Growth performance of indigenous tree species under uneven-aged forest management in Northeast Thailand

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Abstract

For the purpose of conversion of a fast-growing tree plantation into indigenous tree forest in monsoon Asia, growth performances of indigenous tree species under various light conditions were examined. An uneven-aged (two-aged) system in which indigenous trees were underplanted in a fast-growing tree plantation was applied for this conversion on a trial basis in the Sakaerat Silvicultural Research Station, Northeast Thailand. Experimental plots were established from 1987 to 2009 and survival rates and growth in terms of the height of indigenous tree seedlings were examined under various forestry operations (free selection thinning, stripe thinning, group selection thinning in two-aged system, and even-aged system). The results suggest that *Dipterocarpus alatus*, *Hopea odorata*, and *Dalbergia conchinchinensis* could be planted in an open site without a two-aged system. It was recommended that other dipterocarp species (*D. turbinatus*, *H. ferrea*, and *Shorea henryana*) be planted under a two-aged system. Since *H. odorata* and *Xylia xylocarpa* var. *kerrii* adapted to various light conditions, they could be applied to both even- and uneven-aged systems. Group selection thinning was recommended in terms of both the growth performance of the seedlings and the efficiency for logging, when a two-aged system was selected.

Keywords: growth of seedling, light condition, nurse tree, survival rate, thinning

Introduction

Indigenous tree species are expected to provide high-value timber and contribute to the conservation of biodiversity as well as local cultures against the background of decrease and degradation of forest resources around the world (FAO 2010). However, silvicultural techniques for indigenous tree species have not been improved compared with those of exotic fast-growing trees owing to limited experience and a lack of information about site suitability and growth performance in a given environment (Montaginini and Jordan 2005).

One of the negative factors that could bother afforestation of indigenous tree species is high mortality of seedlings, such as that caused by strong sunlight in an open site (Norisada et al. 2005; Hattori et al. 2009). In order to deal with this, uneven-aged forest management (UAFM) has been examined in tropical areas (Kamo et al. 2009; Norisada et al. 2005; Sakai et al. 2009). Advanced studies on uneven-aged forest called “enrichment planting” have been conducted in Malaysia (Chan et al. 2008). Most of them have followed a “two-aged system” in which advanced stands are thinned in a given pattern (random selection, stripe, and group selection) for succeeding stands. In this system, residual canopy trees (nurse trees) are expected to mitigate the effects of strong sunlight on young seedlings. Fire in the dry season is one of the main factors that hamper the establishment of forest plantations in the monsoon climate in Thailand (ITTO 2006). Planting fast-growing trees in large degraded areas of land was significantly effective for containing fires because they covered the ground quickly and suppressed grasses, which often cause fires in the dry season. Thus, planting indigenous trees after the establishment of fast-growing tree plantations could be a reasonable approach to introducing indigenous trees in large areas of degraded land.

The aims of this paper are to review previous studies at the Sakaerat Silvicultural Research Station and to learn lessons on silvicultural techniques from these results. The authors will suggest appropriate species combination and

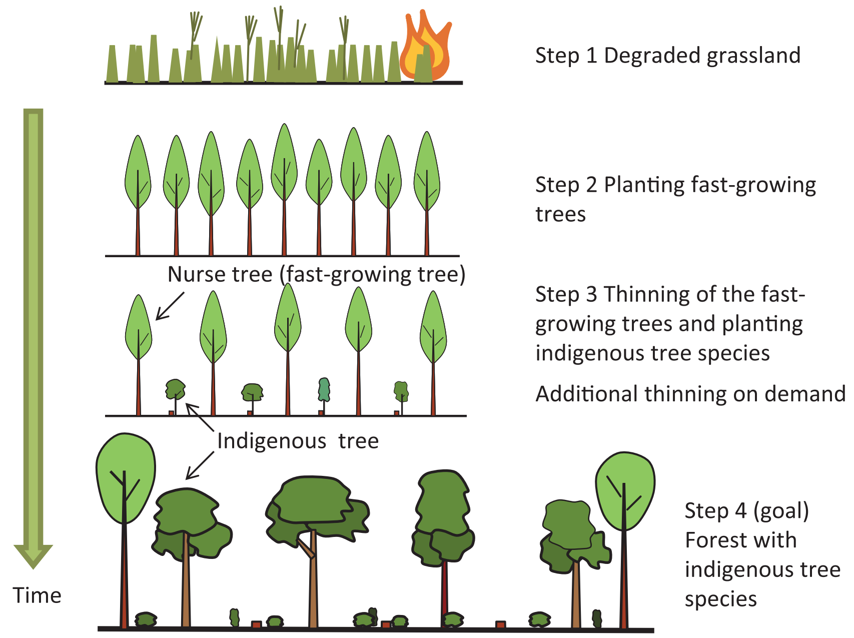

Fig. 1. A schematic diagram illustrating the course starting from degraded land to a forest composed of indigenous tree species.

thinning system suitable for two-aged system by screening the survivorship and growth of indigenous tree species. We will also suggest proper forestry system (normal even-aged system or two-aged system) for proper indigenous tree species by reviewing the results.

Study site

A series of studies were conducted at Sakaerat Silvicultural Research Station, Nakhon Ratchasima Province, in Northeast Thailand. The mean annual air temperature was 25.6 °C and the mean annual rainfall was 1395 mm according to meteorological data collected at the administrative office of the station over the last 10 years (1999 to 2009). This area has a monsoon climate with highly seasonal rainfall and a roughly 4-month-long dry period from November to February. The soil is deep loamy acrisol formed on sandstone laid down in the Triassic to Cretaceous periods (Moormann and Rojanasoonthon 1972) and generally contains a small amount of organic matter (Ando and Iwasa 1987). The vicinity of the study site was covered with dry evergreen forest until the 1960s. The forest was then encroached by local people, who converted it into farmland. Although the farmland was cultivated for a couple of decades, most of it was subsequently abandoned and covered with tall grasses such as *Imperata cylindrica* and *Saccharum spontaneum*. The Research and Training in Re-afforestation Project (RTR Project) conducted by Japan International Cooperation Agency (JICA) and the Royal Forest Department (RFD) was initiated in 1982 with the planting of exotic fast-growing tree species over 2300 ha by 1994. The area is currently covered with mature fast-growing tree plantations mainly composed of *Acacia mangium* and *Eucalyptus camaldulensis*.

Scheme of uneven-aged forest management at the Sakaerat Station

Fig. 1 shows a schematic diagram of degraded land converted into a mature forest composed of indigenous tree species via a fast-growing plantation. After the abandonment of cultivation in deforested areas, tall grasses (*Imperata cylindrica* and *Saccharum spontaneum*) cover the land, often inducing fires (Step 1). By planting fast-growing trees, the degraded area is converted into a plantation, reducing the risk of fires (Step 2). It has been proved that *Acacia mangium* is suitable for afforestation around Sakaerat (Ando and Iwasa 1987). Seedlings of indigenous tree species are planted beneath the canopy of plantation or in a gap formed after thinning (Step 3). Additional thinning or harvest logging will be needed on demand. Thereby, a forest composed of indigenous tree species is created (Step 4). It is expected that this forest will provide high biodiversity of plants, animals, and insects. At present (2011), most of the area around Sakaerat Station is categorized as Step 2, while small experimental sites are at Step 3 or 4.

Methods

Experimental plots

A total of five experimental plots for analysis of the two-aged system were established at Sakaerat Station from 1986 to 2009 (Table 1).

Experiment No. 1

This plot was established in 1986 for the purpose of finding appropriate species combinations in a two-aged system (Table 1) (Sakai et al. 2009). *Hopea odorata* (Dipterocarpaceae) was planted beneath 3-year-old

Table 1. A list of the experimental plots for uneven-aged system at the Sakaerat Station

Experimental plot No	Year of setting	Nurse tree species	Stand age at underplanting	Indigenous tree species	Forestry operation	Grade of lightness
1	1986	*Eucalyptus camaldurensis*	3	*Hopea odorata*	no thinning	4
		Acacia auriculiformus	3	*H. odorata*	no thinning	4
		Senna siamea	3	*H. odorata*	no thinning	4
		-	-	*H. odorata*	open site	14
2	1989	*Leucaena leucocephala*	3	*Dipterocarpus alatus, D. turbinatus, H. odorata, Shorea henryana*	no thinning	5
		-	-		open site	15
3	1999	*Acacia mangium*	14	*Dipterocarpus alatus, D. turbinatus, H. odorata, Afzeria xylocarpa, Dalbergia cochinchinensis, Pterocarpus macrocarpus, Xylia xylocarpa* var. *kerrii*, etc.	no thinning	1
		A. mangium	14		stripe, 50%	7
		A. mangium	14		group selection thinning	11
		-	-		open site	16
4	2007	*A. mangium*	23	*H. odorata, H. ferrea, X. xylocarpa* var. *kerrii*	no thinning	3
		A. mangium	23		random selection, 33%	6
		A. mangium	23		random selection, 67%	8
		-	-		group selection thinning	12
5	2009	*A. mangium*	25	*D. alatus, H. odorata, H. ferrea, S. henryana, P. macrocarpus*, etc.	no thinning	2
		A. mangium	25		stripe 50%	9
		A. mangium	25		stripe 67%	10
		A. mangium	25		group selection thinning	13
		-	-		open site	17

plantations of three legume tree species and in an open site with three replications.

Experiment No. 2

Four dipterocarp species were planted beneath a 3-year-old *Leucaena leucocephala* (Leguminosae) plantation in 1989 (Table 1). The identical dipterocarp species were planted with the same arrangement in an open site adjacent to the *L. leucocephala* plantation.

Experiment No. 3

Study plots were composed of stripe thinning plots with a control plot (no thinning), a group selection thinning plot, and an open site plot. Three dipterocarp species and six legume species were planted beneath a 14-year-old *Acacia mangium* plantation in 1999, after applying stripe thinning or group selection thinning (20 m by 36 m in size) in the *A. mangium* plantations.

Experiment No. 4

Two dipterocarp and one legume species were planted beneath a 23-year-old *A. mangium* plantation in order to test their growth performance beneath a mature stand (Sakai et al. 2011) (Table 1). The indigenous trees were underplanted in 2007 after free selection thinning and group selection thinning (50 m by 60 m in size) was applied to the *A. mangium* plantation. Two grades of thinning rate (33% and 67% of basal area) were set for free selection thinning.

Experiment No. 5

Six indigenous tree species were planted in a 25-year-old *A. mangium* plantation after stripe thinning and group selection thinning (Table 1). One-row-cut one-row-left (50% of trees were removed) and two-rows-cut one-row-left (67%) were set for the stripe thinning. The size of group selection thinning was approximately 50 m by 50 m. The identical indigenous species were planted in an unthinned plantation and an open site.

Overview of the results

Survival rate and size of the major indigenous species at 1.5-3 years after planting were summarized for each experimental plot. Relative light intensity on the forest floor (at 1 m above the ground) at planting was estimated in each experimental plot in accordance with the literature or actual observation, and plots were ranked in order of brightness (Table 1).

Among dipterocarp species, survival rates of *D. turbinatus* were low in general, and those of *D. alatus* were low in dark conditions (Fig. 2). Other dipterocarp species exhibited moderate to high survival rates of over 60% in all light conditions. In particular, *H. ferrea* achieved high survival rates in every light condition. Most dipterocarp species showed high survival rates in the intense thinning plots and group selection thinning plots (Fig. 2).

The dipterocarp species tended to be small in dark conditions (beneath unthinned *A. mangium* plantations) and tall in the group selection thinning plots or heavy thinning plots (Fig. 3). The growth in terms of height was limited in the open sites the same as in the low-impact thinning plots (Fig. 3). *H. odorata* exhibited the highest score among the dipterocarp species in a given light condition. *H. ferrea* also tended to be tallest except in the open sites. *D. alatus* remained small in the unthinned or low-impact thinning sites but grew taller than the other dipterocarps in the open

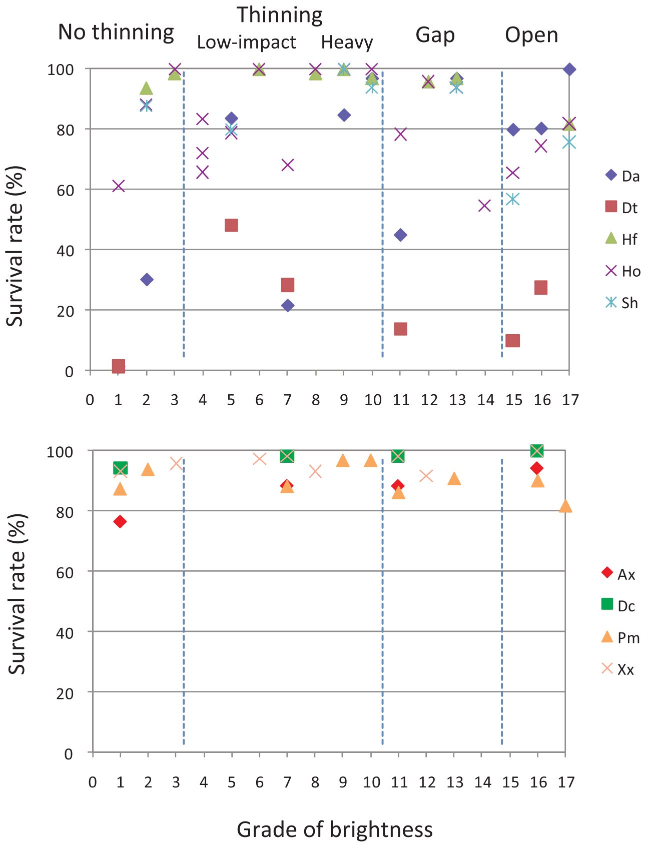

Fig. 2. Initial survival rates of the indigenous tree seedlings in various light conditions in the experimental plots at Sakaerat Station.
Above: Dipterocarpaceae, Below: Legminosae, Da: *Dipterocarpus alatus*, Dt: *D. turbinatus*, Hf: *Hopea ferrea*, Ho: *H. odorata*, Sh: *Shorea henryana*, Ax: *Afzeria xylocarpa*, Dc: *Dalbergia cochinchinensis*, Pm: *Pterocarpus macrocarpus*, Xx: *Xylia xylocarpa* var. *kerrii*

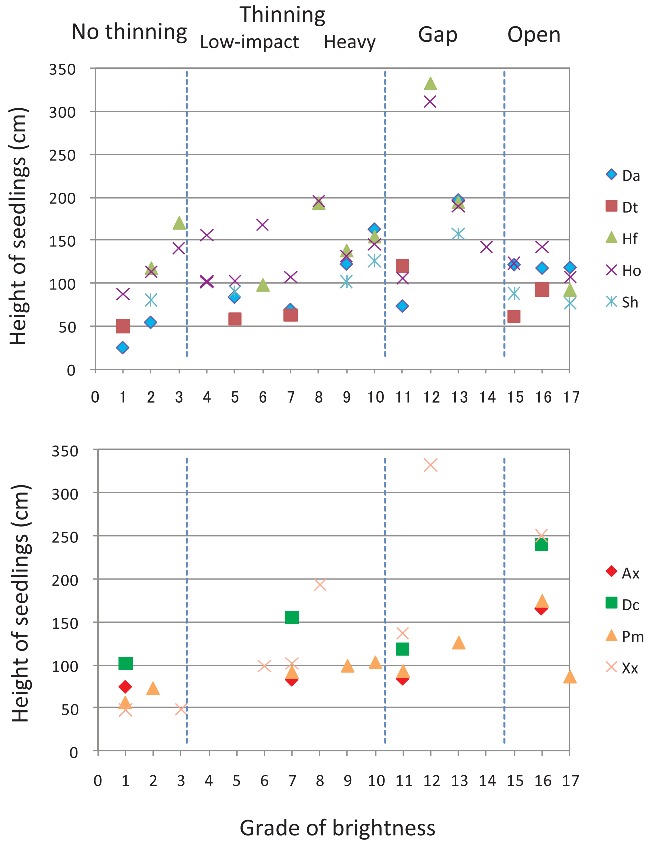

Fig. 3. Initial height of the indigenous tree seedlings in various light condition. Legends are as in Fig. 2.

sites. Meanwhile, the seedlings of *D. turbinatus* and *S. henryana* tended to be small in every light condition.

Legume species showed excellent survival rates of over 80% in every light condition (Fig. 2). All legume species tended to grow as light conditions improved, exhibiting the greatest height in the open sites. In particular, *Xylia xylocarpa* var. *kerrii* and *Dalbrgia conchinchinensis* showed excellent growth in the open sites.

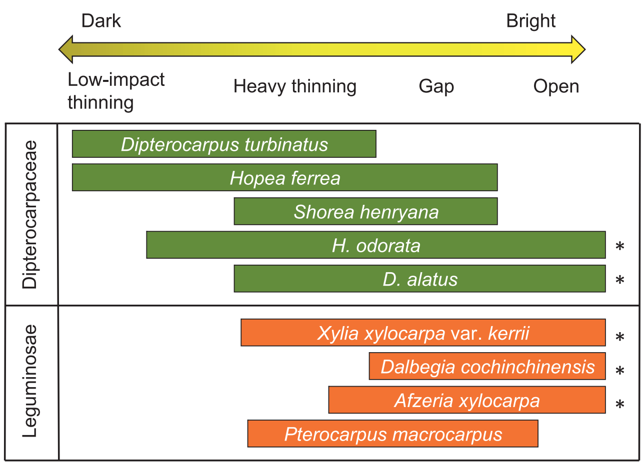

Fig. 4. A schematic diagram indicating suitable forestry operation (light conditions) for each indigenous tree species. The asterisks (*) show tree species possible to plant in an open site.

1. Combination of species

Hopea odorata was the most common species among the indigenous tree species examined at Sakaerat Station, providing a wealth of information on the growth performance of this species. *H. odorata* grew well beneath *Senna siamea* plantations as well as in open sites (Sakai et al. 2009). *H. odorata* also exhibited a high survival rate beneath a *Leucaena leucocephala* plantation, although its growth in terms of height was limited (unpubl. data). Because S. siamea grew slowly, the canopy of *S. siamea* had not closed at the time of underplanting *H. odorata*, providing suitable light conditions for the *H. odorata* seedlings (Sakai et al. 2009). *H. odorata* and other dipterocarp trees could survive and grow under the canopies of *L. leucocephala*, suggesting that this legume tree also provides suitable light conditions, perhaps due to the thin

Table 2. Descriptions of tree species examined at the Sakaerat Station. All species are indigenous to Thailand

Fmily name	Species name	Distribution *	Uses *	Exp. Plot No.
Dipterocarpaceae	*Dipterocarpus alatus*	Indochina, Myanmar, Philipines	construction timber, dammar	2, 3, 5
	D. turbinatus	Indochina	lack of information	2, 3
	Hopea odorata	Indochina, Myanmar, Peninsular Malaysia	timber as “merawan”, dammar	1, 2, 3, 4, 5
	H. ferrea	Indochina, Peninsular Malaysia	timber as “giam”, dammar	4, 5
	Shorea henryana	Southern Indochina, Myanmar, Peninsular Malaysia	construction timber, ship building	2, 5
Leguminosae	*Dalbegia cochinchinensis*	Indochina	furniture, fine arts	3
	Pterocarpus macrocarpus	India, Myanmar, Indochina	construction timber, furniture	3, 5
	Xylia xylocarpa var. *kerrii*	Indochina, Myanmar	construction timber, furniture	3, 4
	Afzeria xylocarpa	Indochina, Myanmar	various woodworks	3

* Arranged by PROSEA (1994; 1998) and Smitinand and Santisuk (1981)

foliage in the canopy (unpubl. data). In contrast, cultivation of *H. odorata* in *A. mangium* or *E. camaldulensis* plantations for a long period without heavy thinning caused irreversible damage to *H. odorata* (Sakai et al. 2009; 2010). In particular, *A. mangium* seems to be unsuitable as a nurse tree owing to its thick foliage. Sakai et al. (2009) found trade-off relationships between basal areas of nurse trees and underplants, suggesting that *H. odorata* would survive and grow in *A. mangium* plantations if thinning was applied at appropriate times.

Our data suggests that *D. alatus* and *H. odorata* could be planted in open sites if the plantation site was carefully tended. Legume trees examined at Sakaerat Station also preferred open sites rather than locations beneath nurse trees (Figs. 2 and 3). However, caution should be taken when putting these findings into practice because these results were obtained in small areas, under well-controlled conditions. Weeding and liana cutting must be practiced three times a year until canopy closure. The planting of several species mixed together is recommended to educe their growth potential and to avoid disease and insect damage (Montagnini and Jordan 2005).

2. Thinning system

Compared with low-impact thinning (thinning rate < 50%), heavy thinning (thinning rate ≧ 50%) tended to have positive effects on the growth of dipterocarp species (Fig. 3). Group selection thinning educed the high performance of dipterocarp species in terms of both survival rate and growth (Fig. 3). Light intensity in the canopy gaps created by group selection thinning was reduced to 60 - 65% of that in the open sites (Sakai et al. 2011), possibly providing suitable light conditions for the indigenous tree seedlings. Although *D. alatus* and *H. odorata* showed excellent growth in the open sites, the survival rates of the seedlings decreased conversely. It was observed that individuals that survived in the open sites grew larger than those in fast-growing tree plantations, compensating the loss of dead individuals (Exp. Plot No. 3, unpubl. data). Lapongan and Kelvin (2009) also reported similar results for dipterocarp species indigenous to Sabah, Malaysia.

It seems that any thinning method is acceptable if the light intensity of the forest floor is kept to approximately 60 -65% of that in open sites. In terms of working efficiency at logging, stripe thinning or group selection thinning seems to be more efficient than free selection thinning because (1) workers could select trees mechanically without expertized skill, and (2) indigenous seedlings would be less damaged at the time of harvest logging of nurse trees. The experiences of this study, however, suggest that stripe thinning in mature *Acacia mangium* plantations was not efficient because large crowns of the nurse trees (approximate 23 m in height) tangled with each other at the time of logging, severely decreasing the working efficiency (Exp. Plot No. 5). We assume that the stripe thinning ought to be applied when the plantation (*A. mangium*) is young (probably < 10 to 15 years). In contrast, early thinning could not maintain good light conditions over long time because the canopy closed quickly in young plantations (Exp. Plot No. 1 and 3). In this case, additional thinning or harvest logging will be needed in the near future (Sakai et al. 2009). It is assumed that group selection thinning is the most efficient system for logging since workers do not need to consider the felling direction of logging trees, especially at Step 3 (Fig. 1). Hence, group selection thinning would be a reasonable system for the conversion from fast-growing tree plantations into indigenous tree forests, in terms of not only growth and health of the indigenous seedlings but also the working efficiency at the time of logging.

Conclusions

Our studies demonstrated that some indigenous tree species such as *Dipterocarpus alatus*, *Hopea odorata*, *Dalbergia conchinchinensis*, and other legume species, which all produce high-quality timber, could grow successfully in open sites without relying on a two-aged system (Fig. 4). However, this is conditional on weed cutting and liana cutting across the whole area in question, as well as controlling the risk of fires in the initial stage. *Dipterocarpus turbinatus*, *Hopea ferrea*, and *Shorea henryana* would be suitable to grow in a two-aged system. Owing to their poor growth performance, these species will be applicable to forest rehabilitation rather than timber production. Long-term planning and practice across every step of forest conversion (cf. Fig. 1) and meticulous maintenance of plantations will be needed. Because *H. odorata* and *Xylia xylocarpa* var. *kerrii* can adapt to various light conditions (e.g. Sakai et al. 2011), they can be applicable to both even-aged and uneven-aged stands. It is worthy of attention for foresters that mixed-species stands result in high growth performance, providing different products at different times (Montagnini and Jordan 2005; Sakai et al. 2009).

Our results suggest that relatively slow-growing trees and/or thin foliage trees (e.g. *S. siamea*, *L. leucocephala*) are suitable as nurse trees in the two-aged system. According to our experience, it is recommended to plant indigenous tree species when the nurse trees are young (3-5 years old), and to harvest all or half of the nurse trees at 5-8 years old, since the indigenous tree seedlings are established by then. The final harvest of the nurse trees should be undertaken within few years, avoiding the long-term vertical overlap of the nurse trees and indigenous trees. At the time of harvesting, the nurse trees would reach a suitable size not only for pulp processing but also for fuel wood and/or charcoal. As Sakai et al. (2009) pointed out, fast-growing trees such as *E. camaldulensis* and *A. mangium* could be used for nurse trees, if strong or frequent thinning was carried out. In the case of utilizing large timber of *A. mangium* or for the purpose of rehabilitation or restoration of natural forests, group selection thinning (the size of the gap is set to double the height of surrounding nurse trees) is recommended in terms of both growth performance of indigenous trees and working efficiency.

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