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Evaluation and Comparison of Mixed Tree Plantation Performance Using Survival-growth Index Formula

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ABSTRACT

Plantation of different tree species with different purpose is an old time practice. Scope of plantation has been improving with the development of silviculture practice, agro-forestry and all other industrial sectors that depend on the trees. Measurement of growth and survival seems the very first step for every type of plantation measurement for their performance, suitability and productivity. It is found that for every tree species height and diameter profile varies from site to site, climatic factors and for other conditions. The survival of individuals also varies in every case. In such cases, if we measure the growth dimensions of a tree species with the survival then it becomes very confusable or tough to state that which plantation or what species is performing better. These questions become even more difficult in cases of mixed plantation. Hence, a simple formulation of 'Survival growth index' is presented in this article to describe the performance of the tree plantation stands. This 'Survival growth index' is found very useful to evaluate the performance of a plantation whether it is a single species or a mixed plantation. The evaluated value of SGI for a plantation of specific age can state its performance using height and diameter profile with the survival percentage.

Key words: Survival and growth index, forest types, tree plantation, height and diameter

INTRODUCTION

Trees have significant impact on the urban microenvironment being natural environment conditioners providing climate buffering services, shade (Rao *et al*., 2007; Nowak *et al*., 2000; Myrup *et al*., 1991), aesthetic beauty including scenic and salubrious pleasure (Talbott *et al*., 1976). Plantations are helpful in reducing noise pollution (Fan *et al*., 2010; Fang and Ling, 2005) act as effective carbon sink (Graham *et al*., 1992), supplier of vital oxygen (Broecker, 1970) conserve soil and water (Gokturk *et al*., 2006). Ecologically, some species assume importance for their conservation because they provide appropriate habitat and support specific and distinct population of flora-fauna thus responsible for biodiversity maintenance (Salamanca *et al*., 2002; Kukshal *et al*., 2009; Kashian *et al*., 2003; Shameem *et al*., 2010; Rouhi-Moghaddam *et al*., 2007; Goma-Tchimbakala and Makosso, 2008). On the other hand, scope of plantation has also been improving with the development of silviculture, agro-forestry and all other industrial sectors that depend on the trees. According to Piotto (2007), the performance of planted native species of economic importance (timber woods) must be known to precisely prescribe appropriate species for enrichment planting for selecting potential species and predict their response.

It is found that for every tree species height and diameter profile and survival are very obvious to be varied from site to site, climatic factors and for other conditions (Piotto, 2007). On the basis of growth dimensions and survival of a tree species it becomes very confusable or tough to state that which plantation or species is performing better. These questions become even more difficult in cases of mixed plantation. In many studies the performance of the different tree plantations have been evaluated by some simple measurement and statistics (Makela *et al*., 2000; Sievanen, 1993; Landsberg and Waring, 1997; Valentine *et al*., 1997; Bartelink, 1998; Albrektson and Valinger, 1985; Hashim, 2005; Piotto *et al*., 2003). Whereas, in some studies (Sievanen *et al*., 2000; Cao *et al*., 2002; Ritchie and Hann, 1986) some predication models also have been developed for tree plantation stand performance, growth and productivity. Sievanen (1993) presented a model for dimensional growth of even-aged stands and Peng (2000) studied several growth and yield models for uneven-aged stands while discussing nature and significance of these models.

The problem is lack of previous data availability (Makela *et al*., 2000) and if such records can be maintain at the time of the plantation the performance of the plantation can be estimated more easily and directly. Hence, a sophisticated formulation of 'Survival Growth Index' is presented in this article to describe the performance of the tree plantation stands.

The main objective of this study was the establishment and implementation of Survival-Growth Index formula to evaluate mixed tree plantation performance comparatively.

MATERIALS AND METHODS

The present study highlights status of tree plantation at a degraded and derelict area of approximately 55 acres situated in Dehradun city, capital of Uttarakhand state India. The site is located in the campus of Survey of India's Headquarters in Dehradun. Before the ecological restoration work, this land piece was characterized by natural waterways to drain the excess rain water ruining in north south direction through gullies and badly eroded undulating slopes. The site was represented by degraded sub-tropical dry deciduous forest with very sparse trees and shrubs. In the eco-restoration plan this site is developed into a park. The selected tree species were planted at this site under these two classified purposes:

- **Development of the major Indian forest types:** To symbolize the great diversity of Indian forests; five different forest types *viz*. tropical evergreen forest, tropical moist deciduous forest, tropical dry deciduous forest, tropical pine forest and subtropical hill forest types have been raised
- **Avenue plantations:** Different tree species e.g., *Pterospermum acerifolium, Peltophorum ferrugineum, Cassia javanica, Pterygota alata, Putranjiva roxburghii* and *Grevillea robusta,* have been planted on the path sides as avenue plantations

These tree plantations were measured for their current height, diameter and survival and discussed with the help of formulation of 'Survival Growth Index' to describe the performance of the tree plantation stands.

The tree species grown in the 5 different forest types and in the 5 avenues at the selected site have been measured for their survival and growth observations in March, 2011. All the tree species were identified and numbers of individuals were counted separately for every species at each area. Height and diameter of each individual of every species were also measured.

This present data set has been put into analysis with the previous information (recorded at the time of plantation in the year 2005 by the Forest Ecology and Environment Division, F.R.I., Dehradun, India). The average values of heights and diameter of present and previous observations are used for the calculations.

In order to show the collective status of survival and growth for each species a simple formula of 'Survival-growth Index' has been developed and applied as following:

$$\text{SGI} = \frac{\%\ \text{Survival}}{100} \times \left[\text{Height increment}\,(\%) + \text{Diameter increment}\,(\%)\right]$$

Where:

$$\text{Height increment}\,(\%) = \frac{\text{Present height}}{\text{Initially recorded height}} \times 100$$

$$\text{Diameter increment}\,(\%) = \frac{\text{Present diameter}}{\text{Initially recorded diameter}} \times 100$$

$$\text{Survival}\,(\%) = \frac{\text{Present number of individuals}}{\text{Number of initially planted individuals}} \times 100$$

The height of the trees was measured directly by lifting the measuring tape end up to the highest twig of the tree with the help of straight bamboo trunks of different lengths up to the 10 meters and in the cases of the higher plants Haga Altimeter was used. Diameter was measured with help of caliper and for distribution of diameter range more efficiently with the height range diameter was measured at the base for up to 2 m tall plants, at 30 cm from the base for >2-4 m tall plants, at 75 cm from the base for >4-6 m tall plants. For the plants more than 6 m tall the diameter of the trunk was measured at breast height i.e., 130 cm from the base.

RESULTS

All results have been shown in the form of graph (Fig. 1-6) for each type of plantation. In all graphs Y-axis represents the % increment in diameter and height collectively in the form of vertical bars. Percentage of the survival of every species is shown at the top of the bar for every species. A mark of SGI value is shown inside the each bar using the same units on Y-axis. All the species in the graphs have been arrayed in the increasing order of SGI values.

The overall survival in Tropical Evergreen Forest type (Fig. 1) is found 73.33% as at the time of study only 33 species were found surviving out of 45 species planted initially. Among all the 33 surviving species the least SGI is shown by *Cassia fistula* (251.05). The highest growth increment was shown by *Caryota urens* (1924.56%) and *Ficus religiosa* (1884.46%). Three species *Agathis Robusta, Hyophorbe lagenicaulis* and *Anthocephalus chinensis* showed 100% survival. *Syzygium cumini* is standing with higher growth (1861.01) and higher survival (93%) with highest SGI (1736.94) followed by *Cinnamomum camphora* which showed 1777.36% growth increment and 95% survival with SGI 1688.89.

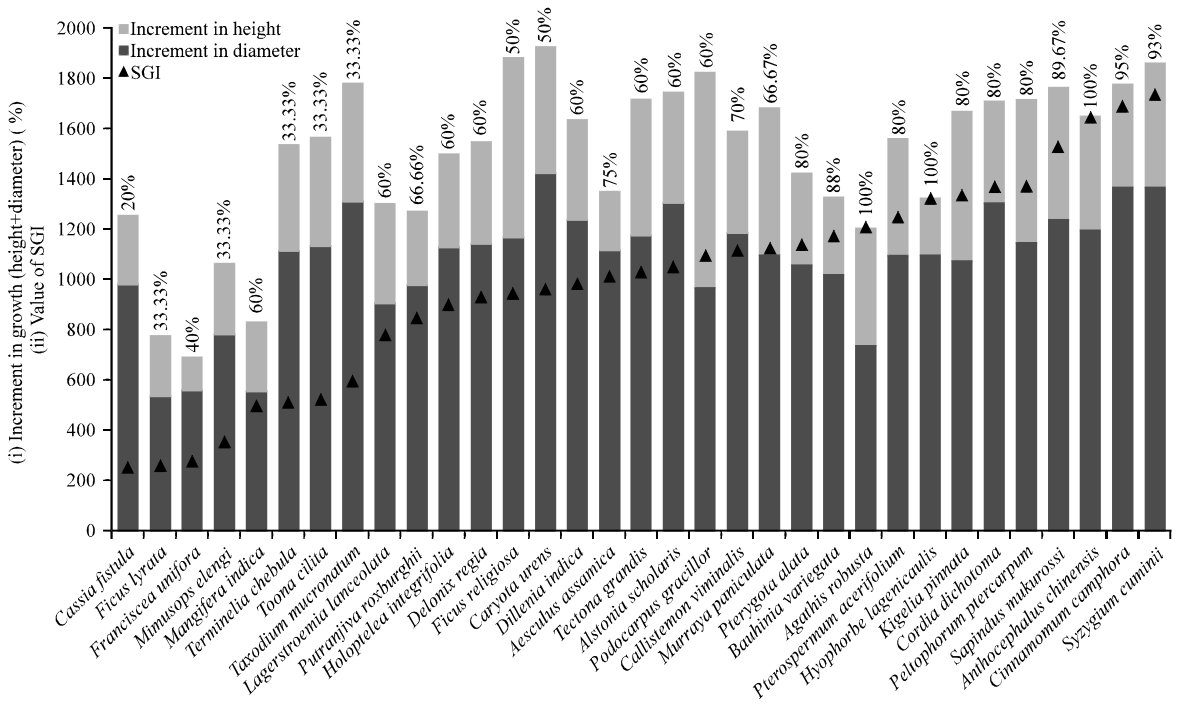

Fig. 1: Tropical evergreen forest type, percentage of the survival of every species is shown at the bar for every species

Six species that were found growing with a high survival and a high growth profile are *Pterospermum acerifolium*, *Cordia dichotoma*, *Kigelia pinnata*, *Anthocephalus chinensis*, *Peltophorum pterocarpum* and *Sapindus mukorossi*.

It is also clear from the graph that five species were flourishing with high growth and moderate survival, these are *Tectona grandis, Alstonia scholaris, Podocarpus gracilior, Callistemon viminalis* and *Murraya paniculata* while four species showed moderate growth with high survival are *Pterygota alata, Bauhinia variegata, Agathis robusta* and *Hyophorbe lagenicaulis*.

Terminalia chebula, Taxodium mucronatum, Toona ciliata, Ficus religiosa and *Caryota urens* possessed high growth and less survival in the surviving species. *Cassia fistula* and *Mimusops elengi* were standing with moderate growth and a less percentage of survival while *Ficus lyrata, Franciscea uniflora* and *Mangifera indica* were found to be showing very less growth and less survival and therefore showed least SGI values.

In the Tropical Moist Deciduous Forest type (Fig. 2) 8 species are surviving out of 11 planted initially hence the overall survival is 72.73%. Among the surviving species *Chukrasia tabularis* showing least SGI (324.92) due to less percentage of survival (40%) and lesser increment in growth (812.30%). *Terminalia myriocarpa* is also showing lesser SGI value (1037.19) with 60% survival.

Mallotus philippensis, Cordial dichotoma, Terminalia chebula and Cinnamomum camphora were standing with moderate growth and high survival while showing moderate values for SGI. *Mallotus philippensis* and *Cinnamomum camphora* showed 90% survival. Two species i.e., *Lagerstroemia lanceolata* and *Toona ciliata* were showing higher SGI (1727.11, 1667.08) values due to higher increment in growth (2031.90 and 2083.85%) with higher survival values (80 and 85%) among all the species.

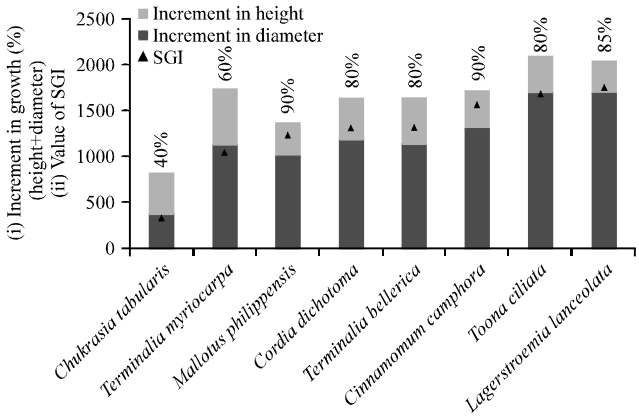

Fig. 2: Tropical moist deciduous forest type, percentage of the survival of every species is shown at the bar for every species

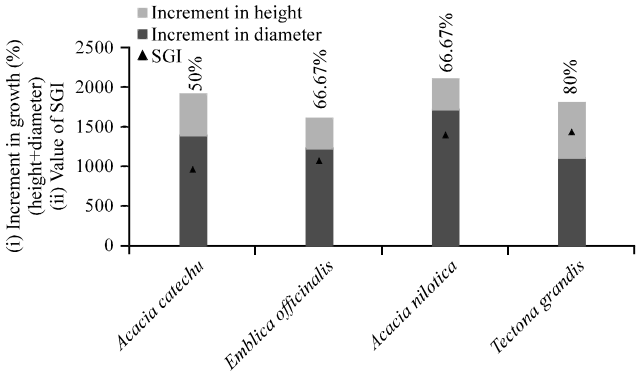

Fig. 3: Tropical dry deciduous forest type, percentage of the survival of every species is shown at the bar for every species

In the Tropical Dry Deciduous Forest type (Fig. 3), only 4 species out of 7 were found to be surviving and the aggregate survival value was 57.14%. *Acacia catechu* showed least value of SGI (957.98) with moderate growth performance while *Emblica officinalis* also showed a lesser value of SGI (1069.27) with least growth increment among the all surviving species. Highest growth increment (2096.09%) was showed by *Acacia nilotica* with SGI (1397.39) and the highest value of SGI was showed by *Tectona grandis* (1435.41) with highest survival (80%) and moderate growth (1125.66%) in comparisons to all the surviving species in this forest type.

In the Sub-tropical Pine Forest type (Fig. 4), the aggregated survival was found 100% as all the seven species planted were found surviving. Among these species *Shorea robusta* is showing least value of SGI (230.56) due to less growth increment and less survival. *Pinus roxburghii* was also showing less growth and less survival and overall a less SGI value 371.32 in comparison to other species.

Least growth was shown by *Holoptelea integrifolia* with 66.67% survival. *Syzygium cumini*, *Mallotus philippensis* and *Emblica officinalis* have showed moderate increment in growth

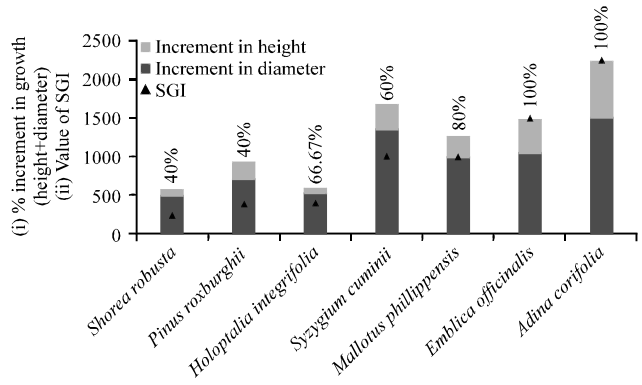

Fig. 4: Subtropical pine forest type, percentage of the survival of every species is shown at the bar for every species

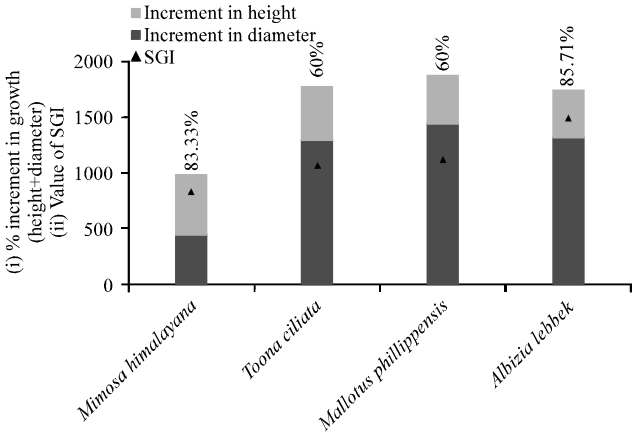

Fig. 5: Subtropical hill forest type, percentage of the survival of every species is shown at the bar for every species

with moderate survival. *Emblica officinalis* and *Adina cordifolia* possessed 100% survival. *Adina cordifolia* stands with highest SGI value (2229.88) pertains to highest increment in growth (2229.88%).

In the case of Sub Tropical Hill Forest type (Fig. 5), 4 species were found surviving out of 5 planted initially. *Shorea robusta* could not be detected surviving. The least SGI value is shown by *Mimosa himalayana* (824.71) due to less increment in the growth. *Toona ciliata* and *Mallotus philippensis* were growing with a good growth profile and moderate percentage of survival i.e., 60%. *Albizia lebbeck* showed 85.71% survival and high growth increment hence, standing with the highest value of SGI (1489.21).

In the case of all avenue plantations (Fig. 6), *Peltophorum ferrugineum* showed highest value of SGI (2395.02) with highest growth increment (2737.17%) and 87.50% survival. *Cassia javanica* has showed 83.33% survival and 2656.36% increment in growth hence found with 2213.63 SGI. *Grevillea robusta* and *Pterospermum acerifolium* were showing medium increment in the growth profile with medium values of SGI (2002.75 and 2031.95, respectively). *Putranjiva roxburghii* and *Pterygota alata* are showing less increment in the growth and less % of survival hence least SGI values (1148.89 and 1384.96, respectively).

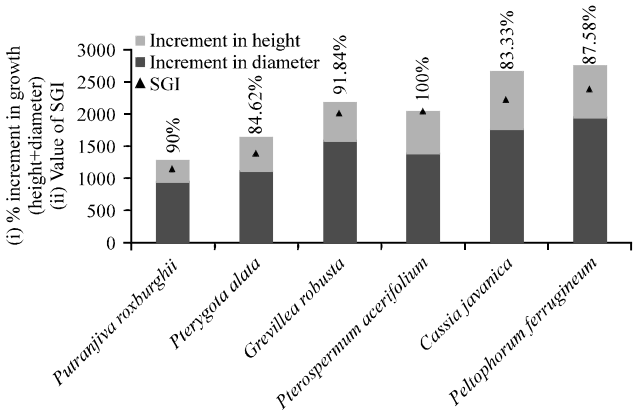

Fig. 6: Avenue plantations, percentage of the survival of every species is shown at the bar for every species

DISCUSSION

According to the previous information total 67 species were planted initially at these 5 different forests types and 5 avenues (in the year 2005). In the present evaluation only 52 species were found surviving (79% survival). On the basis of the SGI values, it was found that *Peltophorum ferrugineum* stands with the highest SGI value among all the species among all the sites. Other species that showed higher values of SGI are *Cassia javanica, Syzygium cumini, Grevillea robusta, Cinnamon camphora, Adina cordifolia, Tectona grandis, Albizia lebbeck* and *Toona ciliata*. Name of some species that showed a very less growth and survival profile with lesser values of SGI, were *Shorea robusta, Ficus lyrata, Franciscea uniflora, Mangifera indica, Cassia fistula, Mimusops elengi and Mimosa himalayana*.

In the above discussion, SGI values were used as a key to evaluate and to compare the tree growth performance in all the dimensions *viz*. for single species performance at a single site, comparison of single species performance with other species at a single site, comparison of single species performance with the same species at others sites and comparison of all species performance with other species at a single site or with other sites. The scope and limitations of SGI have been discussed further under following points.

Scope of the SGI formula: SGI can be used for a single species plantation at a single site. This SGI value can be recorded as a value for this particular stand for that particular age and can be used for the next evaluation of same plantation as well as other stands of the same species of same age at different times and other locations. This index can also state the performance of the different plantation stands of a single species planted at different sites at the same time.

This index can also be evaluated for all the species in a mixed plantation. In such case the SGI value can state that which species are fast growing or most suitable and vice versa, as a result a ranking of performance can be developed. If such mixed plantations of same age are being grown at different locations then SGI values can differentiate all the species separately at each site. Thus, the comparison will be more clear and easy and it can also be evaluated that in a mixed plantation which species are performing better among all the species.

This index is not only useful in the research field but also have great applicability for the industries. This formula can be recommended as an important tool for the Clean Development

Mechanism and Carbon Trading projects involving tree-plantation. If in the plantation projects, all initial data is recorded then the performance of that objective plantation can be simply estimated.

Input requirements of the formula and cautions: A base data of the subjective plantation (i.e., value of parameters at the time of plantation) is very much needed to apply this formula. This base data comprises of average values of initial height and diameter with the number of individuals planted initially.

These following points should also be considered carefully for more accuracy. (A) All the individuals must be counted. (B) A balanced number of individuals should be measured according to the size of plantation to obtain the average height and diameter values. The more number of sample trees measured for the average values of the height and diameter more will be representativeness of SGI.

In case of direct seeding the base data can be taken after 3-6 month after germination. The number of individuals at this stage can be considered as initial number of the individuals and the height and diameter can be recorded at this time as base data. In such cases germination percentile is of no use for this formula.

There may be different ways to measure tree heights. A direct and accurate measurement of height (Solomon and Nolet, 1968) is recommended for the accuracy of SGI. Although it is very difficult in the cases of very tall stature species. It must be noted that SGI varies very sharply with the time for young growing plantations but shows mere fluctuations for mature plantations.

Conventionally, diameter is measured at breast height for trees but for the better applicability of the SGI, the trunk diameter is recommended to be measured at the base for up to 2 m tall plants, at 30 cm from the base for >2-4 m tall plants, at 75 cm from the base for >4-6 m tall plants. For the plants more than 6 m tall the diameter of the trunk can be measured at breast height i.e., 130 cm from the base. This method distributes the diameter range more efficiently with the height range. Taking diameters only at two points (i.e., at the base in smaller individuals or at the breast height in higher individuals) has not been found suitable practically as in many cases the basal diameter of a 4 m tall plant may be more than the DBH of a 6 m tall tree of the same species. This way of measurement may lead to the high inaccuracy in determining of SGI values (human error).

Limitations: The value of SGI is strictly age dependent and varies with age of the stand. The comparison in plantations using SGI (at different sites, for single species plantations or mixed plantations) can be made only when these have attained same age whether at the same time or in different periods.

It is a notable point that range of SGI differs species to species. The higher SGI value for the same age of a species just meant to indicate that this species is fast growing or more suitable one. A low SGI value also never indicates the worse performance of any species. It may be that this species have the range of this much SGI that pertains to its physical stature. If a higher SGI range species showing lesser SGI or vice-versa in different stands or at different locations then of course this abnormality can be a serious issue.

All the factors which control the growth of plants also influence the SGI values directly e.g., the nursery techniques used to grow seedlings (i.e., genetic purity or similarity, the size and the shape of containers, composition of media etc.) and methods of plantation (i.e., pit size, distance between

pits, application of manure etc.). Other factors which influence the SGI values are climatic, edaphic and anthropogenic activities. These factors can be justified by the observer at the time of interpretation.

Goodness/specification of the formula: The values of SGI can separately state the performance of those plantations that appear identical superficially because even minor differences in the plantation performance affect the SGI values. There is no need for the units to be same for height and diameters. The SGI value does not hold any unit as an outcome of only percentage forms.

CONCLUSION

The 'survival growth index' is found very useful to evaluate the performance of a plantation whether it is of a single species or a mixed plantation. The evaluated value of SGI for a plantation of specific age can state its performance using height and diameter profile with the survival percentage. Further this index is also found useful in the case of different plantation stands at different sites or conditions to state that which stand is flourishing better than the others. In brief SGI is a mathematical device that can be very helpful to describe the performance of the plantation in a very easy and simple way, in different cases. It is recommended to make an account of the growth parameters of the seedlings at the time of plantation with the number of the planted individuals. This index can be very useful to observe the plantation performance and estimate their economic benefit in the CDM projects and industrial purposes. This index also has great potential to be used or modified in the volume and productivity models.

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