CHAPTER 4

RESULTS

4.1 Distribution in the park

Ficus hispida, *F. oligodon* and *F. semicordata* were found in all forest types throughout the park. *Ficus hispida* and *F. semicordata* trees were both most common in deciduous forest (<800 m above sea level), whilst *F. oligodon* was common in mixed forest (800-1,200 m above sea level). *Ficus auriculata* and *F. variegata* were found at elevations >800 m above the sea level, mainly in mixed forest. *Ficus fulva* and *F. triloba* were restricted to mixed forest (Fig. 7). The numbers of male and female trees of most species found along the phenology trails were similar, except for *F. fulva* and *F. variegata* (Table 8).

4.2 *Ficus* phenology

4.2.1 General phenology. The peak period of leaf fall for most species generally coincided with the cool-dry period, and was usually negatively correlated with rainfall and temperature (Table 9). There was no difference in leafing pattern between male and female trees of *F. auriculata*, *F. hispida*, *F. oligodon*, and *F. semicordata*. However, *F. fulva*, *F. triloba* and *F. variegata* showed gender differences in leafing phenology (Figs. 9-15; b, d). The gender differences were not homogenous among these three species.

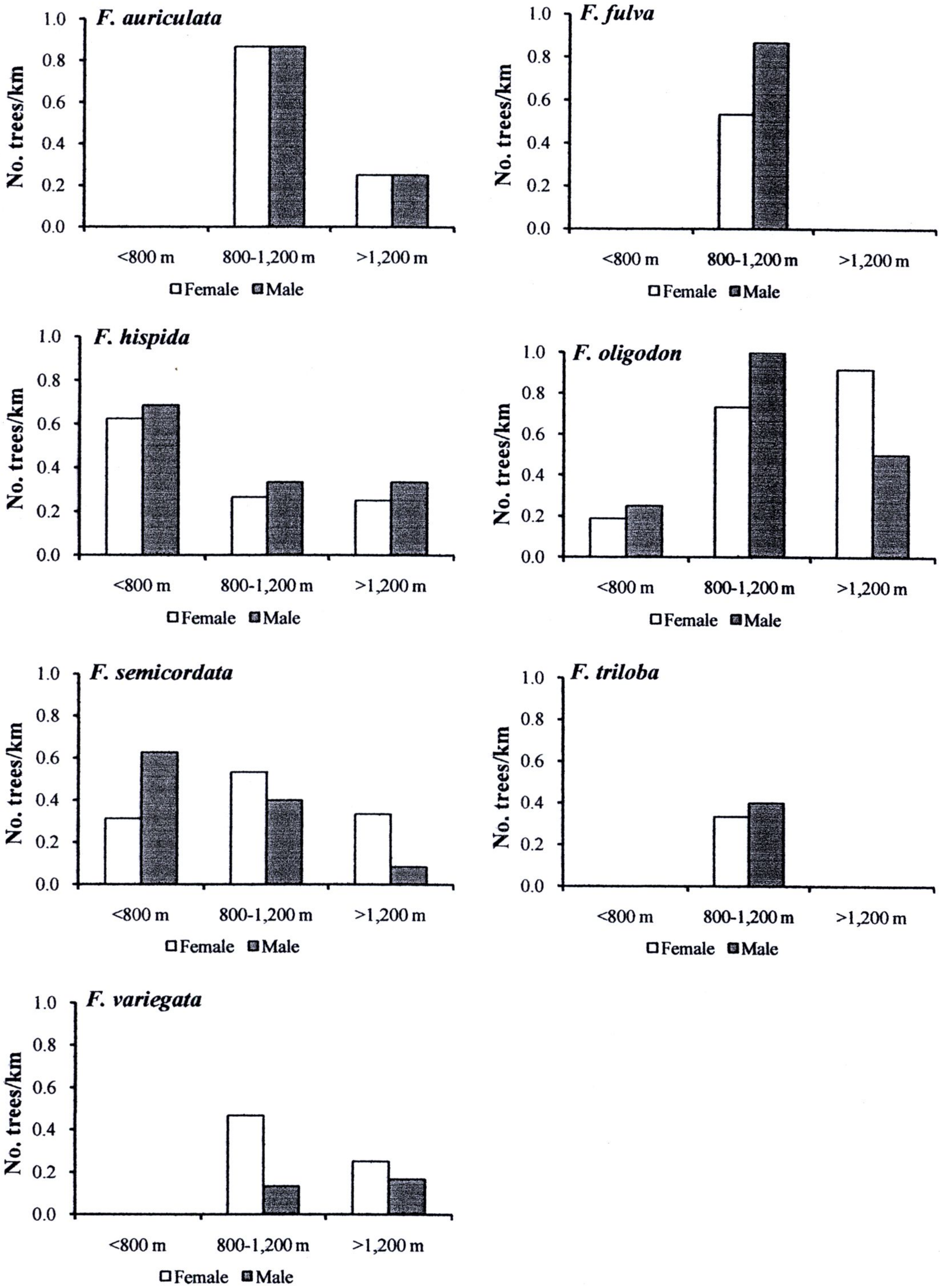
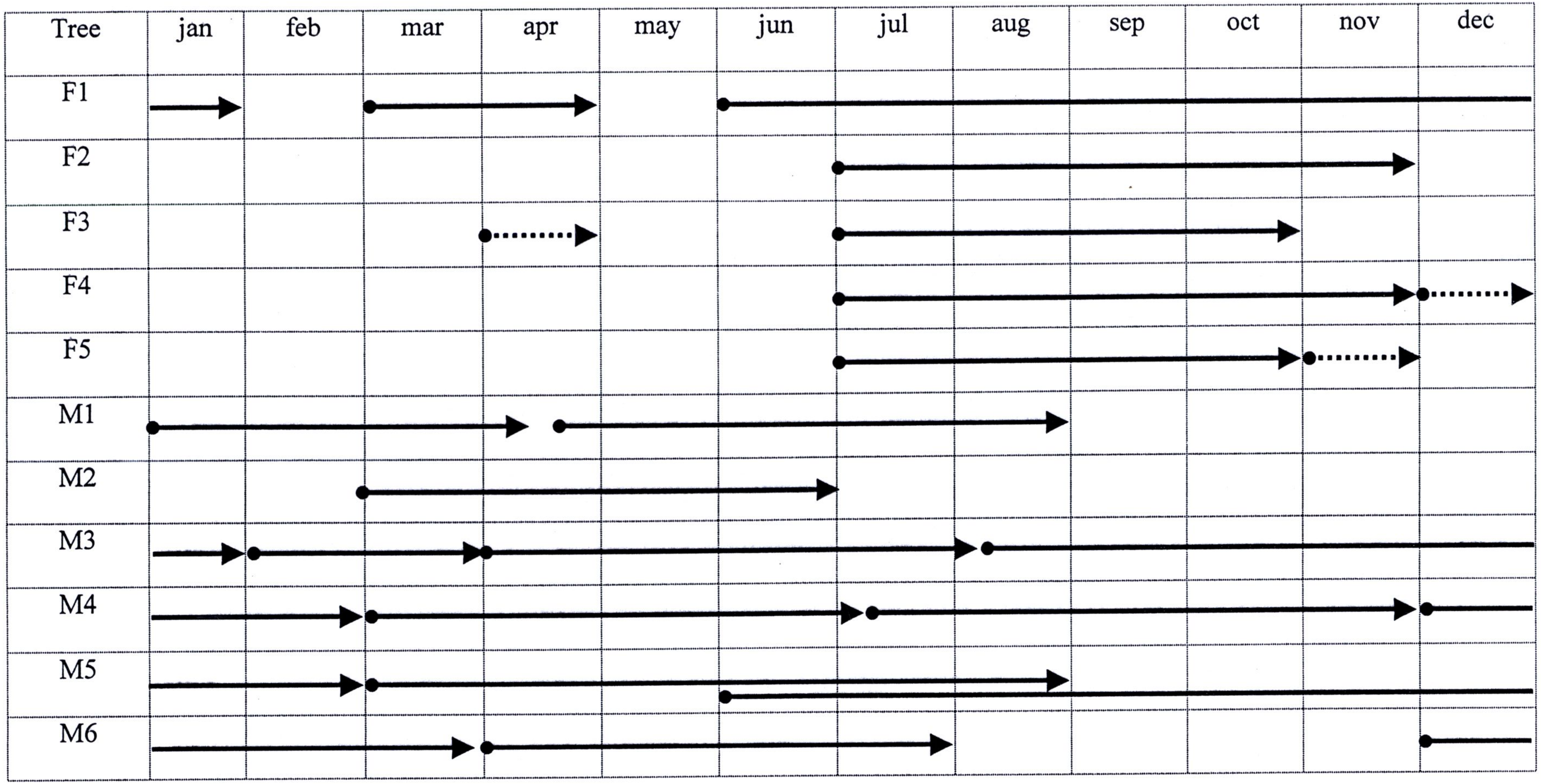


Figure 7 Number of trees per kilometer of phenology trail in each elevation type (<800 m above sea level=16 kilometers, 800-1,200 m above sea level=15 kilometers and >1,200 m above sea level=12 kilometers).

At the population-level, all species bore fig crops several times throughout the year but fig abundance varied seasonally (Figs. 9-15; a, c). For most species, fig developmental phases were not correlated with climatic conditions. However, it seems that, male trees were more sensitive to weather parameters than females (Table 9). At the population-level, receptive phase figs of most species (particularly of female trees) were produced throughout the year, but peaks in receptive phase figs occurred at different times between the sexes. At the receptive phase, female figs of most species were bigger than male figs, whilst at the mature stage the female figs of all species were smaller than male figs (*T*-test, N=50, P<0.05; Table 8). Female trees of most species produced fig crops more frequently than male trees (except for *F. oligodon*, *F. triloba* and *F. variegata*) and the duration of crop development was longer than that of male trees (except for *F. auriculata* and *F. triloba*). The number of seeds of most species was positively correlated with fig size (Table 9). At the individual-level, individual trees of all species had their own rhythm of reproductive phenology (Fig. 8).

For most species, the production of seeds (female trees) and wasps (male trees) varied between seasons. Also, the timing of peak fig production, at the population-level, differed between sexes. Male trees of most species produced their main fig crops mainly in the dry season, about 1-3 months before the peaks in fig production of female trees (depending on species). Seed production of most species peaked at the beginning of rainy season (except for *F. triloba*). A correlation between fig crop initiation and new leaf flushing was more common for female trees rather than for male trees.



F=Female tree, M=Male tree; Completed crop (the periods between fig initiation - ripening), Abortion crop

Figure 8 An example of fig production rhythms of *F. triloba* at the individual-level.

Table 8 Details of selected trees were found along the phenology trails and sexual specialization of the study figs in Doi Suthep-Pui National Park, northern, Thailand (Mean ± SD).

Species	Sex [1]	Elevation (m)	GBH [2] (cm)	Crop duration (months)	Asynchronous fig production [3] (%)	No. of seeds/wasps (per fig)	Fig size at RCP [4] (mm)	Fig size at RPP/RLP [4] (mm)	Crop abortion (%)
F. auriculata	F=16	891-1,319	78.1±35.6	3.3±1.2	30.6	5,969±4,287	48.0 x 46.3[a]	66.2 x 53.7[b]	0.0
	M=16	895-1,299	83.5±29.8	4.7±1.2	5.6	301±96	54.2 x 43.2[a]	86.0 x 65.6[a]	4.8
F. fulva	F=8	923-1,014	48.0±29.0	3.9±2	12.5	858±311	13.0 x 16.0[a]	17.7 x 19.2[b]	5.0
	M=13	989-1,100	49.0±17.9	2.5±0.8	17.2	67±12	12.0 x 11.8[b]	20.3 x 20.0[a]	0.0
F. hispida	F=17	326-1,351	55.5±14.2	2.9±1.2	41.4	1,140±486	17.2 x 14.0[a]	28.5 x 25.4[a]	0.0
	M=20	330-1,268	63.1±14.8	2.9±0.9	41.5	155±7	17.7 x 15.0[a]	29.3 x 23.7[a]	0.0
F. oligodon	F=25	616-1,293	69.2±23.3	5.1±1.9	10.5	8,692±4,244	37.4 x 31.3[a]	61.0 x 53.1[b]	2.7
	M=25	605-1,336	83.3±27.7	4.1±1.4	20.6	1,400±7	36.5 x 30.2[a]	70.7 x 61.1[a]	2.5
F. semicordata	F=17	418-1,531	68.7±25.5	3.3±1.2	57.8	712±413	9.7 x 8.3[a]	23.4 x 19.3[b]	0.0
	M=17	420-1,401	65.4±18.6	3.1±1.1	29.9	163±50	7.0 x 7.0[b]	32.2 x 24.7[a]	0.0

Table 8 (continued)

Species	Sex [1]	Elevation (m)	GBH [2] (cm)	Crop duration (months)	Asynchronous fig production [3] (%)	No. of seeds/wasps (per fig)	Fig size at RCP [4] (mm)	Fig size at RPP/RLP [4] (mm)	Crop abortion (%)
F. triloba	F=5	994-1,172	40.4±14.7	3.4±2.4	3.4	2,755±783	27.0 x 28.0^{b}	30.5 x 35.8^{b}	33.3
	M=6	1,000-1200	60.0±35.1	4.8±1.8	15.4	515±30	28.6 x 35.2^{a}	40.1 x 46.1^{a}	0.0
F. variegata	F=10	899-1,343	212.9±95.4	6.4±2.5	3.4	1,825±978	23.0 x 22.0^{a}	32.6 x 28.7^{b}	0.0
	M=4	1,084-1,205	163.5±2.1	3.4±0.5	6.3	187±15	18.2 x 17.1^{b}	41.5 x 33.5^{a}	0.0

[1] Sex: F = Female trees and M = Male trees.

[2] GBH = Girth at breast height (1.3 m from the ground).

[3] Asynchronous fig production is the mean percentage of total trees observed (of each species) which bore both releasing and receptive figs simultaneously, averaged across the total study period.

[4] Developmental phases; RCP = Receptive phase; RPP = Ripening phase; and RLP = Releasing phase (width x length).

Different letters denote significant differences between sexes according to a *T*-test at a significant level of $P<0.05$.

Table 9 Results of Pearson's correlation test between weather conditions (monthly average rainfall and temperature) with leaf and reproductive phenologies of seven selected fig species. RA=Monthly mean rainfall, TE=Monthly mean temperature; SL=Senescence leaf, BA=Bare area, leaf fall, YL=Young leaf; IMP=Immature phase, RPP=Ripening phase, RLP=Releasing phase, RCP=Receptive phase; FS=Fig size (width x length), SE=Seed number; vs=versus.

Correlations [a]	*F. auriculata*		*F. fulva*		*F. hispida*		*F. oligodon*		*F. semicordata*		*F. triloba*		*F. variegata*	
	F	M	F	M	F	M	F	M	F	M	F	M	F	M
RA vs SL	-0.6*	-0.6*	ns	ns	-0.6*	-0.6*	ns	ns	-0.6*	-0.6*	ns	-0.6*	ns	ns
RA vs BA	ns	ns	ns	-0.5*	ns	-0.6*	ns	-0.5*	-0.6*	ns	ns	ns	ns	ns
RA vs YL	ns	ns	-0.7**	ns	ns	ns	-0.6*	-0.6*	ns	ns	0.6*	ns	ns	ns
TE vs SL	-0.7**	-0.7**	ns	-0.5*	ns	-0.6*	-0.9**	-0.9**	ns	-0.6*	ns	-0.6*	-0.8**	-0.8**
TE vs BA	ns	ns	-0.7**	-0.7*	ns	ns	-0.9**	-0.9**	ns	ns	ns	ns	-0.8**	-0.8**
TE vs YL	ns	ns	ns	ns	ns	ns	ns	ns	0.5*	0.6*	ns	0.5*	ns	ns
RA vs IMP	ns	-0.6*	ns	-0.6*	ns	-0.7**	-0.7**	ns	ns	ns	ns	ns	ns	ns
RA vs RPP	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
TE vs IMP	ns	-0.7**	ns	ns	ns	ns	ns	-0.9**	0.5*	ns	ns	ns	ns	-0.7**
TE vs RPP	ns	ns	0.7*	ns	ns	0.6*	ns	ns	ns	0.6*	ns	ns	ns	ns
IMP vs YL	ns	ns	0.6*	ns	ns	ns	0.9**	ns	ns	ns	ns	ns	0.6*	ns
RLP vs RCP	0.6*	ns	ns	ns	0.8**	ns	0.6*	ns	ns	ns	ns	ns	ns	ns
FS vs SE	ns	-	ns	-	0.8*	-	0.7**	-	0.8**	-	ns	-	0.5**	-

*$P<0.05$, **$P<0.01$, ns = non significant ($P>0.05$); [a] Correlations between weather conditions, leaf phenology and syconia phenology.

4.2.2 Phenology of each species

4.2.2.1 *Ficus auriculata*. *Ficus auriculata* trees were semi-deciduous (dropping leaves at least 50% canopy fullness). Leafing patterns did not differ between male and female trees (Fig. 9b, d). Generally, most trees changed their leaves once per year but the trees were never leafless. However, some individual trees shed leaves all year round but in small amounts, particularly trees located far from streams or moist areas. Leaf senescence and leaf fall occurred during the mid-dry season (January to February) and leaf flushing occurred in March. Leaf senescence was significantly and negatively correlated with rainfall and temperature (Table 9).

At the individual-level, male figs bore up to 3 (mean 1.6) crops a year, female trees up to 10 (mean 2.9). Some female trees bore figs all year round but not male trees. Fig crop duration on female trees was shorter than on male trees (Table 8). Peak ripe fig production on female and male trees occurred in July and April, respectively (Fig. 9a, c). Abortion of young figs occurred only on male trees (about 4.8% of total crops), mainly for crops produced in rainy season.

Within-trees, asynchronous fig production (releasing and receptive figs present simultaneously within an individual tree crown) was common on female trees but was rare on male trees (Table 8). Fig initiation of male trees was negatively correlated with average monthly temperature and rainfall. Peak pollen and wasp production (RLP) coincided with peak female receptivity (Table 9).

4.2.2.2 *Ficus oligodon*. *Ficus oligodon* trees were semi-deciduous, but the trees were never leafless (maximum leaf drop about 60% of the canopy area in December-

January). Both sexes renewed leaves in small quantities all year round. Leafing patterns were the same for male and female trees (Fig. 10b, d). At the population-level both sexes changed their leaves in small amounts all year round but rarely from April to July. At the individual-level, most trees produced their new leaves 1-2 times per year (less than 20% of trees observed produced new leaves nearly year-round). Leaf senescence occurred from August to February, peaking from November to January. Leaf fall mainly occurred from December to January, and new leaf production was highest in February. Leaf flushing was positively and significantly correlated with fig crop initiation for female trees. Also, rainfall and temperature conditions were negatively correlated with leafing phenology of both sexes (Table 9).

At the individual-level, male trees bore up to 4 (mean 2) crops a year; female trees up to 5 (mean 1.5), and some trees of both sexes bore figs all year round. Crop duration of female trees was longer than that of male trees (Table 8). Fig production peaked in March for male trees and in May for female trees (Fig. 10a, c). Abortion of young figs occurred in the small amount of both sexes (2.7% and 2.5% for female and male trees respectively) mainly in crops produced in the rainy season (from July to August).

Within-tree, asynchronous fig production was more common on male trees rather than on female trees (Table 8). Fig initiation on male trees was negatively correlated with average monthly temperature, but for female trees, it was negatively correlated with average monthly rainfall (Table 9). Also, fig initiation of female trees was positively correlated with leaf flushing. Pollen and wasp production (RLP) were also positively correlated with female receptivity (Table 9).

4.2.2.3 ***Ficus variegata***. Leafing phenology differed between the sexes (Fig. 11b, d). Female trees were deciduous while most male trees (3 out of 4 male trees observed) were semi-deciduous (i.e. leaf exchange in small amounts over a prolonged period). Females started to drop their leaves from the mid-rainy season to the dry season (August to March), but leaf exchange on male trees occurred later, mainly starting in the dry season (October-March). However, peaks of leaf senescence, leaf fall and new leaf flushing occurred in November (to December), January and February, respectively for both sexes. Leaf flushing was positive correlated with the fig initiation of female trees but was not correlated with new crops of male trees. Also, leafing phenology of both sexes of *F. variegata* was affected by average monthly temperature, rather than by rainfall (Table 9).

Most of the study trees did not produce figs (61% of all trees observed), although all individuals were apparently mature (mean GBH >100 cm), therefore sex could not be determined for non-fruiting trees. For those that could be sexed, at the population-level, only female trees produced figs all year round. Male trees produced figs for only 4 months of the year (from December to March). At the individual-level, both sexes bore 2 crops a year (mean crop number, 1.3 and 1.1 for male and female trees, respectively), and some individual female trees bore figs all year round. Crop duration of female trees was longer than that of male trees (Table 8). Peak ripe fig production of male and female trees occurred in March and May, respectively (Figure 11a, c).

Within-trees of both sexes, fig production were synchronous (Table 8). Also, fig initiation of female trees coincided with new leaf flushing (Table 9).

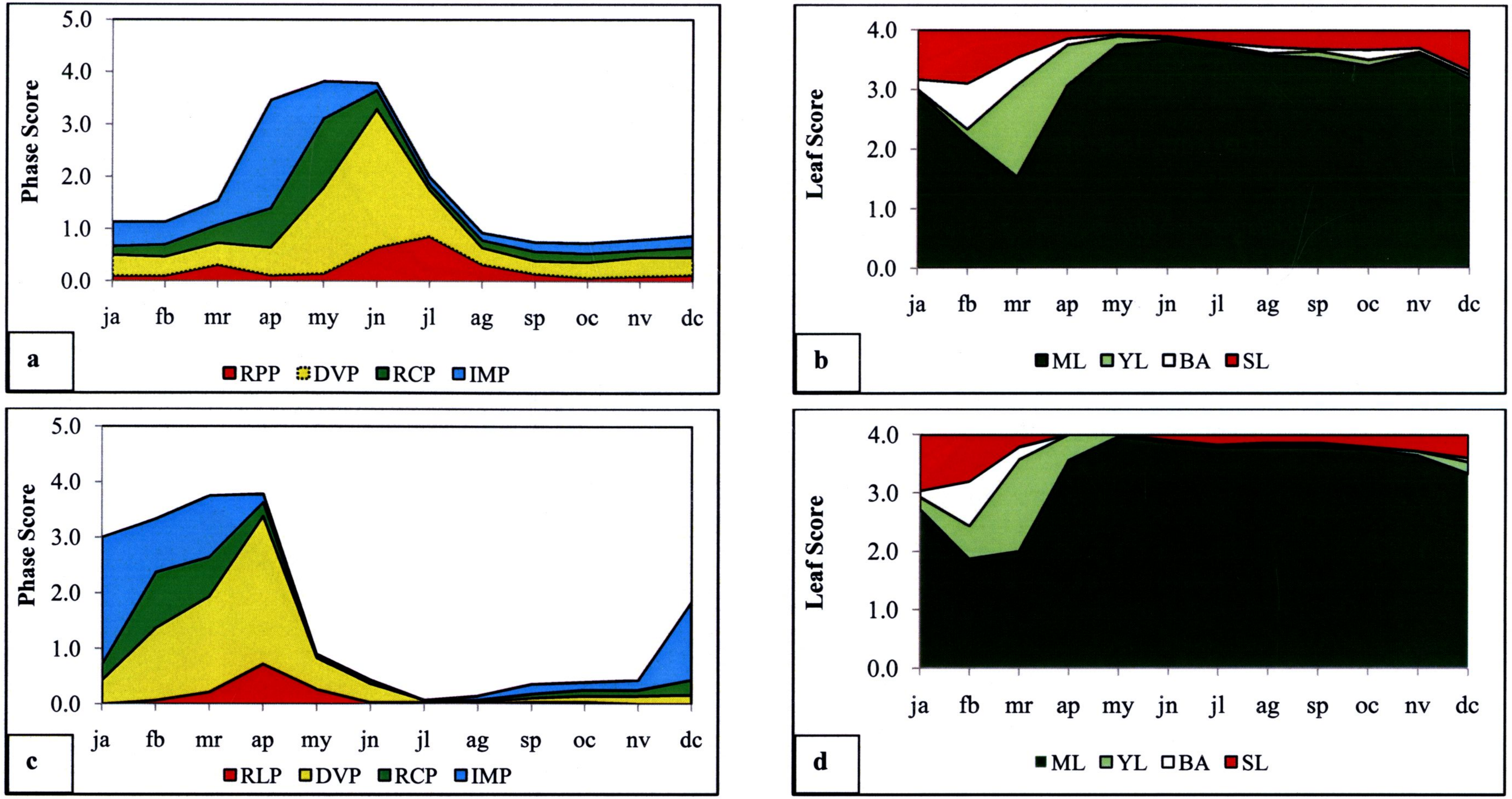


Figure 9 Leaf and fig production rhythms of *Ficus auriculata* at the population-level; female trees (a) reproductive phenology and (b) leafing phenology, male trees (c) reproductive phenology and (d) leafing phenology.

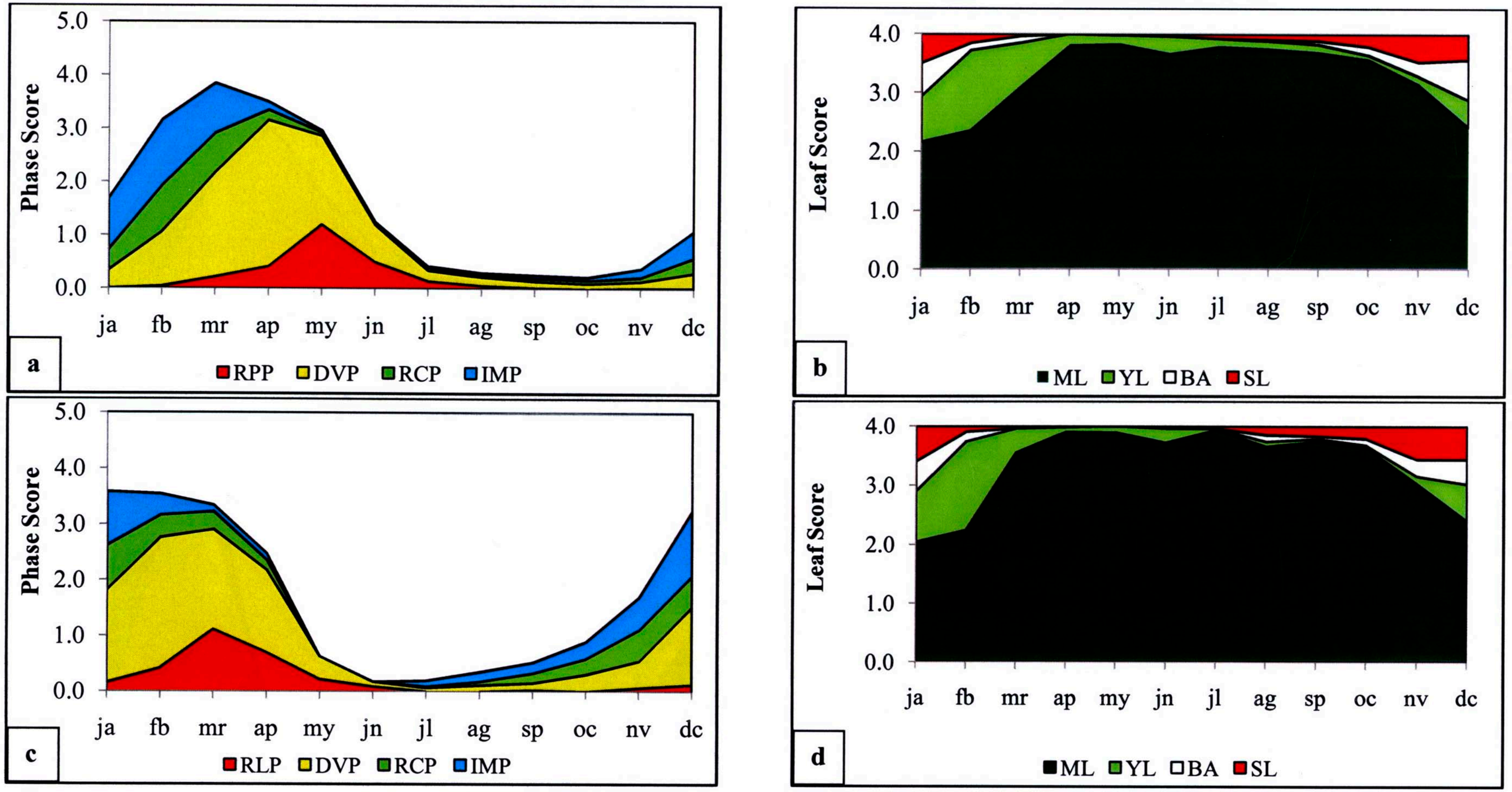


Figure 10 Leaf and fig production rhythms of *Ficus oligodon* at the population-level; female trees (a) reproductive phenology and (b) leafing phenology, male trees (c) reproductive phenology and (d) leafing phenology.

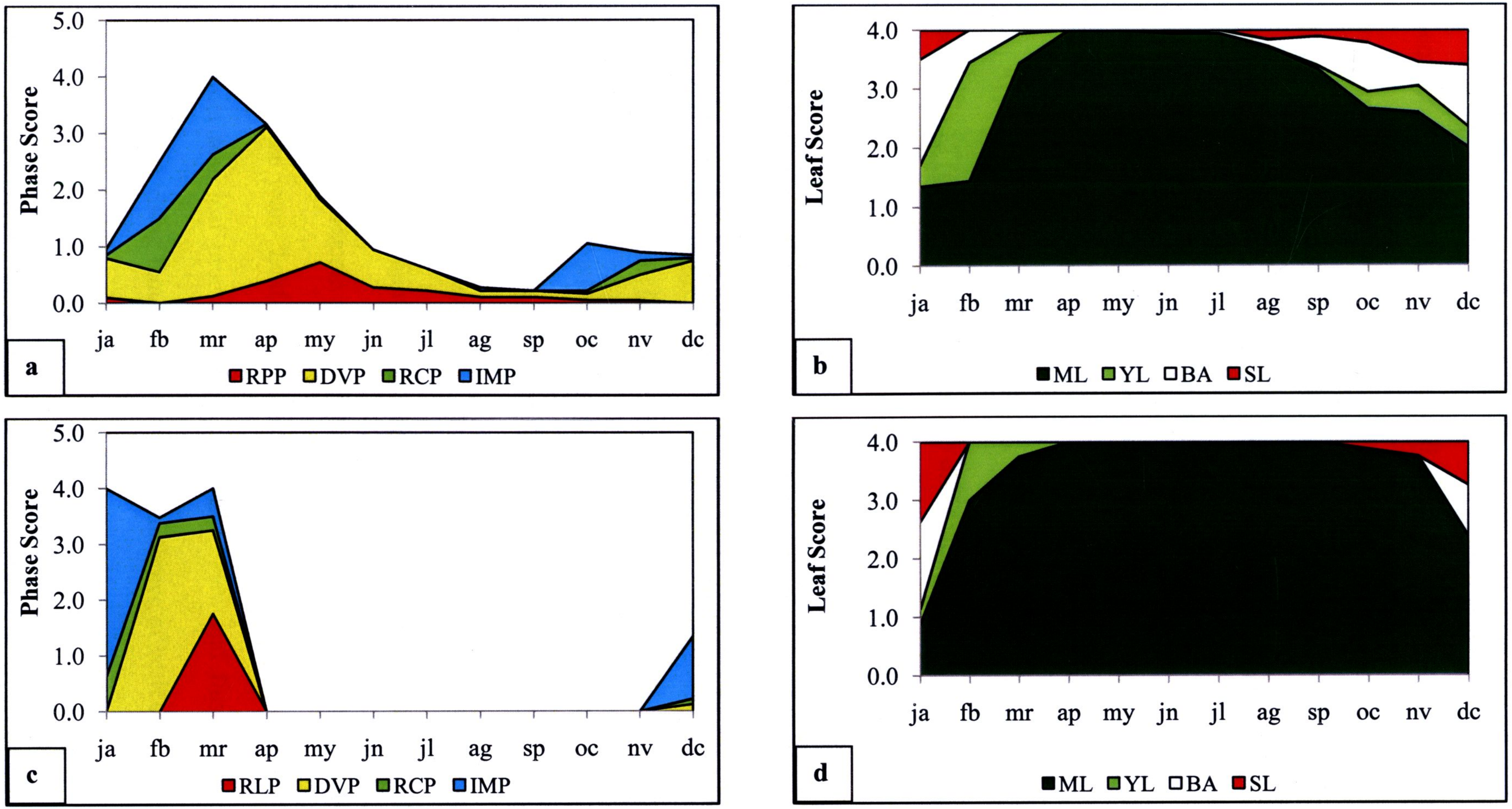


Figure 11 Leaf and fig production rhythms of *Ficus variegata* at the population-level; female trees (a) reproductive phenology and (b) leafing phenology, male trees (c) reproductive phenology and (d) leafing phenology.

4.2.2.4 *Ficus hispida*. Most trees of both sexes (>80% of tree observed) were evergreen, but leaf changing in small amounts occurred at irregular intervals throughout the year (<10% canopy fullness), especially in the dry season (October to May). There were no differences in leafing pattern between the sexes (Fig. 12b, d). Leaf senescence and leaf fall peaked in the dry season (January to April), and leaf flushing peaked in May. Leafing phenology of male tree was more sensitive to climatic conditions (average monthly temperature and rainfall) than that of female tree (Table 9).

At the individual-level, male figs bore up to 8 (mean 5.1) crops a year; female trees up to 12 (mean 5.4). There were no differences in crop duration between female and male trees (Table 8). Wasp and seed production of *F. hispida* occurred year-round but both peaked in May (Fig. 12a, c). Within-tree, asynchronous fig production was fairly common on both sexes. Most trees initiated new figs, whilst some immature figs of the previous crop were still on the tree, and some trees were never without figs throughout the observation period. Fig initiation on male trees was negatively correlated with average monthly rainfall. Pollen and wasp production (RLP) were positively correlated with female receptivity (Table 9).

4.2.2.5 *Ficus semicordata*. *Ficus semicordata* was evergreen. Leaf exchange occurred in small amounts throughout the year. Leafing patterns did not differ between male and female trees (Fig. 13b, d). Some new leaves were produced in all months of the year. Leaf senescence and leaf fall was maximal in February, while maximum new leaf production began in May. New leaf flushing was positively correlated with rising temperature and leaf senescence of both sexes was negatively correlated with rainfall (Table 9).

At the individual-level, male figs bore up to 8 (mean 4.3) crops a year; female trees up to 7 (mean 4.8), and most individual trees of both sexes bore figs all year round. Crop duration of females and males was similar (Table 8). At the population-level, wasp and seed production of *F. semicordata* peaked in July for male trees and in August for female trees (Figure 13a, c). Within-tree, asynchronous fig production was fairly common on both sexes. Most trees started producing new figs while some immature figs of the previous crop were still on the tree, however, asynchronous fig production within female trees was higher than that of male trees (Table 8). Average monthly temperature was positively correlated with fig initiation of female trees and fig ripening of male trees (Table 9).

4.2.2.6 *Ficus fulva*. *Ficus fulva* was deciduous. Both sexes shed all their leaves and expanded new ones within a few weeks. However, leafing patterns of female and male trees were different. Most female trees exchanged their leaves twice per year (from August to January, and from April to May), the highest peaks of leaf senescence, leaf fall and leaf flushing were in November, December and January respectively (Fig. 14b). New leaf production was positively correlated with fig initiation (Table 9). On the other hand, most male trees exchanged their leaves only once per year, the peak of leaf changing generally occurred 3 months after that of female trees. The highest peaks of leaf senescence, leaf fall, and leaf flushing were in February, March and April respectively (Fig. 14d). Temperature was negatively correlated with leaf fall of both sexes (Table 9).

At the individual-level, male figs bore up to 5 (mean 1.9) crops a year; female trees up to 4 (mean 2.4), and some trees (of both sexes) bore figs all year round. Crop duration of female trees was longer than that of male trees (Table 8). Ripe fig production peaked in February and May, for male and female trees respectively (Fig. 14a, c). Abortion of young figs occurred only on female trees (about 5% of total crops), mainly in crops produced at the beginning of the cool dry season (October). Within-tree, asynchronous fig production was rare on both sexes (Table 8). Also, fig initiation of female trees was positively correlated with new leaf flushing (Table 9).

4.2.2.7 *Ficus triloba*. The leafing pattern differed between the sexes of *F. triloba* (Fig. 15b, d). Female trees were semi-deciduous but male trees were deciduous. Leaf senescence and leaf fall of female trees mainly occurred in the dry season (not all leaves) peaking in February and May respectively with leaf flushing peaking in June. Male trees changed their leaves all year round. Most male trees dropped all their old leaves twice per year, with leaf exchange peaking 1 month earlier (January to February) than that of female trees. Leaf senescence and leaf fall peaked in February whilst leaf flushing peaked in April-May. The leafing pattern of male trees was more sensitive to climatic conditions than that of female trees. Leaf flushing of female trees was positively correlated with rainfall and for males it was positively correlated with average monthly temperature (Table 9).

At the individual-level, male figs bore up to 3 (mean 2.2) crops a year; female trees up to 2 (mean 1.8). Some individual male trees bore figs all year round but not so for female trees. Crop duration of female trees was shorter than that of male trees. Abortion of young figs on female trees was high (33.3%; Table 8), especially in crops produced during the dry season. Peak fig production of female and male trees was evident (July for male trees and October for female trees; Figure 15a, c). Within-tree, asynchronous fig production of both sexes was rare, and was mainly seen on male trees rather than on female trees (Table 8).

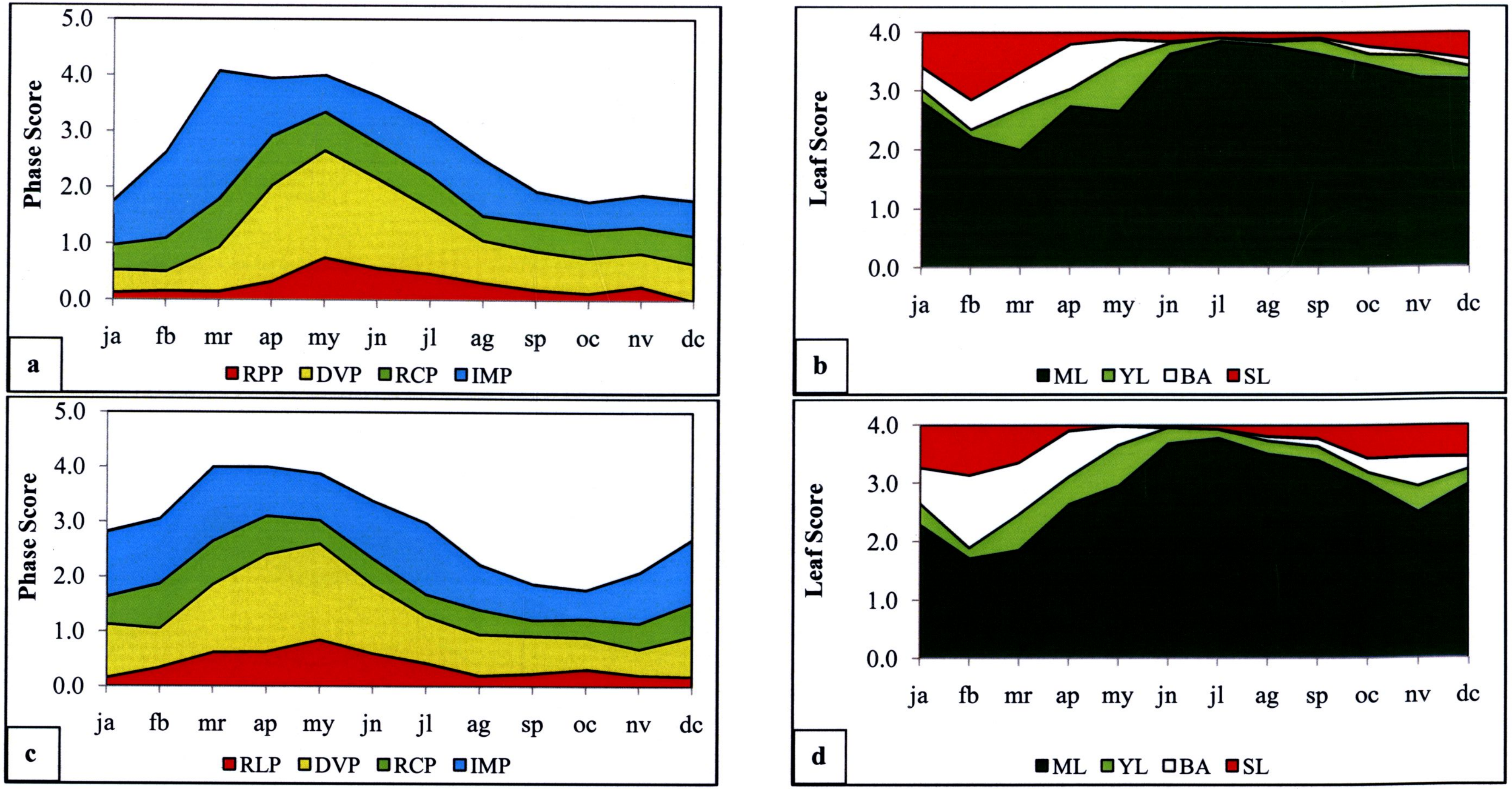


Figure 12 Leaf and fig production rhythms of *Ficus hispida* at the population-level; female trees (a) reproductive phenology and (b) leafing phenology, male trees (c) reproductive phenology and (d) leafing phenology.

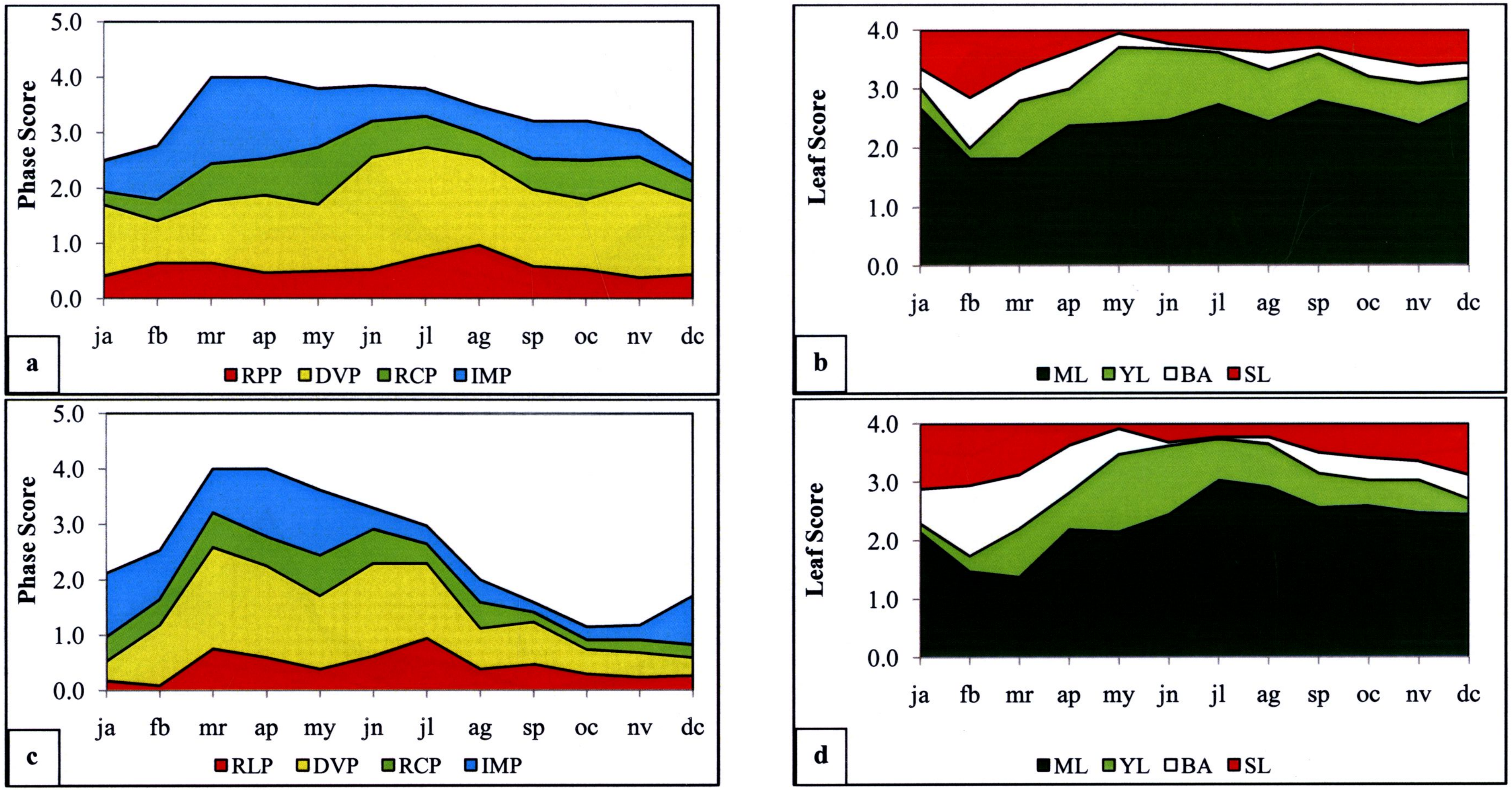


Figure 13 Leaf and fig production rhythms of *Ficus semicordata* at the population-level; female trees (a) reproductive phenology and (b) leafing phenology, male trees (c) reproductive phenology and (d) leafing phenology.

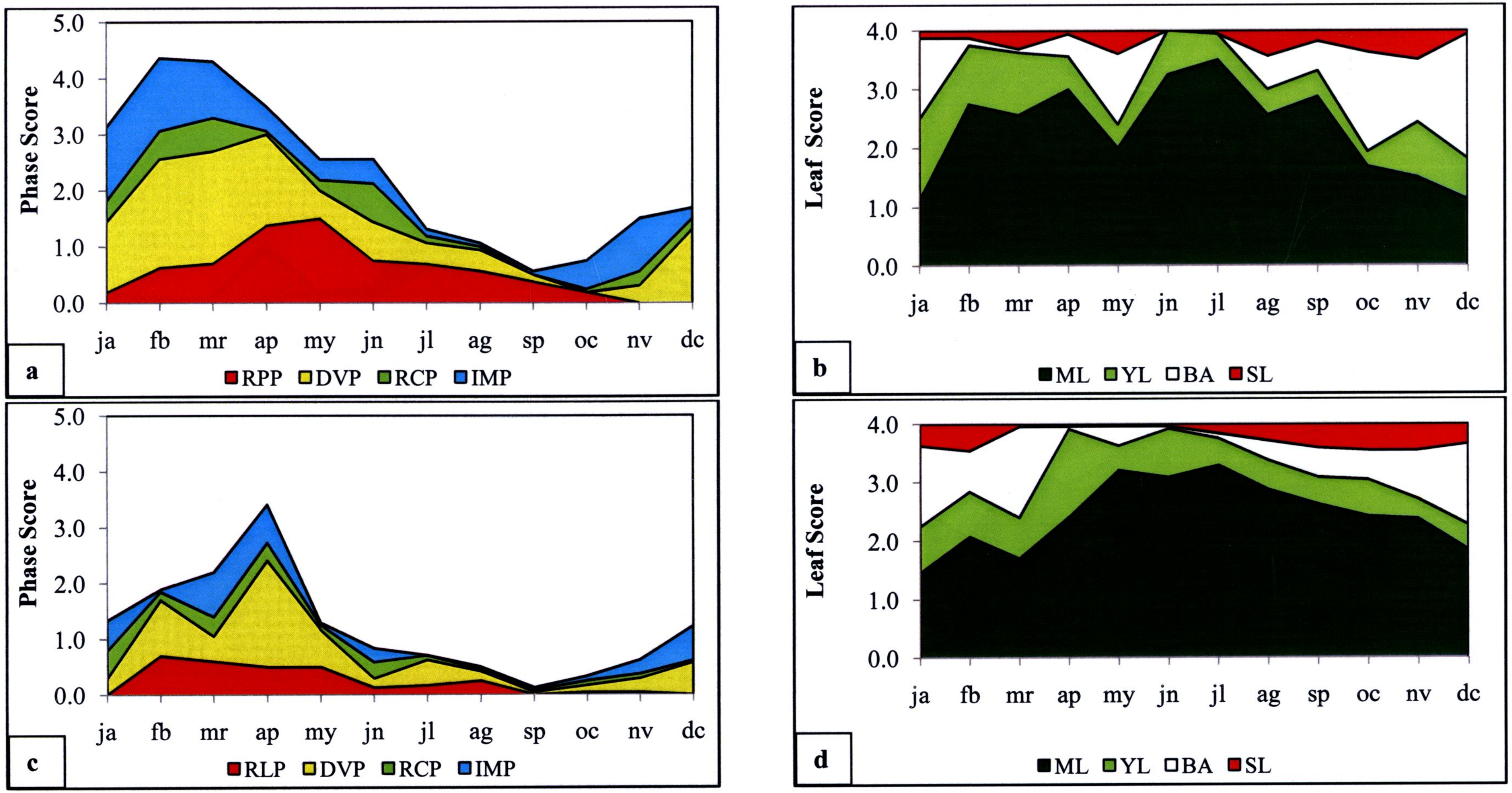


Figure 14 Leaf and fig production rhythms of *Ficus fulva* at the population-level; female trees (a) reproductive phenology and (b) leafing phenology, male trees (c) reproductive phenology and (d) leafing phenology.

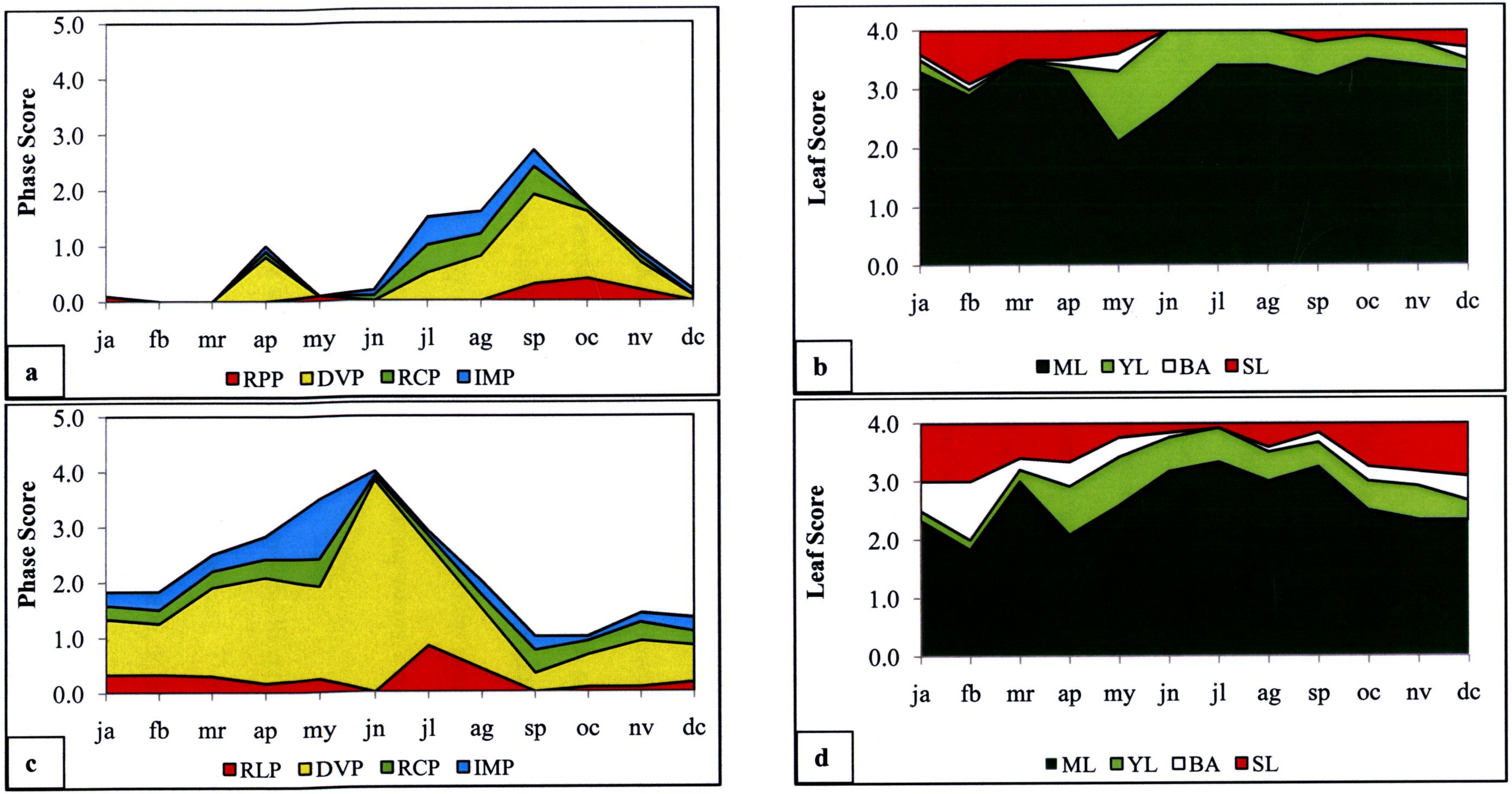


Figure 15 Leaf and fig production rhythms of *Ficus triloba* at the population-level; female trees (a) reproductive phenology and (b) leafing phenology, male trees (c) reproductive phenology and (d) leafing phenology.

4.3 *Ficus* and their associated wasps

4.3.1 General. At receptivity, fig sizes of the selected *Ficus* species varied between sexes. Female figs were larger than males. The number of foundresses per fig varied among *Ficus* species, but exhibited a positive correlation with fig size. Small figs tended to host fewer foundresses than larger ones. For example, in *F. fulva* and *F. semicordata*, the number of foundresses in one fig varied from 1 to 4, whilst in the biggest fig, *F. auriculata* the number of foundresses reached up to 227. For *F. fulva*, *F. semicordata*, *F. triloba* and *F. variegata*, more than 40% of all samples were entered by a single foundress. There was usually no significant difference in foundress number between female and male figs of most species (except for *F. auriculata*, *F. hispida* and *F. variegata*; Table 10). The female fig cavity of most species filled with a jelly-like substance during ripening, except for female figs of *F. hispida*, which dried at fig maturity. At fig maturity, the diameter of male figs was obviously larger than that of female figs (Table 10). However, female figs of all species produced more seeds than male figs produced pollinators (Table 13). Although, the mean number of seeds per fig varied seasonally, seed production of most species in the rainy season was higher than in other seasons (Table 14). Only female figs of *F. oligodon* produced non-pollinating wasps, even through the numbers were few.

In male figs of the seven selected *Ficus* species, 30 species of 7 genera of fig wasp were found. In all species, males were wingless. Two genera of pollinators found consisted of *Ceratosolen* and *Vilisia*. *Ficus fulva*, *F. semicordata*, *F. triloba* and *F. variegata* had specific pollinators, whilst *F. auriculata* and *F. oligodon* shared the same species of *C. emarginatus* as the pollinator, and *F. hispida* had two species as pollinator (Table 11).

The non-pollinating wasp community varied among *Ficus* species but did not depend on the size of fig. On average, there were between three and four NPFWs per host, ranging from 2 (*F. fulva* and *F. triloba*) to 6 (*F. oligodon* and *F. semicordata*). *Philotrypesis*, *Platyneura* and *Sycoscapter* were the dominant groups in most studied figs, whilst *Apocrypta* spp. were rarely recorded (Table 11).

The number of emerging pollinators, averaged per fig, varied from 28 (*F. auriculata*) to 1,400 (*F. oligodon*). The percentage of pollinators in a single fig was higher than that of non-pollinators in most figs (except for *F. auriculata* and *F. fulva*, Table 10). Pollinators accounted for 91% of total fig wasps in *F. oligodon*, 87.9% in *F. triloba*, 87.6% in *F. hispida*, 84.8% in *F. semicordata* and *F. variegata*. However, in *F. fulva* and *F. auriculata* the pollinators accounted for only 48.5% and 9.5% of the total fig wasps.

In general, in dioecious *Ficus* species, fig wasps were mostly found only in male figs but *Platyneura* sp. reproduced in both female and male figs of *F. oligodon*, although *Platyneura* sp. was found on a female *F. oligodon* in only crop in rainy season (June to August).

4.3.2 Effect of fragmentation. Habitat disturbance had contradictory effects on the number of foundresses among *Ficus* species (Table 12) but had a consistent and highly significant effect on seed production. Disturbance significantly reduced seed production (Table 13).

Table 10 Sexual specialization of the selected *Ficus* species in different phases.

Species	Sex	Fig Size (W x L mm)		Mean foundreses per fig	No. of associated fig-wasps per fig		
		RCP	RPP/RLP	(Mean ± SE)	Pollinators	Non-pollinators	Fig wasp ratio (pollinator/non-pollinator)
FIAU	F	48.0 x 46.3[a]	66.2 x 53.7[b]	12.3± 2.7[b]	-	-	-
	M	54.2 x 43.2[a]	86.0 x 65.6[a]	58.7± 14.4[a]	28.5±7.8	272.5±96.9	1 : 9.6
FIFU	F	13.0 x 16.0[a]	17.7 x 19.2[b]	1.8± 0.6[a]	-	-	-
	M	12.0 x 11.8[b]	20.3 x 20.0[a]	2.0± 0.4[a]	66.9±12.0	70.9±9.4	1 : 1.1
FIHI	F	17.2 x 14.0[a]	28.5 x 25.4[a]	7.5± 0.9[a]	-	-	-
	M	17.7 x 15.0[a]	29.3 x 23.7[a]	4.1± 0.5[b]	154.5±7.1	21.9±5.3	1 : 0.1
FIOL	F	37.4 x 31.3[a]	61.0 x 53.1[b]	9.0± 3.3[a]	-	-	-
	M	36.5 x 30.2[a]	70.7 x 61.1[a]	13.9± 5.3[a]	1,400.0±41.7	139.0±30.7	1 : 0.1
FISE	F	9.7 x 8.3[a]	23.4 x 19.3[b]	1.9± 0.3[a]	-	-	-
	M	7.0 x 7.0[b]	32.2 x 24.7[a]	2.2± 0.5[a]	163.1±49.7	29.3±2.9	1 : 0.2
FITR	F	27.0 x 28.0[b]	30.5 x 35.8[b]	5.0± 2.5[a]	-	-	-
	M	28.6 x 35.2[a]	40.1 x 46.1[a]	2.6±1.5[a]	515.0±30.1	71.0±5.0	1 : 0.1
FIVA	F	23.0 x 22.0[a]	32.6 x 28.7[b]	4.7± 0.6[a]	-	-	-
	M	18.2 x 17.1[b]	41.5 x 33.5[a]	3.3± 0.3[b]	186.5±15.3	33.5±10.6	1 : 0.2

FIAU = *F. auriculata*, FIFU = *F. fulva*, FIHI = *F. hispida*, FIOL = *F. oligodon*, FISE = *F. semicordata*, FITR = *F. triloba*, FIVA = *F. variegata*

F = female; M = male; RCP = Receptive phase; RPP = Ripening phase; RLP = Releasing phase; (-) = No wasp in female fig.

Different superscript letters (within a column) denote significant differences between sexes according to a *T*-test at a significant level of $P<0.05$.

Table 11 Fig wasps reared from seven *Ficus* species in Doi Suthep-Pui National Park, during March 2008 - February 2009.

Species	**Families/sub-families of fig wasps** [a]	**Associated fig wasps**	**Pollination mode**
F. auriculata	Agaonidae (*Agaoninae*)	*Ceratosolen emarginatus* Mayr	Pollinator
	Pteromalidae (*Sycoryctinae*)	*Philotrypesis longicaudata* Mayr	Non-pollinator
	Pteromalidae (*Sycoryctinae*)	*Philotrypesis* sp.	Non-pollinator
	Agaonidae (*Sycophaginae*)	*Platyneura* sp.	Non-pollinator
F. fulva	Agaonidae (*Agaoninae*)	*Valisia compacta* Wiebes	Pollinator
	Pteromalidae (*Sycoryctinae*)	*Philotrypesis* sp.	Non-pollinator
	Pteromalidae (*Sycoryctinae*)	*Sycoscapter* sp.	Non-pollinator
F. hispida	Agaonidae (*Agaoninae*)	*Ceratosolen solmsi marchali* Mayr	Pollinator
	Agaonidae (*Agaoninae*)	*Ceratosolen solmsi* Mayr	Pollinator
	Pteromalidae (*Sycoryctinae*)	*Apocrypta bakeri* Joseph	Non-pollinator
	Pteromalidae (*Sycoryctinae*)	*Philotrypesis pilosa* Mayr	Non-pollinator
	Pteromalidae (*Sycoryctinae*)	*Philotrypesis* sp.	Non-pollinator
F. oligodon	Agaonidae (*Agaoninae*)	*Ceratosolen emarginatus* Mayr	Pollinator
	Pteromalidae (*Sycoryctinae*)	*Philotrypesis longicaudata* Mayr	Non-pollinator
	Pteromalidae (*Sycoryctinae*)	*Philotrypesis* sp1	Non-pollinator
	Agaonidae (*Sycophaginae*)	*Platyneura* sp1	Non-pollinator
	Agaonidae (*Sycophaginae*)	*Platyneura* sp 2	Non-pollinator
	Pteromalidae (*Sycoryctinae*)	*Sycoscapter roxberghi*	Non-pollinator

Table 11 (continued).

Species	Families/sub-families of fig wasps [a]	Associated fig wasps	Pollination mode
F. semicordata	Agaonidae (*Agaoninae*)	*Ceratosolen gravelyi* Grandi	Pollinator
	Pteromalidae (*Sycoryctinae*)	*Apocrypta* sp.	Non-pollinator
	Pteromalidae (*Sycoryctinae*)	*Philotrypesis dunia* Joseph	Non-pollinator
	Pteromalidae (*Sycoryctinae*)	*Philotrypesis* sp1	Non-pollinator
	Agaonidae (*Sycophaginae*)	*Platyneura cunia*	Non-pollinator
	Agaonidae (*Sycophaginae*)	*Platyneura* sp1	Non-pollinator
	Pteromalidae (*Sycoryctinae*)	*Sycoscapter trifemmensis*	Non-pollinator
F. triloba	Agaonidae (*Agaoninae*)	*Vilisia esquirolianae* Chen & Chou	Pollinator
	Pteromalidae (*Sycoryctinae*)	*Sycoscapter* sp1	Non-pollinator
	Pteromalidae (*Sycoryctinae*)	*Sycoscapter* sp2	Non-pollinator
F. variegata	Agaonidae (*Agaoninae*)	*Ceratosolen appendiculatus* Mayr	Pollinator
	Pteromalidae (*Sycoryctinae*)	*Philotrypesis bimaculata* Mayr	Non-pollinator
	Agaonidae (*Sycophaginae*)	*Platyneura spinitarsus*	Non-pollinator
	Pteromalidae (*Sycoryctinae*)	*Sycoscapter patellaris* Mayr	Non-pollinator

[a] Taxonomy based on Boucek (1988) and Rasplus *et al.* (1998).

Table 12 The mean number of foundresses per fig was collected from the different collection sites (Mean ± SD).

Species	No. of foundreses per fig			
	Primary forest	Highly disturbed habitat	Planted plot	*P* -Value
F. auriculata	24.3 ± 5.9^{a} (*N*=56)	30.2 ± 8.5^{a} (*N*=33)	24.0 ± 3.0^{a} (*N*=20)	0.699, ANOVA
F. fulva	1.9 ± 1.1 (*N*=19)	-	-	-
F. hispida	2.5 ± 0.5^{a} (*N*=20)	5.7 ± 0.5^{a} (*N*=45)	6.3 ± 3.1^{a} (*N*=30)	0.475, ANOVA
F. oligodon	11.1 ± 2.6 (*N*=19)	-	-	-
F. semicordata	2.3 ± 0.5^{a} (*N*=60)	2.0 ± 0.6^{a} (*N*=30)	2.0 ± 0.3^{a} (*N*= 40)	0.531, ANOVA
F. triloba	11.5 ± 1.5^{a} (*N*=20)	1.6 ± 0.4^{b} (*N*=50)	1.3 ± 0.3^{b} (*N*=40)	*P*<0.05, ANOVA
F. variegata	4.7 ± 0.4^{a} (*N*=33)	1.8 ± 0.3^{b} (*N*=26)	-	*P*<0.05, *T*-Test

Values in a row with different superscript letters are significantly different according to *T*-test or *LSD*-test at *P*<0.05.

(-) = No sample collected.

Table 13 Mean seeds per fig by different sample sites.

Species	Proportion of wasps / seeds produced in single syconium	Seeds per fig: Primary forest Mean ± SD	Seeds per fig: Highly disturbed habitat Mean ± SD	Seeds per fig: Planted forest Mean ± SD	*P* -Value
FIAU	1 : 32	$9,685 \pm 1,560^{a}$ (*N*=17)	$4,812 \pm 3,689^{ab}$ (*N*=17)	$2,801 \pm 45^{b}$ (*N*=12)	0.016, ANOVA
FIFU	1 : 6	858 ± 312 (*N*=24)	-	-	-
FIHI	1 : 8	$1,337 \pm 528^{a}$ (*N*=32)	$1,015 \pm 403^{ab}$ (*N*=37)	812 ± 340^{b} (*N*=25)	0.005, ANOVA
FIOL	1 : 6	8,859 ± 4,115 (*N*=50)	-	-	-
FISE	1 : 4	781 ± 379^{b} (*N*=56)	$1,213 \pm 471^{a}$ (*N*=37)	713 ± 414^{b} (*N*=42)	0.000, ANOVA
FITR	1 : 5	2,755 ± 784 (*N*=35)	-	-	-
FIVA	1 : 11	$2,342 \pm 209^{a}$ (*N*=29)	$1,552 \pm 152^{b}$ (*N*=36)	-	0.03, *T*-Test

FIAU= *F. auriculata*, FIFU= *F. fulva*, FIHI= *F. hispida*, FIOL= *F. oligodon*, FISE= *F. semicoradata*, FITR= *F. triloba*, FIVA= *F. variegata*

Values in a row with different superscript letters are significantly different according to *T*-test or *LSD*-test at $P<0.05$.

(-) = No sample collected.

Table 14 Seasonal effects on seed production (per fig).

Species	**No. of seeds per fig** (Mean ± SE)			
	Rainy Season (June-September)	Cool-dry Season (October-January)	Dry Season (February-May)	*P*- value
F. auriculata	$10{,}759 \pm 2{,}873^{a}$ (*N*=40)	$5{,}798 \pm 1{,}506^{b}$ (*N*=27)	$5{,}028 \pm 805^{b}$ (*N*=30)	$P<0.05$
F. fulva	-	-	858 ± 31 (*N*=24)	-
F. hispida	921 ± 107^{a} (*N*=41)	$1{,}026 \pm 260^{a}$ (*N*=50)	$1{,}192 \pm 65^{a}$ (*N*=58)	$P=0.20$
F. oligodon	$8{,}063 \pm 444^{a}$ (*N*=40)	-	$8{,}883 \pm 657^{a}$ (*N*=44)	$P=0.712$
F. semicordata	951 ± 116^{a} (*N*=32)	613 ± 66^{b} (*N*=30)	693 ± 68^{ab} (*N*=43)	$P< 0.05$
F. triloba	$2{,}742 \pm 221^{a}$ (*N*=33)	$2{,}838 \pm 686^{a}$ (*N*=20)	-	$P=0.88$
F. variegata	$2{,}302 \pm 36^{a}$ (*N*=23)	789 ± 135^{b} (*N*=29)	$2{,}288 \pm 881^{a}$ (*N*=32)	$P<0.05$

Similar superscript letters in the same row indicate means, which are not significantly different.

(-) = No sample collected.

4.4 *Ficus* propagation

4.4.1 Propagation from seed. Seeds of all species began to germinate within 3-4 weeks after sowing and completed germination within 7-8 weeks (Fig. 16). Germination was epigeal and the first true leaves were opposite. Median length of dormancy (MLD) ranged from 19 to 23 days, but was not significantly different among treatments and species. Germination percentages for each species, averaged across all treatments ranged from 36 to 73 %. Statistical analysis divided the species into three germination classes: i) those with high germination: *F. variegata* (73%), *F. fulva* (70%) and *F. auriculata* (68%) and ii) those with moderate germination: *F. semicordata* (51%) and *F. oligodon* (47%), and those with low germination *F. hispida* (36%) (P<0.05, Table 15).

For all species, the germination medium of forest soil alone resulted in the highest germination percentage (63%), followed by 61% for sand/forest soil and 48% for sand/charred rice husk (P<0.05, Fig. 17A). In contrast, after germination, the survival rate of young fig seedlings of all species was significantly higher (67%) in sand/charred rice husk than in both of the other media (P<0.05, Fig. 17B). Fungicide application tended to decrease germination and survival rates (P=0.055, N=216 and P=0.044, N=209, respectively, Fig. 17C-D), whilst fertilizer application reduced only the survival rate of young seedlings (P=0.001, N=209; Fig. 17E-F).

Interactions between media and fungicide application also had a significant effect on germination and survival rates for all species at P<0.01 level (Fig. 18). Maximum overall success of the germination treatments (proportion germinated x proportion survival), averaged across all species, was T9 (P<0.05, N=18; sand and charcoalized rice husk + no fungicide + no fertilizer; Fig. 19).

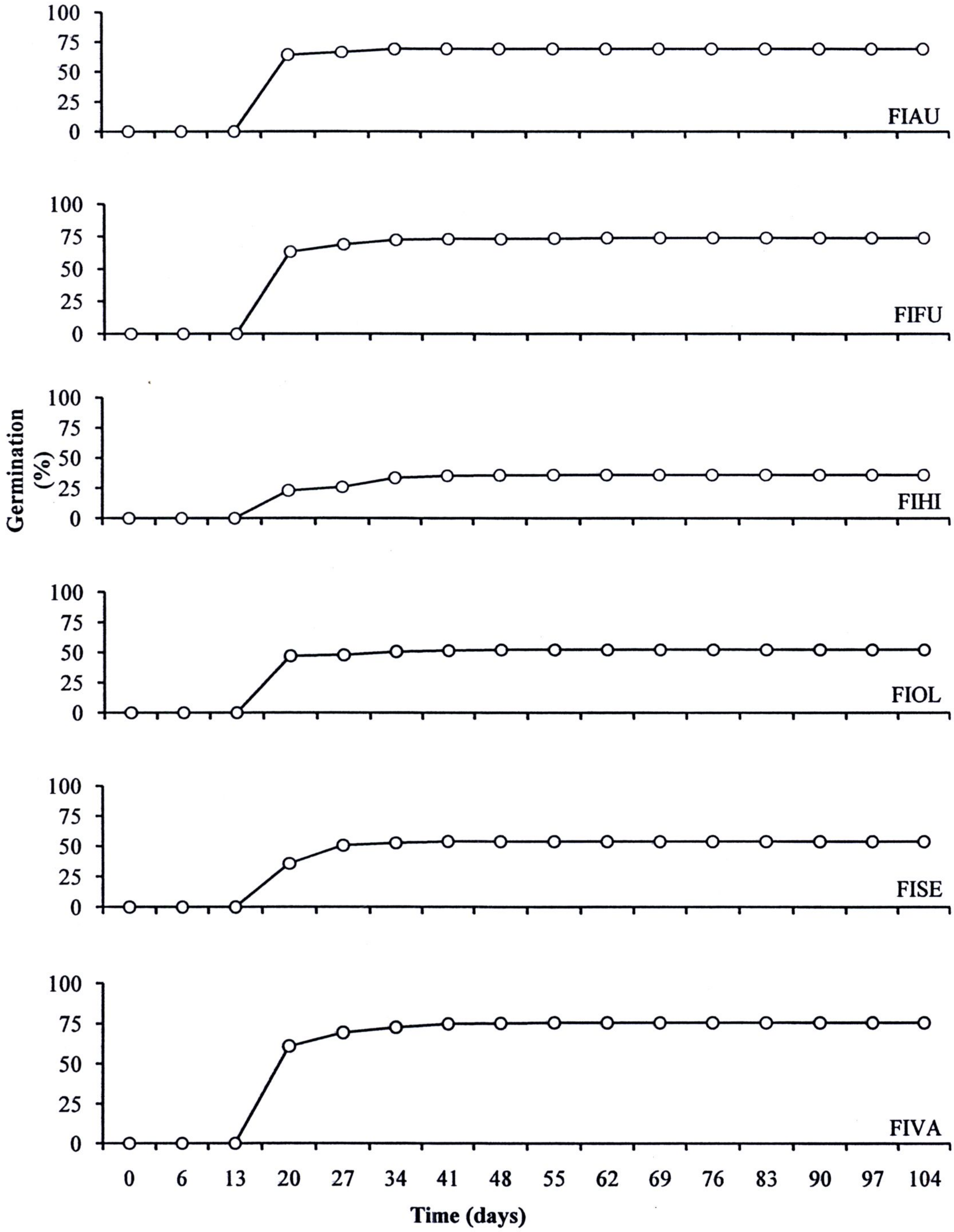


Figure 16 Fig seed germination from control treatment (T1) of each species in the nursery trials (FIAU = *F. auriculata*, FIFU = *F. fulva*, FIHI = *F. hispida*, FIOL = *F. oligodon*, FISE = *F. semicordata* and FIVA = *F. variegata*).

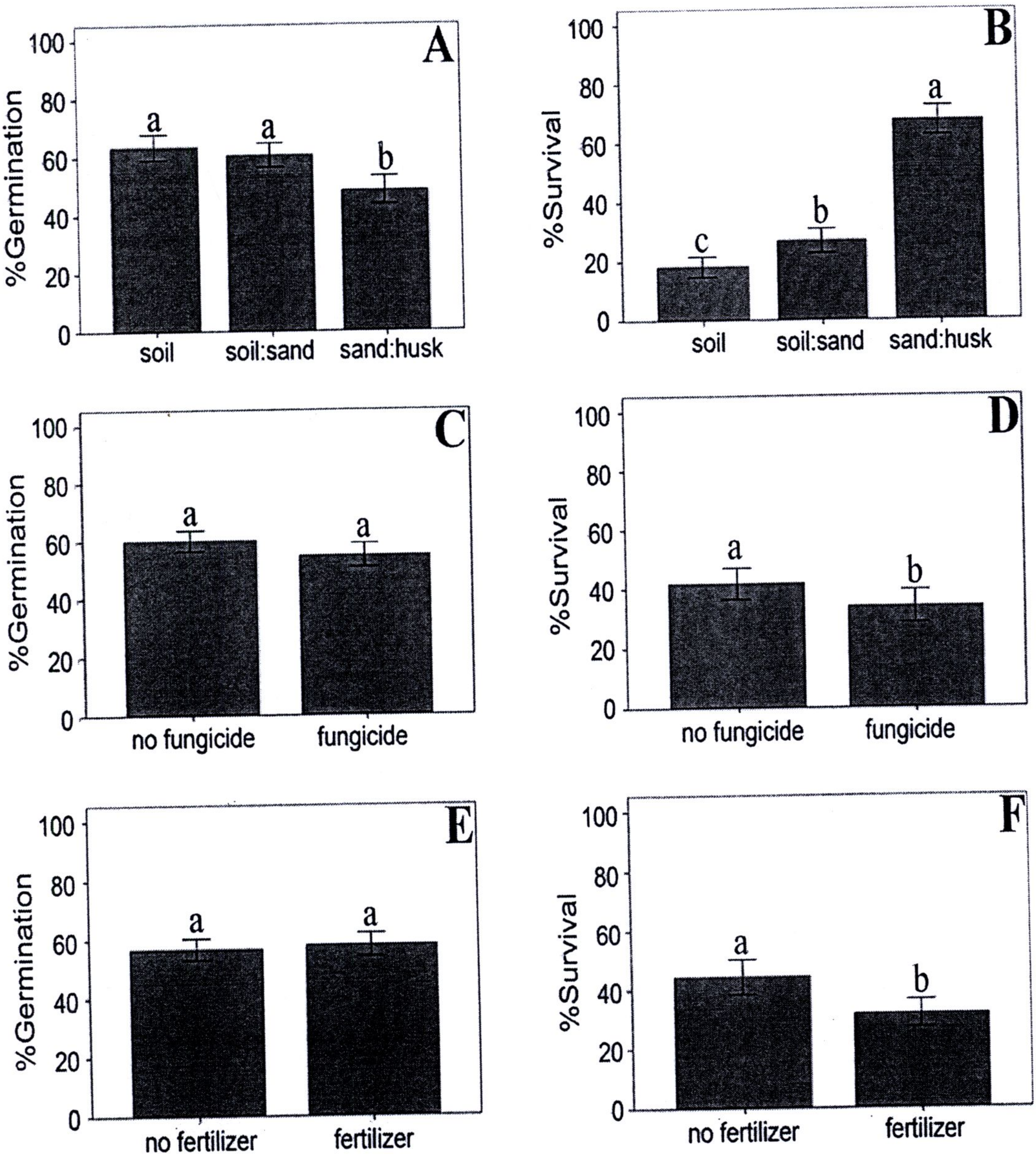
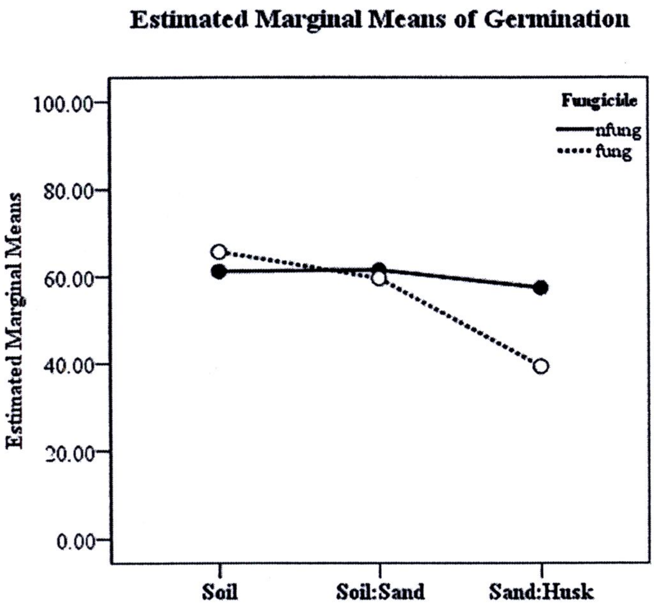


Figure 17 Seed germination trials, averaged across all species. A-B = effect of the germination medium compositions on germination and survival rates, C-D = effect of the fungicide applications on germination and survival rates, and E-F = effect of the fertilizer applications on germination and survival rates. Letters above bars indicate significant differences ($P<0.05$).



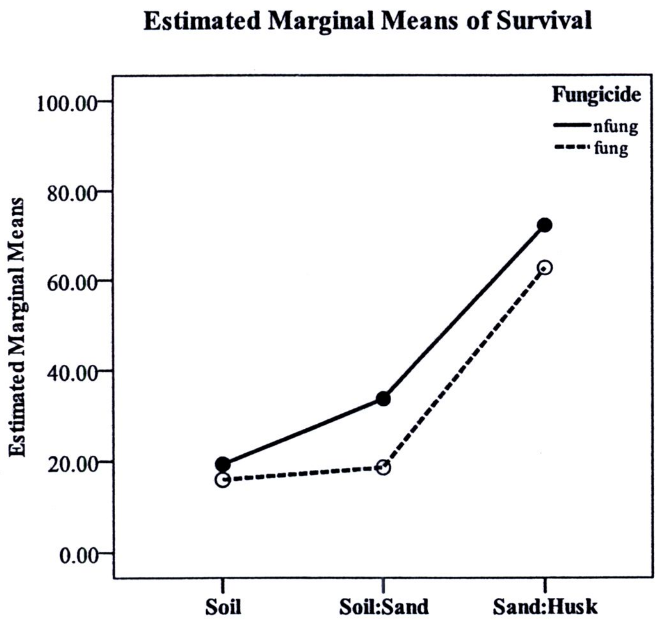


Figure 18 Interactions between the germination medium composition and fungicide application on germination and survival rate, averaged across all species. nfung = no fungicide, fung = fungicide applied.

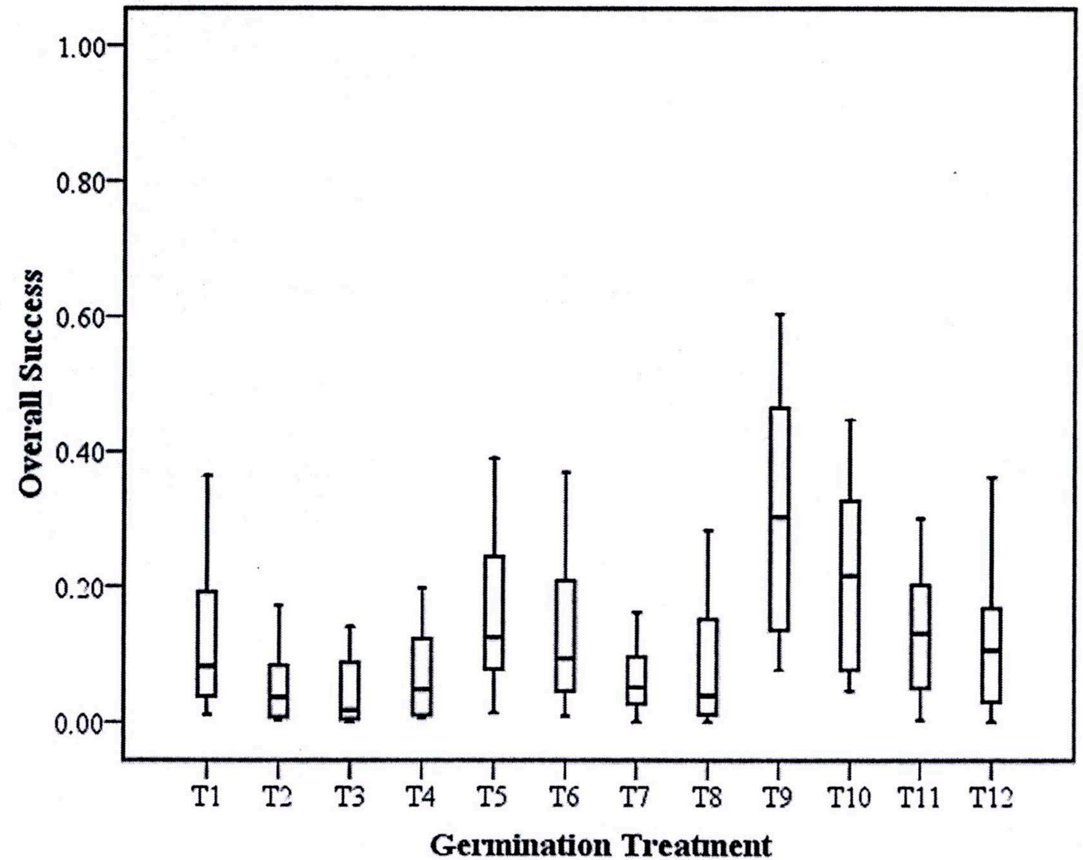


Figure 19 Overall successes (proportion germinated x proportion survival) of the germination treatments by transplanting time, averaged across all species.

Table 15 Results of germination and seedling growth trials on *Ficus* spp. Seeds of all species of all treatments were sown on 17-August-2008, seedlings were pricked out on 31-January-2009.

Species		Seed germination trials			Seedling growth of the most effective treatment (T1= full sun light + 10 granules of fertilizer every 3 months)						
		Averaged across all treatments			1 month after pricking out		4 month after pricking out				
	Seed collection (Month)	MLD (days)	Germination (%)	Survival (%)	RCD (mm)	Height (cm)	RCD (mm)	Height (cm)	RRGR ($\%year^{-1}$)	RHGR ($\%year^{-1}$)	Survival (%)
FIAU	July	21±3	$68±12^{a}$	48±25	1.7±0.2	2.1±0.2	6.6±0.3	22.7±2.5	558.1	966.0	81±11
FIFU	July	20±3	$70±14^{a}$	29±25	1±0.0	1.1±0.1	5.9±1	23.1±11.2	719.8	1,222.0	45±10
FIHI	May	23±2	$36±7^{c}$	34±28	1±0.0	1.2±0.3	5.1±0.3	23.8±1.1	660.7	1,211.5	78±22
FIOL	June	19±2	$47±7^{bc}$	40±29	1.3±0.1	2±0.2	6.2±0.4	17.1±4.8	633.6	876.7	73±19
FISE	July	20±2	$51±9^{b}$	32±31	1.1±0.2	1.5±0.1	5.6±0.6	28.3±6.5	650.3	1,182.4	72±18
FIVA	July	19±3	$73±15^{a}$	40±20	1.2±0.1	1.8±0.3	6.3±0.2	26.5±3.5	661.4	1,083.8	82±14

Mean ± SD; Variables: MLD = Median length day; RCD = Root collar diameter; RRGR = Relative growth rate for root collar diameter, RHGR = Relative growth rate for height. Different superscript letters (in the same column) indicates statistical differences among species (*P*- value<0.05).

Table 16 Details of seedlings propagated by cutting at the first planting season (6 months after removing from the propagator), averaged across all treatments.

Species	Cutting Date	Transplanting Date	Shooting (%)	Rooting (%)	Survival by transplanting time (%)	Mean diameter (mm)	Mean height (cm)	Mean canopy (cm)	RRGR ($\%year^{-1}$)	RHGR ($\%year^{-1}$)	RCGR ($\%year^{-1}$)	Survival by planting time (%)
FIAU	27-Sep-08	10-Nov-08	$75±5^{a}$	$19±4^{ab}$	$53±4^{a}$	12±2	21±2	30±5	42.4	88	113.1	23
FIFU	25-Sep-08	12-Nov-08	$20±4^{b}$	$3±1^{c}$	$7±2^{c}$	8±2	17±2	27±5	106.9	69.2	110.9	17
FIHI	17-Sep-08	10-Nov-08	$63±7^{a}$	$20±5^{a}$	$47±7^{ab}$	10±1	18±2	30±4	94.5	88.4	202.8	33
FIOL	19-Sep-08	10-Nov-08	$67±9^{a}$	$16±4^{ab}$	$48±7^{ab}$	9±2	16±2	26±5	123.3	54.9	171.0	27
FISE	18-Sep-08	12-Nov-08	$75±5^{a}$	$20±2^{a}$	$39±5^{ab}$	8±1	16±2	18±4	89.0	66.0	111.5	17
FIVA	27-Sep-08	11-Nov-08	$53±8^{a}$	$6±2^{ab}$	$28±5^{b}$	12±1	17±2	23±4	68.6	81	156.9	20

Mean ± SD; Variables: RRGR = Relative growth rate for root collar diameter (mm), RHGR = Relative growth rate for height (cm) and RCGR = Relative growth rate for canopy width (cm). Different superscript letters (in the same column) indicates statistical differences among species (*P*-value<0.05).

At time of pricking out (after expansion of the second true leaf pairs) seedlings were tiny; only 1.1 to 2.1 cm tall. However, subsequent seedling growth rate of all species was very high, especially for seedlings in full sunlight with 10 granules of slow release fertilizer (Osmocote) applied every 3 months (T1, Fig. 20). However, it did not differ significantly among species (Fig. 21A-C). By planting time, seedlings had mostly grown taller than 20 cm (>800% year^{-1} height relative growth rate, >500% year^{-1} root collar diameter relative growth rate) and seedlings of all species remained in good health throughout their growth in the nursery (Fig. 21D). Seedling survival rates of most species were also very high (>70% survival; except for *F. fulva*; Table 15). However, the mean overall success (proportion germinated x proportion survival) of all species was fairly low. *Ficus variegata* had the highest mean overall success compared with all other species (SD 0.03, *P*<0.05, Fig. 22).

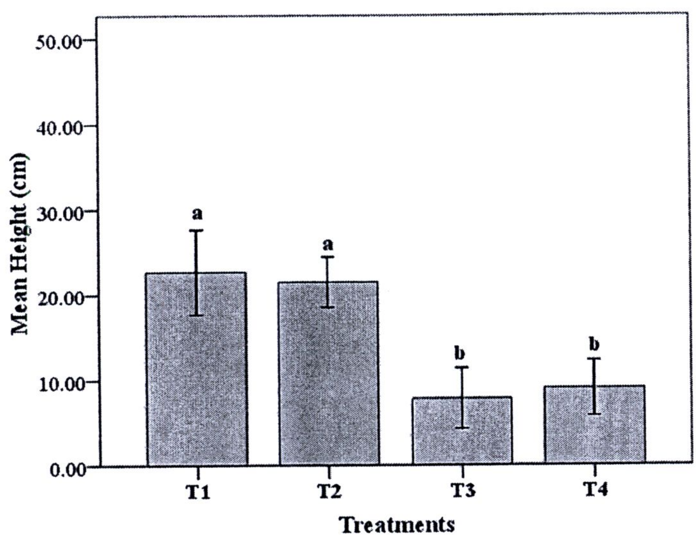


Figure 20 Seedling growth trials, averaged across all species by planting time. Different letters above the bars indicate significant differences among treatments ($p<0.05$).

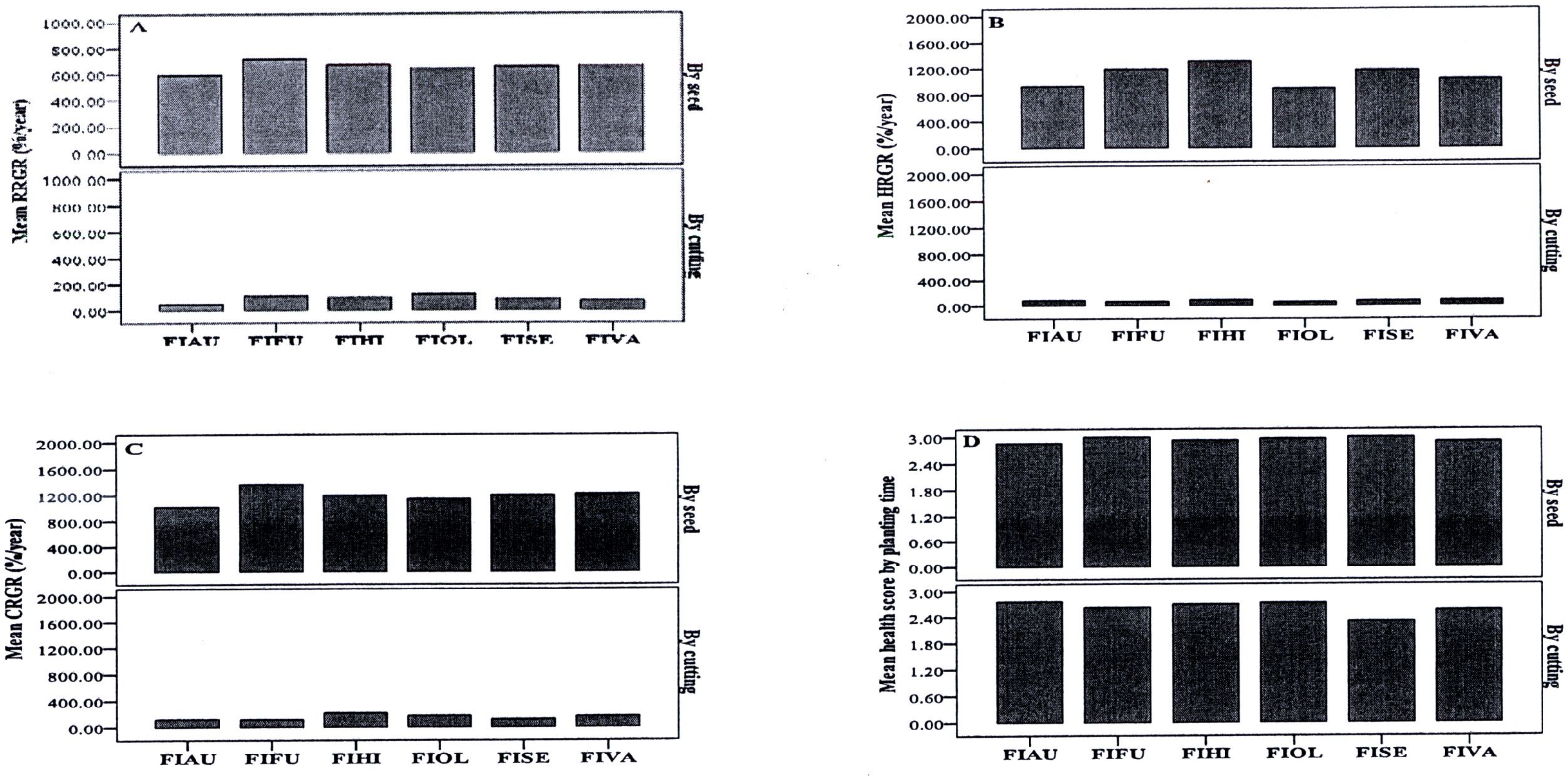


Figure 21 Mean relative growth rates and mean health scores of the most effective treatment by species for each propagation types after 1 year in the nursery. RRGR = relative root collar diameter growth rate (mm), HRGR = relative height growth rate (cm) and CRGR = relative canopy width growth rate (cm).

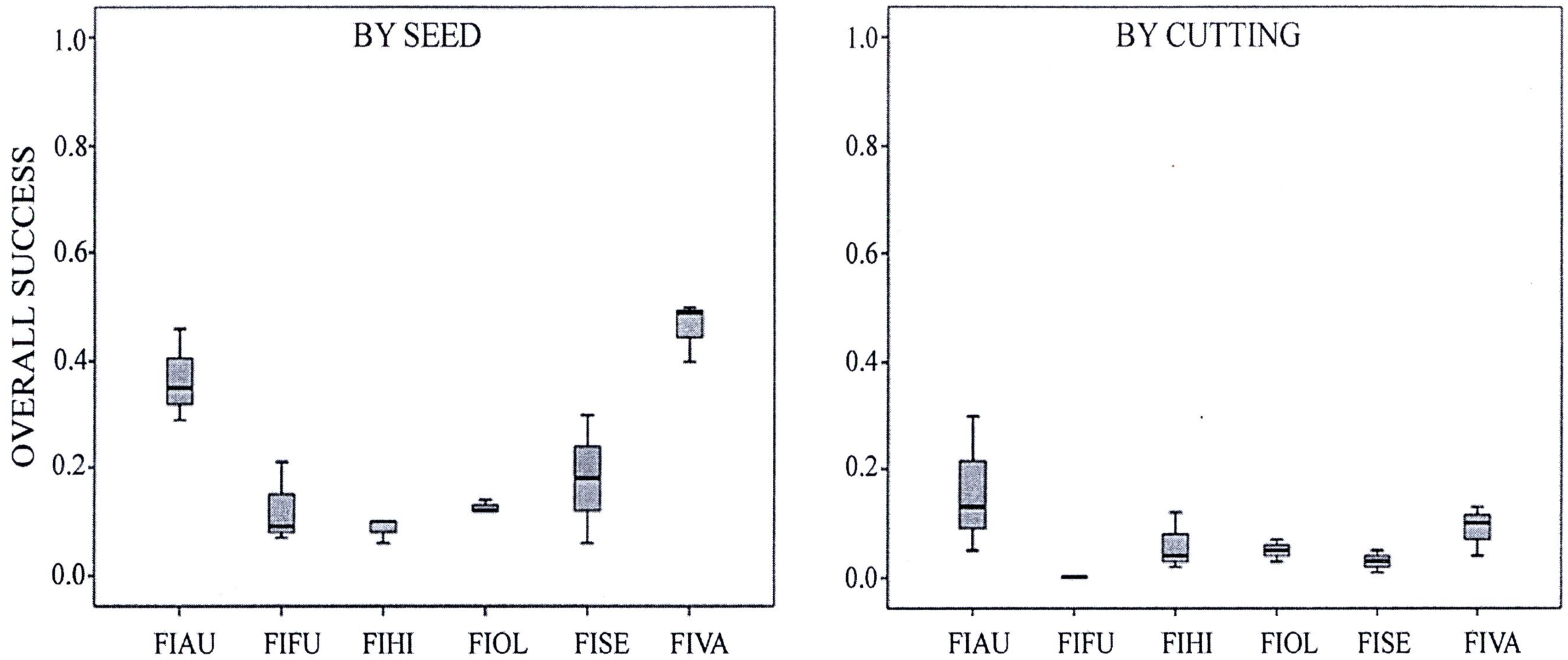


Figure 22 Overall successes (proportion germinated/rooted x proportion survival) of each species by planting time. FIAU = *Ficus auriculata*, FIFU = *Ficus fulva*, FIHI = *Ficus hispida*, FIOL = *Ficus oligodon*, FISE = *Ficus semicordata* and FIVA = *Ficus variegata*.

4.4.2 Propagation from cuttings. All species developed new shoots 2-4 weeks after being placed in the propagation bags, and most cuttings produced new roots about a week after above ground growth initiated. Averaging across all species, the mean shooting/rooting percentage was 59%. Shooting/rooting ability also varied significantly among species (ANOVA, $P<0.05$, Table 16). The older parts of the cuttings sprouted new leaves and roots easier than the younger parts (Fig. 23A-B) and they exhibited high survival rates after shooting/rooting (Fig. 23C). Rooting hormone affected rooting ability of all species ($P<0.05$, Fig. 23D). However, there were no interaction effects between cutting position and hormone application ($P=0.738$ for shooting and $P=0.132$ for rooting).

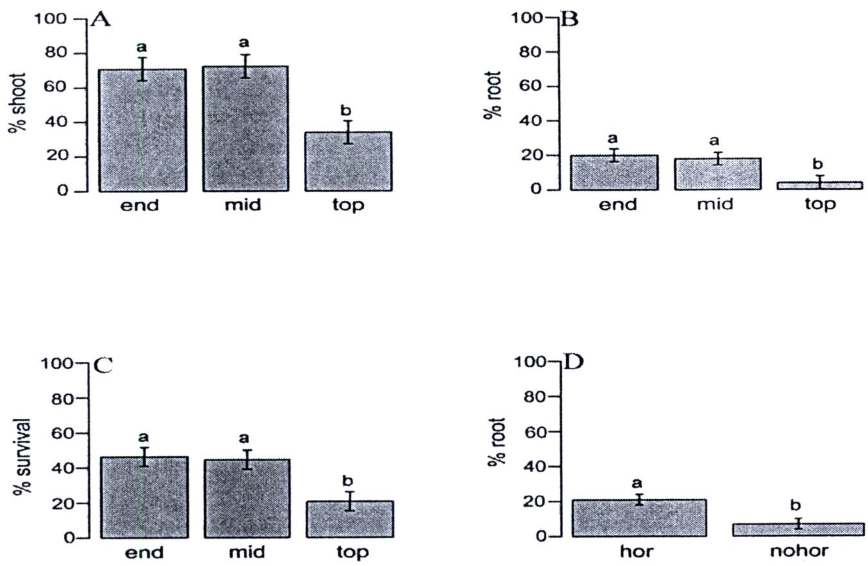


Figure 23 Cutting trials, averaged across all species. (A-C) effect of the cutting positions on percent shooting, rooting and survival, (D) effect of the rooting hormone applications on percent rooting; top = terminal shoot (upper part), mid = middle part, end = lower part; hor = with rooting hormone, nohor = without rooting hormone.

Within 7-8 weeks, cuttings of all species were ready for removal from the enclosed plastic bags (mature leaves produced). Averaging across all species, treatment which resulted in maximum survival rates and production of seedlings ready for transplantation was T6 (lower + rooting hormone; $P<0.05$, $N=18$; Fig. 24).

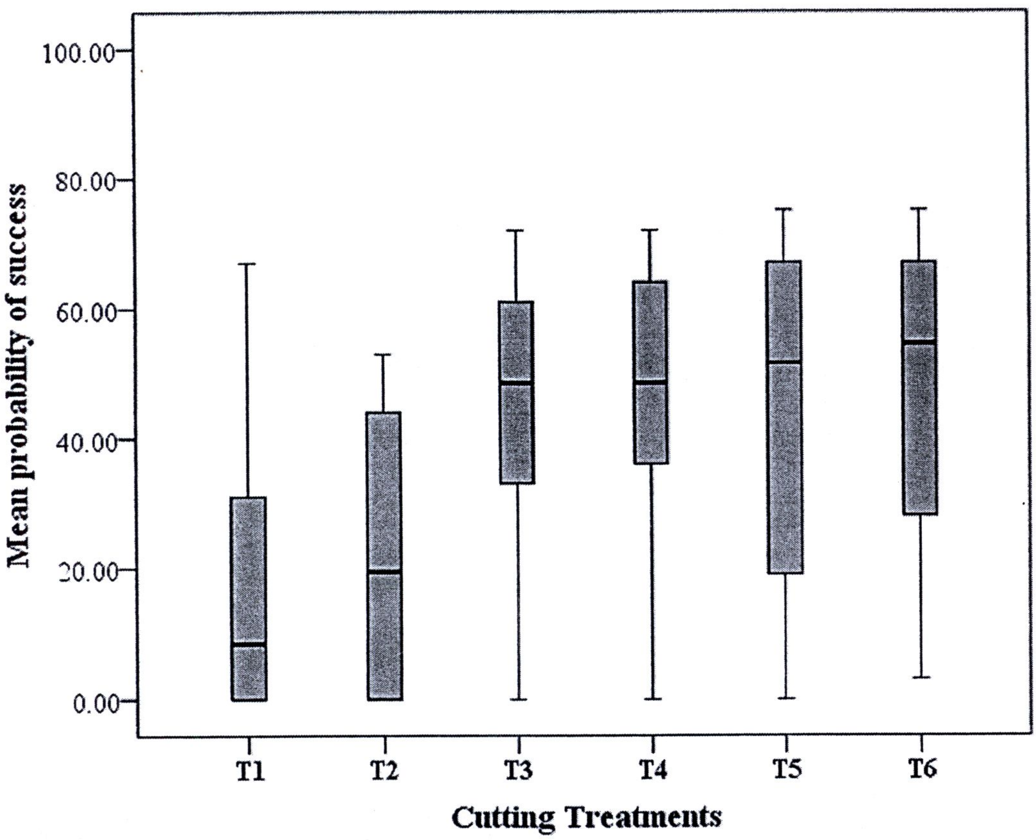


Figure 24 Overall successes (proportion shooted x proportion survival) of each treatment by transplanting time. T1 = upper + without rooting hormone, T2 = upper + with rooting hormone, T3 = middle + without rooting hormone, T4 = middle + with rooting hormone, T5 = lower + without rooting hormone and T6 = lower + with rooting hormone.

However, after the cuttings were removed from the enclosed plastic bags and replanted in a new container, their growth and survival rates were fairly low (<33% survival and RHGR <100 % year^{-1}). By the first planting time, the mean height for individual species ranged from 16 cm for *F. oligodon* and *F. semicordata* to 21 cm for *F. auriculata* (Table 16). *Ficus fulva* had, significantly, the lowest mean overall success, compared with all other species ($P<0.05$, Fig. 22).

4.4.3 Propagation type comparison. During the first 12 months period in the nursery, averaged across all species, the relative growth rate of seedlings (656.7±40.6% year^{-1} for root collar diameter, 1,091.8±164.2% year^{-1} for height and 1,192.0±111.4% year^{-1} for canopy width) was higher than that of rooted cuttings (88.6±8.3% year^{-1} for root collar diameter, 75.6±13.3% year^{-1} for height and 149.1±9.6% year^{-1} for canopy width). Stock plants derived from seed also showed higher success rates than that of stock plants derived from cuttings (0.22 and 0.07 respectively, *T*-Test, $P<0.05$). However, by planting time, seedling size varied among propagation types. Seedlings derived from seed were significantly taller and had higher mean health scores compared with stock plants derived from cuttings (23.0±4.9 cm and 17.7±2 cm for height, 2.9±0.1 and 2.6±0.2 for health score, respectively, *T*-Test, $P<0.05$). Conversely, seedlings propagated from cuttings showed significantly higher mean root collar diameter than that of seedlings propagated from seed (10.1±2 mm and 5.9±0.4 mm respectively, *T*-Test, $P<0.05$). However, there were no significant differences in mean canopy width among the propagation types (29.3±2.1 cm for stock plants derived from seed and 26.3±4.8 cm for stock plants derived from cuttings, *T*-Test, $P=0.19$).

4.5 *Ficus* plantings

4.5.1 Direct seeding. Seed germination in the field ranged from 47.2±8.1% (*F. hispida*) to 73.9±2.8% (*F. auriculata*), the median length of dormancy (MLD) ranged from 20 days (*F. oligodon*) to 28 days (*F. variegata*), but the differences among species were not statistically significant (P=0.27 for germination and P=0.06 for MLD; Fig. 25).

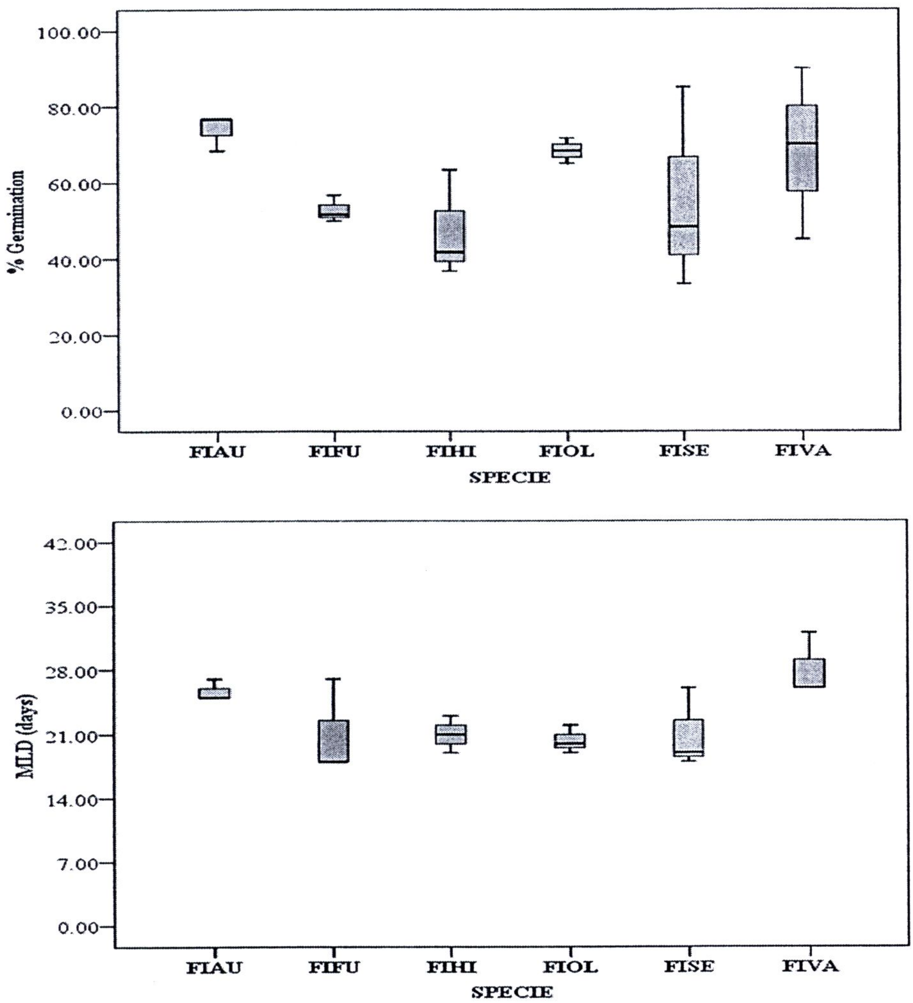


Figure 25 Mean germination and median length of dormancy (MLD) of the direct seeding trials.

However, seedling survival after germination of all species was very low. The highest mortality for all species occurred during the first rainy season (>90% mortality by one month after germination) due to damping-off diseases. Overall mortality rate of most species was 100% during the first dry season, except for *F. hispida* of which only 1.7% (SD 0.3) of seeds planted remained alive at the end of 2nd rainy season (Fig. 26D). Relative growth rates (%RGR year^{-1}) of *F. hispida* saplings that survived the period December 2009 to October 2010 are presented in Fig. 26A-C.

4.5.2 Planting stock-raised in nursery from cuttings. After planting out in disturbed areas, 67% of plants propagated from cuttings died within 7 months (averaged across all species). At the end of the second rainy season, mean survival of saplings across all species was 15.1% (SD 3.5). The mean values for individual species ranged from 0% for *F. fulva* to 36.7% for *F. hispida*, differences among species in relation to survival rate (ANOVA, $P<0.05$, Fig. 26D). The relative growth rate of seedlings propagate from cuttings was also fairly slow, with differences among species statistically significant for mean RRGR and HRGR ($P<0.05$, Fig. 26A-B). *Ficus auriculata* had the highest mean height (77.6 cm), followed by *F. variegata* (69.6 cm) and *F. oligodon* (51.6 cm); significantly taller compared with the other species (ANOVA, $P<0.05$). Whilst, *F. variegata* had, significantly, the highest mean root collar diameter (23.3 mm) and mean canopy width (98.1 cm) compared with all other species (ANOVA, $P<0.05$, Table 17).

4.5.3 Planting stock-raised in nursery from seed. The trees were approximately 20 cm tall when planted (averaged across all species) but they mostly grew taller than 1.5 m after 1.5 years with *F. semicordata* and *F. variegata* reaching 2 m (Table 17). From May 2009 to October 2010, *F. fulva* achieve the highest growth rate (RRGR=141.2±11.3% $year^{-1}$ and HRGR=183.1±12.3% $year^{-1}$), whilst *F. semicordata* had the highest CRGR (115.6±7.2% $year^{-1}$). However, differences in relative growth rates among species were not statistically significant (Fig. 26A-C). At the end of the second rainy season, *F. variegata* had the highest mean root collar diameter and mean height (37.8 mm and 264.6 cm respectively), whilst *F. semicordata* had the highest mean canopy width (141.4 cm), however analysis of variance showed no significant differences among the species means (ANOVA, P=0.59 for root collar diameter, P=0.08 for height and P=0.55 for canopy width). Survival after two rainy seasons averaged 68.1% (SD 5.7) across all species. The mean values for individual species ranged from 63.3% for *F. semicordata* to 78.3% for *F. variegata.* Overall, there were no statistically significant differences for survival among species (Fig. 26D).

4.5.4 Planting stock type comparison. By the end of the second rainy season (1.5 years after planting), averaging across the species, nursery-grown saplings from seeds performed significantly better than other planting stock types. They had, significantly, the highest survival rate (68.1%), highest relative growth rate (126.8±14.1% RRGR $year^{-1}$, 162.2±16.7% HRGR $year^{-1}$ and 105.3±9.8% CRGR $year^{-1}$) and the largest seedling size (31.6±4.1 mm for root collar diameter, 199.3±45.1 cm for height and 122.9±13.3 cm for canopy width).

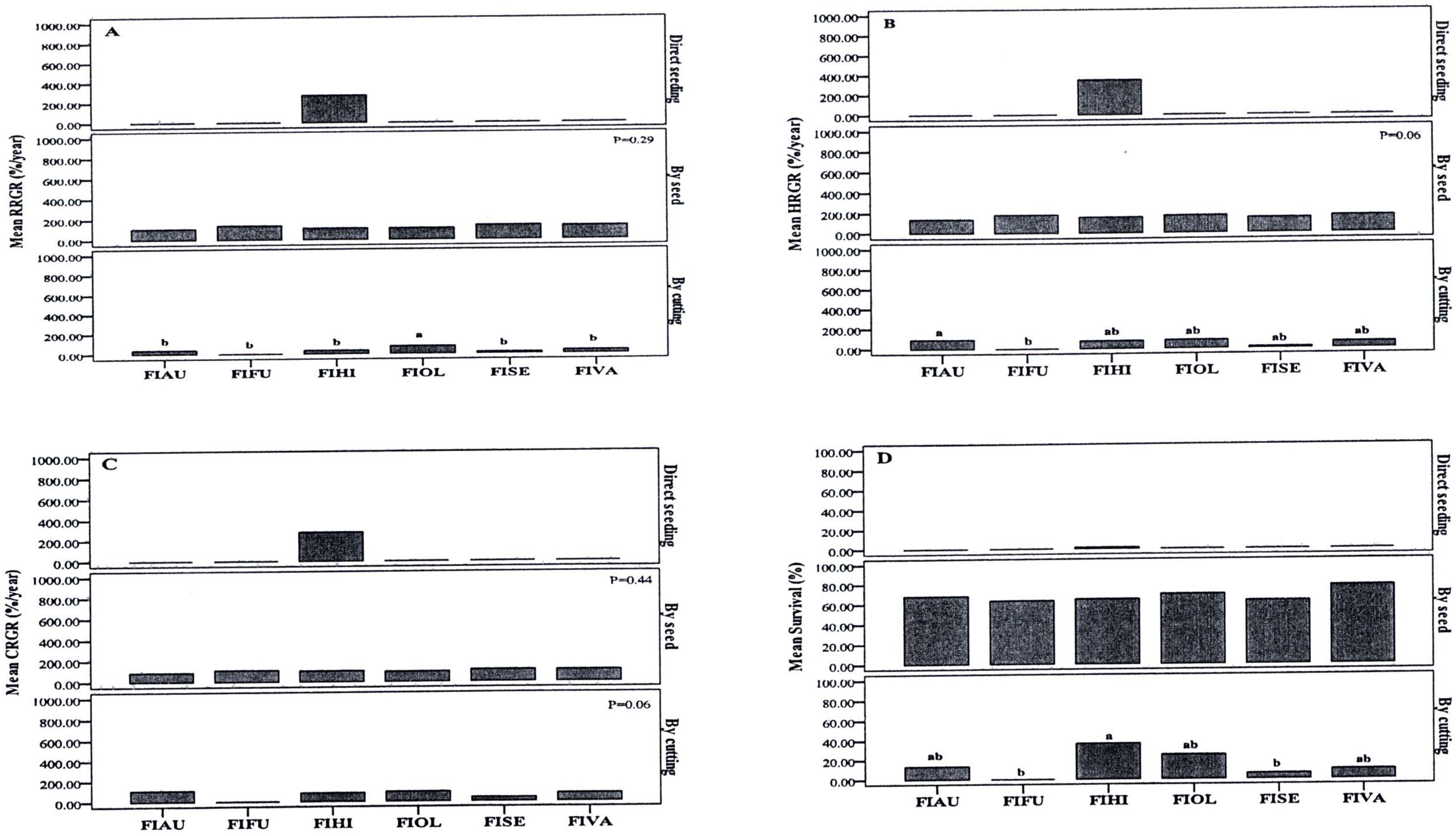


Figure 26 Mean relative growth rate and mean survival by species for each planting stock types after 1.5 years of planting out in disturbed habitats. Different letters above the bars indicate significant differences among species ($P<0.05$).

Table 17 Seedling growth comparison between the planting stock types for each species, which attained at the end of the second rainy season (1.5 years after planting out); RCD = Root collar diameter; Mean ± SD; (-) = All seedlings were dead.

Species	Direct seeding	Planting stock from seed	Planting stock from cuttings
Ficus auriculata			
RCD (mm)	-	31.7 ± 2.8^{a}	21.1 ± 1.0^{b}
Height (cm)	-	162.4 ± 17.6^{a}	77.6 ± 5.4^{b}
Canopy width (cm)	-	119.1 ± 4.0^{a}	93.7 ± 2.9^{a}
Health	-	2.3 ± 0.2^{a}	2.8 ± 0.3^{a}
Ficus fulva			
RCD (mm)	-	30.5±6.0	-
Height (cm)	-	196.1±42.2	-
Canopy width (cm)	-	121.2±35.3	-
Health	-	3.0±0.0	-
Ficus hispida			
RCD (mm)	35.5 ± 13.4^{a}	26.3 ± 8.7^{a}	18.6 ± 2.0^{a}
Height (cm)	188.5 ± 54.4^{a}	154.8 ± 61.3^{ab}	50.1 ± 2.8^{b}
Canopy width (cm)	141.0 ± 84.6^{a}	108.2 ± 27.6^{a}	73.1 ± 2.2^{a}
Health	3.0 ± 0.0^{a}	2.6 ± 0.3^{a}	2.8 ± 0.1^{a}

Table 17 (continued).

Species	Direct seeding	Planting stock from seed	Planting stock from cuttings
Ficus oligodon			
RCD (mm)	-	28.8 ± 5.9^{a}	16.9 ± 1.7^{b}
Height (cm)	-	174.6 ± 33.8^{a}	51.6 ± 12.3^{b}
Canopy width (cm)	-	111.4 ± 23.4^{a}	75.6 ± 15.5^{a}
Health	-	2.7 ± 0.1^{a}	2.7 ± 0.3^{a}
Ficus semicordata			
RCD (mm)	-	34.3 ± 12.0^{a}	12.0 ± 6.9^{b}
Height (cm)	-	243.3 ± 70.0^{a}	29.2 ± 16.7^{b}
Canopy width (cm)	-	141.4 ± 27.0^{a}	68.7 ± 39.3^{b}
Health	-	2.8 ± 0.2^{a}	2.7 ± 0.3^{a}
Ficus variegata			
RCD (mm)	-	37.8 ± 9.7^{a}	23.3 ± 0.4^{a}
Height (cm)	-	264.6 ± 49.8^{a}	69.6 ± 9.1^{b}
Canopy width (cm)	-	136.0 ± 23.3^{a}	98.0 ± 3.2^{a}
Health	-	2.8 ± 0.1^{a}	2.5 ± 0.7^{a}

Values in a row with different letters are significantly different among planting stock types according to *T*-test or *LSD*-test (where needed) at $P < 0.05$.

4.5.5 Cost comparison. Based on our calculations, the cost per plant of each planting stock types are presented in Table 18 (see Appendix J for more details). The major cost of all planting stock types was for labor which account for 79.5%, 70.5% and 77.1% of total costs (for direct seeding, planting stock-raised in nursery from seed and cutting, respectively). If the survival rates are 100 percent, direct seeding was the cheapest technique, but when we took mortality rate into account, planting stock-raised in the nursery from seed was the most cost-effective, compared with the other two techniques.

Table 18 Establishment and maintenance costs (per plant).

Items	**Planting Stock Type**		
	Direct Seeding	Planting stock-raised in nursery from seed	Planting stock-raised in nursery from cutting
Nursery materials [a]	0	$0.03	$0.04
Labor cost in nursery [b]	0	$0.14	$0.40
Field materials [c]	$0.09	$0.20	$0.20
Labor cost in field [d]	$0.35	$0.41	$0.41
Total cost (100% survival)	$0.44	$0.78	$1.05
Establishment cost [e] (per plant established)	**$25.88**	**$1.14**	**$6.95**

[a] Nursery materials include containers, media, fertilizer and rooting hormone; [b] Labor for seed/cutting collection, seed/cutting preparation, seed sowing/cutting, potting, watering, fertilizing, weeding and grading. During the period of study, manual labor cost average $6.53 per day (8 hr); 1 US$=30.65 Thai baht; [c] Field materials include bamboo stakes, bamboo tubes, fertilizers and gasoline; [d] Labor for seeds/seedling transferring, planting, weeding and fertilizing; [e] Based on survival rates at the end of the 2nd rainy season were 1.7% for direct seeding (averaging only for *F. hispida*), 68.1% for seed and 15.1 for cutting (averaging across all species).

Source: Kuaraksa and Elliott (2011).