	32	34.45	24	18	1344	11.92
S-D (Water)	27	31.3	25	12	999	11.21
S-D ($KNO_3 10^{-2}$ M)	72	57.4	34	20	3888	16.32
S-D ($KNO_3 10^{-4}$ M)	32	34.4	31	14	1440	14.33
S-D (PABA 10^{-2} M)	35	36.2	26	12	1330	13.49
S-D (PABA 10^{-4} M)	25	30.0	20	10	750	11.23
S-D (Salicylic acid $^{-2}$ M)	15	22.8	32	16	720	15.39
S-D (Salicylic acid $^{-4}$ M)	15	22.8	20	15	525	12.03
L.S.D. at 0.05P	–	13.6	7	4	–	3.4
L.S.D. at 0.01P	–	17.2	11	NS	–	NS

Table 4.

Effect of hydration-dehydration treatments on germination percentage and dehydrogenase enzyme activity of basil (*Ocimum bascilicum* L.) seed immediately after treatment and after natural ageing under ambient conditions for 2 months (average RH 86 ± 1.22 % and temperature 29.5 ± 1.4 C).

Treatments	Before ageing			Natural ageing		
	Germination		Dehydrogenase activity (OD)	Germination		Dehydrogenase activity (OD)
	%	Arc-sin value		%	Arc-sin value	
Control	84	66.4	0.366	32	34.4	0.086
S-D (Water)	86	68.0	0.397	42	40.4	0.275
S-D (KNO_3 10^{-2} M)	88	69.7	0.387	74	59.3	0.366
S-D ($KNO_3 10^{-4}$ M)	90	71.6	0.387	40	39.2	0.244
S-D (PABA 10^{-2} M)	82	64.9	0.449	38	38.0	0.133
S-D (PABA 10^{-4} M)	84	66.4	0.431	34	35.6	0.096
S-D (Salicylic acid $^{-2}$ M)	86	68.0	0.366	30.0	25	0.102
S-D (Salicylic acid $^{-4}$ M)	86	68.0	0.397	36	36.9	0.113
L.S.D. at 0.0 5P	–	NS	NS	–	7.3	0.018
L.S.D. at 0.0 1P	–	MS	NS	–	10.6	0.116

Recently, Sung and Chiu (2001) have given strong support to the concept of free radical induced lipid peroxidation as a causative factor of seed deterioration in sweet corn *(Zea mays* L.) thereby confirming similar findings of this laboratory.

Aspirin is an anti-inflammatory drug and chemically, it is a weak acid. It may decrease the production of free radicals and superoxide and may interact with adenyl cyclase to alter the cellular concentration of cAMP (Bertram, 1998). Recently, Takaki and Rosim (2000) have reported that aspirin application to *Raphanus sativus* L. seed would increase the tolerance to high temperature and synchronize seed germination. The protein protective role of *ortho-acetyl* salicylic acid (aspirin) may also be operative in viability maintenance in the same fashion. Ascorbic acid used an antioxidant may control the lipid peroxidation of seed (Mandal *et al.,* 1999). KNO_3 is most widely used chemical for promoting germination of seeds which are sensitive to light. The stimulatory effect of KNO_3 influence the respiratory system directly (Adkins *et al.,* 1984) and also by stimulating oxygen uptake (Hilton and Thomas, 1986) or serve as a co-factor of phytochrome, a light sensitive protein pigment (Hilhorst, 1990).

CONCLUSION

Whatever, may be the mechanism ultimately the hydratioivdehydration treatments with water and different solutions specially $KNO_3 10^{-2}$ M and PABA 10^{-2} M showed very positive responses for the maintenance of basil *(Ocimum basilicum* L.) seed germinability and field emergence.

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GENOTYPE-ENVIRONMENT STUDIES OF FIBRE YIELD IN HYBRID JUTE (*Corchorus olitorius* L) UNDER TWO AGRO-ECOSYSTEMS

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ABSTRACT

Eight entries that included five hybrids and three inbreds were evaluated under high fertility irrigated and low fertility rain fed agro-ecosystems over three years, mainly to assess whether a hybrid would consistently show superiority in its performance under either the ecosystems or a separate hybrid would be required for each ecosystem. Results exhibiting significant effect of ecosystem and years for fibre yield indicated that breeders should test the stability of performance including a sample of ecosystem and years when recommending a hybrid. Joint regression analysis including ecosystems and years revealed that a part of the genotype by environment interaction could be accounted for by differences between the fitted regression lines. Differing levels of productivity under two experimental input managements between years had substantial effect on stability parameters. The hybrid, Tanganyika1 x O50-4963 showed a significantly negative regression coefficient, indicating below-average sensitivity to environmental variation. Although, the mean squares for deviation from regression was significant, its performance could still be predicted with some reliance. Another hybrid, Tanganyika1 x Russian Green had a significantly positive regression coefficient, indicating an above-average response to an improvement in the environment. In spite of significant mean squares for non-linear sensitivity, prediction of its performance with some reliability could also be made. Therefore, no single hybrid was found to exhibit consistency in fibre yield under both high and low input management, rather under each production system, different hybrid showed stability in performance. It was also observed that stability in performance and high yield were not mutually exclusive.

INTRODUCTION

Crop varieties whether inbred or hybrid, differ in their adaptability. An ideal crop variety is one that has a high mean yield but a low degree of fluctuation in performance over a range of environments. Hence, growing of varieties in multilocation yield test over years to study the stability is the most common practice followed in a plant breeding programme.

Jute is mainly grown under less favourable i.e. low fertility rain fed ecosystem. But there are farmers who can resist immediate distress sale and sell jute (fibres) in the month of November - December even in January, when sale-price goes up to the maximum. These farmers actually make a substantial profit out of jute farming. They are the target farmers for hybrid that would respond favourably to the high input management. It may not always be easy to identify precisely from the multilocation over years test that whether a hybrid would show high heterosis and give stable yield in both high as well as low fertility environments or a separate hybrid would be needed for each of the two different agro-ecosystem. Perkins and Jinks (1968) suggested that particular attention should be paid to those environmental factors, whether natural or deliberately imposed, that are likely to determine the response of the material to those conditions under which it will be grown.

Hence, the present experiment was conducted to study the stability of performance of five hybrids under both high fertility irrigated and low fertility rain fed ecosystems.

MATERIALS AND METHODS

Eight entries (5 test hybrids and 3 inbreds) were included in the present investigation. Hybrids included were Russian Green x JRO 620, Russian Green x Sallyout, JRO 632 x Russian1, Tanganyika1 x O50-4963,

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and Tangamyika1 x Russian Green. Three inbreds were JRO 632, JRO 36 E and JRO 524. All eight entries were grown under two deliberately created agro-ecosystems over three years in a randomized block design with four replications at the Experimental Farm, Institute of Agricultural Science, University of Calcutta, Baruipur, South 24-Paraganas, W. Bengal. Plot size allotted in each replication was 4.8 m x 5.0 m. Sowing was done within 3rd week of April in each of three years. Spacing between rows and between plants within a row were 30 cm and 5-6 cm respectively. For high fertility irrigated ecosystem, fertilizers: N (urea), P_2O_5 (single super phosphate) and K_2O (muriate of potash) @ 60 : 30 : 30 kg ha^{-1} were applied in each year. Half of urea and whole of super phosphate and potash were applied as basal dose before final land preparation. Other half of urea was applied as topdressing in two equal doses, the first at 3 weeks and the second at 6 weeks after sowing as recommended. While, for low fertility rain fed ecosystem, only basal dose of fertilizers, N (urea), P_2O_5 (single super phosphate) and K_2O (muriate of potash) @ 30 : 30 : 30 kg ha^{-1} were applied before final land preparation in each year. In irrigated experiment, need based 3 irrigations, as recommended, was applied. Rain fed experiment depended solely on rain water. Other recommended intercultural operations were also followed to raise a healthy crop. In each year, at about 120 days crop age, replication and treatment wise whole plot was harvested leaving 0.25 m along the length and 0.30 m along the breadth as boarder. Fibres were extracted by retting green stems under a pool of water, then washed thoroughly, sun-dried and finally weighed in kilograms to estimate fibre yield (g kg plot^{-1}). Data thus obtained, were converted to quintal ha^{-1} for further use.

A regression analysis was conducted following the procedure outlined by Perkins and Jinks (1968) with some modifications as used by Sing and Singh (1980). INDOSTAT software was used for statistical analysis.

The genotype-environment interaction for the individual lines was regressed on to the additive environmental values. Environment was measured by its effects on the fibre yield. The regression mean square was compared with the remainder mean square. Again, the latter was compared with the experimental error to show that the particular i th genotype exhibited a significant non-linear part to the total G x E interaction variation. The r_i^2, a ratio of the regression sum of square of the i th genotype to the total of its regression and deviation from the regression sum of square, was computed. Since the total was fixed for a single set of data, this ratio (r_i^2) was a convenient measure for assessing the degree of linearity for the i th regression. Observed r_i^2 value was then compared with the table value (Fisher and Yates, 1975, Table No. VII) for n - 2 degrees of freedom.

RESULTS AND DISCUSSION

Joint regression analyses (Table 1) showed that main effects and the linear and non-linear part of G x E interaction were significant (P>0.01) against the experimental error. Further, heterogeneity between regressions was found significant (P>0.05) when tested against the remainder. This indicated that there was distinct genetic difference in fibre yield potentiality between the genotypes, there was considerable difference between the two deliberately created environments and the presence of significant G x E interaction. Though both linear and non-linear component of interaction variation were present, prediction of the G x E interaction based on the linear regression will still have considerable practical value. However significant remainder mean square indicated that considerable portion of the G x E interaction was due to non-linear relationships and unexplained deviations from regression.

Table 1.

Joint regression analysis for fibre yield of 5 selected hybrids and 3 checks across 6 environments (2 ecosystems x 3 years)

Source	df	Mean Squares
Entry	7	22.0062 **
Environment	5	280.7556 **
Entry x environment	35	3.3181 **
Heterogeneity between regression	7	7.5882 ** ∫
Remainder	28	2.2506 **
Error	144	1.1522

** Significantly different (P < 0.01) error.
∫ Significantly different (P < 0.01) against remainder.

Stability of a genotype is a function of two parameters, viz. linear (b_{di}) and non-linear sensitivity (S_i^2). The parameter r_i^2 gives an estimate of reliability of the b_{di} coefficient. Above parameters were used to classify the hybrids into the following four classes of stability.

(A) *Absence of G x E interaction:* The estimates of b_{di} and S_i^2 were non-significant. This suggests average stability and wider adaptability.

(B) *Presence of G x E interaction:*

(i) The major portion of the G x E interaction was accounted for by the linear environmental change (significant b_{di}) suggesting responsiveness of the hybrids and some reliability on their predictable performance over the environments.

(ii) Same as under (i) but significant estimate of S_i^2, suggesting high G x E interaction. Prediction of performance can still be made with some reliability, when observed r_i^2 value exceeds the table value (Fisher and Yates, 1975, Table No. VII).

(iii) The estimate of S_i^2 was significant while that for b_{di} was non-significant. This indicates high unpredictability of cultivars.

No hybrid was observed to show absence of G-E interaction (Table 2). Three hybrids viz. Russian Green x JRO 620, Tanganyika 1 x O50-4963 and Tanganyika 1 x Russian Green exhibited high G-E interactions. Nevertheless, prediction about their yield could still be made with some reliability, since r_i^2 value for each of these hybrids was > 0.70. The hybrid, Russian Green x JRO 620 is considered unaccepted due to its poor yield. Another hybrid, Tanganyika 1 x O50-4963 which showed significantly high yield and magnitude of heterosis under low fertility rain fed management, but not so under high input management (Bhattacharya *et al.,* 2014), exhibited below average sensitivity which further indicated its relative insensitivity to increased environmental productivity. Conversely, Tanganyika 1 x Russian Green was observed superior for its highest fibre yield and magnitude of heterosis under high fertility irrigated ecosystem but not so in low fertility rain fed management (Bhattacharya *et al*, 2014). This was further supported by its positive significant b_{di} coefficient and its reliability estimate i.e. r_i^2 >0.70 under high input management. As it showed above average sensitivity, it might suffer from yield loss under the low productive environment, as was reported by the present authors in their earlier communication cited above. Hence, hybrids which exhibit above average stability should be deployed only in high input management to avoid the risk of sudden drop in yield. Rest of the two hybrids i.e. Russian Green x Sallyout and JRO 632 x Russian 1 were unacceptable on account of their high G-E interactions (non-significant b_{di} and significant S_i^2).

Of the 3 inbreds studied, 2 were released cultivars i.e. JRO 632 and JRO 524. The remaining one (JRO 36 E), although a high yielding selection, but not yet been released. At present, JRO 524 is the dominant cultivar which replaced JRO 632 significantly as it, unlike the latter, can fit well to the multiple cropping system with rice. However, both JRO 632 and JRO 524 exhibited significantly negative linear regression coefficient (b_{di} = - 0.057 and - 0.088 respectively) indicating their relative insensitivity to increased environmental productivity. Although non-linear sensitivity estimates for both these varieties were significant, prediction regarding their performance could still be made with some reliance since r_i^2 > 0.70. Since major area of jute is under low fertility rain fed production condition, negative b_{di} value for JRO 524 would explain itself the reason for acceptability of this cultivar over a large area. Maity *et al* (1981) also observed similar results for JRO 524. In the contrary, Aktar *et al.* (210) observed that regression coefficient of JRO-524 had higher value than unity which indicated high responsiveness of this genotype and its suitability for favorable environments.

Most important findings from this experiment are: 1) presence of high G-E interactions, both predictable and unpredictable in nature, that might have limited the expression of potential heterosis, 2) predictable environmental influence can obviously be reduced by minimizing the difference in management, 3) but unpredictable environmental influence, the most serious one, can only be reduced, if heterogeneous hybrid population like F_2 is used rather than F_1, 3) no F_1 hybrid exhibited equally high stability in performance under

Table 3.

Estimates of stability parameters for fibre yield (q ha $^{-1}$) of 5 selected hybrids and 3 checks over 6 environments (2 ecosystems x 3 years)

Hybrid	Stabityparameters		
	b_{di}	S_i^2	r_i^2
Russian Green x JRO 620	0 . 059 **	0 . 448 **	0 . 96
Russian Green x Sallyout	-0 . 037 NS	0 . 905 **	0 . 49
JRO 632 X Russian 1	-0 . 029 NS	0 . 106 **	0 . 57
Tanganyika 1 x O50-4963	-0 . 070 **	2 . 901 **	0 . 89
Tanganyika 1 x Russian Green	0 . 083 **	1 . 368 **	0 . 94
Inbred			
JRO 632	-0 . 057 **	1 . 633 **	0 . 93
JRO 36 E	0 . 139 **	3 . 639 **	0 . 86
JRO 524	-0 . 088 **	-0 . 720 **	0 . 99

*, ** Significant b_{di} (P<0.05) and (P< 0.01) respectively against its residual

** Significant S_i^2 (P< 0.01) against error MS.

both high and low fertility management, 4) the hybrid, Tanganyika1 x Russian Green showed superior stability in performance under high input environment, 5) a different hybrid, Tanganyika1 x O50-4963 exhibited stability under low fertility rain-fed agro-ecosystem, and 6) since these two hybrid combinations were relatively stable in their respective best performing ecosystem, it appeared that it is possible to breed high yielding hybrid with high stability in performance.

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AN OVERVIEW ON NATURAL RESOURCES AND ITS GLOBAL IMPACT

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Natural resources occur naturally within environments that exist relatively undisturbed by humanity, in a natural form. A natural resource is often characterized by amounts of biodiversity and geodiversity existent in various ecosystems. The term was introduced to a broad audience by E.F. Schumacher in his 1970s book Small is Beautiful.

A natural resource may exist as a separate entity such as fresh water, and air, as well as a living organism such as a fish, or it may exist in an alternate form which must be processed to obtain the resource such as metal ores, oil, and most forms of energy. Some natural resources such as sunlight and air can be found everywhere, and are known as ubiquitous resources. However, most resources only occur in small sporadic areas, and are referred to as localized resources. There are very few resources that are considered inexhaustible (will not run out in foreseeable future) – these are solar radiation, geothermal energy, and air (though access to clean air may not be). The vast majority of resources are exhaustible, which means they have a finite quantity, and can be depleted if managed improperly.

Classification

There are various methods of categorizing natural resources, these include source of origin, stage of development, and by their renewability. On the basis of origin, resources may be divided into :

- *Biotic* – Biotic resources are obtained from the biosphere (living and organic material), such as forests and animals, and the materials that can be obtained from them. Fossil fuels such as coal and petroleum are also included in this category because they are formed from decayed organic matter.
- *Abiotic* – Abiotic resources are those that come from non-living, non-organic material. Examples of abiotic resources include land, fresh water, air and heavy metals including ores such as gold, iron, copper, silver, etc.

Considering their stage of development, natural resources may be referred to in the following ways :

- *Potential resources* – Potential resources are those that exist in a region and may be used in the future. For example petroleum occurs with sedimentary rocks in various regions, but until the time it is actually drilled out and put into use, it remains a potential resource.
- *Actual resources* – Actual resources are those that have been surveyed, their quantity and quality determined and are being used in present times. The development of an actual resource, such as wood processing depends upon the technology available and the cost involved.
- *Reserve resources* – The part of an actual resource which can be developed profitably in the future is called a reserve resource.
- *Stock resources* – Stock resources are those that have been surveyed but cannot be used by organisms due to lack of technology. For example, hydrogen.

Renewability is a very popular topic and many natural resources can be categorized as either renewable or non-renewable :

- *Renewable resources* – Renewable resources can be replenished naturally. Some of these resources, like sunlight, air, wind, etc., are continuously available and their quantity is not noticeably affected by human consumption. Though many renewable resources do not have such a rapid recovery rate, these resources are susceptible to depletion by over-use. Resources from a human use perspective are classified as renewable only so long as the rate of replenishment/recovery exceeds that of the rate of consumption.

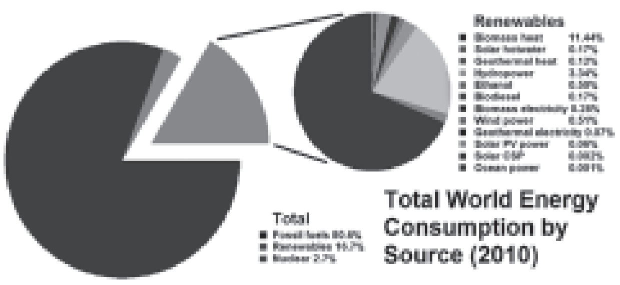
- *Non-renewable resources* – Non-renewable resources either form slowly or do not naturally form in the environment. Minerals are the most common resource included in this category. By the human perspective, resources are non-renewable when their rate of consumption exceeds the rate of replenishment/ recovery; a good example of this are fossil fuels, which are in this category because their rate of formation is extremely slow (potentially millions of years), meaning they are considered non-renewable.

Extraction

Resource extraction involves any activity that withdraws resources from nature. Examples of extractive industries are hunting, trapping, mining, oil and gas drilling, and forestry. Natural resources can add substantial amounts to a country’s wealth, however a sudden inflow of money caused by a resource boom can create social problems including inflation harming other industries (“Dutch disease”) and corruption, leading to inequality and underdevelopment, this is known as the “resource curse”.

Extractive industries represent a large growing activity in many less-developed countries but the wealth generated does not always lead to sustainable and inclusive growth. Extractive industry businesses often are assumed to be interested only in maximizing their short-term value, implying that less-developed countries are vulnerable to powerful corporations. Alternatively, host governments are often assumed to be only maximizing immediate revenue.

Energy development



Schematic of the global sources of energy in 2010
Source: REN21: Renewables 2012 Global Status Report
Total : Fossil; Renewable; Nuclear
Renewables :
Biomass heat; Solar-water; ; Geo-heat; Hydro; Ethanol; Biodiesel; Biomass electric; Wind; Geo-electric; Solar PV; Solar CSP; Oceanic

Energy development is a field of endeavor focused on making available sufficient primary energy sources and secondary energy forms to meet the needs of society. These endeavors encompass those which provide for the production of conventional, alternative and renewable sources of energy, and for the recovery and reuse of energy that would otherwise be wasted. Energy conservation and efficiency measures reduce the impact of energy development, and can have benefits to society with changes in economic cost and with changes in the environmental effects.

Cuba was the only nation in the world in 2006 that met the World Wide Fund for Nature's definition of sustainable development, with an ecological footprint of less than 1.8 hectares per capita, 1.5, and a Human Development Index of over 0.8, 0.855.

Exploitation of natural resources

In regards to natural resources, depletion is of concern for sustainable development as it has the ability to degrade current environments (Salvati and Marco, 2008) and potential to impact the needs of future generations (Schilling and Chiang, 2011). At present, with it being the year of the forest, there is particular concern for rainforest regions which hold most of the Earth's biodiversity. According to Nelson deforestation and degradation affect 8.5% of the world's forests with 30% of the Earth's surface already cropped (Nelson, 2005). If we consider that 80% of people rely on medicines obtained from plants and ¾ of the world's prescription medicines have ingredients taken from plants, loss of the world's rainforests could result in a loss of finding more potential life saving medicines.

The depletion of natural resources is caused by 'direct drivers of change' such as Mining, petroleum extraction, fishing and forestry as well as 'indirect drivers of change' such as demography, economy, society, politics and technology (Nelson, 2005). The current practice of Agriculture is another factor causing depletion of natural resources. For example the depletion of nutrients in the soil due to excessive use of nitrogen and desertification. The depletion of natural resources is a continuing concern for society. This is seen in the cited quote given by Theodore Roosevelt, a well-known conservationist and former United States president, was opposed to unregulated natural resource extraction.

Conservation of energy

In 1982 the UN developed the World Charter for Nature in which it recognised the need to protect nature from further depletion due to human activity. They outline the need for sustainable use of natural resources and suggest that the protection of resources should be incorporated into the law system at state and international level. The World Ethic of Sustainability, developed by the IUCN, WWF and the UNEP in 1990 which set out eight values for sustainability, include the need to protect natural resources from depletion (Fein, 2003).

Conservation biology is the scientific study of the nature and status of Earth's biodiversity with the aim of protecting species, their habitats, and ecosystems from excessive rates of extinction (Soule and Wilcox, 1980). It is an interdisciplinary subject drawing on sciences, economics, and the practice of natural resource management. The term conservation biology was introduced as the title of a conference held University of California at San Diego in La Jolla, California in 1978 organized by biologists Bruce Wilcox and Michael Soulé. Habitat conservation is a land management practice that seeks to conserve, protect and restore, habitat areas for wild plants and animals, especially conservation reliant species, and prevent their extinction, fragmentation or reduction in range.

At the end of 2006, the European Union (EU) pledged to cut its annual consumption of primary energy by 20% by 2020. The 'European Union Energy Efficiency Action Plan' is long awaited. As part of the EU's SAVE Programme, aimed at promoting energy efficiency and encouraging energy-saving behaviour, the Boiler Efficiency Directive specifies minimum levels of efficiency for boilers fired with liquid or gaseous fuels. Bureau of Energy Efficiency is an Indian governmental organization created in 2001 responsible for promoting energy efficiency and conservation.

Compact fluorescent lights use two-thirds less energy and may last 6 to 10 times longer than incandescent lights. According to the International Energy Agency, improved energy efficiency in buildings, industrial processes and transportation could reduce the world's energy needs in 2050 by one third, and help control global emissions of greenhouse gases.

Energy efficiency and renewable energy are said to be the twin pillars of sustainable energy policy.

Compact fluorescent lights

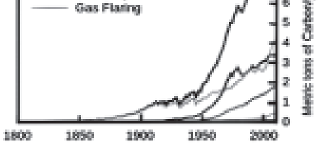
Non-renewable resource

A non-renewable resource (also known as a finite resource) is a resource that does not renew itself at a sufficient rate for sustainable economic extraction in meaningful human time-frames. An example is carbon-based, organically-derived fuel. The original organic material, with the aid of heat and pressure, becomes a fuel such as oil or gas. Fossil fuels (such as coal, petroleum, and natural gas), and certain aquifers are all non-renewable resources.

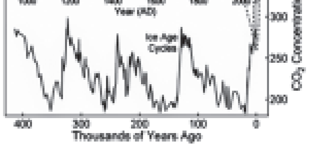
A picture of the Udachnaya pipe, anopen-pit diamond mine in Siberia. An example of a non-renewable natural resource.

Fossil fuel

Fossil fuels are fuels formed by natural processes such as anaerobic decomposition of buried dead organisms. The age of the organisms and their resulting fossil fuels is typically millions of years, and sometimes exceeds 650 million years (Paul *et al.*, 2009). The Energy Information Administration estimates that in 2007 the primary sources of energy consisted of petroleum 36.0%, coal 27.4%, natural gas 23.0%, amounting to an 86.4% share for fossil fuels in primary energy consumption in the world (U.S.EIAIES, 2010). Non-fossil sources in 2006 included hydroelectric 6.3%, nuclear 8.5%, and others (geothermal, solar, tidal, wind, wood, waste) amounting to 0.9% (IEA, 2009). World energy consumption was growing about 2.3% per year. Fossil fuels are of great importance because they can be burned (oxidized to carbon dioxide and water), producing significant amounts of energy per unit weight.



Global fossil carbon emission by fuel type, 1800–2007. Note: Carbon only represents 27% of the mass of CO_2



Carbon dioxide variations over the last 400,000 years, showing a rise since the industrial revolution.

Combustion of fossil fuels generates sulphuric, carbonic, and nitric acids, which fall to Earth as acid rain, impacting both natural areas and the built environment. Monuments and sculptures made from marble and limestone are particularly vulnerable, as the acids dissolve calcium carbonate. Fossil fuels also contain radioactive materials, mainly uranium and thorium, which are released into the atmosphere. Harvesting, processing, and distributing fossil fuels can also create environmental concerns. Coal mining methods, particularly mountaintop removal and strip mining, have negative environmental impacts, and offshore oil drilling poses a hazard to aquatic organisms.

Environmental regulation uses a variety of approaches to limit these emissions, such as command-and-control (which mandates the amount of pollution or the technology used), economic incentives, or voluntary programs. An example of such regulation in the USA is the "EPA is implementing policies to reduce airborne mercury emissions. Under regulations issued in 2005, coal-fired power plants will need to reduce their emissions by 70 percent by 2018."

In economic terms, pollution from fossil fuels is regarded as a negative externality. Taxation is considered one way to make societal costs explicit, in order to 'internalize' the cost of pollution. This aims to make fossil fuels more expensive, thereby reducing their use and the amount of pollution associated with them, along with raising the funds necessary to counteract these factors.

Fossil water

Fossil water or paleowater is groundwater that has remained sealed in an aquifer for a long period of time. Water can rest underground in "fossil aquifers" for thousands or even millions of years. When changes in the surrounding geology seal the aquifer off from further replenishing from precipitation, the water becomes trapped within, and is known as fossil water.

The Nubian Sandstone Aquifer System is among the most notable of fossil water reserves. Fossil aquifers also exist in the Sahara, the Kalahari, and the Ogallala underlying the US Great Plains. A further potential store of ancient water is Lake Vostok, a subglacial lake in Antarctica.

The world's largest irrigation project –transport of pipe segments for the Great Manmade River in the Sahara desert, Libya : a network of pipes that supplies water from the Nubian Sandstone Aquifer System, tapped from a fossil water aquifer in the Sahara Desert of Libya.

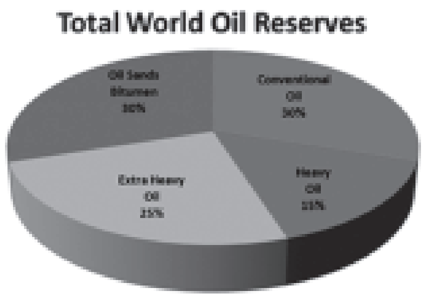
Oil Reserves

Total possible conventional crude oil reserves include all crude oil with 90–95% certainty of being technically possible to produce (from reservoirs through a wellbore using primary, secondary, improved, enhanced, or tertiary methods), all crude with a 50% probability of being produced in the future, and discovered reserves that have a 5–10% possibility of being produced in the future.

As conventional oil becomes less available, it can be replaced with production of liquids from oil sands, ultra-heavy oils, gas-to-liquids technologies, coal-to-liquids technologies, biofuel technologies, and shale oil. In the 2007 and subsequent International Energy Outlook editions, the word "Oil" was replaced with "Liquids" in the chart of world energy consumption. In 2009 biofuels was included in "Liquids" instead of in "Renewables". Unconventional sources, such as heavy crude oil, oil sands, and oil shale are not counted as part of oil reserves.

Unconventional resources are much larger than conventional ones.

Despite the large quantities of oil available in non-conventional sources, Matthew Simmons argued in 2005 that limitations on production prevent them from becoming an effective substitute for conventional crude oil.



The largest consumer of fossil fuels in modern agriculture is ammonia production (for fertilizer) via the Haber process, which is essential to high-yielding intensive agriculture. The specific fossil fuel input to fertilizer production is primarily natural gas, to provide hydrogen via steam reforming.

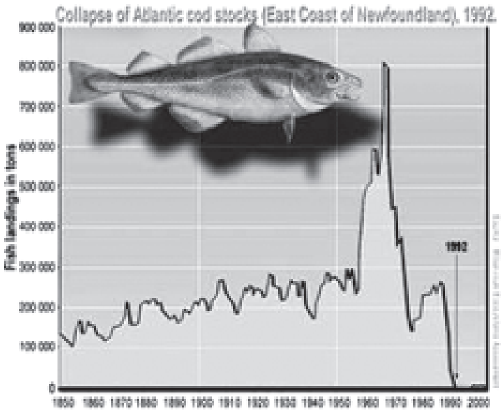
Renewable resource

A renewable resource is a natural resource which can replenish with the passage of time, either through biological reproduction or other naturally recurring processes. Renewable resources are a part of Earth's natural environment and the largest components of its ecosphere.

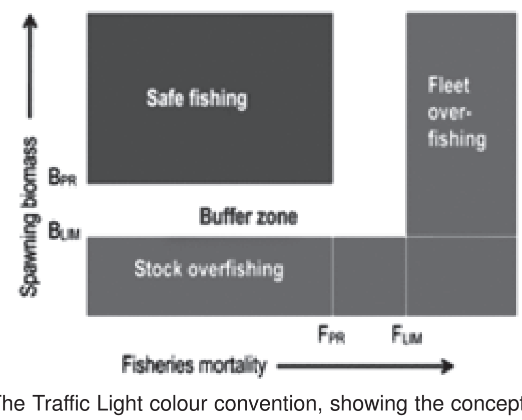
Renewable resources endangered by the industrial world

Overfishing

Tuna meat is driving overfishing as to endanger some species like the bluefin tuna. The European Community and other organisations are trying to regulate fishery as to protect species and to prevent their extinctions (Council Regulation, 2002). The United Nations Convention on the Law of the Sea treaty deals with aspects of overfishing in articles 61, 62, and 65 (UNC, 2012). Examples of overfishing exist in areas such as the North Sea of Europe, the Grand Banks of North America and the East China Sea of Asia (Lu, 2006). The decline of penguin population is caused in part by overfishing, caused by human competition over the same renewable resources.



Atlantic cod stocks were severely overfished in the 1970s and 1980s, leading to their abrupt collapse in 1992



The Traffic Light colour convention, showing the concept of Harvest Control Rule (HCR), specifying when a rebuilding plan is mandatory in terms of precautionary and limit reference points for spawning biomass and fishing mortality rate.

Sustainable agriculture

The Food and Agriculture Organisation of the United Nations estimates that in coming decades, cropland will continue to be lost to industrial and urban development, along with reclamation of wetlands, and conversion of forest to cultivation, resulting in the loss of biodiversity and increased soil erosion (FAO, 2003). Although air and sunlight are available everywhere on Earth, crops also depend on soil nutrients and the availability of water. Monoculture is a method of growing only one crop at a time in a given field, which can damage land and cause it to become either unusable or suffer from reduced yields. Monoculture can also cause the build-up of pathogens and pests that target one specific species. The Great Irish Famine (1845–1849) is a well-known example of the dangers of monoculture.

Polyculture practices in Andhra Pradesh

Crop rotation and long-term crop rotations confer the replenishment of nitrogen through the use of green manure in sequence with cereals and other crops, and can improve soil structure and fertility by alternating deep-rooted and shallow-rooted plants. Methods to combat erosion include no-till farming, using a keyline design, growing wind breaks to hold the soil, and widespread use of compost. Chemical fertilizer and pesticides can also have an effect of soil erosion, which can contribute to soil salinity and prevent other species from growing.

Deforestation

The destruction of rain forests is one of the critical causes of climate change. Deforestation causes carbon dioxide to linger in the atmosphere. As carbon dioxide accrues, it produces a layer in the atmosphere that traps radiation from the sun. The radiation converts to heat which causes global warming, which is better known as the greenhouse effect (Mumoki, 2012).

Illegal slash and burn practice in Madagascar, 2010

Endangered species

Some renewable resources, species and organisms are facing a very high risk of extinction caused by growing human population and over-consumption. It has been estimated that over 40% of all living species on Earth are at risk of going extinct. Many nations have laws to protect hunted species and to restrict the practice of hunting. Other conservation methods includes restricting land development or creating preserves. The IUCN Red List of Threatened Species is the best-known worldwide conservation status listing and ranking system (IUCN, 2011). Internationally, 199 countries have signed an accord agreeing to create Biodiversity Action Plans to protect endangered and other threatened species.

Water resources

Groundwater is usually removed from an aquifer at a rate much greater than its very slow natural recharge, and so groundwater is considered non-renewable. Removal of water from the pore spaces may cause permanent compaction (subsidence) that cannot be renewed. 97% of the water on the Earth is salt water, and 3% is fresh water; slightly over two thirds of this is frozen in glaciers and polar ice caps (USGS, 2009). The remaining unfrozen freshwater is found mainly as groundwater, with only a small fraction (0,008%) present above ground or in the air.

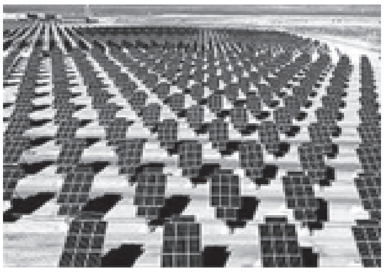
Renewable energy

Renewable energy is energy from natural resources such as sunlight, wind, rain, tides, waves and geothermal heat. Common applications of renewable energies are electricity generation and motor fuels.

Solar Energy

Solar power is the conversion of sunlight into electricity, either directly using photovoltaics (PV), or indirectly using concentrated solar power (CSP). Concentrated solar power systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam (Buchan, 2010). Photovoltaics convert light into electric current using the photoelectric effect.

There are many domestic applications of solar power including solar cookers, solar stills, solar water heating, solar heating and air conditioning.



Nellis Solar Power Plant, 14 MW power plant installed 2007 in Nevada, USA

Wind Power

Wind power is the conversion of wind energy into a useful form of energy. Most modern electrical wind power is generated by converting the rotation of turbine blades into electrical currents by means of an electrical generator.

Windmills provide mechanical power, and were originally developed for milling grain for food production. Other industrial uses of windmill machinery are windpumps, used for water pumping or drainage. Wind power is also used to propel ships using sails.

Wind is a natural resource that can be used to generate electricity, as with these 5MW wind turbines in Thorntonbank Wind Farm 28 km (17 mi) off the coast of Belgium

Hydropower

Hydropower is energy derived from the movement of water in rivers and oceans, originally used for irrigation. Conventional hydroelectric power involves creating a dam, and using the resulting water force to turn a water turbine and generator. Other electricity generating methods are run-of-the-river hydroelectricity, which captures the kinetic energy in rivers or streams, without the use of dams, and pumped-storage hydroelectricity, operating which stores water pumped during periods of low demand to be released for generation when demand is high.

The Three Gorges Dam is the largest hydroelectric power station, at 22,500 MW.

Geothermal Energy

Geothermal energy comes from the Earth's crust and originates from the original formation of the planet (20%) and from radioactive decay of minerals (80%) (Turcotte and Schubert, 2002). Geothermal electricity is electricity generated from geothermal energy using technologies like superheaters, flash steam power plants and binary cycle power plants. The first geothermal power station was built at Landrello, Italy.

The Nesjavellir Geothermal Power Plant in Iceland is an example of renewable energy.

Other countries that have geothermal power stations are Japan, Iceland, the Philippines and the United States. In Iceland, geothermal energy is used for electricity and heat.

Biofuel

A biofuel is a type of fuel whose energy is derived from biological carbon fixation. Biofuels include fuels derived from biomass conversion, as well as solid biomass, liquid fuels and various biogases (Divakara *et al.*, 2010)

Bioethanol is an alcohol made by fermentation, mostly from carbohydrates produced in sugar or starch crops such as corn, sugarcane or switchgrass.

Biodiesel is made from vegetable oils and animal fats. Biodiesel is produced from oils or fats using transesterification and is the most common biofuel in Europe.

Biogas is methane produced by the process of anaerobic digestion of organic material by anaerobes, etc. is also a renewable source of energy.

Renewable materials

Biomass is biological material from living, or recently living organisms, most often referring to plants or plant-derived materials. As a renewable energy source, biomass can either be used directly, or indirectly—once or converted into another type of energy product such as biofuel. The use of biomass helps to sustain climate change, increase energy efficiency, and decrease greenhouse gas emission (NREL, 2013).

Bioplastics

Bioplastics are a form of plastics derived from renewable biomass sources, such as vegetable fats and oils, corn starch, pea starch or microbiota (Hong *et al.*, 1999). The most common form of bioplastic is thermoplastic starch. Other forms include Cellulose bioplastics, biopolyester, Polylactic acid, and bio-derived polyethylene.

Bioasphalt

Bioasphalt is an asphalt alternative made from non-petroleum based renewable resources. Manufacturing sources of bioasphalt include sugar, molasses and rice, corn and potato starches, and vegetable oil based waste. Asphalt made with vegetable oil based binders was patented by Colas SA in France in 2004.

Present and Future/Global human impact on biodiversity

Energy production usually requires an energy investment. Drilling for oil or building a wind power plant requires energy. The fossil fuel resources that are left are often increasingly difficult to extract and convert. They may thus require increasingly higher energy investments. If investment is greater than the energy produced, than the resource; It is no longer an effective energy source.

Between 1950 and 1984, as the Green Revolution transformed agriculture around the globe, world grain production increased by 250%. The energy for the Green Revolution was provided by fossil fuels in the form of fertilizers (natural gas), pesticides(oil), and hydrocarbon fueled irrigation (Andrew and Robert, 2008). The peaking of world hydrocarbon production (peak oil) may lead to significant changes, and require sustainable methods of production. One vision of a sustainable energy future involves all human structures on the earth's surface (i.e., buildings, vehicles and roads) doing artificial photosynthesis (using sunlight to split water as a source of hydrogen and absorbing carbon dioxide to make fertilizer) efficiently than plants (Mandil, 2008).

Management of human consumption of resources is an indirect approach based largely on information gained from economics. Herman Daly has suggested three broad criteria for ecological sustainability: renewable resources should provide a sustainable yield (the rate of harvest should not exceed the rate of regeneration); for non-renewable resources there should be equivalent development of renewable substitutes; waste generation should not exceed the assimilative capacity of the environment (Daly and Farley, 2004)

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EDITORIAL

We are delighted to publish the Indian Biologist, volume 46, No. 1, 2014 as a special volume on agricultural scenario covering natural resources along with other important aspects within the stipulated date.

We are glad to announce that next two issues will be published as special issues on two burning problems of our environment which affect the very existence of a large number of biological species including human species. Topics of coming two special issues of Indian Biologist are as follows : (i) Food, Nutrition and Food Adulteration, and (ii) Genetically Modified Crops.

Usual research papers of our Members on other biological topics will also be included in those special issues.

The Indian Biologist is circulated to all major countries around the world and abstracts of its articles are now being published regularly in leading abstracts of the world in different languages. During the last 45 years, Indian Biologist has gained notable reputation in India and abroad mainly due to the constant patronage from our members and well wishers. The quality of its publication are commendable. We would like to inform our members and research contributors that we have modified the getup of our journal from this issue which will also be beneficial for the higher NAAS ranking. The 'Indian Biologist' has been rated 2.29 by the NAAS academy for the year, 2014. We are trying hard to improve the quality of the research article as well as printing for further higher rating of our Journal by the NAAS academy. We hope, the authors/ contributors of the research papers or articles will bear us in this regard.

The contributors are cordially requested to send their manuscripts/ articles in original for publication in the journal of "Indian Biologist". We will try our level best to publish the issue on scheduled time.

We sincerely request our members and well wishers to offer their patronage and co-operation as before.

T. M. Das and A. K. Mandal

Indian Biologist, ***Vol. 46 (1)***, *pp 61 - 64 (2014)*

WORLD HUMAN POPULATION INDEX

The world population is estimated by the United States Census Bureau to be 7.165 billion. The US Census Bureau estimates the 7 billion number was surpassed on 12 March 2012. According to a separate estimate by the United Nations, Earth's population exceeded seven billion in October 2011, a milestone that offers unprecedented challenges and opportunities to all of humanity, according to UNFPA, the United Nations Population Fund.

According to literature published by the United States Census Bureau, the world population hit 6.5 billion on 24 February 2006. The United Nations Population Fund designated 12 October 1999 as the approximate day on which world population reached 6 billion. This was about 12 years after world population reached 5 billion in 1987, and 6 years after world population reached 5.5 billion in 1993. The population of some countries, such as Nigeria, is not even known to the nearest million, so there is a considerable margin of error in such estimates.

Country name	2009	2010	2011	2012
Afghanistan	27,708,187	28,397,812	29,105,480	29,824,536
Albania	3,151,185	3,150,143	3,153,883	3,162,083
Algeria	36,383,302	37,062,820	37,762,962	38,481,705
American Samoa	56,245	55,636	55,274	55,128
Andorra	78,659	77,907	77,865	78,360
Angola	18,926,650	19,549,124	20,180,490	20,820,525
Antigua and Barbuda	86,300	87,233	88,152	89,069
Argentina	40,023,641	40,374,224	40,728,738	41,086,927
Armenia	2,968,154	2,963,496	2,964,120	2,969,081
Aruba	101,418	101,597	101,932	102,384
Australia	21,691,700	22,031,800	22,340,000	22,722,000
Austria	8,365,275	8,389,771	8,406,187	8,429,991
Azerbaijan	8,947,243	9,054,332	9,173,082	9,295,784
Bahamas, The	354,492	360,498	366,331	371,960
Bahrain	1,191,539	1,251,513	1,292,764	1,317,827
Bangladesh	149,503,100	151,125,475	152,862,431	154,695,368
Barbados	279,006	280,396	281,804	283,221
Belarus	9,507,000	9,490,000	9,473,000	9,464,000
Belgium	10,796,493	10,895,586	11,047,744	11,128,246
Belize	301,016	308,595	316,280	324,060
Benin	9,240,783	9,509,798	9,779,795	10,050,702
Bermuda	65,636	65,124	64,564	64,806
Bhutan	704,542	716,939	729,429	741,822
Bolivia	9,993,406	10,156,601	10,324,445	10,496,285
Bosnia and Herzegovina	3,853,446	3,845,929	3,839,322	3,833,916
Botswana	1,951,715	1,969,341	1,986,701	2,003,910
Brazil	193,490,922	195,210,154	196,935,134	198,656,019
Brunei Darussalam	394,400	400,569	406,512	412,238
Bulgaria	7,444,443	7,395,599	7,348,328	7,305,888
Burkina Faso	15,094,967	15,540,284	15,995,313	16,460,141
Burundi	8,926,687	9,232,753	9,540,362	9,849,569
Cabo Verde	485,714	487,601	490,556	494,401
Cambodia	14,144,225	14,364,931	14,605,862	14,864,646
Cameroon	20,103,945	20,624,343	21,156,272	21,699,631
Canada	33,628,571	34,005,274	34,342,780	34,754,312
Cayman Islands	54,275	55,509	56,601	57,570
Central African Republic	4,266,247	4,349,921	4,436,217	4,525,209
Chad	11,371,325	11,720,781	12,080,037	12,448,175
Chile	16,991,729	17,150,760	17,308,449	17,464,814
China	1,331,260,000	1,337,705,000	1,344,130,000	1,350,695,000
Colombia	45,802,561	46,444,798	47,078,792	47,704,427
Comoros	666,097	683,081	700,216	717,503
Congo, Dem. Rep.	60,486,276	62,191,161	63,931,512	65,705,093
Congo, Rep.	3,995,146	4,111,715	4,225,359	4,337,051

Country name	2009	2010	2011	2012
Costa Rica	4,601,424	4,669,685	4,737,680	4,805,295
Cote d'Ivoire	18,601,342	18,976,588	19,389,954	19,839,750
Croatia	4,429,000	4,417,800	4,280,600	4,267,600
Cuba	11,288,826	11,281,768	11,276,053	11,270,957
Curacao	145,890	149,311	150,612	152,056
Cyprus	1,090,553	1,103,685	1,116,513	1,128,994
Czech Republic	10,443,936	10,474,410	10,496,088	10,510,785
Denmark	5,523,095	5,547,683	5,570,572	5,591,572
Djibouti	821,865	834,036	846,646	859,652
Dominica	70,996	71,167	71,401	71,684
Dominican Republic	9,884,265	10,016,797	10,147,598	10,276,621
Ecuador	14,756,424	15,001,072	15,246,481	15,492,264
Egypt, Arab Rep.	76,775,023	78,075,705	79,392,466	80,721,874
El Salvador	6,183,484	6,218,195	6,256,242	6,297,394
Equatorial Guinea	676,851	696,167	715,996	736,296
Eritrea	5,557,889	5,741,159	5,932,852	6,130,922
Estonia	1,338,498	1,336,887	1,334,948	1,329,301
Ethiopia	84,838,032	87,095,281	89,393,063	91,728,849
Faeroe Islands	49,600	49,581	49,551	49,506
Fiji	852,479	860,559	867,921	874,742
Finland	5,338,871	5,363,352	5,388,272	5,413,971
France	64,702,921	65,031,235	65,371,613	65,696,689
French Polynesia	265,412	268,065	270,874	273,814
Gabon	1,519,155	1,556,222	1,594,034	1,632,572
Gambia, The	1,628,332	1,680,640	1,734,966	1,791,225
Georgia	4,410,900	4,452,800	4,483,400	4,490,700
Germany	81,902,307	81,776,930	81,797,673	80,425,823
Ghana	23,691,533	24,262,901	24,820,706	25,366,462
Greece	11,282,760	11,307,502	11,123,213	11,092,771
Greenland	56,323	56,905	56,890	56,810
Grenada	104,296	104,677	105,074	105,483
Guam	158,621	159,440	160,858	162,810
Guatemala	13,988,988	14,341,576	14,706,578	15,082,831
Guinea	10,593,248	10,876,033	11,161,530	11,451,273
Guinea-Bissau	1,550,905	1,586,624	1,624,228	1,663,558
Guyana	781,055	786,126	790,882	795,369
Haiti	9,765,153	9,896,400	10,032,864	10,173,775
Honduras	7,469,844	7,621,204	7,776,669	7,935,846
Hong Kong SAR, China	6,972,800	7,024,200	7,071,600	7,154,600
Hungary	10,022,650	10,000,023	9,971,727	9,920,362
Iceland	318,499	318,041	319,014	320,716
India	1,190,138,069	1,205,624,648	1,221,156,319	1,236,686,732
Indonesia	237,486,894	240,676,485	243,801,639	246,864,191
Iran, Islamic Rep.	73,542,954	74,462,314	75,424,285	76,424,443
Iraq	30,163,199	30,962,380	31,760,020	32,578,209
Ireland	4,535,375	4,560,155	4,576,794	4,586,897
Isle of Man	83,293	83,992	84,654	85,284
Israel	7,485,600	7,623,600	7,765,800	7,910,500
Italy	60,192,698	60,483,385	60,723,569	59,539,717
Jamaica	2,681,386	2,690,824	2,699,838	2,707,805
Japan	127,557,958	127,450,459	127,817,277	127,561,489
Jordan	5,915,000	6,046,000	6,181,000	6,318,000
Kazakhstan	16,092,701	16,321,581	16,556,600	16,791,425
Kenya	39,824,734	40,909,194	42,027,891	43,178,141
Kiribati	96,272	97,743	99,250	100,786
Korea, Dem. Rep.	24,371,865	24,500,520	24,631,291	24,763,188
Korea, Rep.	49,182,038	49,410,366	49,779,440	50,004,441
Kosovo	1,761,474	1,775,680	1,790,957	1,807,106

Country name	2009	2010	2011	2012
Kuwait	2,850,102	2,991,580	3,124,705	3,250,496
Kyrgyz Republic	5,383,300	5,447,900	5,514,600	5,607,200
Lao PDR	6,267,968	6,395,713	6,521,314	6,645,827
Latvia	2,141,669	2,097,555	2,059,709	2,034,319
Lebanon	4,246,924	4,341,092	4,382,790	4,424,888
Lesotho	1,989,873	2,008,921	2,029,516	2,051,545
Liberia	3,821,440	3,957,990	4,079,697	4,190,435
Libya	5,964,325	6,040,612	6,103,233	6,154,623
Liechtenstein	35,851	36,120	36,388	36,656
Lithuania	3,162,916	3,097,282	3,028,115	2,987,773
Luxembourg	497,783	506,953	518,347	530,946
Macao SAR, China	521,617	534,626	546,278	556,783
Macedonia, FYR	2,100,558	2,102,216	2,103,890	2,105,575
Madagascar	20,495,695	21,079,532	21,678,934	22,293,914
Malawi	14,573,338	15,013,694	15,457,531	15,906,483
Malaysia	27,790,324	28,275,835	28,758,968	29,239,927
Maldives	319,660	325,694	331,964	338,442
Mali	13,559,296	13,985,961	14,416,737	14,853,572
Malta	412,477	414,508	416,268	419,455
Marshall Islands	52,341	52,428	52,495	52,555
Mauritania	3,516,077	3,609,420	3,702,763	3,796,141
Mauritius	1,275,032	1,280,924	1,286,051	1,291,456
Mexico	116,422,752	117,886,404	119,361,233	120,847,477
Micronesia, Fed. Sts.	103,983	103,619	103,424	103,395
Moldova	3,565,604	3,562,045	3,559,986	3,559,519
Monaco	36,314	36,845	37,261	37,579
Mongolia	2,672,223	2,712,738	2,754,209	2,796,484
Montenegro	619,408	620,078	620,644	621,081
Morocco	31,276,564	31,642,360	32,059,424	32,521,143
Mozambique	23,361,025	23,967,265	24,581,367	25,203,395
Myanmar	51,540,490	51,931,231	52,350,763	52,797,319
Namibia	2,143,498	2,178,967	2,217,618	2,259,393
Nepal	26,544,943	26,846,016	27,156,367	27,474,377
Netherlands	16,530,388	16,615,394	16,693,074	16,754,962
New Caledonia	245,580	249,992	254,024	258,121
New Zealand	4,315,800	4,367,800	4,405,200	4,433,100
Nicaragua	5,743,329	5,822,209	5,905,146	5,991,733
Niger	15,302,948	15,893,746	16,511,462	17,157,042
Nigeria	155,381,020	159,707,780	164,192,925	168,833,776
Northern Mariana Islands	55,278	53,860	53,230	53,305
Norway	4,828,726	4,889,252	4,953,088	5,018,573
Oman	2,663,224	2,802,768	3,024,774	3,314,001
Pakistan	170,093,999	173,149,306	176,166,353	179,160,111
Palau	20,344	20,470	20,606	20,754
Panama	3,615,846	3,678,128	3,740,282	3,802,281
Papua New Guinea	6,704,829	6,858,945	7,012,977	7,167,010
Paraguay	6,347,383	6,459,721	6,573,097	6,687,361
Peru	28,934,303	29,262,830	29,614,887	29,987,800
Philippines	91,886,400	93,444,322	95,053,437	96,706,764
Poland	38,151,603	38,183,683	38,534,157	38,535,873
Portugal	10,568,247	10,573,100	10,557,560	10,514,844
Puerto Rico	3,740,410	3,721,208	3,694,093	3,667,084
Qatar	1,564,082	1,749,713	1,910,902	2,050,514
Romania	20,367,487	20,246,871	20,147,528	20,076,727
Russian Federation	141,910,000	142,389,000	142,960,000	143,533,000
Rwanda	10,529,668	10,836,732	11,144,315	11,457,801
Samoa	184,704	186,029	187,429	188,889
San Marino	30,698	30,861	31,048	31,247

Country name	2009	2010	2011	2012
Sao Tome and Principe	173,240	178,228	183,177	188,098
Saudi Arabia	26,796,375	27,258,387	27,761,728	28,287,855
Senegal	12,586,827	12,950,564	13,330,737	13,726,021
Serbia	7,320,807	7,291,436	7,258,745	7,223,887
Seychelles	87,298	89,770	87,441	88,303
Sierra Leone	5,641,182	5,751,976	5,865,491	5,978,727
Singapore	4,987,600	5,076,700	5,183,700	5,312,400
Sint Maarten (Dutch part)	39,133	37,850	38,486	39,088
Slovak Republic	5,386,406	5,391,428	5,398,384	5,407,579
Slovenia	2,039,669	2,048,583	2,052,843	2,057,159
Solomon Islands	514,964	526,447	537,997	549,598
Somalia	9,380,854	9,636,173	9,907,903	10,195,134
South Africa	50,222,996	50,895,698	51,579,599	52,274,945
South Sudan	9,520,571	9,940,929	10,381,110	10,837,527
Spain	46,362,946	46,576,897	46,742,697	46,761,264
Sri Lanka	20,450,000	20,653,000	20,869,000	20,328,000
St. Kitts and Nevis	51,731	52,352	52,971	53,584
St. Lucia	175,200	177,397	179,271	180,870
St. Martin (French part)	29,820	30,235	30,615	30,959
St. Vincent and the Grenadines	109,249	109,316	109,357	109,373
Sudan	34,853,178	35,652,002	36,430,923	37,195,349
Suriname	520,173	524,960	529,761	534,541
Swaziland	1,173,678	1,193,148	1,212,159	1,230,985
Sweden	9,298,515	9,378,126	9,449,213	9,519,374
Switzerland	7,743,831	7,824,909	7,912,398	7,996,861
Syrian Arab Republic	21,031,546	21,532,647	21,961,676	22,399,254
Tajikistan	7,447,396	7,627,326	7,814,850	8,008,990
Tanzania	43,639,752	44,973,330	46,354,607	47,783,107
Thailand	66,277,335	66,402,316	66,576,332	66,785,001
Timor-Leste	1,110,071	1,142,502	1,175,880	1,210,233
Togo	6,144,457	6,306,014	6,472,304	6,642,928
Tonga	103,557	104,098	104,554	104,941
Trinidad and Tobago	1,322,518	1,328,095	1,333,082	1,337,439
Tunisia	10,439,600	10,549,100	10,673,800	10,777,500
Turkey	71,241,080	72,137,546	73,058,638	73,997,128
Turkmenistan	4,978,962	5,041,995	5,106,668	5,172,931
Turks and Caicos Islands	30,247	30,993	31,726	32,427
Tuvalu	9,808	9,827	9,844	9,860
Uganda	32,864,328	33,987,213	35,148,064	36,345,860
Ukraine	46,053,300	45,870,700	45,706,100	45,593,300
United Arab Emirates	7,718,319	8,441,537	8,925,096	9,205,651
United Kingdom	62,238,723	62,747,868	63,259,912	63,612,729
United States	306,771,529	309,326,225	311,587,816	313,914,040
Uruguay	3,360,431	3,371,982	3,383,486	3,395,253
Uzbekistan	27,767,400	28,562,400	29,339,400	29,774,500
Vanuatu	230,833	236,299	241,778	247,262
Venezuela, RB	28,583,040	29,043,283	29,500,625	29,954,782
Vietnam	86,025,000	86,932,500	87,840,000	88,772,900
Virgin Islands (U.S.)	106,707	106,267	105,784	105,275
West Bank and Gaza	3,702,218	3,811,102	3,927,051	4,046,901
Yemen, Rep.	22,229,625	22,763,008	23,304,206	23,852,409
Zambia	12,825,031	13,216,985	13,633,796	14,075,099
Zimbabwe	12,888,918	13,076,978	13,358,738	13,724,317

Source : (1) United Nations Population Division. World Population Prospects, (2) United Nations Statistical Division. Population and Vital Statistics Report (various years), (3) Census reports and other statistical publications from national statistical offices, (4) Eurostat: Demographic Statistics, (5) Secretariat of the Pacific Community: Statistics and Demography Programme, and (6) U.S. Census Bureau: International Database.

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