SEEDLING REGENERATION IN RELATION TO TIME AND DEGREE OF SALINITY IN THE SUNDARBANS MANGROVE FOREST

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ABSTRACT

Data collected from twelve permanent sample plots (PSP) in the Sundarbans mangrove forest on seedling regeneration from 1981 to 1987 indicated two main problems i.e., appearance of insufficient number of seedlings compared to the vast area of seedling regeneration and failure of seedlings to survive and establish themselves. Average number of seedlings appearing per year was 35,625/ha. There was, of course, wide variation in the availability of seedlings among the plots located in different representative areas of the forest. Of the total new seedlings, *Heritiera fomes* constituted 41.27%; and *Excoecaria agallocha* 54% while the remaining 4.73% were seedlings of other species.

Any decreasing trend in yearly appearance of seedlings was not noticed. Salinity of the area might influence the regeneration which decreased with increasing soil salinity. Relationship between regeneration status and number of standing trees was found insignificant. In some plots, seedlings appeared abundantly. However, seedling half-life for *H. fomes* in less saline and strongly saline areas was 11.15 and 10.10 months respectively and for *E.agallocha* 7.15 and 11.80 months respectively. Seedlings of other species completely disappeared within 27 months. Factors other than salinity might also be involved in matters of survival of seedlings.

সারসংক্ষেপ

সুন্দরবনের বিভিন্ন এলাকায় অবস্থিত ১২টি স্থায়ী প্লটে চারা পুনরুৎপত্তির উপর ১৯৮১ হতে ১৯৮৭ সাল পর্যন্ত উপাত্ত সংগ্রহ করা হয়। চারা উৎপাদনের ক্ষেত্রে দু'টি প্রধান সমস্যা পরিলক্ষিত হয়–বনের বিস্তৃত এলাকায় চারার অপ্রতুলতা এবং টিকে থাকার ব্যর্থতা। বর্ণিত সময়ে গড়ে বৎসরে হেক্টর প্রতি ৩৫,৬২৫ টি চারা জন্মায়, যদিও বিভিন্ন প্লটের মধ্যে এলাকাভেদে এ সংখ্যার ব্যাপক তারতম্য বিদ্যমান। আবির্ভূত চারার ৪১·২৭% সুন্দরী, ৫৪% গেওয়া এবং বাকী ৪·৭৩% অন্যান্য প্রজাতির।

বাৎসরিক চারা উৎপাদনের ক্ষেত্রে কোন অধঃগামী প্রবণতা পরিলক্ষিত হয় নাই। লবণাক্ততা চারা জন্মানোর হারকে প্রভাবিত করতে পারে এবং লবণাক্ততা বৃদ্ধির সাথে সাথে চারার সংখ্যা হ্রাস পায়। চারার ঘনত্বের সাথে গাছের সংখ্যার কোন তাৎপর্যপূর্ণ সম্পর্ক পরিলক্ষিত হয়নি। কিছু এলাকার প্লটে প্রচুর সংখ্যক চারার আবির্ভাব হয়। অবশ্য কম লবণাক্ত এলাকায় ১১·১৫ মাসে এবং অধিক লবণাক্ত এলাকায় ১০·১০ মাসে সুন্দরীর অর্ধেক চারা মারা যায়। গেওয়ার ক্ষেত্রে ইহা যথাক্রমে ৭·১৫ এবং ১১·৮০ মাস। অন্যান্য প্রজাতির সমস্ত চারা ২৭ মাসের মধ্যে মারা যায়। চারার টিকে থাকার ক্ষেত্রে লবণাক্ততা ছাড়া অন্যান্য ক্ষতিকর কারণ থাকতে পারে।

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INTRODUCTION

The Sundarbans, the largest continuous mangrove forest in the world, is located at the southern extremity of the Ganges River Delta i.e. plain bordering the Bay of Bengal to the south. The forest covers a total area of about 10,000 km^2 of which 62% falls within the territory of Bangladesh while the remaining portion belongs to India (Hendrichs 1975, Chakrabarti 1984). The Bangladesh part of the Sundarbans, spreading over an area of 5,800 km^2, lies between the latitudes 20° 31 and 22° 31 N and the longitudes 89°E and 90°E. *Heritiera fomes* is the principal species constituting 73% of the growing stock followed by *Excoecaria agallocha* (16%). Other minor species are *Xylocarpus mekongensis, Sonneratia apetala, Avicennia officinalis, Ceriops decandra and Nypa fruiticans (Forestal* 1960, Choudhury 1968). According to ODA (1985) *H. fomes, H. fomes - E. agallocha, E. agallocha- H. fomes and C.decandra - E. agallocha* forest type covered 21%, 29.7%, 14.8% and 14.46% of the area respectively. Chaffey and Sandom (1985) listed 66 tree species from the Sundarbans.

The Sundarbans of Bangladesh may broadly be divided into three zones as per Hassan (unpublished); according to degree of salinity of soil - slightly saline, moderately saline and strongly saline zones (Figure 1). *H. fomes* grows well in areas inundated by tides with low degree of salinity (Troup 1921) and is the dominant species in the slightly saline zone while *E. agallocha and H. fomes* predominate in the moderately saline zone. *C. decandra* is the major species in the strongly saline zone, generally accompanied by a sparse distribution of *E. agallocha.*

The forest is managed under a selection system with a 20-year felling cycle (Khattak 1979). Productivity of the forest is higher in the slightly saline zone where vegetation is dense, followed by the moderately saline zone. In the strongly saline zone, vegetation is sparse and productivity is low. The average annual wood productivity of the forest is 1.12 m^3/ha (Khan 1977).

Regeneration is inadequate over the greater part of the forests. Shafi (1982) claimed that regeneration decreased by 100% in 1981 as compared to that of 1959-60. Natural regeneration is insufficient in the Indian Sundarbans also. Attempts were made for artificial regeneration with mangrove species in Bangladesh (Habib 1982, Siddiqi 1986) as well as in Indian Sundarbans (Banerjee and Choudhury 1986). Regeneration is a problem in Thailand and Malaysia also where commercial exploitation of forest is practised (FAO 1982).

As the Sundarbans is a natural forest, it is absolutely dependant on natural regeneration for future stocking. Scientific studies have not yet been made to investigate into the causes and quantify any decline of regeneration. Regeneration may be affected by an increase in salinity, reduction of number of "seedling" trees, inadequate seed production, rising of land, formation of depressions, changes in soil character, period of inundation or other related factors. The Mangrove Silviculture Division of Bangladesh Forest Research Institute (BFRI) has been collecting information on seedling regeneration since 1981. The present paper reports on the status of seedling regeneration in different sample areas of the forests including regeneration

patterns in relation to time and varying degree of soil salinity.

MATERIALS AND METHODS

Twelve permanent sample plots, each with an area of 400 m^2, were laid out in 1981 on a stratified random basis in different salinity zones vis-a-vis different site quality classes of the Sundarbans (Figure 1). Since then these plots were visited twice a year during May (premonsoon) and November (post monsoon), and data on the appearance and survial/longevity of seedlings of different species were collected by using a circular quadrat having an area of 0.75 m^2. Sixteen points were demarcated in each plot by 4 stakes each to the north, the south, the east and the west equidistant from the centre of the plot. Data were recorded from only these fixed spots by placing the quadrat with its centre on the wooden stakes.

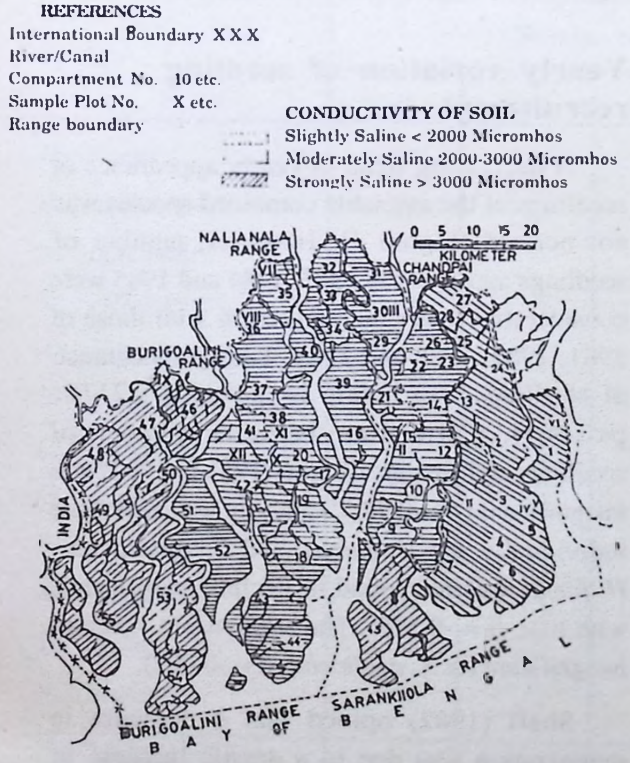

Figure 1 Map of the Sundarbans showing the locations of permanent sample plots in different salinity zones

It was desirable to have a higher number of sample plots to represent the large forest but owing to logistic constraints, the number could not be increased. By and large, germination of seeds of different species completed by September (Das and Siddiqi 1985). Consequently the first visit was made during November to record the emergence of seedlings and mortality of seedlings of previous year. The second visit during May was made only to record further mortality of seedlings. Such recording of data contained for 33 months. The species composition and diameter class of the trees in each of the plots were also recorded in 1981 and 1983.

Soil salinity in the Sundarbans reaches its peak during April-May (Shafi 1982, Hassan 1984). Accordingly, soil samples (surface to 15 cm depth) from 12 sample plots were collected in May, 1986. The samples were analysed in the BFRI for salinity and texture. It was found that soils were silty clay or silty clay loam. Soils of the forests are generally neutral to mildly alkaline and pH value does not vary sufficiently (Hassan and Razzaque 1981 and Alim 1984) to influence regeneration. So, tests for pH of the soil of the sample plots were discontinued subsequently.

RESULTS AND DISCUSSION

An inventory made in the Sundarbans (ODA op. cit) showed a depletion in the merchantable standing volume of *H. fomes* of the order of 40% and a decrease in that of *E. agallocha* of 45% over the period from 1959 to 1983. There has been a

serious fall of forest stands during the recent years. Such a decrease in standing volume might be due to over-exploitation of the forest though it is managed on a sustained yield basis. Inadequate recruitment of new regeneration during this period cannot be ruled out as one of the causes. Two main problems with seedlings regeneration were noticed - firstly, the appearance of insufficient numbers of seedlings and, secondly, the failure of the appeared seedlings to survive and establish.

Status and composition of seedling recruitment

The first observation during November showed the number of seedlings that appeared during the year. A total of 3591 new seedlings were recorded during the period from 1981 to 1987 in the sample plots over an area of 144 m^2 (0.75m^2 x 16 x 12). Average number of seedlings appeared per year was 35,625/ha.

Figure 2 suggests a wide variation in appearance of seedling among the sample plots (χ^2 = 4939; p<0.001). Such variation individually exists for *H. fomes* (χ^2 = 4770; p<0.001) and *E. agallocha* (χ^2 = 5147; p<0.001) and other species together (χ2 = 264; p<0.001). Of the seedlings (3 months) recorded, *H. fomes* alone consisted 41.27%, *E. agallocha* 54% and the remaining 4.73%, consisted of other species namely, *A. officinalis, X. mekongensis, Aegiceras corniculatum, Bruguiera gymnorrhiza, C. decandra, Cynometra ramiflora, Phoenix paludosa, Amoora cucullata* and *S. apetala* (Figure 3 and Table 1).

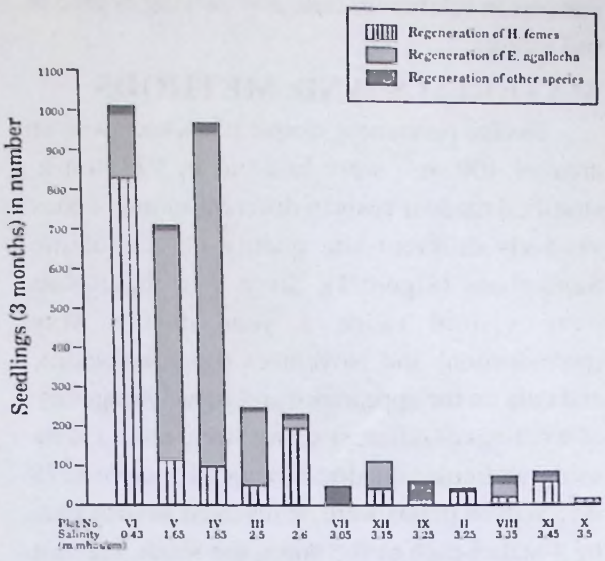

Figure 2. Total yearly appearance of different species of seedlings during the period from 1981 to 1987 in 12 permanent sample plots

Yearly variation of seedling recruitment

A decreasing trend in yearly appearance of seedlings of the available combined species was not noticed (Figure 4). However, number of seedlings appearing in 1983, 1984 and 1985 were considerably lower in comparison with those of 1981, 1982, 1986 and 1987. Yearly appearance of seedlings was highly irregular (χ^2=2110; p<0.001). Correlation between number of seedlings and passage of time (1981 to 1987) was insignificant (r = -0.74.). Analysis was also made individually for *H. fomes* and *E. agallocha*. *H. fomes* was not found to decline significantly with time (r = -0.575). The relationship was also insignificant for *E. agallocha* (r = -0.002).

Shafi (1982) opined that a decrease in regeneration was due to a drastic increase in

salinity of the Sundarbans. Monthly soil salinities were recorded during the period of study from the representative salinity zones. Yearly salinity of the Sundarbans as computed from means of monthly salinity of the representative zones from 1981 through 1987 were 2.22, 3.14, 3.27, 2.97, 3.32, 3.87 and 4.37 m. mhos/cm respectively. When yearly salinity was plotted against number of seedlings of the corresponding years, the correlation was not significant (r=-0.040). The correlation was also insignificant independantly for *H. fomes* (r = 0.467) and *E. agallocha* (r = 0.232).

Siddiqi (unpublished) observed variation in yearly production of seeds for *H. fomes* and *E. agallocha* and suggested that such variation might influence yearly availability of seedlings. However, Hassan and Howlader (1971) claimed that there was no periodicity in *H. fomes*.

Seedling density in three salinity zones

The sample plots were located in slightly saline (soil salinity <2 m.mhos/cm), moderately saline (2-3 m.mhos/cm) and strongly saline (>3 m.mhos/cm) areas. However, the soil salinity of all the plots was analysed and found to vary from the general salinity classification of the forest due to some local factors. A significant variation was

Table 1. Status and composition of seedling recruitment (3 months) for 12 plots

Species	Number of seedlings (3 months) for 12 plots						
	1981	1982	1983	1984	1985	1986	1987
H. fomes	604	436	2	114	4	43	279
E. agallocha	92	736	153	72	9	746	131
A. officinalis	-	-	1	-	3	29	10
X. mekongensis	2	1	-	2	5	22	1
A. corniculatum	-	1	-	1	9	9	6
B. gymnorrhiza	-	3	-	-	5	7	9
C. decandra	-	5	-	-	2	7	3
C. remiflora	-	4	-	2	-	4	-
P. paludosa	-	-	-	-	-	4	6
A. cucullata	-	1	-	1	-	1	-
S. apetala	-	3	-	-	-	-	-
N. fruticans	-	-	-	-	-	-	-
Mean soil Salinity (m. mhos / cm)	2.22	3.14	3.27	2.97	3.32	3.87	4.37

found among the areas of different degrees of salinity in respect to availability of seedlings (Figure 2) when χ^2 test was done (χ^2 = 398; p <0.001). Such variations were found to be

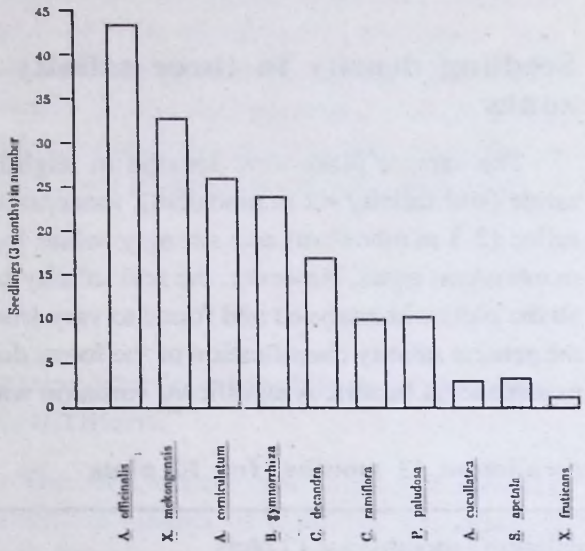

Figure 3. Total appearance of seedlings of different species other than *H. fomes* and *E. agallocha* during the period from 1981 to 1987 in 12 permanent sample plots

significant individually for *H. fomes* (χ^2 = 325; p <0.001) and *E. agallocha* (χ^2 = 706; p <0.001). On average, plots in slightly saline, moderately saline and strongly saline areas contained 127.85 seedlings, 34 seedlings and 8.77 new seedlings respectively in an area of 12 m^2. The figures for *H. fomes* in slightly, moderately and strongly saline areas were 49.85, 18.64 and 3.55 seedlings respectively and for *E. agallocha* 76.61, 14.46 and 2.55 seedlings respectively.

Attempts were made to find out the causes of the wide variation in the quantity of seedlings in different parts of the forests. Numbers of newly appearing seedlings in the sample plots for the period from 1981 to 1987 were plotted against soil salinity of the plots. It was found that total number of seedlings significantly decreased with the increase in the degree of salinity (Figure 5), the value of being - 0.935; (p <0.001). The correlation coefficients for *H. fomes* (r = -0.832; P<0.001) and *E. agallocha* (r = -0.577; p<0.05) were also significant. Both *H. fomes* (Troup op. cit) and *E. agallocha* (Saenger 1986) prefer low salinity areas. Both the species were virtually confined to slightly saline and moderately saline zones.

Recruitment in relation to standing trees

Vegetation is dense in the slightly saline zones followed by moderately saline zone. In the strongly saline zone vegetation is sparse. The standing trees (trees above 5 cm diameter at breast height) were measured for each sample plot. No significant relationship between the number of standing trees of a plot and its seedlings status existed (r = 0.066).

As trees were the source of seed supply and might also help in the anchorage of seeds, it was expected that a relationship existed between tree density of the plot and availability of seedlings. It seemed that seeds falling on the forest floor of the plots were washed away by tide water and, either failed to germinate or germinated in a locality with different site characteristics. Owing to paucity of relevant data, it was not possible to study the effect of elevation of ground (raised, depression, etc.), duration of inundation, behaviour of currents or changes in soil on the availability of seedlings. These factors also might have influenced the regeneration patterns.

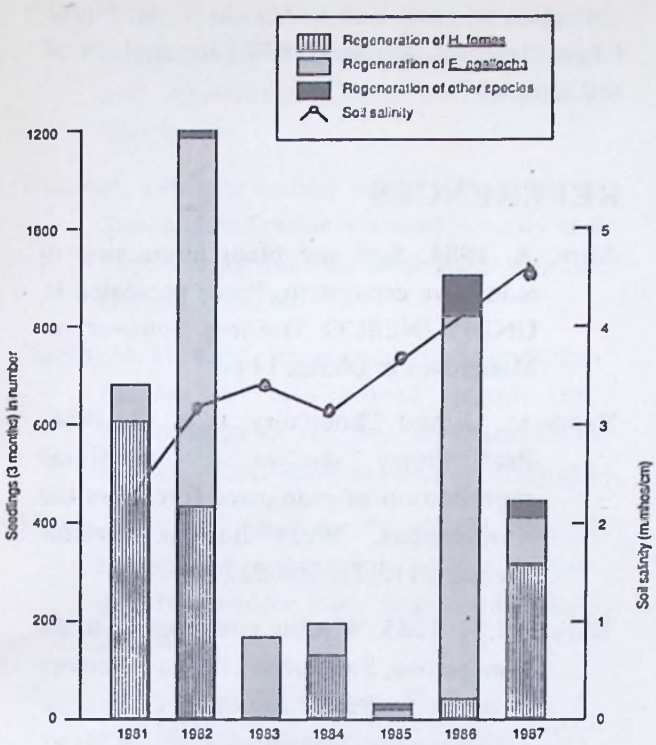

Figure 4. Yearly appearance of seedlings of diferent species during the period from 1981 to 1987 over an area of 144m² in the combined 12 permanent sample plots and soil salinity of the forest

Survival of seedlings

In some plots, abundant seedlings appeared (Figure 2) but most of these seedlings disappeared within a couple of years (Figure 6). Causes for failure of these seedlings to establish themselves are not known. Salinity, again, may have a role to play in seedling survival. Respective percentages of survival of seedlings up to 33 months for *H. fomes* in less saline (<3 m. mhos/cm) areas were 9.42 and 4.05 in strongly saline (>3 m. mhos/cm) areas. Survival of *E. agallocha* in less saline areas was 0.31% compared to 12.84% in strongly saline areas. This showed better survival of *E. agallocha* in more saline areas compared to that of *H. fomes*. Seedlings of other species could not establish themselves and disappeared within 27 months.

Seedling half-life (i. e., time for 50% of seedlings to disappear) for *H. fomes* in less saline areas and strongly saline areas was 11.15 and 10.10 months respectively. Half-life for *E. agallocha* in these two salinity areas was 7.15 and 11.80 months respectively. Half-life for other species in the combined salinity areas (12 sample plots) was 7.30 months.

Factors other than salinity might also be invloved in the survival of seedlings. For example, the rate of disappearance of *H. fomes* seedlings during dry seasons, when salinity is higher, was 34.60%, whereas during wet seasons, when salinity was considerably lower it was 54.07%. *E. agallocha* showed the opposite behaviour; 79.60% of seedlings disappeared during dry seasons and only 18.60% during wet seasons.

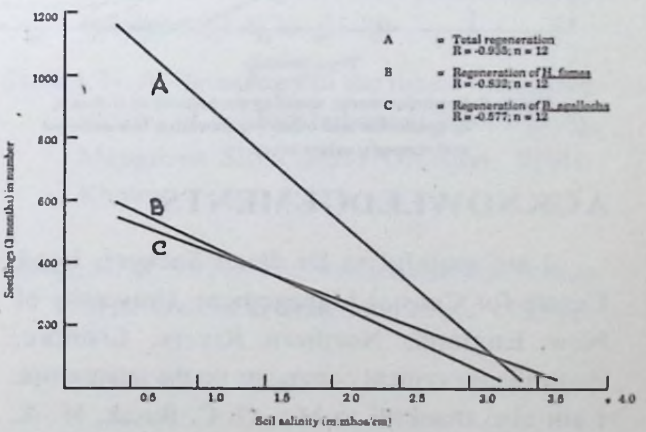

Figure 5. Relationship between salinity and availability of seedlings

Studies in Australian mangroves have shown that around 90% of seedlings of some species, particularly *Avicennia marina*, are removed within a week of arriving by grapsid crabs (Dr. Peter Saenger, personal communication). In the Sundarbans, the Spotted deer *(Axis axis)* with a population size of 80,000 individuals (Hendrichs as quoted by Blower 1985) are likely to play an important role in controlling seedling regeneration.

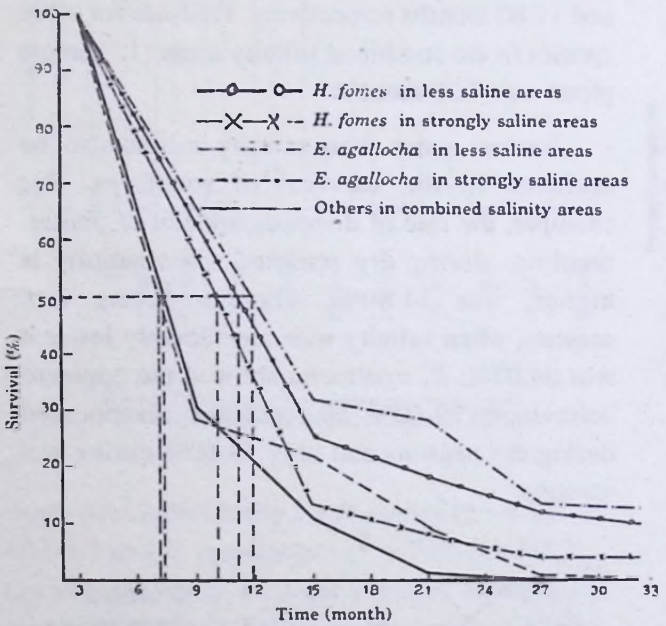

Figure 6. Depletion curve showing the half-life of *H. fomes*, *E. egallocha* and other regeneration in less saline and strongly saline areas

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