FRUIT SET, SEED GERMINATION AND SEEDLING GROWTH OF *MESUA FERREA* (CLUSIACEAE) IN RELATION TO LIGHT INTENSITY

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KHAN, M. L., BHUYAN, P., SINGH, N. D. & TODARIA, N. P. 2002. Fruit set, seed germination and seedling growth of *Mesua ferrea* (Clusiaceae) in relation to light intensity. Variation in fruit set and fruit size on sunlit and shaded parts of individual trees of *Mesua ferrea* was observed. Fruit set was significantly higher in parts of the individual exposed to sunlight than in parts not exposed to sunlight. However, shaded parts produced heavier and larger fruits than sunlit parts. Seeds from fruits of shaded parts were significantly heavier than that of sunlit parts. One to four seeds are produced in a fruit of *M. ferrea*. Seed weight decreased with increase in number of seeds per fruit. Seeds from one-seeded fruits were heavier than two-, three- and four-seeded fruits. One-seeded fruits per tree were numerous in parts exposed to sunlight whereas three-seeded fruits were more abundant in parts of the individuals not exposed to sunlight. Seeds from four-seeded fruits germinated earlier and their germination percentage was significantly higher than the other three categories of seeds. In general, seeds from fruits of shaded parts germinated earlier and showed better germination than sunlit parts, both in laboratory and greenhouse conditions. Seedling survival and growth were significantly affected by origin of fruit, either shaded or sunlit parts, and seed category. Seedlings that emerged from one-seeded fruits survived and grew better than those from two-, three- and four-seeded fruits. Further, seedlings emerged from shaded parts showed better survival and growth than their counterparts from sunlit parts.

Key words: Seed size - number of seeds - light aspect - germination - seedling survival - seedling growth

KHAN, M. L., BHUYAN, P., SINGH, N. D. & TODARIA, N. P. 2002. Kaitan kejadian buah, percambahan biji benih dan pertumbuhan anak benih *Mesua ferrea* (Clusiaceae) dengan keamatan cahaya. Variasi dalam kejadian buah dan saiz buah dicerap bagi bahagian pokok *Mesua ferrea* yang terdedah dan ternaung daripada cahaya matahari. Kejadian buah adalah lebih tinggi dengan bererti di bahagian pokok yang terdedah kepada cahaya matahari berbanding bahagian pokok yang tidak terdedah kepada

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cahaya matahari. Bagaimanapun bahagian yang ternaung menghasilkan buah yang lebih berat dan lebih besar berbanding bahagian yang terdedah kepada cahaya matahari. Biji benih daripada buah di bahagian yang ternaung lebih berat dengan bererti daripada buah di bahagian yang terdedah kepada cahaya matahari. Setiap buah *M. ferrea* menghasilkan satu hingga empat biji benih. Berat biji benih berkurangan dengan bertambahnya bilangan biji benih di dalam setiap buah. Biji benih daripada buah yang berbiji benih tunggal lebih berat daripada buah berbiji benih dua, tiga dan empat. Buah berbiji benih tunggal dalam setiap pokok adalah banyak di bahagian yang terdedah kepada cahaya matahari manakala buah berbiji benih tiga banyak terdapat di bahagian pokok yang tidak terdedah kepada cahaya matahari. Biji benih daripada buah berbiji benih empat bercambah lebih awal dan peratusannya adalah lebih tinggi dengan bererti daripada tiga kategori biji benih yang lain. Secara umumnya, biji benih daripada bahagian buah yang ternaung bercambah lebih awal dan menunjukkan percambahan yang lebih baik berbanding bahagian yang terdedah kepada cahaya matahari, dalam kedua-dua keadaan makmal dan rumah hijau. Kemandirian dan pertumbuhan anak benih dipengaruhi dengan bererti oleh asal buah, sama ada daripada bahagian yang ternaung atau bahagian yang terdedah kepada cahaya matahari, serta kategori biji benih. Anak benih daripada buah berbiji benih tunggal lebih mandiri dan tumbuh lebih baik daripada buah berbiji benih dua, tiga dan empat. Anak benih daripada bahagian yang ternaung menunjukkan kemandirian dan pertumbuhan yang lebih baik daripada anak benih di bahagian yang terdedah.

Introduction

The size of fruits and seeds has long been regarded as an important variable in the reproductive biology of plants. Salisbury (1942) suggested that seed size increases with the successional maturity of the community. Baker (1972) reported a correlation of seed size with moisture availability and altitude for plant communities in California. Differences in seed size within species, have been attributed to successional maturity (Werner & Platt 1976) or disturbance level (Solbrig & Simpson 1974, Barik *et al.* 1996). Seed size may also be influenced by the season of flowering and fruiting (Murali 1997). This trait is an important factor in determining the dispersal distance, growth and survival of seedlings in tree species (Augspurger & Hogan 1983, Foster 1986).

Most studies have linked intraspecific or interspecific variation in seed size with species fitness (Murali 1997). However, ecological adaptiveness of multi-seeded fruits is not well-demonstrated (Bradford & Smith 1977, Garrison & Augspurger 1983). In this paper, we have presented the fruit set pattern and fruit size variation in individual trees of *Mesua ferrea* (Clusiaceae) and the effects of multi-seeded fruits on seed size, germination and seedling fitness of this species. This is an attempt to assess the importance of fruit size variation and existence of multi-seeded fruits in a population of this species. A possible relation of these effects with seedling fitness and ultimately with maternal plant fitness, can probably aid in a more comprehensive understanding of the adaptive nature of observed variation in fruit size and seed number.

Materials and methods

Species

Mesua ferrea is a moderate-to large-sized, handsome, evergreen tree often buttressed at the base. In the tropical rain forests in India, it forms part of the emergent layer, attaining a height of 45 m or more. It occurs mostly at elevations from about 60 to 1200 m, although its altitudinal range extends up to 1500 m. It is a pronounced shade bearer, particularly in its young stage. In its dense evergreen habitat, established regeneration thrives best if overhead light and free growing space are available; otherwise growth is considerably retarded. Fully grown trees tolerate plenty of light. *Mesua ferrea* regenerates adequately under natural condition. However, its growth is rather slow. As soon as some gaps are created in the canopy, it grows faster. It has poor coppicing power and reproduces mainly through seeds. The seeds germinate mostly in moist places.

The tree begins to produce fertile seed at the age of 15 to 20 years. Isolated trees flower and seed abundantly almost every year, while in the forest, good seed year occurs at frequent intervals. The time of fruits ripening varies according to regions, however, seeds fall from middle of July to December. Seeds germinate from October to May depending on moisture at the forest floor. There are four ovules in an ovary, two each in two locules. Hence, an ovary may produce one, two, three or four seeds.

Fruit set and weight

Ten fruiting trees of *M. ferrea*, growing at the campus of NERIST (North-Eastern Regional Institute of Science and Technology), 27° 07' N, 93° 22' E, 100 m altitude, near Itanagar in the state of Arunachal Pradesh, were randomly selected and tagged in July 1996. The number of fruits produced were counted separately along the south-east (sunlit parts–parts exposed to sunlight) and north-west (shaded parts–parts not exposed to sunlight) parts of these trees. Appearance of brown colour on the fruit coat was taken as an indicator of maturity. Aborted fruits were not included in determining fruit set. Fruits were counted just before maturation in mid-September. The fruit set for each tree was estimated following the method outlined by Barik *et al.* (1996).

Total fruit set = Total number of branches × mean number of sub-branches per main branch × mean number of fruits per sub-branch.

For each tree, mean number of fruits per sub-branch was calculated from a random sample of 10 sub-branches. Differences in fruit set at the south-east and north-west parts (henceforth will be referred to as sunlit and shaded parts respectively) were statistically tested.

Weight and diameter of individual fruits were determined by weighing 100 fresh fruits collected separately from sunlit and shaded parts of each tagged tree. At the shaded part, whenever there were less than 100 fruits, all of them were measured for weight and diameter. Average fruit weight and diameter were determined from the composite samples of 100 fresh fruits each collected from sunlit and shaded parts of the tagged trees. Proportion (%) of fruits containing different number of seeds (one, two, three and four) was determined by five replicates of 20 fruits for each of the parts. For determination of average seed weight, five replicates of 10 seeds from each fruit type were taken and the seeds were individually weighed.

Seed germination and seedling growth

Laboratory condition

For germination, seeds of the four categories (one-, two-, three- and four-seeded fruits) collected from the fruits of sunlit and shaded parts were separately soaked for 24 hours in distilled water at room temperature (25 ± 2 °C). The soaked seeds were placed on moist blotting paper underlaid with cotton in plastic trays (30 × 25 cm) line with cotton for germination. To maintain the moist condition, a small quantity of water was added to the trays on alternate days. A tray containing 20 seeds served as one replicate for each category. There were five replicates for each category of seeds. Seeds were considered germinated when the radicle protruded approximately 1 mm beyond the seed coat. Germination was recorded daily for 60 days, after which practically no germination occurred.

Greenhouse condition

To study the effect of sunlit and shaded parts as well as the category of seeds on seed germination, seedling survival and growth of *M. ferrea* were observed under greenhouse conditions. Five replicates containing 20 seeds each were maintained for each part and seed category. Thus the experiment was set up in a factorial design comprising four seed categories, two light exposure parts and five replicates. Seeds were sown separately at 5 cm depth in polythene bags of 20 × 17 cm size, filled with garden soil. The soil used for the experiment was lateritic sandy loam, with pH 5.2, 0.3% nitrogen and 3.8% organic matter. Seeds were sown on 17 September 1996 and each bag was supplied with 150 ml tap water at three-day interval to moisten the soil. Seedling emergence was recorded at three-day intervals for 180 days until no further seedling emerged.

Seedling survival was calculated after one year. Growth performance of the seedlings was assessed in terms of their height, diameter, leaf number, leaf area and dry matter yield. For this purpose, five randomly selected seedlings of each category were excavated and washed thoroughly with water to remove adhering soil particles. Leaf area was measured by LICOR-3000A-leaf area meter. Dry matter yield was determined by drying the plant material at 60 °C to constant weight in an oven.

Statistical analysis

The data were statistically analysed by means of analysis of variance using SYSTAT (version 6) 1996, SPSS INC.

Results

Fruit set was significantly greater on sunlit parts than shaded parts. The fruits from shaded parts were heavier and larger than those from sunlit parts (Figure 1 and Table 1). The majority of fruits from the shaded parts contained more than one seed, while almost half of the fruits from sunlit parts were one-seeded. The seeds from all four categories (one-, two-, three- and four-seeded fruits) were significantly heavier from the shaded parts than the ones from sunlit parts (Figure 2 and Table 2). Seeds from one-seeded fruits were heavier than two-, three- and four-seeded fruits. An increase in number of seeds per fruit reduces the size and weight of seeds (Photo 1).

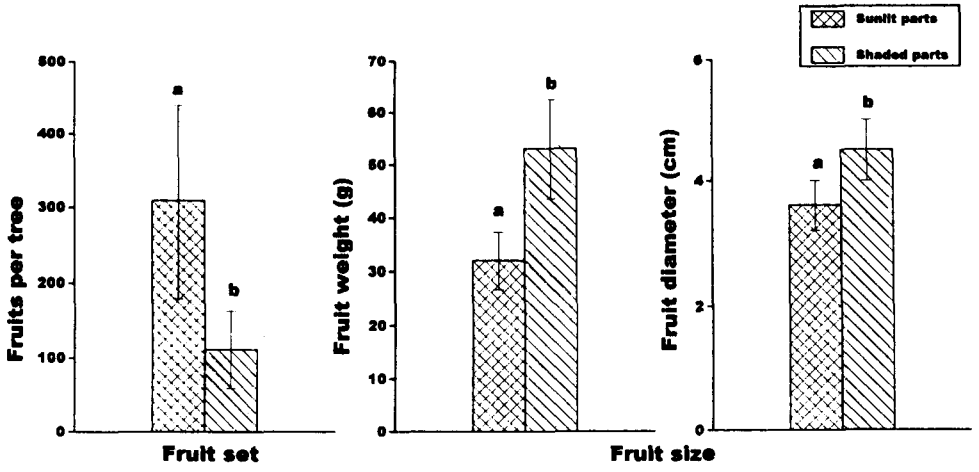

Figure 1 Variation in fruit set as well as fruit weight and size in sunlit and shaded parts of *Mesua ferrea*. Means in column bar followed by the same letter are not significantly different as tested by F-ratio. Line bar indicates the mean ± SD.

Table 1 Analysis of variance of the data presented in Figure 1

Parameter	Source of variation	df	MS	F-ratio	p-level
Fruits set	Sunlit vs. shaded	1	195031.25	19.77	0.000
	Error	18	9864.80		
Fruit weight	Sunlit vs. shaded	1	22317.72	375.37	0.000
	Error	18	59.46		
Fruit diameter	Sunlit vs. shaded	1	41.12	202.43	0.000
	Error	18	0.20		

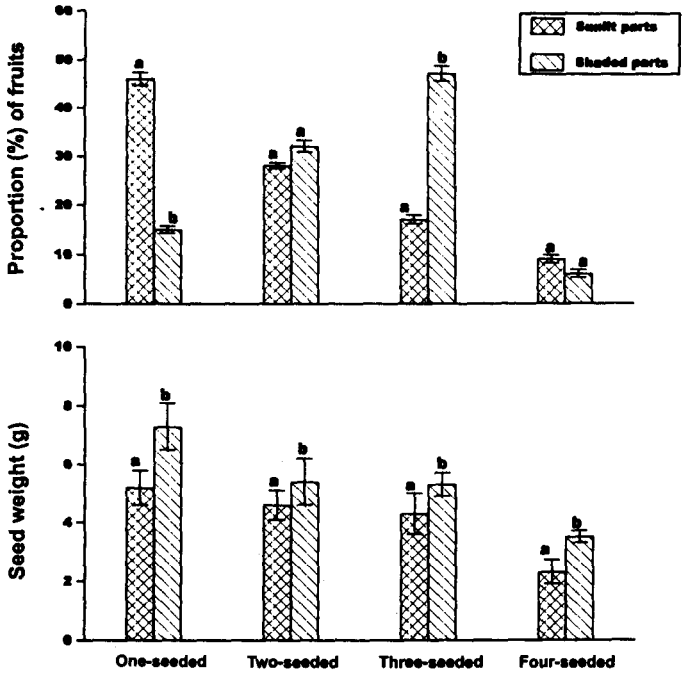

Figure 2 Proportion (%) of one-, two-, three- and four-seeded fruits (n = 100) and seed weight of these four types of fruits (g seed^{-1}) (n = 50) of *Mesua ferrea* collected from sunlit and shaded parts. Means in column bar followed by the same letter are not significantly different as tested by F-ratio. Capital and small letters stand for differences due to seed number and light intensity respectively. Line bar indicates the mean ± SD.

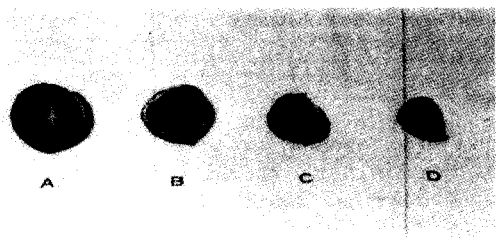

Photo 1 Variation in seed size and weight of *Mesua ferrea*. Seeds from one-seeded (A), two-seeded (B), three-seeded (C) and four-seeded (D) fruits.

Seeds from four-seeded fruits germinated earlier and their germination percentage was significantly higher than the other three categories of seeds. Seeds from one-seeded fruits showed poor and delayed germination. In general, seeds from the fruits of shaded parts germinated earlier and showed better germination than that of the sunlit parts under both laboratory and greenhouse conditions (Figure 3 and Table 3).

Table 2 Analysis of variance of the data on proportion of fruits and seed weight presented in Figure 2

Parameter	Source of variation	Proportion of fruits				Seed weight			
		df	MS	F-ratio	p-level	df	MS	F-value	p-level
Fruit category									
One-seeded	Sunlit vs. shaded	1	90.00	58.065	0.000	2	56.36	106.00	0.00
	Error	8	1.55			97	0.53		
Two-seeded	Sunlit vs. shaded	1	1.60	2.000	0.195	2	7.58	16.64	0.00
	Error	8	0.80			97	0.46		
Three-seeded	Sunlit vs. shaded	1	96.10	87.364	0.000	2	12.10	36.40	0.00
	Error	8	1.10			97	0.33		
Four-seeded	Sunlit vs. shaded	1	0.90	1.286	0.290	2	9.08	87.19	0.00
	Error	8	0.70			47	0.10		
Light intensity									
Sunlit parts	Seed number	3	66.27	55.22	0.00	3	48.28	134.66	0.00
	Error	16	1.20			171	0.36		
Shaded parts	Seed number	3	51.33	58.67	0.00	3	88.02	205.77	0.00
	Error	16	0.88			171	0.43		

Seedling survival was affected by fruit origin and seed category. Seedlings that emerged from one- and two- seeded fruits survived significantly better than those from the three- and four-seeded fruits. Survival of seedlings was greater for the seeds collected from shaded parts; however, differences were not significant (Figure 4 and Table 4).

Growth performance was also significantly affected by fruit origin and seed category. Seeds from one-seeded fruits produced healthier seedlings than seeds from two-, three- and four-seeded fruits. Further, the growth of seedlings emerging from seeds from shaded parts was better compared to those from sunlit parts but differences were not significant (Figure 5 and Table 5).

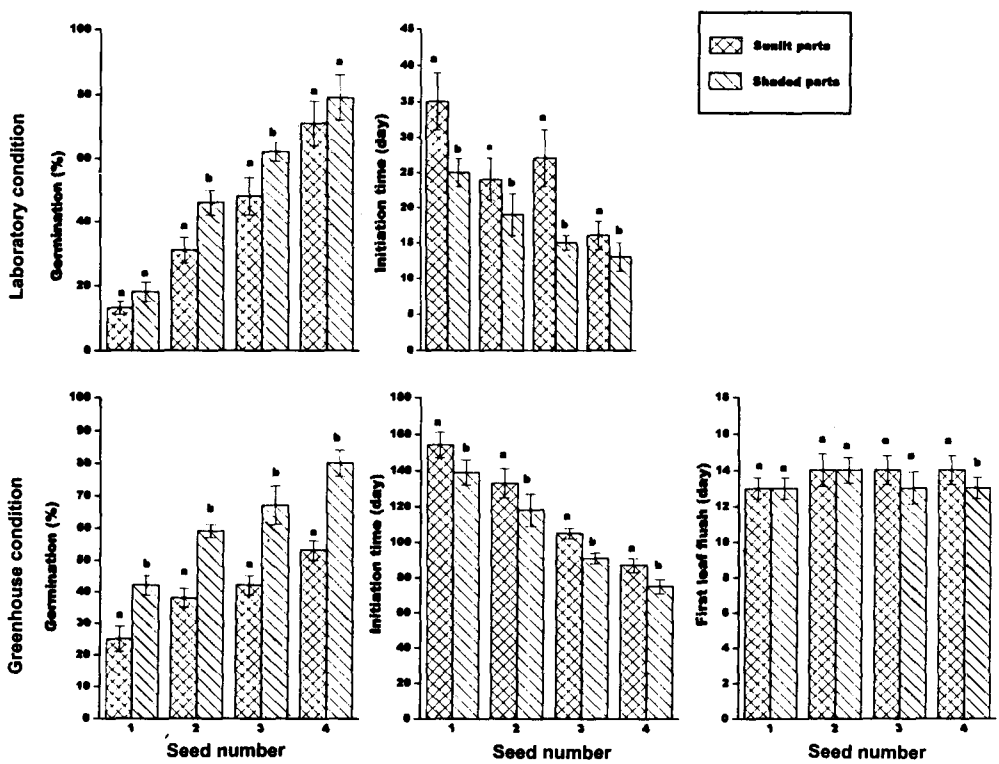

Figure 3 Germination (%), period taken for initiation of germination (day) and first leaf flush (day) in laboratory and greenhouse conditions in seeds of *Mesua ferrea* collected from the fruits of sunlit and shaded parts. Means in column bar followed by the same letter are not significantly different as tested by F-ratio. Capital and small letters stand for differences due to seed number and light intensity respectively. Line bar indicates the mean ± SD.

Table 3 Analysis of variance of the data on germination in laboratory and greenhouse conditions presented in Figure 3

Parameter	Source of variation	Laboratory conditions								Greenhouse conditions											
		Germination				Initiation time				Germination				Initiation time				First leaf flush			
		df	MS	F-ratio	p-level	df	MS	F-ratio	p-level	df	MS	F-ratio	p-level	df	MS	F-ratio	p-level	df	MS	F-ratio	p-level
Seed type																					
One seeded	Sunlit vs. shaded	1	62.5	1.6	0.2	1	250	26.5	0.001	1	722.5	72.3	0.0	1	57.6	13.3	0.007	1	0.009	0.02	0.88
	Error	8	38.8			8	9.5			8	10.0			8	43.5				8	0.40	
Two seeded	Sunlit vs. shaded	1	562.5	32.1	0.0	1	52.9	5.2	0.05	1	1323	211.6	0.0	1	610.0	8.87	0.02	1	0.58	0.09	0.37
	Error	8	17.5			8	10.2			8	6.3			8	72.0				8	0.64	
Three seeded	Sunlit vs. shaded	1	490.0	24.5	0.001	1	396.9	39.7	0.0	1	1563	78.13	0.0	1	464.2	38.9	0.0	1	0.26	0.34	0.58
	Error	8	20.0			8	10			8	20.0			8	12.7				8	0.76	
Four seeded	Sunlit vs. shaded	1	160.0	3.3	0.1	1	16.9	7.04	0.03	1	1823	182.3	0.0	1	367.2	34.4	0.0	1	3.14	5.95	0.04
	Error	8	48.8			8	2.4			8	10.0			8	10.67			8	0.53		
Light intensity																					
Sunlit parts	Seed number	3	3054.6	88.9	0.0	3	318.0	28.27	0.0	3	668.3	76.4	0.0	3	4331.3	128.7	0.0	3	0.81	1.31	0.31
	Error	16	34.38			16	11.3			16	8.8			16	33.6			16	0.62		
Shaded parts	Seed number	3	3364.6	119.6	0.0	3	139.5	29.4	0.0	3	1263	87.9	0.0	3	3935.7	109.8	0.0	3	0.102	0.19	0.90
	Error	16	28.13			16	4.8			16	14.4			16	35.83			16	0.54		

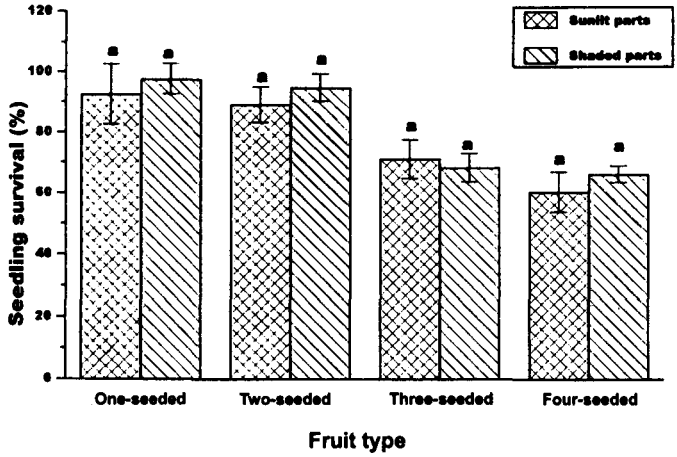

Figure 4 Survival (%) of seedlings after one year of emergence in greenhouse from four types of fruits of *Mesua ferrea* collected from sunlit and shaded parts. Means in column bar followed by the same letter are not significantly different as tested by F-ratio. Capital and small letters stand for differences due to seed number and light intensity respectively. Line bar indicates the mean ± SD.

Table 4 Analysis of variance of the data on survival of seedlings presented in Figure 4

Parameter	Source of variation	df	MS	F-value	p-level
Fruit type					
One-seeded	Sunlit vs. shaded	1	65.54	1.03	0.34
	Error	8	63.51		
Two-seeded	Sunlit vs. shaded	1	82.37	2.87	0.13
	Error	8	28.69		
Three-seeded	Sunlit vs. shaded	1	21.85	0.69	0.43
	Error	8	31.53		
Four-seeded	Sunlit vs. shaded	1	82.08	3.28	0.11
	Error	8	25.06		
Light intensity					
Sunlit parts	Seed number	3	1149.68	20.53	0.00
	Error	16	55.99		
Shaded parts	Seed number	3	1416.63	76.97	0.00
	Error	16	18.40		

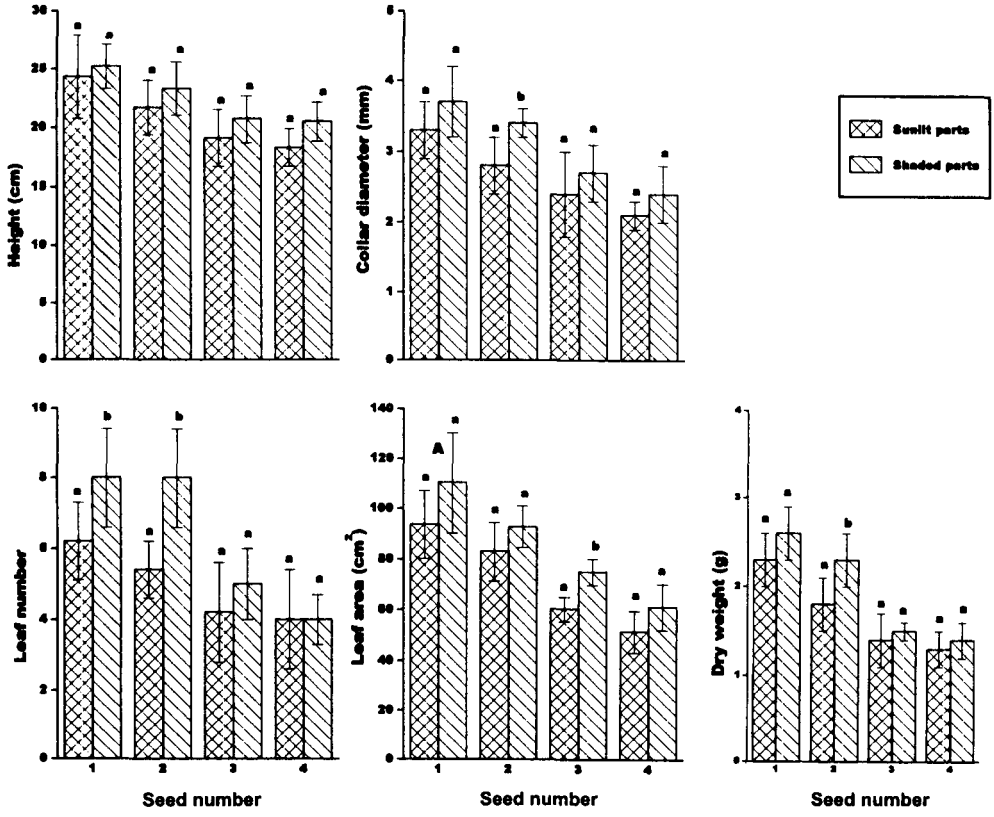

Figure 5 Growth (per seedling) after one year of survival of seedlings in greenhouse emerged from four types of fruits of *Mesua ferrea* collected from sunlit and shaded parts. Means in column bar followed by the same letter are not significantly different as tested by F-ratio. Capital and small letters stand for differences due to seed number and light intensity respectively. Line bar indicates the mean ± SD.

Discussion

Fruit set in individuals of *M. ferrea* varied depending on light intensity. Higher fruit set in sunlit parts may be attributed to the stimulation of flowering under sunlight. High light intensity may elevate bud temperature, which may lead to increase concentrations of growth regulators particularly gibberellins (Pharis & Kuo 1977, Ross *et al.* 1983), stimulating flowering and fruiting. Further, increase in branching, and their retarded growth on sunlit parts (personal observations), may have contributed to greater fruit set as they are regarded favourable to flowering (Ross *et al.* 1985). Due to high light regime on sunlit parts, temporary water stress may be created which is known to stimulate bud initiation in some forest trees (Kozlowski 1981).

Variations in seed size within a plant have been discussed by Harper *et al.* (1970). However, the reason for the production of smaller fruits on sunlit parts compared to shaded parts is not known. It is generally held that seed size is inversely related to seed number. In addition environmental conditions such as reduced

Table 5 Analysis of variance of the data on different growth parameters of seedlings presented in Figure 5

		Height				Collar diameter				Leaf number				Leaf area				Dry weight			
Parameter	Source of variation	df	MS	F-ratio	p-level	df	MS	F-ratio	p-level	df	MS	F-ratio	p-level	df	MS	F-ratio	p-level	df	MS	F-ratio	p-level
Fruit type																					
One-seeded	Sunlit vs. shaded	1	2.0	0.24	0.6	1	0.7	3.33	0.1	1	8.1	5.06	0.06	1	690.4	2.37	0.2	1	0.26	3.37	0.1
	Error	8	8.3			8	0.2			8	1.6			8	291.6			8	0.08		
Two-seeded	Sunlit vs. shaded	1	5.9	1.06	0.3	1	0.8	10.2	0.01	1	17	12.07	0.008	1	242.06	2.4	0.2	1	0.728	10.46	0.01
	Error	8	5.6			8	0.1			8	1.4			8	102.13			8	0.07		
Three-seeded	Sunlit vs. shaded	1	6.9	1.32	0.28	1	0.3	1.09	0.32	1	1.6	1.0	0.35	1	531.88	21.08	0.002	1	0.04	0.88	0.4
	Error	8	5.2			8	0.2			8	1.6			8	25.23			8	0.04		
Four-seeded	Sunlit vs. shaded	1	8.3	3.09	0.11	1	0.3	2.26	0.173	1	0.0	0.0	1.0	1	233.9	3.1	0.12	1	0.06	1.55	0.25
	Error	8	2.7			8	0.1			8	1.3			8	75.3			8	0.04		
Light intensity																					
Sunlit parts	Seed number	3	36.8	5.36	0.01	3	1.1	6.86	0.003	3	5.4	3.47	0.04	3	1902.9	18.66	0.0	3	1.06	15.9	0.0
	Error	16	6.9			16	0.2			16	1.6			16	101.99			16	0.07		
Shaded parts	Seed number	3	70.5	17.45	0.0	3	1.7	10.0	0.001	3	21	15.46	0.0	3	2275.5	15.68	0.0	3	1.74	37.77	0.0
	Error	16	4.0			16	0.2	7		16	1.4			16	145.14			16	0.05		

irradiance may cause reduction in seed number and lead to the production of heavier seeds. Variation in fruit weight may be due to greater number of fruits at sunlit parts. This causes less translocation of photosynthate to individual fruits and/or severe water stress in the canopy of sunlit parts during maturation which reduces fruit size (Kozlowski 1981).

The heavy fruits from shaded parts produced heavier seeds than that from sunlit parts. In general, seeds from one-seeded fruits were heavier than those from two-, three- and four-seeded fruits. Each seed from four-seeded fruits weighed only half of the seed from one-seeded fruits. Uma Shaanker and Ganeshaiah (1997) stated that seeds developing in close physical and temporal proximity in a fruit interact intensely among themselves for resources. A fixed amount of energy is available for fruit set, and the total number of seeds produced is inversely related to the energy expenditure per seed (Bradford & Smith 1977). Therefore multi-seeded fruits are significantly larger and expected to contain more nutrients and energy than one-seeded fruits; the total nutrients and energy per seed is expected to be greatest for one-seeded fruit.

Seed germination varied with the number of seeds in a fruit of *M. ferrea*. Germination was positively correlated with the increase in number of seeds and it was maximum in the seeds from four-seeded fruits. Further, all categories of seeds from shaded parts showed significantly better germination. Such variations might be ascribed to comparatively hard seed coat of the seeds from fewer seeded fruits and low moisture content of the seeds from sunlit parts. Seeds from multi-seeded fruits were smaller than the seeds from one-seeded fruits. There are many reports that show small seeds having rapid and greater germination (e.g. Murali 1997), but the information concerning many forest trees is somewhat contradictory (e.g. Barik *et al.* 1996).

A better seedling form and growth from seeds of one-seeded fruits can be linked to bigger seed and thereby larger amounts of nutritive reserves (Vera 1997, Negi & Todaria 1997, Singh & Khan 1998).

The ecological consequences of the variable number of seeds per fruit infer possible selective factors affecting the offspring fitness, e.g. dispersal efficiency as well as post-dispersal seedling survival and growth (Uma Shaanker & Ganeshaiah 1997). Production of more multi-seeded fruits may have an advantage over single-seeded fruits in terms of dispersal. However, multi-seeded fruits have smaller seeds which produce smaller seedlings with lower survival and presumably lower competitive ability (Tripathi & Khan 1990).

These results demonstrate that there may be conflicting selective pressures on seed number per fruit in *M. ferrea*. Being a persistent species, it produces more one-seeded fruits or heavier seeds in general, and fewer and heavier seeds in shaded parts in particular. Seeds from multi-seeded fruits with greater dispersal efficiency as well as rapid and better germination may colonise small forest opening areas, while one-seeded fruits or heavier seeds may produce seedlings that are competitive in forest understory with limiting light.

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