SOME MORPHOLOGICAL RESPONSES OF COASTAL PLANT FORMS IN BATTICALOA TO TIDAL WAVES

A SHORT COMMUNICATION

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INTRODUCTION :

Indonesian (Sumatra) oceanic earth quake that occurred in December 2004 caused a rise in sea levels that flooded extensive coastal areas with sea water in Indonesia, Sri lanka. Southern India, Thailand, and Bangladesh. This possibly caused the loss of some vegetation (halophytes and non-halophytes) either partly or fully because of flooding and salinity resulting from natural processes and imposed hydrological changes. Although, the causes of flooding and salinizaion of soils are known and many plant responses to flooding and salinity have been characterized (Kozlowaski, 1997), our understanding of the precise mechanisms by which flooding with saline water inhibits plant growth are poorly understood. The precise mechanisms by which salinity inhibits growth are complex and controversial. An attractive model incorporates a two-phased response of plants (Kozlowaski, 1997). Growth is first reduced by water stress effect followed by a specific effect. In angiosperms, salt injury includes leaf scorching or mottling, leaf shedding, and twig dieback (Salisbury and Ross, 1994). In non-halophytes, salt-induced inhibition of plant growth is accompanied by metabolic dysfunctions, including decreased photosynthetic rates, and changes in protein and nucleic acid metabolism and enzymatic activity. In halophytes, physiological processes may be stimulated or not altered by salt concentrations that are inhibitory in nonhalophytes.

Eastern coastal region of Sri Lanka has either been naturally selected or planted with various plant forms, such as trees, shrubs, herbs and prostrate forms. Their benefits are many folds for socio-economic life of all living beings along the eastern coastal regions. Recent tidal waves have devastated some plant forms either permanently or temporarily along the coastal belts in Batticaloa. Most devastation reportedly occurred within 500 m habitat sites from the seashore or riversiJe. Majority of plant forms were abundant at least 200 to 300 m away from the seashore and they could be classified under nonhalophytes. Some halophytes (salt loving forms) were established within 200 to 300 m range from the seashore. It has been noted that tidal wave influenced either directly from the sea or indirectly through bar mouths and other connected water body intrusions the extensive flooding of coastal areas with salt water.

In Sri Lanka, both the animate and the inanimate were either partly damaged or devastated by recent tidal waves that extended along the coastal lines. There are several rehabilitation works that are being accelerated to restore the life of tidal wave victims in

Sri Lanka, which is also more essential. Data on the loss of human lives and properties were taken and estimated for necessary compensations and some form of immediate compensation is being done. To our knowledge, it is not known how the coastal lines of plant forms either partly damaged or devastated are taken into consideration by various governmental and nongovernmental organizations, as they do in other cases. Socio-economic importance of plant forms for coastal villages could have been under estimated or for various reasons, this work could have been left out while giving priority for human rehabilitation works. Thus, it was decided to carry out preliminary studies on the morphological responses of coastal line vegetations that were devastated by tidal waves in Batticaloa, to keep as benchmarks for future reference.

METHODOLOGY

SITES AND INSPECTIONS

Tidal wave (Tsunami) that occurred on the 26th of December 2004 (between 8.15 am and 8.40 am) devastated both the animate and the inanimate along the coastal line of Batticaloa, over 500 m range circumference from the seashore.

In this preliminary study, the effect of tidal waves (both salinity and velocity concerned waves) on plant forms (classified under animate) was studied as to whether plant forms have been morphologically altered or devastated and regenerated. The study was conducted at three points in Batticaloa" namely Pooenochiemunnai, Navalady and Muhathuevarem villages. Pooenochiemunnai and Navalady were directly affected by tidal wave, whereas Muhathuevarem was exposed to two conditions, one was direct exposure to sea tidal waves and other one was through river.

Data were collected by inspections during regular visits to three villages and by personal communication with locals. Plants were identified by personal experiences with a guide of the Sri Lankan Forester (The Ceylon Forester). In some occasions, photographs were taken using Nikon Digital Camera. Data (no quantitative estimation) were observed and noted from the second day of tidal wave (28-12-2005) to one hundred and one day (0904-2005). Visits were made on the 2nd, 20th 45th, 75th and 101st day to monitor and assess

The morphological and regenerative changes which occurred in> different plant forms. In each site, two blocks were randomly and temporarily marked, one from the seashore and other on the opposite side, where some sites were previously occupied by village people. Each site area was blocked to 200 square meters and by several foot walks, relevant inspections were made. Blocked sites were kept same throughout this study period.

RESULTS AND DISCUSSION

IMPACT OF TIDAL WAVES

Impact of tidal waves on plant forms were reportedly high when tidal waves hit directly from the sea compared with any other connected water body intrusion of sea. It was observed that tree forms, such as Terminalia arjuna (Roxb.) Wight and Am. Cocus nucifera L. and Casuarina equisitifolia showed more resistance to sea tidal waves of saline with wave's velocity in three villages. But, some were dislocated from their vertical strands and orientations seem inclined in Navalady village. But young forms were exceptional, where they were uprooted, even died in Navalady and Poonochiemunai. Shrub forms of mangroves (Excoecaria sp) were either partly uprooted or their canopies were pa11ly damaged with necrotic symptoms in Muhathuevarem. Tallest Plumeria obtuse Ail. F. was unaffected and standstill along with other tree forms in Navalady and Muhathuevarem. Prostrate forms like Ipomea pes-caprae (L.) R. Br., and Spinifex littoreus (Burm.f.) Merr. totally disappeared from the seashore. This is possibly due to excess layers of soil covers that carpeted these rhizome forms. Pandanas sp. survived with some of sacrificed branches in Poonochiemunai and Muthathuevarem. Some tree forms such as Azadirachta indica A. juss., Eucalyptus camaldulensis, Anacardium occidentale L., Thespesia populnea (L) Soland. ex Corr, Pongamia pinnata (L.) Pierre., Ricinus communis L., Morinda tinctoria, M(mgifera indica (L).,

Samanea saman (Jacq.) Merr., and Moringa olifera Lam. and Musa paradisiac a L. shed their entire leaves on the 20th day and are now being regenerated with new leaves. The most affected tree form was Borassusjlabellifer L. most of which were uprooted or died or wilted in all villages. It could be noted that Borassus flabellifer L. palms anchored next to river beds in Muhathuevarem was unaffected. Second order damage was Anacardium occidentale

L., except being uprooted, most canopy was defoliated and most were diebacked in Poonochiemunai.

Table 1 Some plant forms and their site associations which were observed in three selected sites in Muhathuevarem (MY), Poonochiemunai (PN) and Navalday (NO) in Batticaloa.

Binomial Names	Family	Sites	Plant forms associated
Phoenix sp	Palmae	MV	Between sea and river
Vitex negundo L	Verbanaceae	MV; PN	River site
Thespesia populnea	Malvaceae	MV; PN;ND	Sea and river sites
Terminalia arjuna	Combretaceae	MV; PN;ND	Sea and river sites
Cocus nucifera L	Palmae	MV; PN;ND	Sea and river sites
Borassus flabellifer L.	Palmae	MV; PN;ND	Sea and river sites
Croton sp	Euphorbiaceae	MV	River site (residential)
Excoecaria sp	Euphorbiaceae	MV	between sea and river
Azadirachta indica	Meliaceae	MV; PN;ND	Residential sites-sea
Pandanas sp	Pandanaceae	MV; PN	Sea and river sites
Moringa olifera	Moringaceae	MV; ND	Residential site-Sea
Ipomea pes-caprae	Convolvulaceae	MV; PN;ND	Sea shore
Spinifex littoreus	Graminae	MV; PN;ND	Sea shore
Samanea saman	Leguminosae	MV; ND	Residential site-Sea
Combretum sp	Combretaceae	MV; PN;ND	Sea and river sites
Cerbera manghas	Apocynaceae	MV; PN	River sites
Bougainvillea spectabilis	Nyctaginaceae	MV	Residential sites-River
Musa paradisiacal	Musaceae	MV	River sites
Calotropis gigantea	Asclepiadaceae	ND	Sea shore and residential
Casuarina equisetifolia	Casuarinaceae	ND	Sea shore
Ricinus communis	Euphorbiaceae	ND	Residential site-Sea
Datura metel	Solanaceae	ND	Residential site-Sea
Eucalyptus camaldulensis	Myrtaceae	ND	Residential site-Sea
Plumeria obtuse	Apocynaceae	ND	Residential site-Sea
Morinda tinctoria	Rubiaceae	ND	Residential site-Sea & River
Rosa indica	Rosaceae	MV	Residential site-River
Anacardium occidentale	Anacardiaceae	PN	Residential site-Sea
Pongamia pinnata	Leguminosae	PN; ND	Between river and sea site; Residential site-Sea

Plant forms exhibited from tidal waves showed morphological symptoms such as leaf scorching within the next two days from the occurrence of tidal waves. These symptoms were more apparent in Borassus flabellifer L., Anacardium occidentale L., Pongamia. pinnata and Azadirachta indica A. juss. Ranges of symptoms in the components of tall trees appeared up to the raised level of tidal waves (sea water) and even helped to scale the tidal wave height. It is noted that tidal waves that reached via. river beds or other water bodies did not make any significant effects like direct sea tidal waves. Borassus flabellifer L. that was more susceptible to direct exposure of sea tidal waves was not affected by sea tidal waves that arose through river. Furthermore some of the home gardens occupied by Bougainvillea spectabilis Willd, Croton sp., Rosa indica and Mangifera indica (L) were unaffected by this tidal wave effects. This is possibly due to the synergetic effect, as a consequence of intermingled sea water with river that ultimately reduced the threshold of salinity grades with waves flow velocity that could not possibly targeted other plant components and the root system.

It was observed that vegetation, both naturally selected and planted was highly affected in Navalday compared with that of Poonochiemunai and Muhathuevarem. A few reasons . could be put forward to discuss why this trend has changed among the villages (sites). One could presume that terrain in Poonochiemunai is a little elevated than that of Navalady and this gives a strong barrier between the sea and people housed sites with few forms of vegetation. But, the village of Navalady was densely populated with forms of vegetations and that became ultimately affected by the tidal waves. In Muhathuevarem, the situation is different from the other two villages. The coastal side is mostly occupied with very few vegetation forms. Further, infiltrated sea water of the tidal waves possibly decreased the salinity level with velocity when the tidal waves intermingled with the river. This was one of the reasons, why the river shore standing vegetations were less susceptible compared with those of the other two villages.

There were concrete arguments on ranges of susceptibilities of Cocus nuciftra L. compared with Borassus flabellifer L. which comes under the same family of Palmae. Generally, there may be by two reasons, one is possibly by salinity effect which is related to the physiology of plant forms and next by velocity of tidal wave that ultimately uprooted or damaged at the soil-root interface. Borassus flabellifer L. was one of the palms, at least 75 % of which were uprooted or died. Cocus nucifera L. looks more resistant to this salinity based tidal waves than Borassus flabellifer L. For this, some reasons may be placed in support of Cocus nucifera L. regardless of any scientific revealing and effect salinity of palms is unknown. It was observed that the root system of Cocus nucifera L. has greater ability to resist any mode of soil-root interface erosions (e.g.: by velocity of tidal wave) because of its vast nature of fibrous, mesh like spread out root system that could help to anchor effectively. Usually palms tend to have unbranched stems with no vascular cambium. A palm trunk. once formed can never adds new vascular tissue (Tyree and Ewers, 1991). The palm stem represents soft wood, but compared with these two palms, Cocus nucifera L. seems to have more hard and durable wood than Borassus flabellifer. Further, Borassus flabellifer has large quantities of hollow pith extending from roots to apices and could be expected to increase cell to cell water transport. Thus, any effect of salinity (lower water potential) could have highest impact on Borassus flabellifer and resulted greatest mortality by means of physiological responses. Cocus nucifera L. have efficient, flexible orientations systems (e.g.: vertical , and inclined tropisms) with proportionally extended crown. Further, main trunk of Cocus nucifera L. is taller with tapering aerial apical ends from basal trunk and outside surface of trunk is slippery (waxed) without notable frictions (embedded leaf scars) causing surface areas. These features were unlike in Borassus flabellifer L. and that could be considered as one of the reasons for their susceptibility by means of morphology. Further, Borassus flabellifer L. main trunk persists with broad leaf bases as well as with number of whorl leaf scars up to the height of 4 to 6 meters and that could have been increased the frictional rate when water tidal wave collided at trunk levels, and appears uprooted. However, further comparative studies between identified plant forms in three villages are required to confirm this, and to see the physio-morphological responses for salinity effect.

REGENERATIONS OF SOME PLANT FORMS

Regeneration of those plant components or new saplings appeared in two weeks after the tidal waves and continued over six to eleven weeks to establish at whole canopy level. The tallest Plume ria obtuse Ait. F. flowered after 45 days of tidal waves in Navalady. Azadirachta indica A. juss. showed a top canopy with dieback symptoms at 40th and 100th day of observations in Pooenochiemunai and Navalady. But, young shootings appeared on the main trunk at 100 th day. However, newly formed shootings showed some level of abnormalities and rosette appearances. Eucalyptus camaldulensis, Moringa olifera Lam. and Ricinus communis sprouted their coppices from the basal trunk where top and main trunk diebacked. Eucalyptus camaldulensis sprouted within 40 days, whereas Moringa olifera Lam. only after 80 days from the date of tidal wave. First regeneration of Ipomea pes-caprae (L.) R. Br. is evidenced after 80 days of this effect and by 101 st day, three to four leaflets were formed in the sites of Pooenochiemunai and Navalady. Thespesia populnea (L) Soland. ex Corr, which was mostly uprooted or in slanted orientations, indicated more profuse sprouting leaves from the main trunk from the 20th day onwards. Seedlings of Ricinus communis germinated and grew up to Hoot height at its 10 1 st day of observation and this suggests sustainability of soil fertility, even after this effect of tidal wave. Similarly, Datura metel L seedlings appeared by the 75th day of observation. Spinifex littoreus (Burm.f.) Merr. did not show any sign of . regeneration on the seashore, even at 10 1 st day of observation. Young saplings of Casuarina equisetifolia were shown dieback, but they produced young sprouting from the basal part by its 60th day, which is dark green in colour in Navalady. Borassus flabellifer L. which stood next to the river bed did not show any signs of variable differences. Phoenix sp and Vitex negundo L. did not show any significant effect and they had normal growth.

CONCLUSIONS

Flood and salinity tolerance vary greatly among plant species, genotypes and rootstocks and are influenced by plant age, time and duration of flooding, condition of the floodwater and site characteristics. In this preliminary study, which was confined to three selected sites in Batticaloa and conducted as a benchmark for any future assessments which is essential to preserve the coastal lines of vegetation from any such disaster conditions. There were two observations, based on their morphological changes that appeared in the anchored plant forms of coastal lines immediately after the effect of tidal wave. At one, plant components were most immediate vulnerable organs and the range was extended up to the height of tidal wave that wets the components (e.g.: sea water raised even to the height (6m) of middle of Borassus flabellifer L. trees canopIes subjected to necrotic appearances, but left behind the top of canopies). Secondly, regardless of heights of tidal waves that either wets the plant components or not, the whole plant were damaged, but it has been exhibited as a long term effect and took nearly ten to twenty days. Looking at the above, there may be an urgent need to reveal some of the important features when such types of vegetations are exposed to conditions like salinity and based tidal waves. Therefore, future studies to be proposed on, a) to identify most resistant / suitable species based on their morphological-physiological responses to sea water (salinity), b) to identify the site or organs of effect, selected species may be subjected to sea water treatments, one at canopy, soil-root, canopy-soil-root levels with controls could be studied for short and long term exposures in potted trials and, c) results of (a & b), possibly help us to recommend relevant species for future plantations along the Eastern coastal line to save our terrestrial regions.

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