CHAPTER 4

SURVIVAL AND GROWTH OF THE TREE SPECIES

The measurements of girth or diameter, total height and volume of trees are necessary for making inventory of growing stock. These measurements are becoming increasingly important under agroforestry practices. As agroforestry practice involves growing trees and crops in close proximity, the presence of a plant can change the environment of its neighbours due to interactions at the tree/crop interfaces (Rao & Coe, 1991). The interactions between species in agroforestry situations (Anderson & Sinclair, 1993) are mediated by the environment through the 'response and effect' principle (Goldberg & Werner, 1983), which states that the plant and its environment modify one another. Thus the environment causes a response in plant function and growth, and the plant then has an effect upon the environment by changing one or more of its factors (Goldberg & Werner, 1983). The nature of the interactions within and between species therefore concerns the ways in which a plant can influence its neighbours by changing their environment, either directly, by addition or subtraction (e.g. nutrients), or indirectly. In recent times most studies on intercropping with tree species have focussed attention on the effect of the tree species on the crop yield (Singh & Dayal, 1974; Andrews & Kassam, 1976; Tustin *et al.*, 1979; Willey, 1979; Mishra & Prasad, 1980; Saxena, 1980; Szott, 1987; Vinaya Rai & Suresh, 1988; Ahmed, 1989; Singh *et al.*, 1989). But studies on the reciprocal

effects of the crop on the tree are scanty (Samraj *et al.*, 1982; Redhead *et al.*, 1983; Suresh & Vinaya Rai, 1991). Therefore, the data on survival, height and diameter increment, crown width and timber volume of the four tree species under the 'tree+crop' and 'tree only' situations were recorded over a period of 2 years.

MATERIALS AND METHODS

Survival, growth and timber volume of trees:

Survival, height, diameter at breast height (dbh) and crown width of the tree species in each plot were recorded at six- monthly intervals, synchronising with cropping period. Height was measured using a dendrometer. The instrument is based on the trigonometric principles. In order to verify the measurements, a pole graduated in metres and centimetres was also used. Diameter at breast height (dbh) of trees was measured at 1.37 m above ground with a calliper. It was recorded by taking the mean of two diameter readings at right angles to each other.

The developmernt of tree depends on its crown, hence, crown measurement is of great interest. The measurement of crown involves measurement of its length and width, however, in agroforestry, measurement of crown width due to its shade effect is of greater importance than crown length, and hence it was recorded in present study. *Crown width* is defined as *the maximum spread of the crown along its widest diameter.* It indicates the functional growing space occupied by the tree. For measurement of crown width of trees, the tape was extended across the full length of the tree-crown first in one

direction and then in the opposite side of the crown. The values thus obtained were added and average crown width was calculated. In case of irregular crowns, diameter was measured three or four times from different positions and the arithmetic mean of these readings gave the crown width.

The volume of tree depends mainly upon three variables, viz. diameter, height and form. Form is defined as *the rate of taper of a log or stem. Taper is the decrease in diameter of a stem of a tree or of a log from base upwards* (Chaturvedi & Khanna, 1982). Form of trees of the four species was studied by comparison of standard form ratios i.e. form factor, which is defined as *the ratio of the volume of a tree or its part to the volume of a cylinder having the same length and cross section as the tree*. The form factor may be represented as;

$$F = V_{/Sh}$$

Where F is the form factor,
V is the tree volume (m^3)
S is the basal area at breast-height (m^2), and
h is the height of the tree (m).

Form factors were compiled into tabular form giving average form factor values of trees of different diameter and height classes. These tables were used to estimate volume of standing trees by measuring their dbh and height.

Increments

Increment could be the increase in diameter, height, volume, biomass etc. of trees during a given period. Two parameters viz. current annual increment (CAI) and mean annual increment (MAI) were utilized to depict growth rate of the tree species. These parameters are described below.

Current Annual Increment (CAI)

It is the increment in growth which a tree puts on in a single year. In practice, CAI refers to average rate of increase in growth over the past one year.

Mean Annual Increment (MAI)

It is the mean volume or biomass or height of a tree at a given age divided by the age in years.

The two parameters were calculated taking into account the height, diameter and volume of the four tree species in the 'tree +crop' and the 'tree only' situations.

All the data were subjected to an analysis of variance and treatment differences tested for significance.

RESULTS

Survival

Survival of trees was not influenced by the presence of crops. But the species differed with regard to their survival. Alder and mandarin recorded 100% survival after six years of planting followed by cherry with 95%, and albizia with 90% (Table 4.1). Survival percentage of the four tree species did not vary under the two situations ('tree+crop' and 'tree only') during the entire period of study.

Diameter and height growth

There were significant ($P<0.1$) differences in diameter (dbh) and height growth among the four tree species in both years (Table 4.1). The maximim height growth at sixth year was recorded by albizia (12 m) followed by alder (11 m) and cherry (9 m), and mandarin (4.5 m) showed the minimum height. Alder had the highest dbh (19.7 cm) followed by albizia (14.7 cm)

Table 4.1. Survival, growth characteristics and timber volume of the four tree species in the 'tree+crop' and 'tree only' situations.

Parameters	'Tree only' situation				'Tree+crop' situation				C.D.
	Alder	Albizia	Cherry	Mandarin	Alder	Albizia	Cherry	Mandarin	at 0.05
Sixth year									
Survival(%)	100.00	90.00	95.00	100.00	100.00	90.00	95.00	100.00	-
Height(m)	11.01	12.05	9.06	4.50	13.25	12.60	9.28	4.53	0.88
DBH(cm)	19.7	14.7	12.8	10.9	20.9	17.2	14.1	12.7	1.64
Crown width(m)	6.40	4.52	3.92	1.68	7.75	5.56	4.69	1.58	-
Timber volume ($m^3 plant^{-1}$)	0.271	0.166	0.092	0.017	0.365	0.246	0.118	0.017	0.037
Seventh year									
Survival(%)	100.00	90.00	95.00	100.00	100.00	90.00	95.00	100.00	-
Height(m)	12.78	13.20	10.02	5.00	14.38	13.88	10.34	5.20	1.05
DBH(cm)	21.5	16.4	14.7	11.3	23.2	19.6	15.7	12.9	1.67
Crown width(m)	7.04	5.24	4.45	2.03	7.90	6.66	5.19	2.09	-
Timber volume ($m^3 plant^{-1}$)	0.373	0.225	0.136	0.026	0.490	0.348	0.166	0.026	0.185

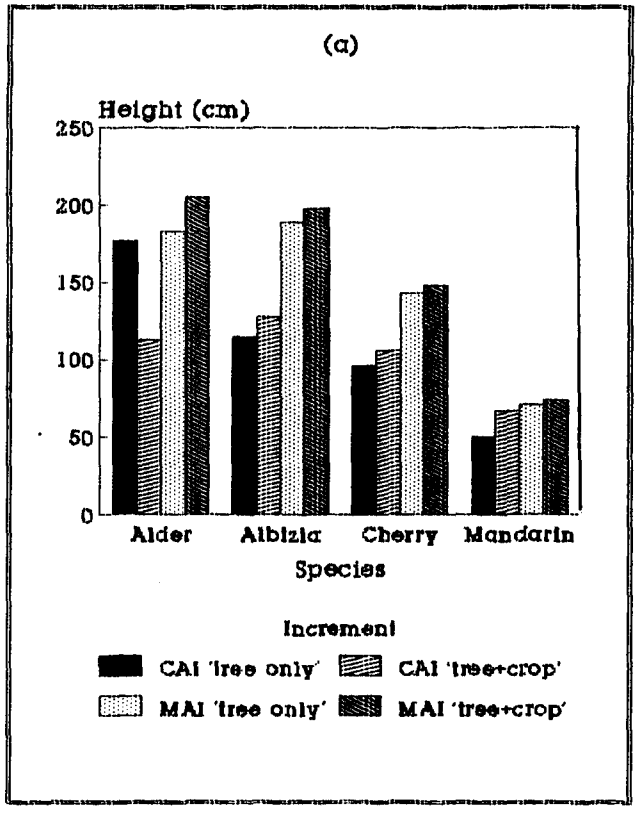
DBH- diameter at breast height.

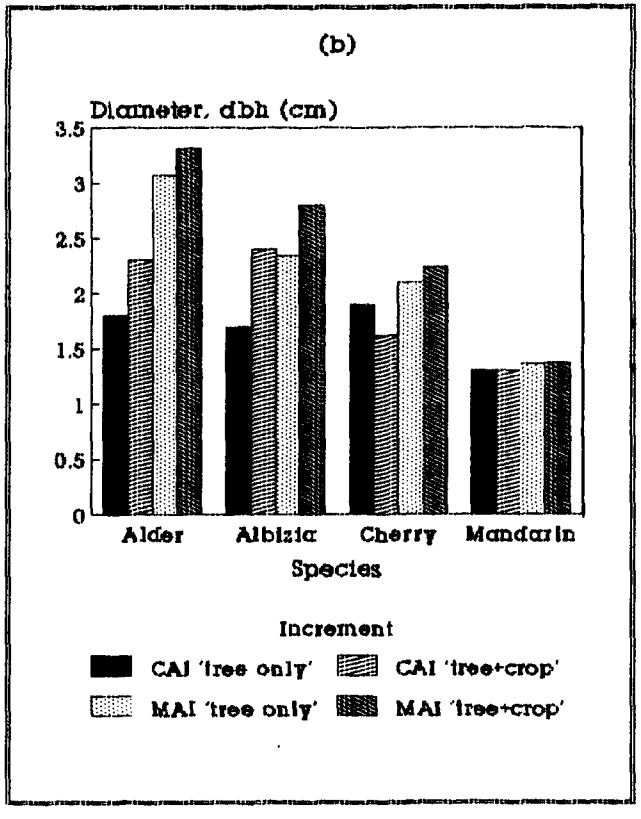
and cherry (12.8 cm), while mandarin (10.9 cm) had the lowest value. At seventh year too, a similar trend was observed, but the values were greater by 10-16% in height, and by 4-15% in diameter (dbh) than in the sixth year. The mean annual increment (MAI) for height ranged between 0.7-1.9 m, the lowest being in mandarin and highest in albizia. MAI in diameter in the four tree species ranged between 1.4-3.1 cm. The current annual increment (CAI) in height ranged between 0.5-1.8 m in mandarin and alder, and for diameter 1.3-1.9 cm in mandarin and cherry, respectively. The MAI values were greater than the CAI in respect of height and diameter in the four tree species (Fig. 4.1a, b, c). In terms of height growth, the species ranked albizia> alder> cherry> mandarin; while for diameter, the ranking was alder> albizia> cherry> mandarin. The over all ranking was alder> albizia> cherry> mandarin.

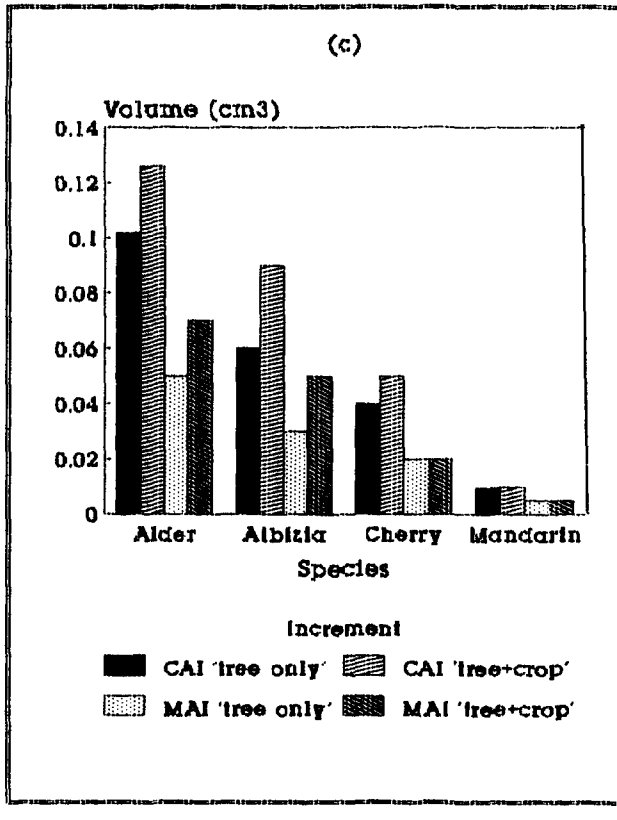
Crown width and timber volume

Alder (6.4 m) had the maximum crown width, followed by albizia (4.5 m) and cherry (3.9 m), while mandarin (1.7 m) had the minimum width in the sixth year (Table 4.1). At the seventh year, crown width followed the trend similar to sixth year, but the values were higher by 10-21% in the four species. The four tree species differed significantly ($P<0.1$) in timber volume production. Alder had maximum survival (100%) and maximum timber volume (0.271 $m^3 plant^{-1}$), while mandarin had the least timber volume during the sixth year. In the seventh year, though the trend was same as in the sixth year, the values were higher by 36-53%. Mean annual increment of timber

Fig. 4.1. Current annual increment (CAI) and mean annual increment (MAI) of the tree species in 'tree+crop' and 'tree only' situations in height (a), diameter (b) and volume (c).







volume was lower than CAI in all the four tree species.

Effect of intercrops on tree growth and timber volume

The overall growth, in terms of increment in diameter (dbh) and height, was greater in the 'tree+crop' than in the 'tree only' situation . There was positive and significant ($P<0.1$) effect of intercropping on height growth of alder where it was greater by 20% in sixth year and 13% in seventh year than in the 'tree only' situation. But the height increment in albizia and cherry was marginally (2-5%) higher in the 'tree+crop' than in the 'tree only' situation in both years. The diameter (dbh) increment in all the four tree species was 6-17% more in presence of the crops than in the tree monoculture during the sixth year and 8-20% during the seventh year; the maximum % increase in the 'tree+crop' situation over the corresponding 'tree only' situation was recorded in alder and minimum in albizia. The crown width of alder, albizia and cherry was 12 to 27% more as compared to the corresponding 'tree only' situation. Among all the parameters, timber volume recorded highest increment in the 'tree +crop' than the 'tree only' situation in alder, cherry and albizia. The maximum increase in timber volume (48% and 55% during the sixth and seventh year respectively) was recorded in albizia followed by alder with 35 and 31%, and cherry 28 and 22% during the same years. In the case of mandarin, however, there was no appreciable difference between growth increments under 'tree+crop' and 'tree only' situations. The crown width in this species was slightly more (6%) in the 'tree only' than in the 'tree+crop' situations

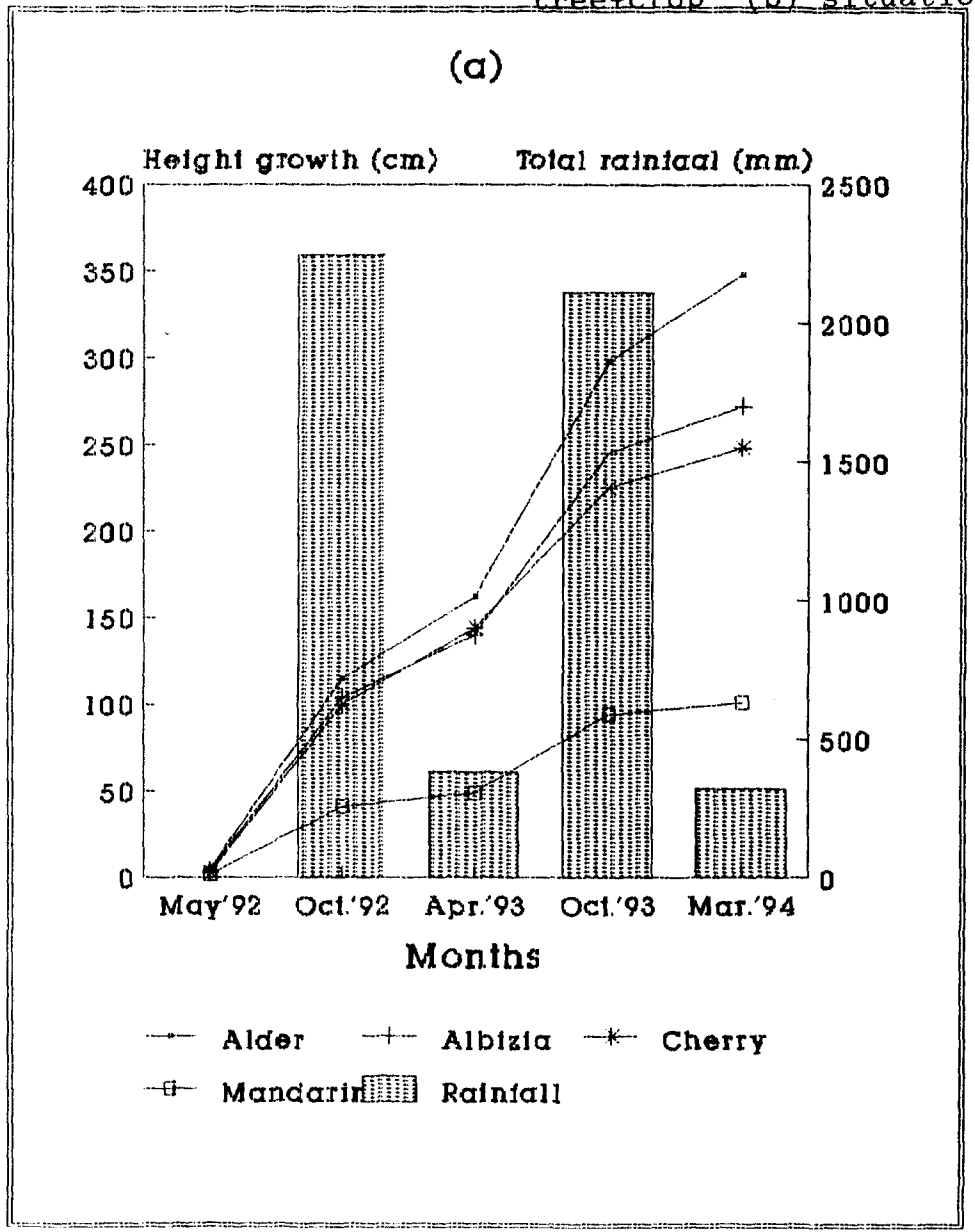
during the sixth year. Interestingly, the CAI and MAI values (Fig. 4.1a, b, c) indicated slight favourable effect of associating crops with mandarin on its growth. The MAI was generally higher than CAI for height and diameter but lower for timber volume in all the four species in the 'tree+crop' situation.

Effects of intercrops on periodic tree growth

In general the tree growth in terms of increment in diameter (dbh) and height was greater in the 'tree+crop' than in 'tree only' situation and seems to be positively correlated with rainfall (Fig. 4.2 a, b; 4.3a, b). During soybean and groundnut cropping period (May-October), there was a total rainfall of 2245 and 2111 mm in first and second year of cropping, respectively, and it was well distributed during the six month long cropping period. Height and stem diameter in all the four species rapidly increased during this period. However, the growth (height and diameter) slowed down over the next six months (November-April) largely due to low temperature and dry weather. During this period, there was quite low rainfall (ca 323-382 mm). Winter (rabi) crops viz. linseed and mustard were intercropped during this period. A positive correlation between growth and rainfall has also been reported for *Gliricidia sepium* in an alley cropping system in Sierra Leone by Karim and Savill (1991).

Growth of albizia, cherry and mandarin in terms of height increment in the 'tree+crop' (soybean) situation was only slightly greater (1-5%) than in corresponding tree monocultures. The height growth of alder in 'tree+crop'

Fig. 4.2. Mean height of the tree species as related to rainfall during cropping period in the 'tree only' (a), and 'tree+crop' (b) situations.



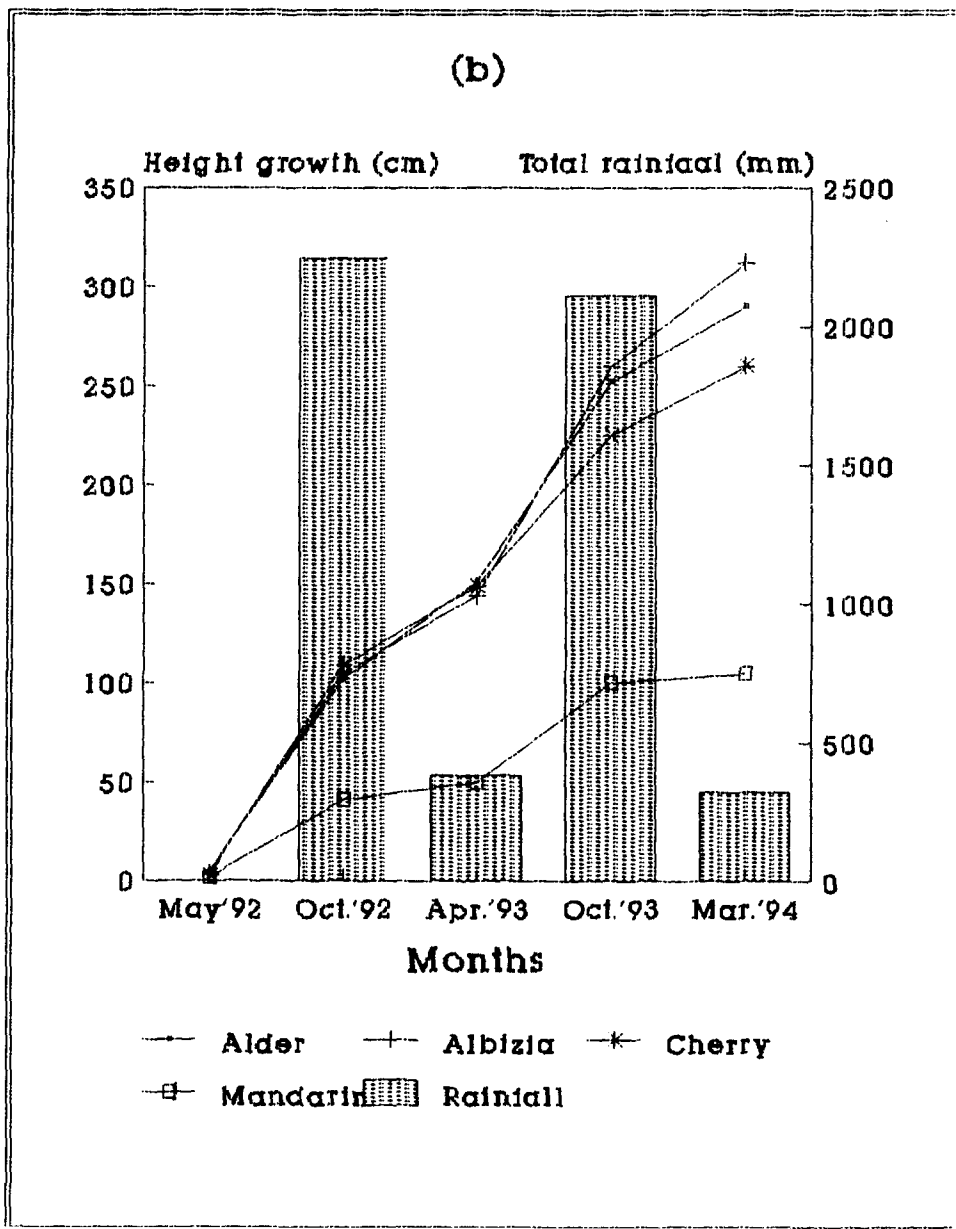
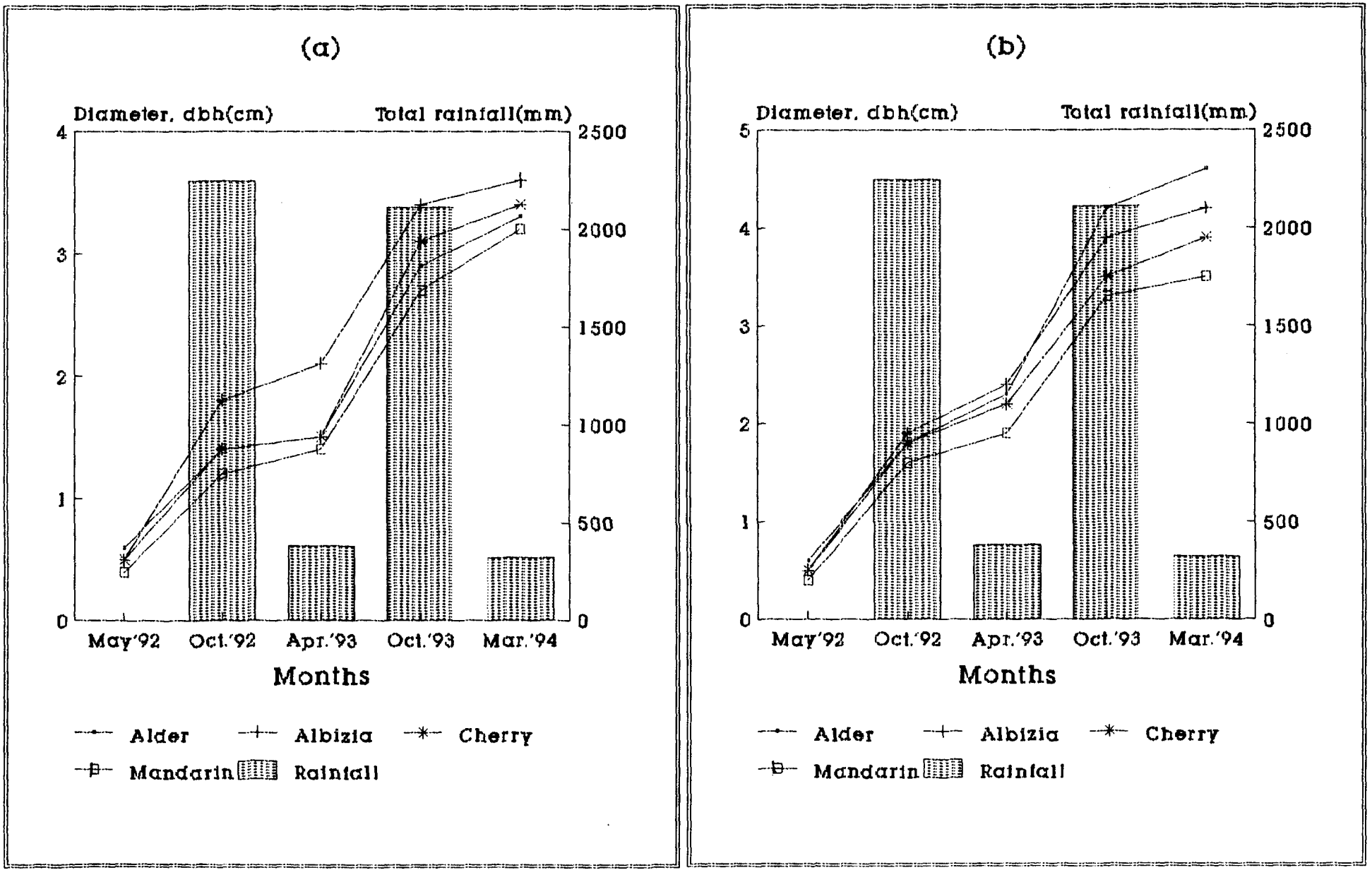


Fig. 4.3. Mean diameter of the tree species as related to rainfall during cropping period in the 'tree only' (a), and 'tree+crop' (b) situations.



situation was 14% lower than the 'tree only' situation. Overall, the four crops (soybean, linseed, groundnut and mustard) affected the height growth of alder adversely at 6, 12, 18 and 24 months. But in albizia and mandarin, the crops had favourable affecct on the height growth. Soybean and linseed crops had positive influence on height growth of cherry, but groundnut and mustard caused slight reduction.

Growth increment in diameter (dbh) was significantly ($P<0.1$) higher in the 'tree+crop' than in 'tree only' situation in all four tree species, though the magnitude varied between species. The most positive effect of intercropping on tree diameter growth was observed in alder, where the positive influence was greater by 42-64% for the four crops viz. soybean, linseed, groundnut and mustard. The corresponding influence was greater by 15-53% in cherry, and 15-45% in mandarin respectively. In albizia also intercropping caused significant ($P<0.5$) increase in dbh but the magnitude of increase was much less (13-20%) compared to the other tree species.

DISCUSSION

Survival and growth performance of alder, mandarin, cherry and albizia differed from one species to another. This could be explained by their differential genetic make up. The adoptability of alder, cherry and albizia species may be attributed to the soil and climatic conditions of this area which are similar to their native environment. The site of the present study, is characterized by low pH and high exchangeable aluminium (Chapter 3, Table 3.3), which is similar to as

is commonly encountered in alder, cherry and mandarin's natural environment. However, albizia, a species native of South-east Asis, also performed reasonably well. Under optimum conditions albizia (*Paraserianthes falcataria*) is reported to attain a height of 12 m and above in third year (Duguma *et. al.*, 1994; Duguma & Tonye, 1994), however, it did not grow so well on the present site. In one of the studies, albizia was reported to attain maximum height growth among the ten multi-purpose trees (Duguma *et. al.*, 1994). Relatively better growth of albizia could be attributed to its well developed and extensive rooting with profuse fine roots well distributed within the rhizosphere. Besides, secretion of root exudates might have helped this species in complexing exchangeable Al, a potential cause of infertility of acid soils in the region (Prasad *et al.*, 1985; Singh *et al.*, 1994], and eventually increasing the availability of P which might have contributed to its adaptability to local soil and climatic conditions. Apart from this, biological nitrogen-fixation also takes place in the roots of albizia, whereby an adequate supply of nitrogen is ensured for its growth and development under sloping land conditions, where inorganic-nitrogen is mostly subjected to leaching losses due to torrential and high rainfall in the area.

Increment in height and stem diameter growth is a good indicator of site conditions (soils) (Foroughbakhch *et. al.*, 1987). The present study site is having low pH and high exchangeable Al (Chapter 3). Various growth attributes viz. height, stem diameter, crown width and timber volume in all

the tree species were better in the 'tree+crop' than in the 'tree only' situation (Table 4.1, and Fig. 4.1). Similar results have been reported by Roy and Gill (1991) while studying an agri-silvicultural system. The better growth performance and biomass production observed in the 'tree+crop' situation are mainly due to application of fertilizers and weeding opearation in the plots where crops were grown with trees. Use of fertilizers and amelioratives in the 'tree+crop' situation also provided congenial soil environment for optimum soil microbial activity, which in turn, might have caused rapid mineralization of organic matter and eventually adequate uptake of nutrients by the trees. Singh *et. al.*, (1995) have reported suitability of MPTS in ameliorating infertility of acid soils especially under intercropping. Nair (1989) has also confirmed the sustainable production per unit area by incorporating trees with arable crops. Beneficial effects of growing crops in tree plantations on the tree growth have also been reported by several workers under different soil and climatic conditions (Mann & Shanakrnarayan, 1980; Yamoah, 1986b; Tejwani, 1987; Singh *et. al.*, 1989; Atta-Krah, 1990; Basri *et. al.*, 1990; Evensen *et. al.*, 1990; Kang *et. al.*, 1990, 1991; Kass *et. al.*, 1992; Campbell *et. al.*, 1994).

In the case of all four species the mean annual increment (MAI) for height and diameter (Fig. 4.1a, b), was higher than current annual increment (CAI). The greater values of MAI indicates that the present site is suitable for good growth of the four tree species in general, and alder and albizia in particular. Alder and albizia, established well on the acid

soils and showed fast growth with large crown diameter. Both species are known to be nitrogen fixing (Brewbaker, 1987) and play useful role in preventing soil erosion and land slips as well as conserving soil. Due to their multiple use (CSIR, 1990) these two tree species are widely used in afforestation and reforestation. They also provide shade, suppress weeds and improve soil fertility (Chapter 8) and thus in the humid lowlands of this region, albizia and alder appear to have potential for agro-forestry technologies. The growth and development of the indigenous cherry, however, was slow over the first six years, though, it also established well and recorded cent per cent survival. The growth of mandarin, in terms of increment in height, diameter and timber volume was very poor compared to the other three tree species which fall under the MPTS category. This may be due to the fact that mandarin is primarily grown for its fruits, and the entire mandarin orange cultivation in the north-eastern region is based on seedling plants (Gupta, 1979) which are highly susceptible to diseases and pests.
