热带亚热带植物学报　1999, 7(1):37－46
Journal of Tropical and Subtropical Botany

南亚热带森林24种乔木的种子萌发和幼苗生长

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摘要　以膨胀珍珠岩为基质，在光和暗的条件下，对24种南亚热带森林乔木的种子萌发和幼苗生长进行了研究。种子的形态和重量与种的演替阶段有关，种子的重量也与不同的种有关。不同种的萌发率差异较大，种子较大的种，萌发率较高。肉质果实的种子，开始萌发的时间较长。光和暗条件对萌发率和萌发速度无明显影响。幼苗高度和种子重量呈正相关，这一相关在光条件下比暗条件下更明显。暗条件明显地引起群落演替早期的树种的茎徒长，限制根的生长，而对演替后期种无显著的影响。幼苗地上部分和根系生物量的分配与种的演替阶段有关，也与不同的科有关。幼苗地上部分和根系生物量的分配也受光暗条件的影响，而不受种子重量的影响。根和叶的生物量分配和种在其群落演替阶段有关。幼苗的生物量与种子重量有显著的正相关。幼苗的相对生长率相差较大，在没有营养供应的生长基质中，以演替中间阶段的种的相对生长率较大。幼苗从种子的物质利用效率与种子重量呈负相关，而与种的演替阶段无明显的相关。

关键词　南亚热带森林乔木；种子萌发；幼苗生长

中图分类号　Q945.3

SEED GERMINATION AND SEEDLING GROWTH OF 24 TREE SPECIES IN LOWER SUBTROPICAL FOREST

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Abstract Seed morphology and germination, seedling morphology and biomass of 24 tree species in the lower subtropical forest of China were studied comparatively in light and dark conditions on expanded perlite as germination and growth medium. Seed morphology and seed mass were related with species of different successional stages of the forest and with species from different families. Percentage of germination was obviously different among various species. Heavier seeds had higher percentages. Seeds from pulpy fruit usually showed significantly later germination. Light and dark conditions did not significantly affect germination percentage and germination speed of the species. Seedling height was positively correlated with seed weight. The correlation between seed weight and seedling height seemed to be more obvious under light treatment. Dark condition caused the

国家自然科学基金资助项目（39270140, 39670138）.

1998－03－25　收稿；　1998－11－16　修回

stem etiolation and limited the growth of root of the early seral (successional) species. However it was not so obvious for late seral species. Seedlings of about half of the species had higher shoot biomass than root biomass in both light and dark conditions. Shoot and root biomass allocation was related with different families, and with different seral stages of the species. It was also affected by light and dark conditions. Seed weight appeared not to affect the biomass ratio of shoot to root in seedlings. Root and leaf biomass allocation were related with species. Biomass of the seedlings was positively related with seed weight. Relative growth rate (RGR) of the seedlings without nutrient supply was quite different among the species. Higher RGR was found in the mid seral species. Matter utilization efficiency (MUE) of the seedling from seed was obviously negatively related with seed weight, and appeared not to be related with seral stages of the species.

Key words Lower subtropical forest; Tree; Seed germination; Seedling growth

1 Introduction

Studies on ecology of seed germination and seedling performance have led to an encouraging understanding of looking into the ecological adaptability to their environment of the species. The researches include those on tropical forests[1-6], temperate forests[7-9], a whole flora[10,11] or several floras[12]. However, the following aspects are still less known: (1) Very few works have been carried out on subtropical humid forests. Do the seeds and seedlings have the same adaptive strategies as those in tropical and temperate forests? If not, what is the difference between them? (2) For seed germination and seedling growth, almost all researches which have been done are carried out in better soil condition or for seed germination with water for a very short time. Ecological strategies of the seed germination as well as seedling growth and establishment can be affected by soil conditions, such as nutrient content, water content, micro-organisms, etc. In media without nutrient for seed germination and seedling growth, the relation between seed and seedling, the response of the seeds and seedlings to selective pressures of environment might be different from those in the soil with normal nutrient supply. This might provide an understanding into the intrinsic attributes of ecological strategies of the species. (3) Studies have been mostly carried out on comparison of few ecologically clear and distinct species, such as pioneers and late seral species. However, attributes of adaptation to a certain environment of species might present a continuous distribution[5]. How does the ecological adaptation of seeds and seedlings of a regime of species vary continuously? In consideration of the above questions, we used 24 tree species of gradient light demanding or successional phases in the lower subtropical forest of China to study the ecological performance of the species, and used expanded perlite without detectable nutrient elements as germination and growth medium to probe the ecological performance of different species under nutrient deficiency pressure.

2 Metarials and methods

Twenty-four tree species studied are mostly distributed in the lower subtropical forest in China. Most of them are dominant or common species in the forest. They represent a regime of ecological characteristics in terms of light demanding or successional phases: from pioneer species to late seral trees. *Castanopsis fissa, Schima superba, Oroxylum indicum, Lithocarpus glaber* and *Albizzia lebbeck* are early seral trees. *Machilus chinensis, Ormosia glaberrima, Ormosia pachycarpa, Cryptocarya concinna* and *Ardisia quinquegonq* are late seral species. The other species are intermediate ones between the pioneer species and the late seral species. We try to build a sequence in an increasing order of shade-tolerance for the species according to our field experience (Table 1, in number order), although we have not enough experiments and data to test the sequence. Three types, however, are reliable, i.e. early- and late seral species, such as species 1－5, and 20－24, respectively, and the intermediate type such as species 8－15.

Seeds of most species were collected from the forest at Heishiding in Guangdong Province in 1994 and 1995. *Oroxylum indicum* was collected from the forest in Guangxi Province, and *Albizzia lebbeck,* from the forest in Chaozhou of Guangdong Province. Seed and/or fruit morphology was noted, and seed and/or fruit dimension, fresh and dry weights, and water content were measured usually with 50－100 seeds for each species. Seeds were stored in dryer after they were dried in the air in laboratory for the low-water-content seeds, and kept freshly in refrigerator (5－8 ℃) in hermetically-sealed plastic bags for fleshy fruits and high-water-content seeds. All the seeds were stored for at most 1－2 months before germination experiment.

Seeds germinated and seedlings grew in growth cabinets at day temperature of 25 ± 1℃ and night temperature of 20 ± 1 ℃. For the light treatment, both light time (day time) and dark time (night time) were 12 hours. Radiation intensity during light time was about 50 μmol $m^{-2}s^{-1}$. For the dark treatment, radiation intensity was zero throughout the experiment. Germination was checked and seedlings were observed in the dark with very weak light masked with thick green cloths. In order to avoid extra nutrient, we used expanded perlite as the germination medium. There were no detectable nutrient elements in the medium after it was washed with deionized water. Seeds were imbibed in deionized water for about 12 hours before being laid in the medium which was held in transparent plastic boxes with size of 21 × 15 × 7 cm. Each box generally contained 20－50 seeds. Seeds in pulpy fruits were picked out by getting rid of the fleshy part before they were imbibed.

The medium was kept humid with deionized water during the experiment.

Seedlings were harvested at 30 days and 60 days after germination. Generally 10－20 seedlings for each treatment of each species were harvested each time. Shoot height, root length, root number and leaf number were measured. Fresh weight of leaf, stem and root were measured respectively for each seedling. Dry weight of the organs was measured after drying at 80 ℃ to constant weight.

3 Results

3.1 Morphology and weight of the seeds

Four types of seeds were included in this experiment: low water content (<30%) seeds with wings (species 2,3,13,16); low water content seeds without wings (species 5,7,21); fruits or seeds with higher water content (36%－50%) but without pulpy carpodermis (species 1,4,6, 9－12,22); and seeds in pulpy fruit and with very high water content (50%－80%)(species 8,

Table 1 Some characteristics of the seeds and seed germination

Tree species	Seed weight* (mg)	Water content of seed (%)	Days needed for beginning germination		Days from the beginning to the end of germination		Germination (%)	
			Light	Dark	Light	Dark	Light	Dark
1 *Castanopsis fissa*	679± 96	48.7	8	8	27	34	100	87
2 *Schima superba*	3.51± 0.71	27.6	11	11	9	13	11	7
3 *Oroxylum indicum*	98± 11	7.8	7	7			67	77
4 *Lithocarpus glaber*	662± 87	38.1	50	59	22	10	31	12
5 *Albizzia lebbeck*	96± 20	23.4	3	3	5	5	67	63
6 *Quercus hui*	3206± 853	46.0	10	1	22	14	92	84
7 *Erythrophleum fordii*	762± 72		10	1	16	2	70	90
8 *Cinnamomum porrectum*	33± 5.1	63.8	158		14		6	
9 *Pithecellobium clypearia*	225± 63	43.2	6	9	12	13	90	93
10 *Sterculia lanceolata*	502± 86	46.7	10		13		49	
11 *Lithocarpus hancei*	665± 91	37.0	31	31	26	30	40	22
12 *L. tremulus*	831± 199	36.0	68		42		22	
13 *Altingia chinensis*	10± 2.5	22.5	8	8	13	17	32	31
14 *Aporosa chinensis*	39± 6.3	54.9	13	14	27	8	12	7
15 *Artocarpus styracifolius*	58± 9.2	77.8	31		14		65	
16 *Engelhardtia roxburghiana*	25± 3.8	16.9	16	17	12	11	18	19
17 *Ilex memecylifolia*	1.57	35.6	6	9	25	20	61	53
18 *Diospyros morrisiana*	147± 19	46.9	19	2	18	22	26	27
19 *Garcinia oblongifolia*	454± 83	46.3	174	152	27	18	88	100
20 *Machilus chinensis*	337± 49	42.5	62	62	1	1	35	15
21 *Ormosia glaberrima*	163± 35	9.7	16	13	9	18	36	32
22 *O. pachycarpa*	1191± 389	43.5	47	6	25	28	100	95
23 *Cryptocarya concinna*	402± 53	50.1	24	26	23	18	79	80
24 *Ardisia quinquegona*	36.5± 11.3	56.6	50	46	30	31	63	75
Mean	450.5		33.8	24.3	18.8	16.5	55.9	53.5

*Dry weight per seed is the average of 50 to 100 seeds. Data are means± SD

14, 15, 17－20, 23, 24). The first two types were mostly of early seral species, and the last type largely of late seral species.

Seed (or fruit in some cases) weight had weak correlation with successional status of the species. Most of the late seral species, such as species 20－24, had heavier seeds. Seed weight was related to taxa. Fagaceae species (species 1, 4, 6, 11, 12) had heavier fruits, and their mean weight per fruit was 1 209 mg, even the early seral species of this family had heavy fruits (Table 1).

3.2 Germination of seeds

Percentage of germination which was related to seed weight was different among species, ranging from 6% to 100%. Heavier seeds usually had higher percentage (Fig. 1). Percentage of germination seemed not to be related with seral phases of the species. However, all the late seral species except *Diospyros morrisiana* had percentages higher than 40%. This fact might be also related with that late seral species usually had heavier seeds. Light and dark did not significantly affect germination percentage of the seeds (Table 1).

Most of the species (15 species) began to germinate within 3 weeks. Seeds of the late seral species showed later germination. It was noticed that seeds from pulpy fruits usually took longer germinating time. Three species showed delayed germination according to Ng's standard[1], which included *Ormosia glaberrima* with physical dormancy because of its hard seed coat, and can begin germinating within about two weeks if the seed coat was scarified. The other two species having fleshy fruits were of earlier seral species and the other of late seral species. Most of the species finished their germination during 10－30 days (with the most rapid one being 2 days and the slowest, 34 days). Light and dark conditions did not significantly affect the germination rate (Table 1).

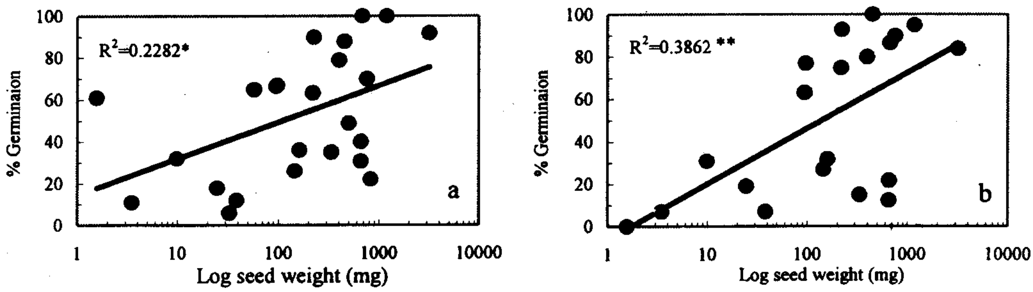

Fig. 1　Correlation between seed weight and germination percentage under light (a) and dark (b) treatments
*, **, significant at 0.05 and 0.01 levels, respectively, same for other Figs.

3.3 Seedling morphology and biomass

Morphology　Seedling height was related to a certain extent to seed weight (Fig. 2). Correlation between seed weight and seedling height seemed more significant in light treatment. Seedling height was also related with light and dark conditions. Dark condition caused the stem elongation in early seral species (species 1－7)(Fig. 3a). However, it was not so obvious for late seral species, such as species 19, 20, 22–24 (Fig. 3a). Some late seral species (species 19, 20, 23, 24) had shorter stems in the dark than in the light. For most species, light condition was more favourable to the increase of root number and root length growth than dark condition (Fig. 3b,c).

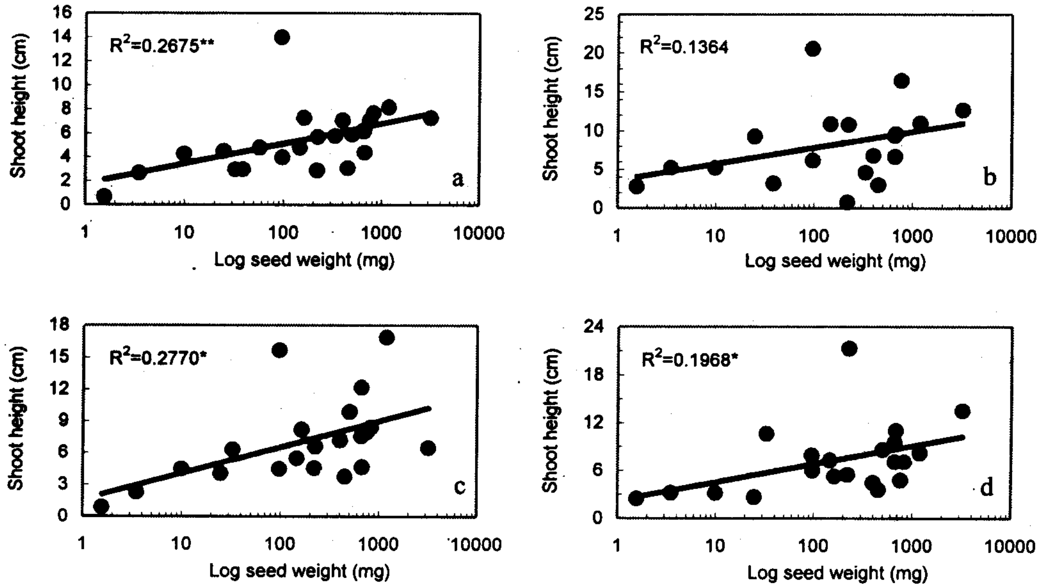

Fig.2 Correlation between seed weight and shoot height of the seedlings

a 30-day seedlings (Light); b. 30-day seedlings (Dark); c. 60-day seedlings (Light); d. 60-day seedlings (Dark)

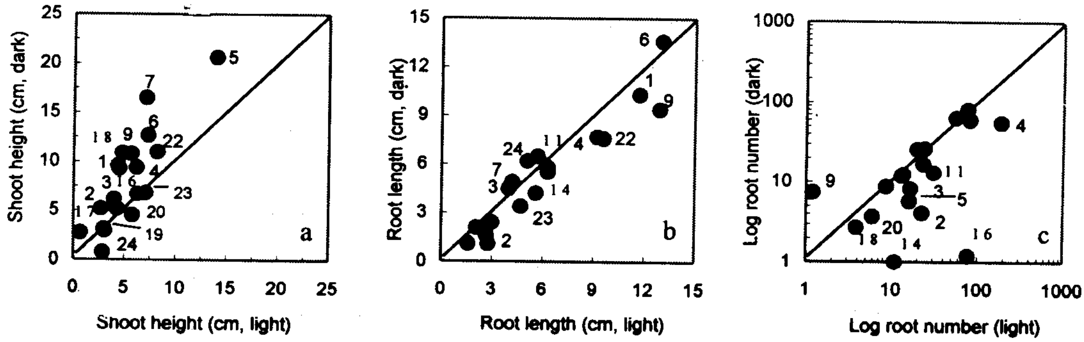

Fig. 3 Comparison of the growth of shoots and roots in 30-day seedlings under light and dark

a. Shoot height; b. Root length; c. Root number

Biomass The 30-day seedlings of about half of the species had higher shoot biomass than root biomass in both light and dark conditions, and the values of root to shoot ratio for all the 24 species were 0.72 in light and 0.98 in dark. Shoot and root biomass allocation was related to taxa. Species from Fagaceae (species 1, 4, 6, 11, 12) had higher root:shoot values, with 0.67–1.89 (average 1.20) in light condition and 0.58–2.19 (averaged 1.22) in dark condition. Shoot and root biomass allocation seemed to be related with seral stages of the species. The later seral species 18–24 had root:shoot values of 1.04 in light condition and 2.08 in dark condition, while earlier seral species (species 1－10) having 0.67 and 0.59, respectively. The later seral species had much higher value in dark than in light. The 60-day seedlings had lower root:shoot values (averaged 0.35 in light and 0.45 in dark) than the 30-day seedlings. Seed weight seemed not to affect shoot:root ratio of the seedlings. Ratios of root:total weight of most of the species were not significantly affected by light conditions (Fig. 4). The late seral species 20－24 had slightly higher ratio values in dark than in light, and earlier seral species higher ratio value in light than in dark. Values of leaf:total biomass were higher in light than in dark for almost all the species. Leaf biomass of species 2, 3, 7, 13, 14, 16, 17, 18 had higher percentage in dark than other species (Fig. 4). This was due to their cotyledons (all of these species are epigeal). Biomass of the seedlings was closely related with seed weight (Fig. 5).

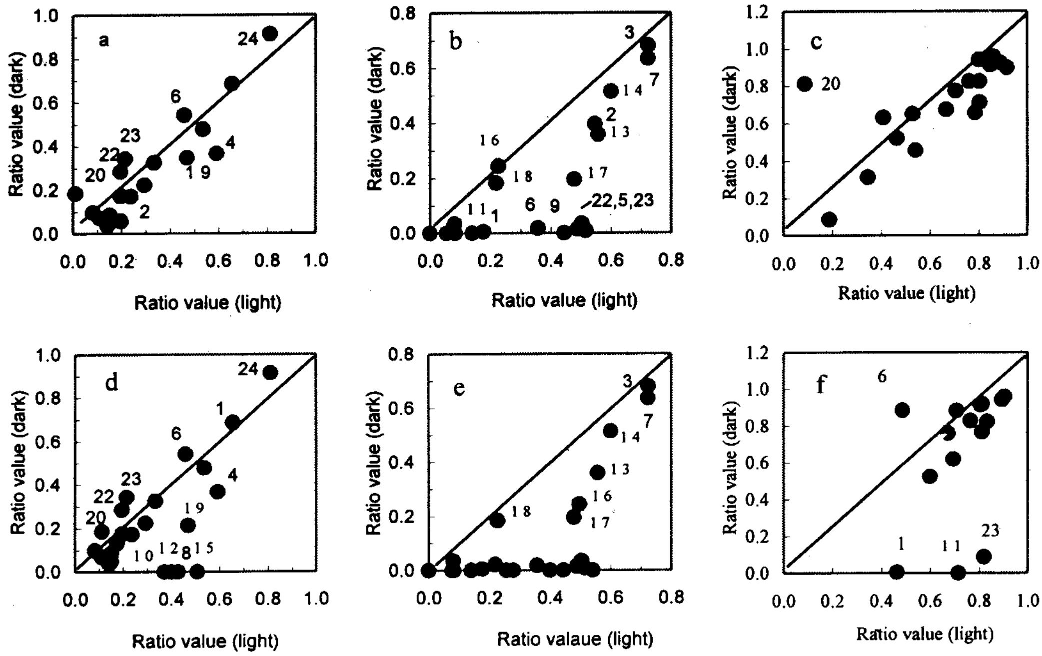

Fig. 4 Biomass in different parts of seedling under light and dark treatments
a. The ratio of root weight to total seedling weight in 30-day seedlings;
b. The ratio of leaf weight to total seedling weight in 30-day seedlings;
c. The ratio of shoot weight to total seedling weight in 30-day sedlings;
d. The ratio of root weight to total seedling weight in 60-day seedlings;
e. The ratio of leaf weight to total seedling weight in 60-day seedlings;
f. The ratio of shoot weight to total seedling weight in 60-day seedlings.

Relative growth rate and matter utilization efficiency* Relative growth rate (RGR) of the seedlings was quite different among the species. It appeared that middle seral species had higher RGR. The late seral species had higher RGR than early and middle seral

*Matter utilization efficiency (MUE)=Ratio of average dry weight of the seedlings in the dark to average dry weight of the seeds.

species in dark condition in comparison with that in light (Fig. 6). Matter utilization efficiency (MUE) of the seedling from seed was significantly negatively related with seed weight (Fig. 7). It appeared that MUE was related with the seral status.

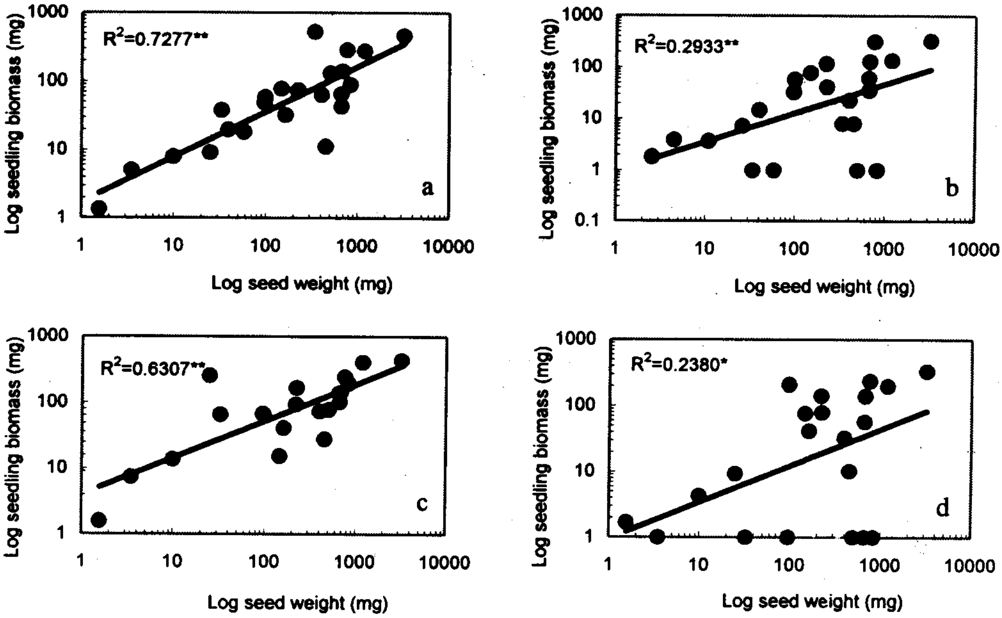

Fig.5 Correlation between seed weight and seedling biomass of species
a. 30-day seedlings (Light); b. 30-day seedlings (Dark); c. 60-day seedlings (Light); d. 60-day seedlings (Dark)

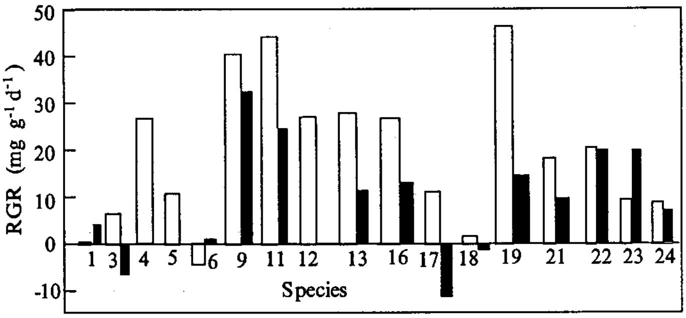

Fig. 6 Relative growth rate (RGR) of the seedlings during 30–60 days in light and dark

□ Light; ■ Dark

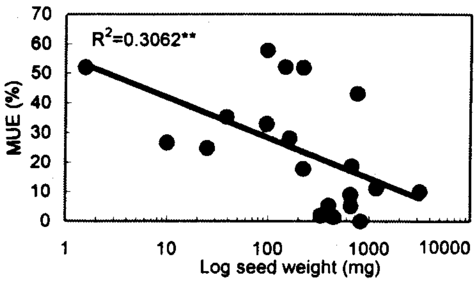

Fig. 7 Correlation between seed weight and matter utilization efficiency (MUE) of the 30-day seedlings

4 Discussion

Studies on germination of the tree seeds in tropical forests[1,4,13] have revealed that there are two types of germination strategies: rapid and delayed germinations. Most of the late seral species show rapid germination, while delayed germination is the characteristics of some pioneers and gap demanding species. In this study three species represented delayed germination among which one is a leguminous species which has hard seed coat, another is early seral species, and the third one is late seral species, the latter two species both have fleshy fruits. It is interesting that the fleshy-fruit species, mostly typical late seral species, represented later germination. The most light-demanding species in this study showed quite fast germination. We do not know if these are the characteristics of subtropical forest trees because species studies in such forest are still very limited.

It has been reported that RGR of seedling is related to seral stage of the species. Pioneer tree species have higher RGR. In this study the intermediate seral species had higher RGR, and the early seral species showed quite low values. This might relate to the growth medium. Seedlings of the early seral species might have shorter nutrient supply than that of the late seral species in the growing medium which have no nutrient supply. It is suggested that higher RGR of early seral species might be more dependent upon soil conditions such as nutrients.

The ratio of root to shoot biomass in natural seedlings was found to be different between early- and late-seral species. Seedlings of late seral species had higher value[14]. This is also true for the seedlings in our experiment condition. The ratio was also different between light and dark conditions. The later seral species had much higher value in the dark than in the light, although there was no apparent difference for the earlier seral species. Ratio root:total weight of the seedlings was also related with seral stages. Typical late seral species 20－24 have higher root:total biomass values in dark condition (Fig. 4). It appeared that darkness severely limited the root growth of early seral seedlings but did not limit or not so severely limit the root growth of late seral seedlings. Root: total biomass ratio was also found to be correlated with seral stages of species in natural seedlings[15,16]. It is suggested that ratio root:total weight of seedlings might be an useful index in predicting species shade tolerance.

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