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PRELIMINARY OBSERVATIONS ON THE PRODUCTION OF DRY MATTER BY SAL (*SHOREA ROBUSTA* GAERTN. F.)

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INTRODUCTION

"There are abundant data of the productivities of different woodland in terms of the volume of marketable stem but relatively few data of the weights of bole, branch, leaf and root material produced......" (Ovington 1960). The extent of information available on this aspect for temperate and western Pacific region is reviewed by Ovington (1962, 1965), Bray and Gorham (1964), and Kira and Shidei (1967). Surprisingly little is known about the monsoon tropical deciduous forests. In India, except for a few studies on litter production (Puri 1953, Upadhyaya 1955, Singh, J. S. 1962 a and b, Seth *et al.* 1963, Singh, K. P. 1967), and estimate of biomass of Sal through volume tables (Kaul *et al.* 1963) no work is available in production ecology of forest trees. Recently Misra (1967) emphasized the need of active research in this direction, so that the productivity potential of forest and its components can be assessed properly. A series of demonstrations arranged by the authors, during the School on Plant Ecology held in October, 1966 and the Summer Institute in Biology held during June, 1967, in this department, yielded interesting data on the production of dry matter by Sal. Some of these data are discussed in this paper.

DESCRIPTION OF THE AREA

The site selected for the present study lies in the Dudhi forest division of Mirzapur district, U.P. It has slightly undulating topography and is zig-zagged by a few small streams, which dry up during summer. The red coloured soil, which has been derived from ferruginous sandstone, is sandy loam in texture and its thickness ranges upto 2-3 meters. The area receives approximately 1000 mm rainfall annually, which is distributed on monsoonic pattern. Vegetation is of mixed deciduous type and shows at least two storeys. The top storey with closed canopy is chiefly constituted by *Shorea robusta*, *Eleodendron glaucum*, *Terminalia tomentosa* and *Mitragyna parviflora*. The second storey is comprised of younger trees of the species of the first storey, and *Diospyros melanoxylon*, *Buchanania lanzan*, *Lagerstroemia parviflora*, *Woodfordia fruticosa*, *Holarrhena* *antidysentrica*, etc. The forest is managed under 30 year rotational felling by the forest department. No fire has been recorded at least for the last ten years.

PRESENTATION OF DATA

Sal trees of 30 and 50 year age were sampled during June, 1967. Earlier, during October, 1966, a 18 year old tree of this species had been sampled. In 8 × 8 m quadrats laid around the 30 and 50 year old trees, the tree density was 8 and 12, respectively; whereas 18 year old tree had no associate in the quadrat.

TREE DIMENSIONS

After measuring the crown area, trees were felled and the following measurements were made: (1) height, (2) depth of canopy and (3) variation in the circumference of trees at various heights. The data are set in table 1.

TABLE 1. *Tree dimensions for Sal*

Measurements	Age in years		
	18	30	50
Height (m)		14.5	20.4
Crown area (sq.m)	18.8	13.5	18.7
Depth of canopy (m)		12.0	18.7
Trunk circumference (cm)			
At the base		67.0	197.0
3 m ht		60.0	105.0
6 m ht		55.0	77.0
9 m ht		35.0	67.0
12 m ht		25.0	52.0
15 m ht		—	30.0

ABOVEGROUND BIOMASS

Leaves were handpicked from different segments of the canopy and weighed separately. The fresh weight of the total twig biomass was also recorded. The trunk was cut into 3 m pieces with the help of a saw and their individual fresh weights were recorded. Samples from trunk segments, twigs and leaves were brought to the laboratory for determination of dry weight. The data on fresh and dry weights of various components of the trees are given in table 2.

TABLE 2. *Standing aboveground biomass in Sal (Kg/tree)*

	18 year old		30 year old		50 year old	
	Fresh wt	Dry wt	Fresh wt	Dry wt	Fresh wt	Dry wt
Trunk biomass						
0- 3 m			92.0	75.9	270.5	208.3
3- 6 m			67.0	55.2	120.0	93.9
6- 9 m			35.0	27.1	85.0	56.5
9-12 m			22.0	18.0	73.0	48.5
12-15 m			9.0	6.8	70.0	47.6
Total	132.2	88.8	225.0	183.0	682.5	500.1
Twig biomass	46.7	33.3	79.0	45.4	116.0	66.7
Leaf biomass						
0- 3 m			1.2	0.4	4.7	1.9
3- 6 m			1.5	0.6	3.8	1.5
9-12 m			3.5	1.5	—	—
12-15 m			4.0	1.7	3.5	1.4
15 m			3.5	1.5	5.5	2.2
					17.0	6.7
Total	23.3	10.9	12.7	5.7	34.5	13.7
Total non-photosynthetic biomass	178.9	122.1	304.0	228.4	798.0	566.8
Total photosynthetic biomass	23.3	10.9	12.7	5.7	34.5	13.7
Grand Total	202.2	133.0	316.7	234.1	832.5	580.5
Non-photosynthetic/ photosynthetic ratio		11.2		40.0		41.0

LEAF DIMENSIONS

From a random sample, the leaves were arbitrarily divided into three size classes based upon their area. Weighed samples having known number of leaves of different size classes were brought to the laboratory and their dry weight and area (one side of lamina only) were determined. From this the average dry weight and area per leaf were computed. With the dry weight and area relationship thus determined, and the dry weight of the leaf biomass, the total leaf area, and leaf area indices were computed for the trees. These data are presented in table 3.

TABLE 3. *Various leaf dimensions for Sal*

Characters	Age in years		
	18	30	50
Average dry wt/leaf (g)	1.22	0.744	1.36
Average area/leaf (sq. cm)	91.0	99.3	126.4
Area of total leaf crop (sq. m)	81.5	73.1	127.3
Leaf area index (sq.m leaf area/sq.m ground)	4.3	5.3	6.8

EXTENT OF LEAF DAMAGE

While sampling the leaves of different size classes care was taken to collect damaged and undamaged leaves separately. The difference between the dry weights of the two was used to assess the amount of primary consumption (Table 4).

TABLE 4. *Percentage loss in dry weight of leaves due to primary consumers*

Size class	Average area/leaf (sq.cm)	Percentage loss
I	176.4	1.4
II	126.4	12.0
III	76.6	14.9

ANNUAL INCREMENT

Average annual increment in non-photosynthetic aboveground biomass was calculated by dividing the weight of trunk and twig biomass by number of years (age).

Average annual increment in non-photosynthetic biomass of Sal

0—18 years	6.7 Kg/tree/Yr
18—30 years	8.8 Kg/tree/Yr
30—50 years	16.9 Kg/tree/Yr

In the case of photosynthetic biomass (leaves) total production over the life period was computed with the help of biomass/age ratios. The values given in table 5 represent accumulated leaf weights over 18, 30 or 50 year period as the case may be.

TABLE 5. *Total aboveground production in Sal (Kg/tree)*

Age	Non-photosynthetic	Photosynthetic	Total
18	122.1	102.6	224.7
30	228.4	90.1	318.5
50	566.8	174.1	740.9

Peterken and Newbould (1966) have calculated the total weight of the foliage produced by *Ilex aquifolium* through the following expression :

$$\frac{\text{Age of tree}}{\text{Mean leaf longevity}} \times \text{Weight of living foliage}$$

If mean leaf longevity in Sal is taken to be 0.8 yr and this formula is applied, the total foliage produced by 18, 30 and 50 year old trees works out to be 156.9, 136.8 and 548.0 Kg/tree. These values are considerably higher than our estimate. But the above formula is based on the assumption that the foliage weight of each tree had remained constant with time. However, in the case of Sal, the leaves are annual and the foliage production varies with age, hence this formula may not be applicable.

DISCUSSION

From the data presented above, it is apparent that both fresh as well as dry weights of trunk and twigs increase with age, the maximum values being found for 50 years old trees. As regards leaf biomass the values for 50 year old tree are maximum and those of 30 year old minimum. It may be recollected here that the 18 year old tree was sampled in the month of October, by which time most of the leaves attain maximum size and weight under the existing conditions. Moreover, this particular tree was growing isolated and there was minimum, if any, shade effect from the surrounding trees. Under these circumstances higher biomass may be expected for this tree. Higher crown area of this tree supports this contention.

Seth *et al.* (1963) have reported the average standing oven dry leaf weight of Sal to be 5018 Kg/ha (tree density 778/ha) at an age of 35 years. However, this value represents the weight of leaf litter and hence, cannot be accepted as true weight of the leaf crop. On this basis (5018 Kg/ha), Kaul *et al.* (1963) have calculated the leaf weight per tree (tree density 472/ha) for site quality I and have made reductions in leaf weight according to decrease in the diameter of the tree for other site qualities. According to these authors, leaf biomass in this species ranges from 6.07 — 10.63 Kg/tree at an age of 35 years. It may, however, be noted that the tree diameter is not always the determinant of leaf weight. The latter is influenced much by the time of sampling and stand density. According to Kira and Shidei (1967), the leaf biomass also varies with the stand age, community structure and other factors. Satoo (1962, 1966) found that the regression of foliage amount on dbh differs markedly among the stands of different ages in birch. Shinozaki *et al.* (1964) have proposed that the amount of leaves should have the closest correlation not with dbh but with the diameter of the bole at the joint of the lowest living branch. It has been argued by Kira and Shidei (1967) that "a tree growing in a closed stand cannot have an infinitely large amount of foliage, however big the tree may be. Instead, it seems that there is a certain upper limit of foliage biomass for a tree in a given stand". Therefore, it is essential to bear these points in mind before presenting an estimate of leaf biomass.

However, if the present values of leaf biomass have to be compared with those reported by Seth *et al.* (1963) and Kaul *et al.* (1963) it has to be taken into consideration that the stand density at the present site (for 30 and 50 year old trees) is considerably greater (1500 trees/ha) and hence lower value may be expected. Evidently further work is required to establish correlations of leaf biomass with tree dimensions in our country.

The total non-photosynthetic biomass increases considerably with the advance in age. The non-photosynthetic/photosynthetic biomass ratio also shows an increase of about 4 times between 18 and 30 and 18 and 50 years (Table 2). This clearly shows the accumulation of non-photosynthetic matter in Sal during later years of the life-history.

According to Kaul *et al.* (1963), the non-photosynthetic biomass (wood + bark) of 35 year old Sal tree varies between 95.8 (site quality IV) to 381.39 (site quality I) Kg/tree and the corresponding value reported by Seth *et al.* (1963) is 275 Kg/tree. These values have been calculated from volume tables of Sal and are not actual measurements. However, the value obtained for 30 year old tree in the present investigation lies within this range.

The estimate of average annual increment in trunk plus twig biomass is maximum between 30 and 50 years, the rate being almost double that of the preceding years. The total aboveground production is again maximum for 50 year old tree.

A comparison of the aboveground biomass data for *Shorea robusta* (Table 2) and those of certain temperate forest trees of comparable ages (Table 6) indicates considerably higher biomass of trunk, twigs and leaves in the species presently studied.

TABLE 6. *Aboveground biomass of certain trees (Kg/tree)*

Species	Age	Trunk	Twigs	Leaves	Total	Authority
Pinus sylvestris	17	2.88	2.12	1.59	6.6	Ovington (1957)
	31	34.4	9.67	3.5	47.5	—do—
	56	127.2	29.3	9.5	166.0	—do—
Pseudotsuga taxifolia	30	19.8	5.5	6.9	32.2	Heilman (1961)
	52	151.0	15.4	10.4	176.8	—do—
Quercus borealis	57	139.8	61.8	4.3	205.9	Ovington and Heitkamp (cited by Ovington 1962)
Betula sp.	27	27.5	3.9	0.5	31.9	Ovington and
	53	137.0	32.5	2.2	171.7	Madgwick (1959)

On area basis, the range of the dry weight of plant biomass in well grown forests irrespective of climatic zones has been suggested by Ogawa *et al.* (1961) to be 200—350 $\times$ 10^3 Kg/ha. On the other hand, Whittaker (cited by Ovington 1965) has recorded values upto 600 $\times$ 10^3 Kg/ha in Appalachian mountains. In well stocked matured Sal forests the aboveground tree biomass may vary between 350—870$\times 10^3$ Kg/ha as indicated by our preliminary observations. The above estimates are, however, based on the assumption that the forest is composed of 30 or 50 year old trees with a density of 1500/ha. Thus, the tropical deciduous forests dominated by Sal may represent far greater biomass than hitherto reported. This may indicate greater dry matter production by Sal in the existing climatic conditions. In this respect net production and the rate of production of trunk dry matter in this species have been compared with those in *Pinus sylvestris* and *Betula* sp. These two species were selected because the former one is an evergreen needle leaf tree, while the other is a broad leaf deciduous tree; both being temperate species. It is evident from Table 7 that both the net production and the rate of trunk dry matter production in Sal are far greater. This may be due to higher leaf area index, greater total leaf area or greater photosynthetic efficiency.

TABLE 7. *Net production of dry matter and rate of trunk dry matter production in different tree species*

Species	Age	Net production (Kg/tree)	Age	Rate of trunk dry matter production (Kg/year/tree)	Authority
Pinus sylvestris	17	12.9	0-17	0.17	Ovington (1957)
	31	75.7	17-31	2.25	do
	55	267.4	31-55	3.87	do
Betula sp.	27	47.8	0-27	1.01	Ovington & Madgwick (1957)
	53	219.4	27-53	4.21	
Shorea robusta	18	224.7	0.18	4.90	Present study
	30	318.5	18-30	7.80	do
	50	740.9	30-50	15.85	do

Table 8 shows that the leaf area index of *Shorea robusta* lies well within the usual range as reported for a number of species. Tadaki and Schidei (1960) have reported that in deciduous woodlands the leaf area index varies between

TABLE 8. *Leaf area indices of certain forest trees.*

Species	Place	Age	Leaf area index	Authority
Quercus petraea	England	40-120	4.75-5.47	Carlisle *et al.* (1966)
Q. robur	Hungary	51-60	5.95-6.55	Jāro (1959)
Betula sp.	Hungary	10-30	4.39-5.65	Jāro (1959)
Pinus sylvestris	England	20	3.31	Ovington (1957)
Heava braziliensis	Malaya	1-33	0.14-9.91	Shorrocks (1965)
Elais guineensis	Nigeria	17-22	4.39	Ress & Tinker (1963)
Tilia cordata	Hungary	45	6.60	Jāro (1959)
Fagus sylvatica	Denmark	30-200	3.19-7.48	Moller (1945)

2.2—7.9. Thus, leaf area index of 4.3 to 6.8 of this species is not an exceptional one. The total leaf area per tree is, however, greater in the present case as against that of *Betula* and *Pinus* (Tabe 9).

TABLE 9. *Total leaf area per tree.*

Species	Age	Total leaf area (m^2)	Authority
Pinus sylvestris	17	16.45	Ovington (1957)
	31	36.07	do
	55	98.32	do
Betula sp.	27	14.20	Ovington and Madgwick (1959)
	53	58.30	do
Shorea robusta	18	81.5	Present study
	30	73.12	do
	50	127.30	do

In order to obtain an estimate of the production of trunk dry matter and its relation to the total leaf area produced by the tree within different age periods, the leaf area in sq. m/Kg leaf dry matter was first calculated for *Pinus*, *Betula* and Sal. Then the total trunk dry matter produced by these species between age periods was computed. From these two values the trunk dry matter production in Kg per sq. m of leaf area has been calculated. It is evident from table 10 that in the case *Pinus sylvestris* maximum trunk dry matter production per m^2 of leaf area occurs between 17-31 years, while in *Betula* this value remains almost the same from 0-53 years. On the other hand in Sal the maximum value is obtained after 30 years of age. Further, it is brought out that between 30-50 years, 3-4 times more dry matter is accumulated in the trunk of *Shorea robusta* for each square meter of leaf surface, as compared to the other two trees.

TABLE 10. *Relation of total leaf area produced and the production of trunk dry matter*

Species	Age	Trunk dry matter per sq.m leaf area (Kg)	Calculated from
Pinus sylvestris	0-17	0.11	Ovington (1957)
	17-31	0.23	do
	31-55	0.14	do
Betula sp.	0-27	0.17	Ovington and Madgwick (1959)
	27-53	0.16	do
Shorea robusta	0-18	0.14	Present study
	0-30	0.16	do
	30-50	0.47	do

The abovementioned facts indicate that the greater dry matter production in the present species under the existing environmental conditions is due to larger leaf area, greater efficiency of the leaf surface and probably greater crown exposure. It may be mentioned here that the growing period under tropical conditions is longer than that in the temperate climate, and as reported by Bray and Gorham (1964) greater insolation is received in tropics during period. According to Kira and Shidei (1967), gross production is lower in temperate regions and "the decline of productivity at higher latitudes may be caused either by the shortened growth period or by the decrease of solar radiation and associated decrease of leaf area index...the gross productivity of broad leaf forests tends to be proportional to the length of growing season in months multiplied by the leaf area index".

According to Bray (1964), the percentage utilization of attached leaves of forest trees by primary consumers ranges from 5.9 (Swamp forest)—10.6% (*Quercus* forest). The mean leaf consumption values reported by Lindquist (1938), Rothacher *et al.* (1954), and Bray (1964) is 7.5%. In Sal the percentage loss in leaf dry weight due to primary consumers ranges from 1.4% to 14.9%. The minimum value is obtained for mature leaves, while the maximum value for younger ones. It clearly indicates, therefore, that leaves coming late in season are more susceptible to primary consumption.

SUMMARY

Estimates of dry matter production by 18, 30 and 50 year old trees of Sal based on actual weighings, have for the first time been presented in this paper. Leaf area indices and primary consumption of the attached leaves have also been computed. The results indicate maximum dry matter accumulation between 30-50 years. The comparison of these data with those of certain trees of temperate forests indicates greater standing biomass and net annual production in Sal under existing climatic conditions

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