EFFECTS OF SALINITY ON THE GROWTH OF MANGROVE SEEDLINGS

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BASAK, U. C., GUPTA, N., RAUTARAY, S. & DAS, P. 2004. Effects of salinity on the growth of mangrove seedlings. Growth analysis was done with mangrove trees, namely *Bruguiera gymnorrhiza, B. parviflora* and *Ceriops tagal* to study the establishment of seedlings. Seedlings were grown for 120 days in a glasshouse in varied NaCl salinity regimes (0, 10, 15 and 20 ppt). *Bruguiera gymnorrhiza* thrived up to a maximum salinity of 15 ppt with highest biomass produced at 10 ppt. *Bruguiera parviflora* and *C. tagal*, however, grew well up to 20 ppt NaCl salinity but with a reduced rate of growth. The relative growth rate in *C. tagal* increased by more than 90% over the control at a salinity of 10 ppt, followed by 42% in *B. parviflora* and 32% in *B. gymnorrhiza* at 15 ppt. Growth analysis showed that both net assimilation rate and leaf area ratio accounted for differences in relative growth rate in all the species studied. *Bruguiera gymnorrhiza* was found most sensitive to high salinity compared with the other species. Depletion of this species can be reduced by growing them in low salinity regimes for successful seedling establishment.

Key words: *Bruguiera* – *Ceriops* – LAR – NAR – RGR – Rhizophoraceae

BASAK, U. C., GUPTA, N., RAUTARAY, S. & DAS, P. 2004. Kesan kemasinan terhadap pertumbuhan anak benih bakau. Analisis pertumbuhan dijalankan ke atas pokok bakau *Bruguiera gymnorrhiza, B. parviflora* dan *Ceriops tagal* untuk mengkaji pertumbuhan anak benih. Anak benih ditanam selama 120 hari di dalam rumah kaca di bawah kemasinan berbeza-beza (0 ppt, 10 ppt, 15 ppt dan 20 ppt NaCl). *Bruguiera gymnorrhiza* dapat hidup biak sehingga kemasinan 15 ppt. Biojisim tertinggi dihasilkan oleh *B. gymnorrhiza* pada kemasinan 10 ppt. Sebaliknya, *B. parviflora* dan *C. tagal* dapat hidup biak sehingga kemasinan 20 ppt tetapi kadar pertumbuhan berkurang. Pada kemasinan 10 ppt, kadar pertumbuhan relatif *C. tagal* bertambah lebih daripada 90% berbanding dengan kawalan. Ini diikuti oleh *B. parviflora* (42%) dan *B. gymnorrhiza* (32%) pada kemasinan 15 ppt. Analisis pertumbuhan menunjukkan bahawa kadar asimilasi bersih dan nisbah luas daun mempengaruhi kadar pertumbuhan relatif kesemua spesies yang dikaji. *Bruguiera gymnorrhiza* paling peka kepada kemasinan tinggi berbanding dengan spesies lain. Pengurangan spesies ini boleh diatasi dengan menanam anak benih dalam keadaan kemasinan rendah.

Introduction

The concept of growth analysis has proven highly effective in studying a plant's reaction to environmental conditions. Plants appear to have a genetically determined potential for growth and adapt certain strategies to overcome varying environmental factors (Leopold & Kriedemann 1975). Mangroves, in general, are

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salt-tolerant plants growing at the land-sea interface of tropical and subtropical coastlines (Smith *et al.* 1996). It is well known that in their own environment, mangroves are subjected to several physical factors such as salinity which has deleterious effects on growth and development (Morgan 1990).

Bruguiera gymnorrhiza, B. parviflora and *Ceriops tagal* are mangrove trees sporadically found in the Mahanadi delta (20°4'–20°8' N, 86°45' E) of Orissa, India. These species produce viviparous propagules which upon maturity detach from the mother plant to establish themselves in the saline substrata. There are many reports on the growth of halophytes in response to different salinity regimes (Schwarz & Gale 1984, Jansen *et al.* 1986) but few reports are available on the growth analysis of mangrove seedlings (Ball 1988, Ball *et al.* 1997). To achieve better growth performance, establishment of mangrove seedlings against varied salinity is the prerequisite of successful aforestation programme. Although there is considerable variations in the salt tolerance between seedling and adult tree (Hutchings & Saenger 1987), it is imperative to produce baseline data on growth and development of young seedlings of mangrove prior to exposure in their native environment for successful establishment.

Materials and methods

Mature and healthy propagules (called hypocotyls) of *B. gymnorrhiza, B. parviflora* and *C. tagal* were collected from the Mahanadi delta (20° 4'–20° 8' N, 86° 45' E) in Orissa from May till June. The water salinity ranged from 15 to 20 ppt (Banerjee & Rao 1990). About 200 propagules were screened on the basis of uniform length which roughly indicates the size of the propagule (Tomlinson 1986). The selected propagules were planted in polybags (20 × 8 cm) containing soil-sand mixture (1:1) as growing media irrigated with fresh water and cultivated under glass house conditions at 32 ± 2 °C and 80 ± 5% relative humidity. Ten seedlings from each species were sampled randomly after 75 days of growth to measure the dry weights of root, hypocotyl, stem and leaves after oven drying at 80 °C. The leaf area was measured with Li-Cor leaf area meter (LI 3000, USA) before oven drying the leaf samples. At the beginning of the experiment, the values for total dry weight biomass of the seedlings were 1.82 ± 0.13 g, 4.26 ± 0.59 g and 2.17 ± 0.17 g in *B. gymnorrhiza, B. parviflora* and *C. tagal* respectively. The values for average leaf area per plant were 4.52 ± 0.28 cm^2 in *B. gymnorrhiza*, 2.56 ± 0.29 cm^2 in *B. parviflora* and 7.92 ± 1.72 cm^2 in *C. tagal.*

A total of 40 uniform seedlings in each species were distributed into four salinity treatment groups, i.e. 10 seedlings of each group were sub-irrigated with 0, 10, 15 and 20 ppt NaCl (prepared with tap water) for 120 days. The maximum salinity treatment in this experiment was selected based on field report that about 15 ppt salinity (which was equivalent to 60% sea water salinity) causes or induces substantial stress in all the tree species studied (Banerjee & Rao 1990). The seedlings were finally harvested to measure the dry weights of different component parts. Leaf area was recorded with leaf area meter before oven drying the leaves. Growth was characterised by measuring relative growth rate (RGR), net assimilation rate (NAR) and leaf area ratio (LAR) following standard equations (Leopold & Kriedemann

1975). The data were evaluated for correlation and linear regression of RGR with NAR and LAR using Graph Pad Prism 2.1 software.

Results and discussion

Bruguiera gymnorrhiza showed growth activity in salinity ranging from 0 to 10 ppt (Figure 1). It accumulated maximum biomass when grown in 10 ppt salinity. Growth declined gradually with further increase in salinity. In contrast, *B. parviflora* and *C. tagal* grew well in salinity ranging from 0 to 20 ppt, with maximum biomass at 10 and 15 ppt respectively. In a salinity ranging from 10 to 15 ppt, *B. gymnorrhiza* yielded more biomass, followed by *B. parviflora* and *C. tagal.* Similar trend in the development of stem height was recorded in all the species studied. In *B. parviflora* and *C. tagal,* a slight increase in the leaf area was, however, noticed in subsequent higher salinity over the control. Hence, growth of all species declined with increase in salinity, with *B. gymnorrhiza* being the most sensitive species. Ball *et al.* (1997) observed that *Rhizophora apiculata* showed similar trend of declined growth when subjected to a salinity up to 350 mM (23 ppt).

The RGR, changed in accordance to that of dry biomass, stem height and leaf area in all the species (Figure 2). In 10 ppt salinity, where growth of all species was maximum, NAR measured 0.51 mg cm^{-2} day^{-1} in *B. gymnorrhiza,* 0.26 mg cm^{-2} day^{-1} in *B. parviflora* and 0.20 mg cm^{-2} day^{-1} in *C. tagal* (Figure 2).

In *B. parviflora* and *C. tagal,* RGR correlated positively with NAR ($r^2 = 0.97$ and 0.88 respectively; Figure 3). However, a negative correlation was found in *B. gymnorrhiza* ($r^2 = 0.45$). The opposite trend was observed in the case of LAR, where *B. parviflora* and *C. tagal* showed negative correlation with RGR. *Bruguiera gymnorrhiza,* however, showed positive correlation with NAR ($r^2 = 0.90$).

It appears that differences in growth rates were thus due to differences in NAR and LAR. In *B. parviflora,* RGR increased by 31% (at 10 ppt) and 42% (at 15 ppt) over the control but reduced by 25% at 20 ppt salinity. Although LAR increased considerably at higher salinity conditions, NAR decreased suddenly (by 56% over control) at 20 ppt salinity. *Ceriops tagal* showed greater RGR (increased by 92% over control) at 10 ppt but the RGR decreased gradually with increasing salinity.

While all species showed better growth in low salinity, *C. tagal* had an inherently greater relative growth rate. Our results corresponded to the findings of Smith (1988). In *B. parviflora,* increased RGR was recorded up to a salinity of 15 ppt, beyond which the species failed to survive. Maximum RGR (an increase by 33% over control) was recorded in seedlings grown at a salinity of 15 ppt. Interspecific differences in RGR were due to both NAR and LAR under optimal growth conditions. NAR values in *B. parviflora* and *C. tagal* were higher up to 15 ppt salinity in comparison with LAR. Surprisingly, LAR was maximum at higher salinity with lowered NAR contributing to a decline in the RGR. However, there seems to be no consistent pattern of change in RGR due to the fluctuation of LAR and NAR. High salinity decreased RGR invariably by reducing NAR and enhancing LAR and a reduction in the former was brought due to lower photosynthetic productivity per unit leaf area (Reynolds *et al.* 2001).

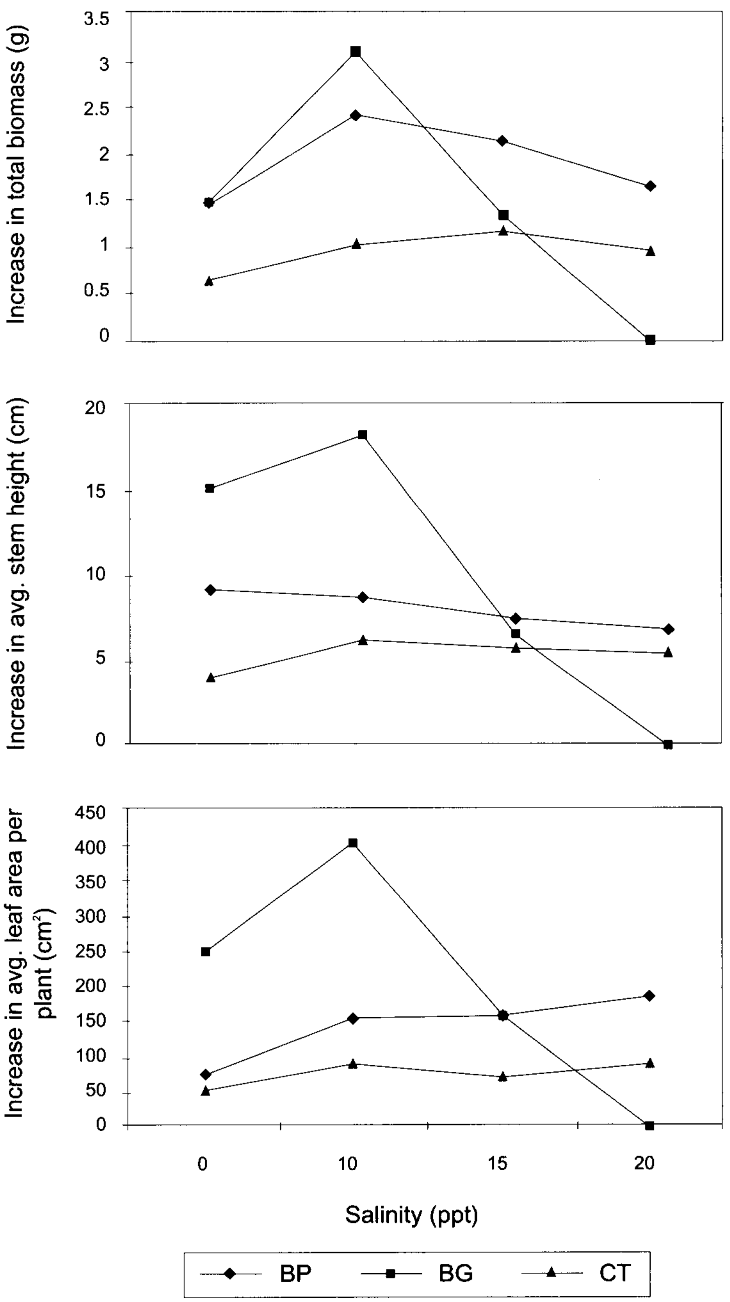

Figure 1 Increase in total biomass, stem height and leaf area of *Bruguiera parviflora* (BP), *Bruguiera gymnorrhiza* (BG) and *Ceriops tagal* (CT) grown under different salinity conditions

The high salt tolerance of *C. tagal* and *B. parviflora* was reflected in the proportional distribution of biomass in different parts, i.e. root, hypocotyl, stem and leaves (Figure 4). Higher salinity treatments affected *B. gymnorrhiza* in

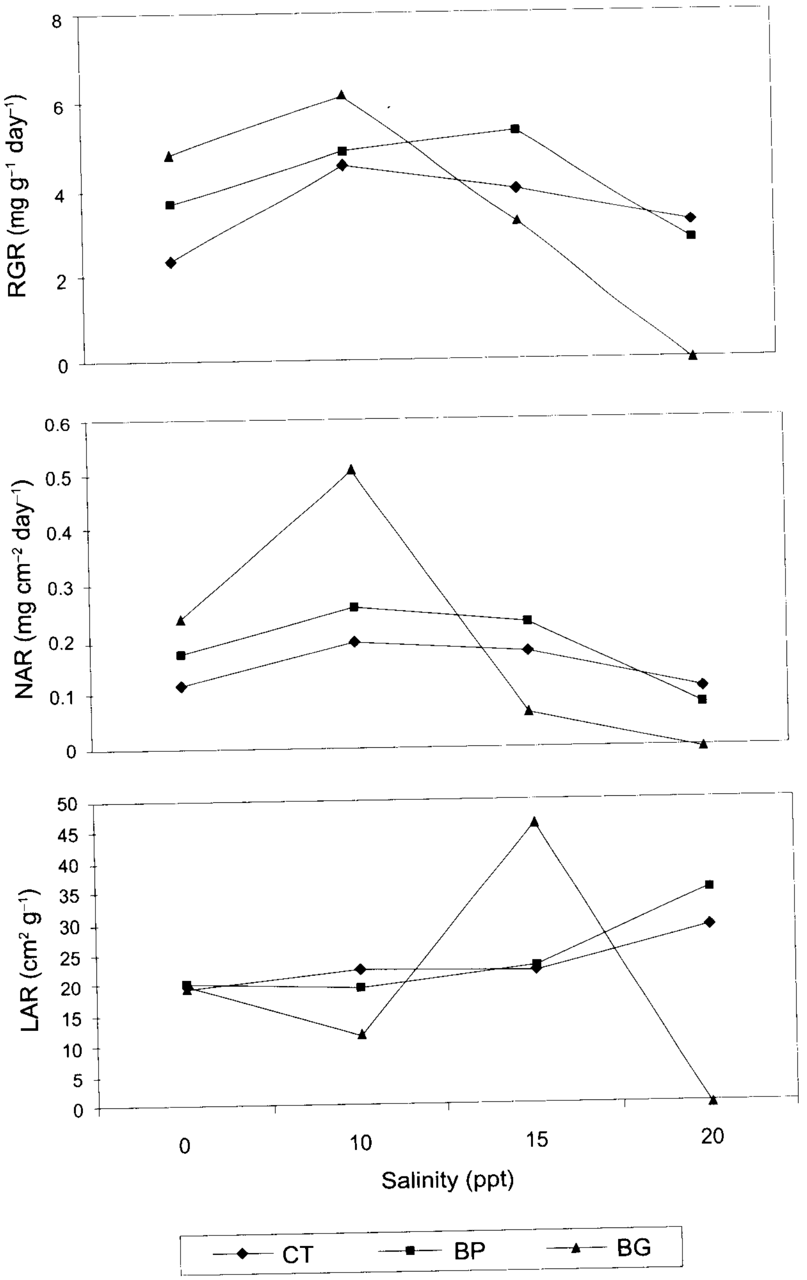

Figure 2 Relative growth rate (RGR), net assimilation rate (NAR) and leaf area ratio (LAR) in *Bruguiera parviflora* (BP), *Bruguiera gymnorrhiza* (BG) and *Ceriops tagal* (CT) grown under different salinity conditions

proportional distribution of biomass in roots and leaves. The inability of *B. gymnorrhiza* to thrive on salinity beyond 15 ppt in the present experiment corresponds to the findings of Chapman (1975) who observed that the species grew very well in culture with 1% NaCl but soon died at 3% NaCl. Though growth

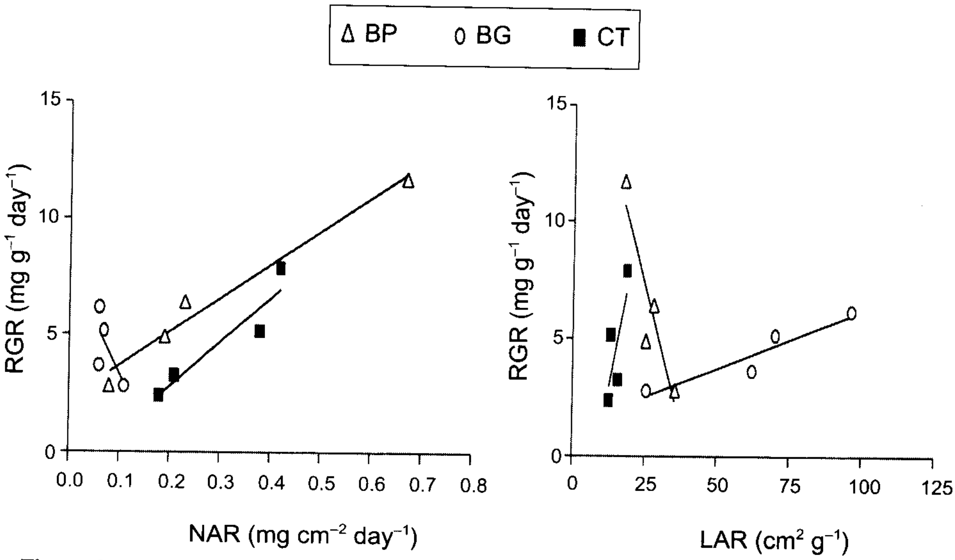

Figure 3 Relative growth rate (RGR) of *Bruguiera parviflora* (BP), *Bruguiera gymnorrhiza* (BG) and *Ceriops tagal* (CT) as a function of net assimilation rate (NAR) and leaf area ratio (LAR) due to salinity as a source of variation in growth

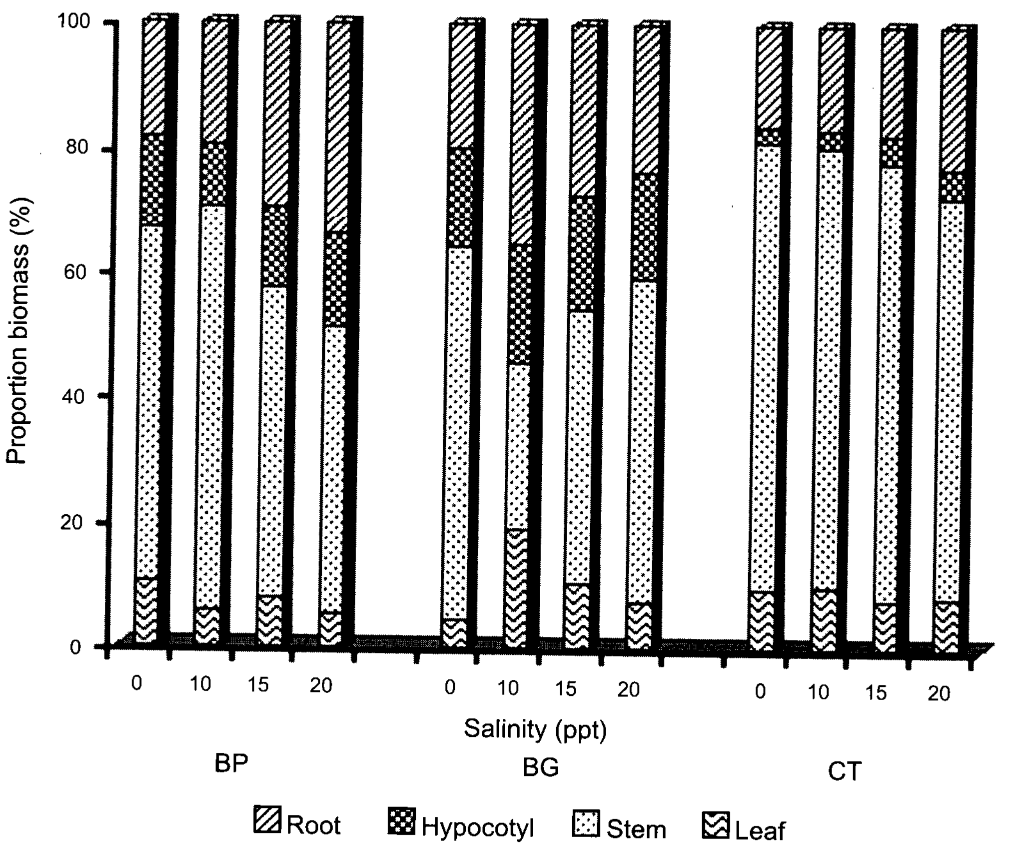

Figure 4 Proportional distribution of biomass (% dry wt.) in root, hypocotyl, stem and leaves of *Bruguiera gymnorrhiza* (BG), *Bruguiera parviflora* (BP) and *Ceriops tagal* (CT) grown under different salinity conditions

responses to salinity varied in all three species along the natural salinity gradient across the coastal environment of the Mahanadi delta of Orissa, yet it is to be concluded that gradual depletion of *B. gymnorrhiza* due to increased salinity in the environment can be reduced at least by growing them in comparatively less saline area of high tide zone in the remnant forests. The other two species, i.e. *B. parviflora* and *C. tagal* may thrive on high salinities with little effect on their growth and development.

Acknowledgement

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