RESULTS AND DISCUSSION

A) Leaf Area :

The photosynthetic area per leaf in Sesbania grandiflora Pers., Moringa pterygosperma Gaertn.Fruct., Emblica offcinalis Gaertn.Fruct., Tamarindus indica Linn.; Azadirachta indica A. Juss., Acacia arabica Willd., Polyalthia longifolia Benth. and Hook and Leucaena leucocephala Linn. has been recorded in Table 1. The leaf area has been calculated following the method using mm graph and by calculating the leaf area factor (Table 2).

Except P.longifolia, in case of all other plants the area of leaflets in a single leaf has been considered. It is evident that the compound leaves of S.grandiflora and A.indica seem to be larger among the leaves of tree species studied. It can be seen that the compound leaf of S.grandiflora has the photosynthetic area of about 62 cm^2 while that of A.indica records about 60 cm^2. The simple leaf of P.longifolia has the average photosynthetic area of about 35 cm^2 compound leaves of L.leucocephala and T.indica have this area of about 19 and 15 cm^2 respectively. The lowest photosynthetic area per leaf has been observed in A.arabica (about 2 cm^2). The photosynthetic area per leaf in M.pterygosperma is about 7 cm^2.

Table No.1 : Leaf area factor (F = A/(L x B)) in *S.grandiflora*, *M.pterygosperma*, *E.officinalis*, *T.indica*, *A.indica*, *A.arabica*, *P.longifolia* and *L.leucocephala*.

No. Observation	*S.grandiflora*	*M.pterygosperma*	*E.officinalis*	*T.indica*	*A.indica*	*A.arabica*	*P.longifolia*	*L.leucocephala*
1.	0.81	0.46	0.60	0.84	0.67	0.57	0.32	0.69
2.	0.71	0.49	0.63	0.77	0.57	0.61	0.73	0.64
3.	0.50	0.49	0.57	0.74	0.64	0.50	0.66	0.55
4.	0.70	0.36	0.57	0.86	0.65	0.57	0.65	0.56
5.	0.57	0.35	0.54	0.74	0.67	0.56	0.68	0.49
6.	0.62	0.37	0.50	0.85	0.60	0.64	0.95	0.67
7.	0.64	0.38	0.44	0.85	0.61	0.51	0.82	0.59
8.	0.71	0.28	0.42	0.71	0.62	0.62	0.59	0.47
9.	0.62	0.27	0.48	0.69	0.64	0.66	0.67	0.50
10.	0.73	0.24	0.52	0.87	0.60	0.51	0.64	0.66
F =	0.66±0.09	0.37±0.09	0.52±0.07	0.79±0.07	0.63±0.03	0.58±0.06	0.67±0.16	0.58±0.08

A = average leaf area (cm^2).

L = average leaf length (cm).

B = average maximum leaf breadth (cm).

± = SD

Table No.2 : Leaf area of *S.grandiflora*, *M.pterygosperma*, *E.officinalis*, *T.indica*, *A.indica*, *A.arabica*, *P.longifolia* and *L.leucocephala*.

No.of observations	Leaf area (cm^2)							
	S.grandiflora	*M.pterygosperma*	*E.officinalis*	*T.indica*	*A.indica*	*A.arabica*	*P.longifolia*	*L.leucocephala*
1.	70.92	17.05	08.77	14.10	102.90	0.99	11.04	25.90
2.	56.65	16.47	11.25	14.45	57.16	1.30	85.09	21.39
3.	63.25	15.03	16.46	8.24	43.94	1.21	28.54	23.99
4.	76.78	5.66	6.22	18.83	82.71	2.00	11.00	28.75
5.	65.23	7.52	11.46	19.15	89.26	1.95	56.75	27.69
6.	56.41	3.53	9.78	14.88	89.01	2.06	32.99	19.96
7.	53.58	1.82	11.81	15.40	24.11	1.36	70.65	10.84
8.	41.25	1.19	6.26	15.54	54.62	1.37	46.10	13.26
9.	64.00	1.65	7.62	15.36	18.96	1.66	4.00	8.95
10.	70.73	1.31	8.63	17.56	37.20	1.66	3.09	16.57
Area =	(61.88 ± 10.28)	(7.12 ± 6.59)	(9.83 ± 3.09)	(15.35 ± 3.07)	(59.99 ± 29.52)	(1.56 ± 0.37)	(34.93 ± 28.97)	(19.23 ± 7.08)

± SD

Among the tree species studied here, S.grandiflora and L.leucocephala are well known for their rapid and luxurient growth. Very high photosynthetic area per leaf in S.grandiflora may be an adaptive feature for it's very rapid growth and development. However, in case of L.leucocephala there may be some other factor(s) besides the photosynthetic leaf area for it's fast growing nature. Highly reduced leaf area in A.arabica may be due to it's growth habitat of extreme conditions. Reduced leaf area is a xeric character. P.longifolia has moderate growth rate so also the photosynthetic area per leaf.

To relate the growth rate of a tree species with the photosynthetic area per leaf will be of premature nature. It is essential, therefore, to compute the total photosynthetic leaf area of a tree species at every developmental stage to correlate it to the growth rate of the species.

B) Moisture Percentage :

The moisture in the developing leaves (young, mature and senescent), stem and bark of S.grandiflora, M.pterygosperma, E.officinalis, T.indica, A.indica, A.arabica, P.longifolia and L.leucocephala has been recorded in Table 3 and Fig.7 and 8. It is evident that the moisture level in the young leaves of M.pterygosperma, P.longifolia and L.leucocephala is nearly the same (about 80, 78 and 78% respectively), which is the highest among the tree species studied. Young leaves of E.officinalis

Table No.3 : Moisture content of different parts of S.grandiflora, M.pterygosperma, E.officinalis, T.indica, A.indica, A.arabica, P.longifolia and L.leucocephala.

Plant part	Moisture % fresh wt							
	S.grandiflora	M.pterygosperma	E.officinalis	T.indica	A.indica	A.arabica	P.longifolia	L.leucocephala
Young leaves	71.86	79.60	42.15	62.86	71.18	55.67	77.69	77.92
Mature leaves	72.20	76.93	46.00	63.14	65.27	45.20	56.36	69.59
Senescent leaves	70.84	72.18	45.96	70.04	63.91	34.99	51.43	42.51
Stem	74.66 (294.63)	78.63 (367.95)	43.18 (75.99)	36.18 (56.69)	65.51 (189.94)	43.75 (77.78)	68.15 (213.97)	51.25 (105.13)
Bark	43.67 (77.53)	72.40 (273.19)	52.14 (108.94)	33.21 (49.72)	63.34 (172.78)	36.93 (58.55)	73.22 (273.41)	65.94 (193.60)

The values in bracket are percent dry wt.

have shown the lowest moisture content (42%). S.grandiflora, A.indica and A.arabica have exhibited intermediate values for the moisture content in their young leaves.

The mature leaves of M.pterygosperma have shown the highest moisture level (77%) which is followed by those of S.grandiflora (about 72%). The mature leaves of L.leucocephala, A.indica, T.indica and P.longifolia contain considerable amount of moisture in their tissue. Mature leaves of E.officinalis and A.arabica have shown the lowest values for moisture content (46 and 45% respectively).

During senescence the leaves of M.pterygosperma, S.grandiflora, and T.indica have maintained considerable amount of moisture (72 to 70%). Senescent leaves of A.indica also have considerable amount of moisture (about 64%). However, from the leaves of A.arabica, L.leucocephala, E.officinalis and P.longifolia, there is a tremendous loss of moisture during senescence. This is quite clear from the lower values for moisture content of the senescent leaves in those tree species.

From the data it can also be seen that the moisture level in the leaves of almost all tree species studied, is reduced remarkably, during senescence, particularly in case of A.arabica, L.leucocephala, P.longifolia and M.pterygosperma. While, it is slightly decreased in case of S.grandiflora, E.officinalis and A.indica. The leaves of T.indica, however,

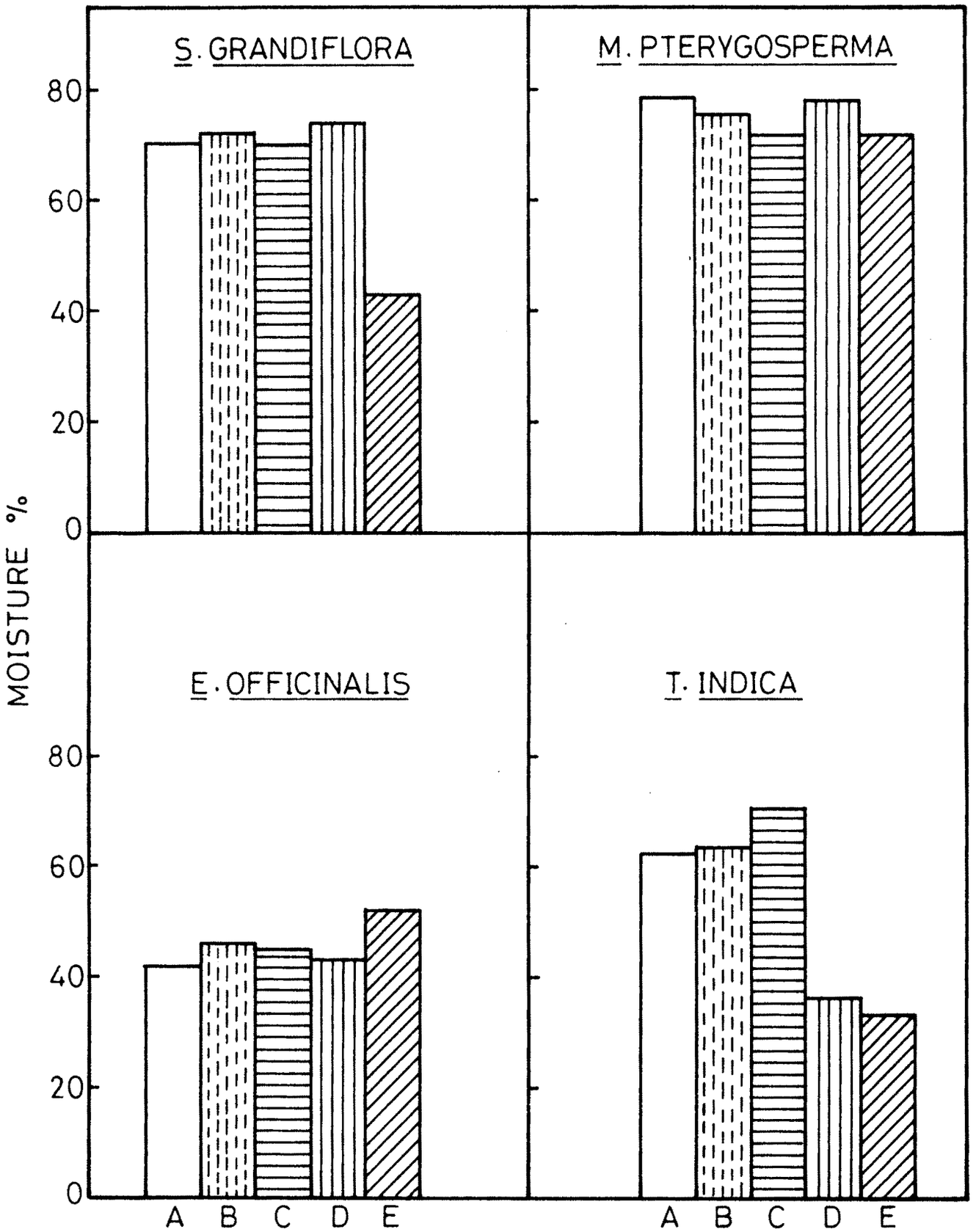

Fig. 7 MOISTURE CONTENT OF DIFFERENT PARTS OF S. GRANDIFLORA, M. PTERYGOSPERMA, E. OFFICINALIS AND T. INDICA.

A: YOUNG LEAVES, B: MATURE LEAVES, C: SENESCENT LEAVES, D: STEM, E: BARK.

have shown an exceptional trend in which there is marked increase in the moisture level during senescence.

Several investigators have observed increased moisture level in the senescent leaves. Joshi and Mishra (1970) and Jamale and Joshi (1976) have made such observations in Clerodendrum inerme and in number of mangroove species respectively. According to them the increase in moisture content of senescent leaves may be attributed to an increase in Na^+ and Cl^- which are accumulated during senescence and known for causing hydration of proteins (Walter, 1955). It appears that due to the presence of more water in the tissue of aging leaves they may remain on the plant for a considerable time. This may be true in T.indica, S.grandiflora, M.pterygosperma, and to some extent in A.indica. On the other hand, a rapid loss of water from the leaves of L.leucocephala, A.arabica and to some extent in P.longifolia may be the reason for high rate of leaf fall in those species. It can be concluded that most of the tree species investigated here show relatively low rate of leaf fall which can be considered as a beneficial factor towards tree productivity.

The stems of M.pterygosperma, S.grandiflora, P.longifolia and A.indica have shown higher moisture content. On the other hand those of L.leucocephala, A.arabica, E.officinalis and T.indica contain considerably low amount of water. The stem of M.pterygosperma has recorded the highest moisture level

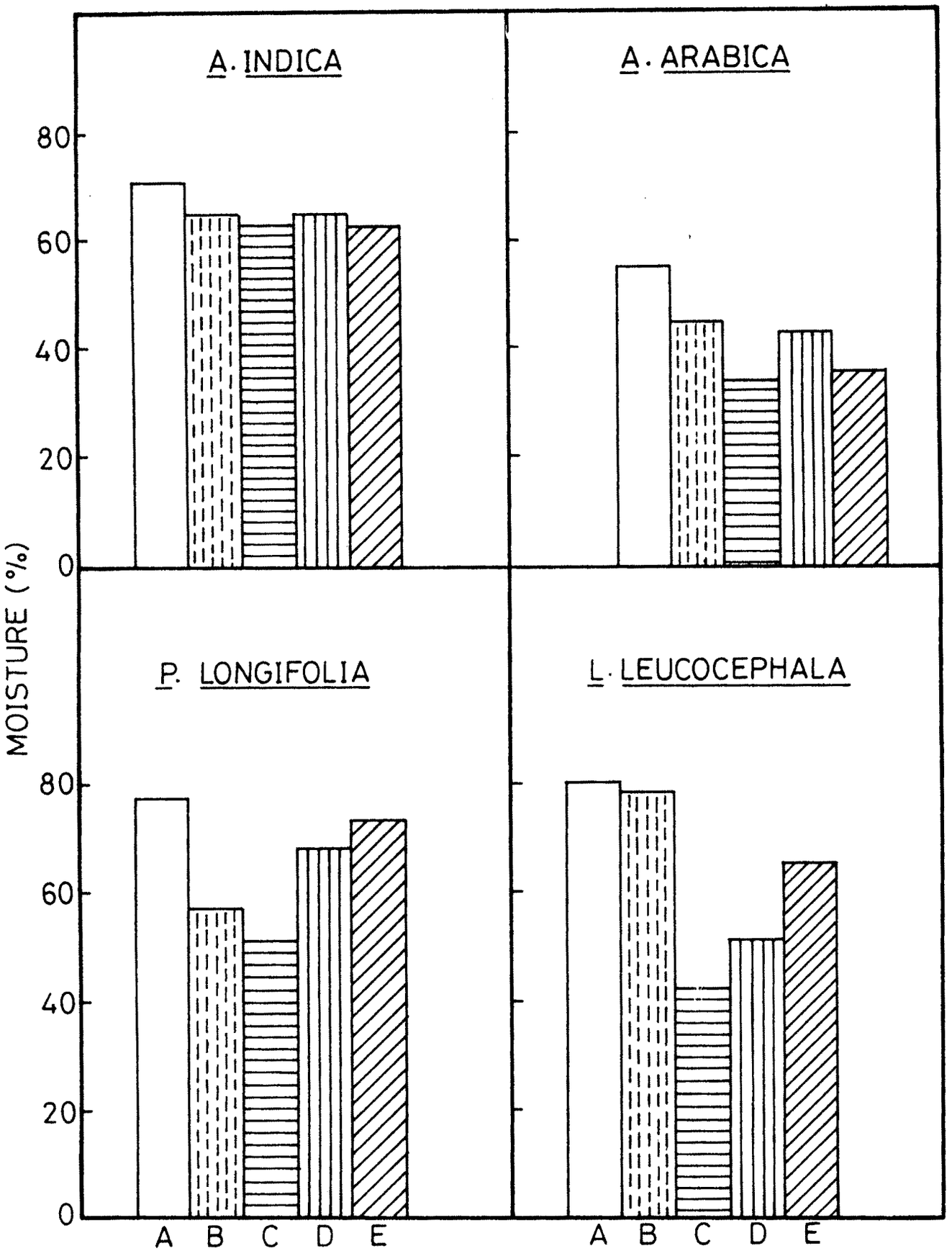

FIG. 8 MOISTURE CONTENT OF DIFFERENT PARTS OF A. INDICA, A. ARABICA, P. LONGIFOLIA AND L. LEUCOCEPHALA.
A: YOUNG LEAVES, B: MATURE LEAVES, C: SENESCENT LEAVES, D: STEM, E: BARK.

(about 79% fresh wt, 368% dry wt). While, T.indica stem contains the least amount of water (about 36% fresh wt, 57% dry wt). The bark of M.pterygosperma and P.longifolia has shown the highest moisture level (72 and 73% fresh wt, 273% dry wt each respectively) of all the tree species investigated. The bark of L.leucocephala, A.indica and E.officinalis has moderate level of moisture. On the other hand the bark in case of S.grandiflora, A.arabica and T.indica has recorded the lower amount of water. The bark of T.indica has recorded the lowest moisture level (33% fresh wt, 50% dry wt).

The values for moisture content (percent dry wt) in the stem and bark or in the wood of the above 8 tree species are well comparable to those in case of various gymnosperm and angiosperm species. Kramer and Kozlowski (1960) have given the moisture content (percent dry wt) of sap wood and heart wood in various gymnosperm species. The values for moisture content of the sap wood vary from 85 to 262% in which Lodgepole pine has recorded the lowest moisture level (85 to 165%). While, northern white sedar shows 236 to 262% moisture in it's sap wood.

C) Chlorophylls :

The chlorophyll contents in the developing leaves (young, mature and senescent), stem and bark of S.grandiflora, M.pterygosperma, E.officinalis, T.indica, A.indica, A.arabica,

P.longifolia and L.leucocephala have been recorded in Table 4 and 5, and depicted in Fig.9 and 10. It is evident that in all the species studied, the chlorophyll content of the leaves markedly increases with the age till maturity. While, there is a rapid decline in it during senescence. It is also evident that leaf is the major plant part containing large amount of chlorophylls. In all the species studied the stem and bark on the growing branches also contain measurable amount of chlorophylls.

It is clear from the observations that among the young leaves of the tree species the highest chlorophyll content has been recorded in case of A.arabica, E.officinalis and T.indica. On the other hand the young leaves of P.longifolia and M.pterygosperma contain the least amount of chlorophylls among the tree species studied. While, Young leaves of A.indica, L.leucocephala and S.grandiflora show a moderate amount of chlorophylls. The mature leaves of P.longifolia and L.leucocephala have shown the highest amount of chlorophylls, (4.63 and 4.37 mg 100^{-1} g fresh tissue respectively) of all the tree species. The lowest values for chlorophylls have been recorded for the mature leaves of S.grandiflora and A.indica (2.55 and 2.41 mg 100^{-1} g fresh tissue respectively). It is also evident that A.arabica and E.officinalis are able to retain sufficient amount of chlorophylls in the leaves during senescence. It can be seen that the value for chlorophylls in

Table No.4 : Chlorophyll contents* of different parts of *S.grandiflora* *M.pterygosperma*, *E.officinalis* and *T.indica*.

Plant Part	Chlorophylls (g kg^{-1} fresh matter)															
	S.grandiflora				*M.pterygosperma*				*E.officinalis*				*T.indica*			
	Chl. 'a'	Chl. 'b'	Total Chl.	Chl. a/b	Chl. 'a'	Chl. 'b'	Total Chl.	Chl. a/b	Chl. 'a'	Chl. 'b'	Total Chl.	Chl. a/b	Chl. 'a'	Chl. 'b'	Total Chl.	Chl. a/b
Young leaves	0.79	0.60	1.39	1.31	0.53	0.29	0.82	1.87	1.86	0.75	2.61	2.46	1.69	0.87	2.56	1.93
Mature leaves	1.76	0.79	2.55	2.21	2.23	1.03	3.26	2.16	2.20	1.07	3.27	2.71	2.21	1.12	3.33	1.97
Senescent leaves	0.13	0.10	0.23	1.27	0.24	0.13	0.37	1.90	1.09	0.85	1.94	1.29	0.27	0.17	0.44	1.65
Stem	0.09	0.06	0.15	1.44	0.10	0.07	0.17	1.50	0.15	0.08	0.23	1.68	0.13	0.13	0.26	1.03
Bark	0.07	0.05	0.12	1.31	0.51	0.30	0.81	1.75	0.15	0.12	0.27	1.23	0.26	0.25	0.51	1.03

* Each values is mean of three determinations.

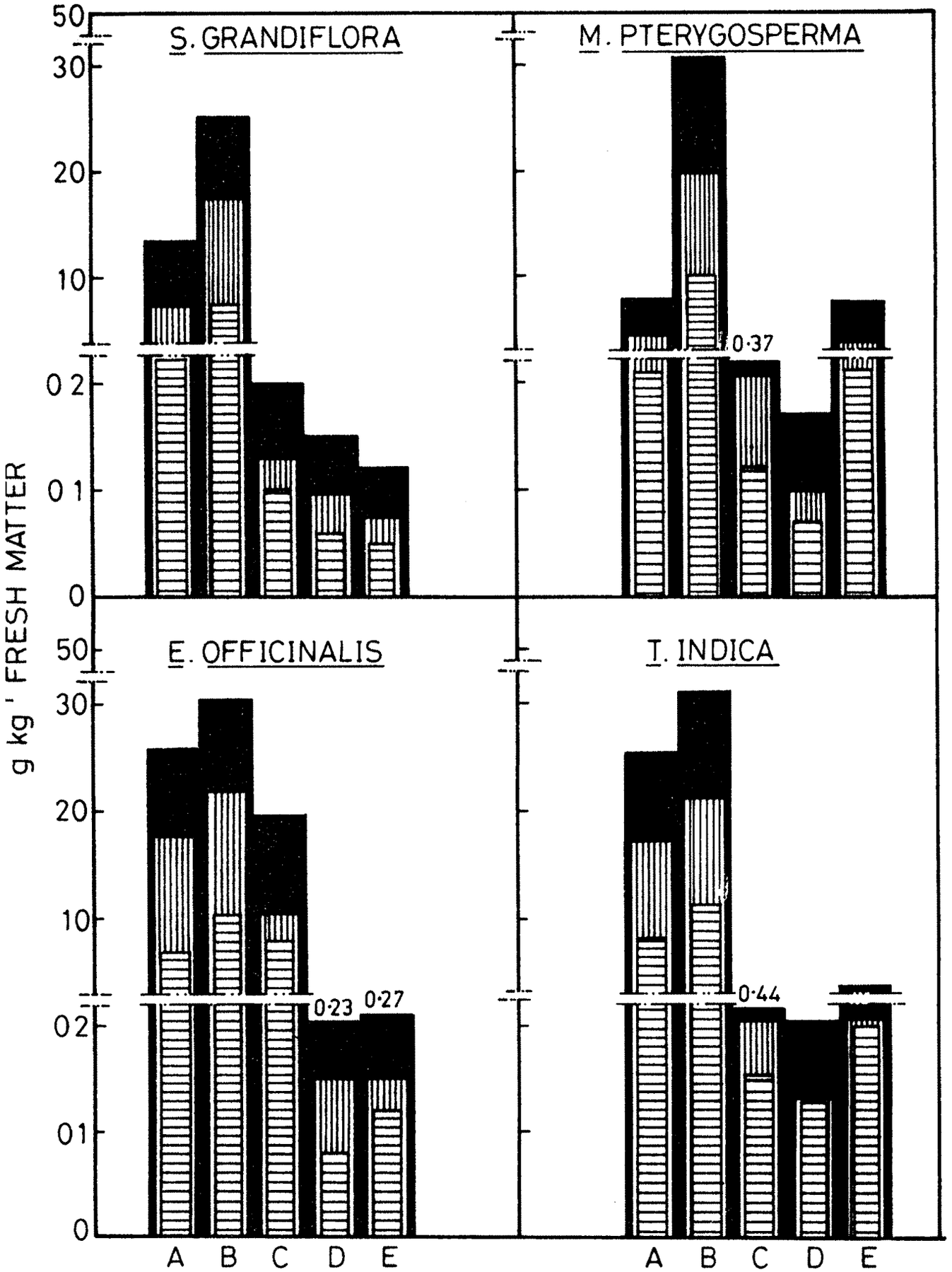

FIG. 9 CHLOROPHYLL CONTENT OF DIFFERENT PARTS OF S. GRANDIFLORA, M. PTERYGOSPERMA, E. OFFICINALIS, T. INDICA. A: YOUNG LEAVES, B: MATURE LEAVES, C: SENESCENT LEAVES, D: STEM, E: BARK.

A.arabica declines from 3.44 mg 100^{-1}g in the mature leaves to 2.12 mg 100^{-1}g fresh tissue in the senescent leaves. Similarly in B.officinalis it falls down from 3.27 mg 100^{-1}g in the mature leaves to 1.94 mg 100^{-1}g fresh tissue in senescent leaves. It appears that there is a very rapid loss of chlorophylls in the leaves of P.longifolia, L.leucocephala and S.grandiflora during senescence. From these results it can be suggested that B.officinalis and A.arabica have got a very good capacity of retaining chlorophylls in the leaves for a long time and even during senescence. This can be taken as an adaptive feature of these tree species.

It is general trend that during leaf development chlorophylls accumulate up to maximum and then the rate of degradation overtakes that of synthesis. It appears that chlorophylls are high during early phase of leaf growth till maturity. However, later the chlorophyll synthesis does not keep pace with the rate of leaf development. It has also been reported that the extent and rate of chlorophyll disintegration in aging leaves vary among tree species. Wieckowski (1958) reported that, whereas rapid chlorophyll disintegration occured in a species of Magnolia (35 days) slow break down took place in white malbery (more than 60 days). Before they abscised, leaves of cycamore, maple and beech lost practically all their chlorophyll, whereas, those of lialac lost only 40%. Wolf (1956) demonstrated a wide variation in the chlorophyll content of the

Table No.5 : Chlorophyll contents* of different parts of *A.indica*, *A.arabica*, *P.longifolia* and *L.leucocephala*.

Plant part	Chlorophylls (g kg^{-1} fresh matter)															
	A.indica				*A.arabica*				*P.longifolia*				*L.leucocephala*			
	Chl. 'a'	Chl. 'b'	Total Chl.	Chl. a/b	Chl. 'a'	Chl. 'b'	Total Chl.	Chl. a/b	Chl. 'a'	Chl. 'b'	Total Chl.	Chl. a/b	Chl. 'a'	Chl. 'b'	Total Chl.	Chl. a/b
Young leaves	0.95	0.46	1.41	2.06	1.84	0.78	2.62	2.36	0.58	0.30	0.88	1.93	1.14	0.50	1.64	2.25
Mature leaves	1.53	0.88	2.41	1.74	2.43	1.01	3.44	2.40	3.13	1.50	4.63	2.08	2.96	1.41	4.37	2.10
Senescent leaves	0.72	0.43	1.15	1.67	1.18	0.94	2.12	2.30	0.27	0.18	0.45	1.47	0.48	0.32	0.80	1.45
Stem	0.15	0.09	0.24	1.59	0.18	0.09	0.27	1.94	0.20	0.12	0.32	1.58	0.21	0.11	0.32	1.86
Bark	0.25	0.16	0.41	1.62	0.14	0.08	0.22	1.68	0.27	0.17	0.44	1.58	0.50	0.26	0.76	1.91

* Each value is mean of three determinations.

leaves and in the rate of chlorophyll breakdown during their aging. He has also reported that chlorophyll 'a' was destroyed more rapidly than chlorophyll 'b' in many species.

In the present investigation it has been found that in most of the tree species studied, except A.indica and L.leucocephala, chlorophyll a:b ratio is considerably increased with age of a leaf till maturity, whereas during the later stages of development it is drastically decreased. However, in A.indica and L.leucocephala this ratio is high during the early phase of development. This ratio falls continuously with the advancement of leaf age. These observations indicate that the synthesis and breakdown of chlorophylls 'a' and 'b' are influenced differentially during leaf development. It appears that the synthesis of chlorophyll 'a' dominates that of 'b' upto leaf maturity. However, the rate of degradation of chlorophyll 'a' seems to be higher than that of chlorophyll 'b' during senescence. The present results support the early observations made by Wolf (1956).

Holden (1973) studied the pigment composition in C_3 and C_4 plants and according to him chlorophyll a:b ratio ranges from 3.1 to 5.6 for C_4 dicotyledons; while, it ranges from 2.5 to 3.7 in C_3 dicotyledons. It is clear from the observations in the present investigation that the chlorophyll a:b ratio in the young and mature leaves is about 2 to 3. This clearly indicates that all the tree species most probably belong to C_3 dicotyledons group of plants.

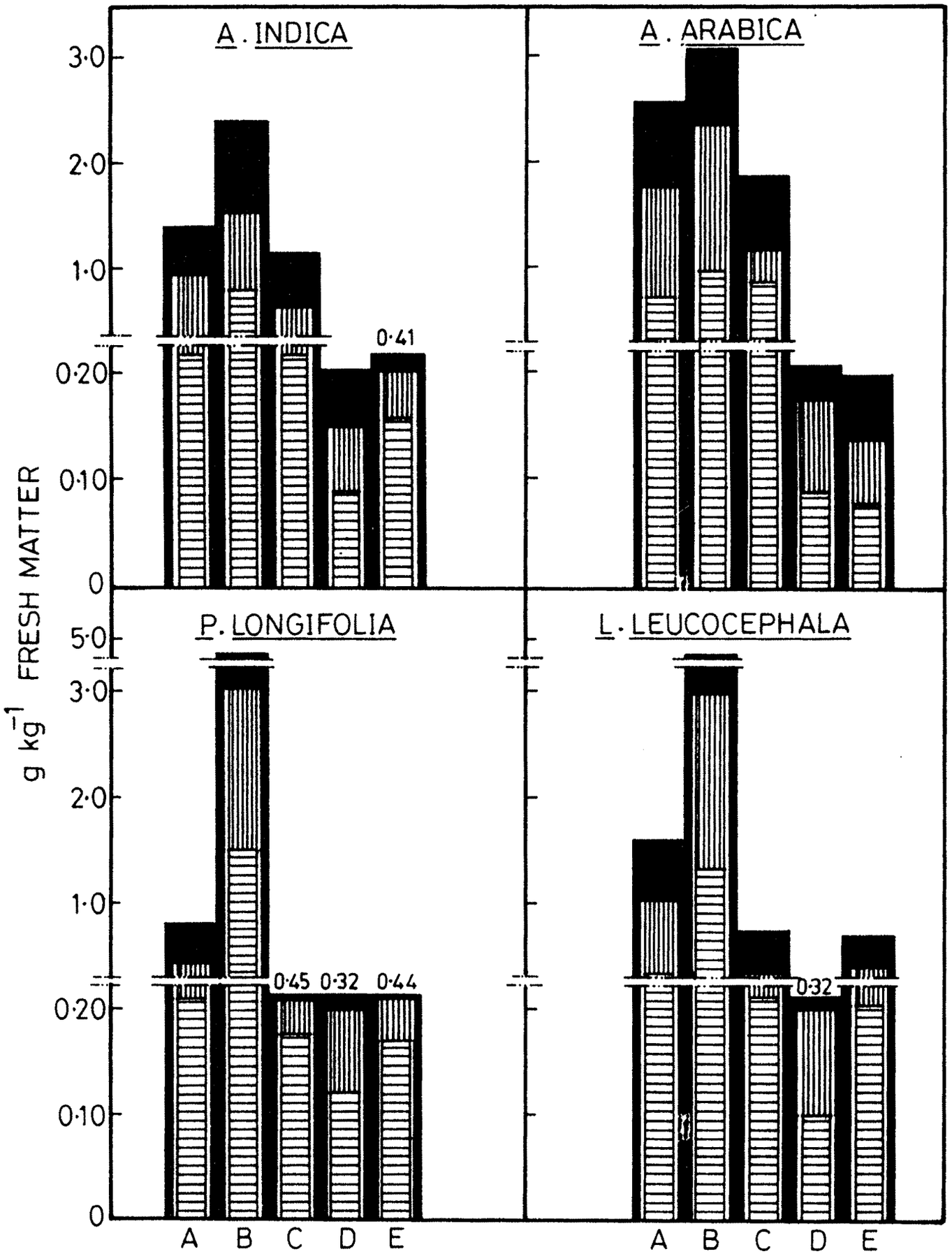

FIG. 10 CHLOROPHYLL CONTENT OF DIFFERENT PARTS OF A: INDICA, A: ARABICA, P: LONGIFOLIA AND L. LEUCOCEPHALA. A: YOUNG LEAVES, B: MATURE LEAVES, C: SENECENT LEAVES, D: STEM, E: BARK.

Most of the studies during leaf ontogeny have shown a direct relationship between chlorophyll content and photosynthesis (Sestak and Catsky, 1962; Sestak, 1963 a). Based on present observations, it can be suggested that probably the rate of photosynthesis in P.longifolia and L.leucocephala in the mature leaves is higher than that in any other tree species investigated. The rapid growth in L.leucocephala may be due to high rate of photosynthesis as a result of higher chlorophyll content.

It is evident from Tables 4 and 5 that the chlorophyll level in the stem of S.grandiflora and A.arabica is higher than that in the bark. In remaining species the bark dominates significantly over stem with respect to chlorophyll content. From these results it is very clear that bark is the next important plant part which is green, may take part in photosynthesis.

D) Carotenoids :

Carotenoids are the only naturally occuring tetraterpens which have the formula $C_{40}H_{56}$. The carotens are pure hydrocarbons which include red, orange and yellow pigments occurring in all organs of plants. They apparently are involved in light trapping in photosynthesis and probably protect chlorophylls from photo-oxidation. The xanthophylls are yellow or brownish pigments which occur commonly in leaves

and also in algae. Carotens have several isomers, of which β-carotene, the precurser of vitamin A, is most abundent and may make up as much as 0.1% of the leaf dry wt.

As carotenoids are more resistant than chlorophylls to distruction under unfavourable conditions, leaves kept in darkness for several days or subjected to water stress usually become yellow because, distruction of the chlorophyll exposes the yellow carotenoid pigments. The more rapid distruction of chlorophylls than of carotenoids also brings about the yellow colouration of leaves of some species in the autumn.

Table 6 and Fig.11 and 12 records the carotene contents of young, mature and senescent leaves; stem and bark of different tree species undertaken. It is quite evident that leaves are very rich in carotenoids. Stem and bark of these tree species contain very little amount of carotenoids. Among the leaves, the mature leaves seem to be the major source of carotenoids. It can be seen that the mature leaves of all the species have higher quantity of carotenoids. It is also clear that the mature leaves of P.longifolia and L.leucocephala are very rich in carotenoids. The mature leaves of M.pterygosperma, E.officinalis, T.indica and A.arabica have shown a moderate level of these pigments. Other species, namely S.grandiflora and A.indica, have very less amount of carotenoids in their mature leaves as compared to that in the remaining species. Among the young leaves those of E.officinalis, T.indica and

Table No.6 : Carotene contents* of different parts of *S.grandiflora*, *M.pterygosperma*, *E.officinalis*, *T.indica*, *A.indica*, *A.arabica*, *P.longifolia* and *L.leucocephala*.

Plant part	*S.grandiflora*	*M.pterygosperma*	*E.officinalis*	*T.indica*	*A.indica*	*A.arabica*	*P.longifolia*	*L.leucocephala*
	Carotenes g Kg^{-1} fresh material							
Young leaves	0.19	0.11	0.42	0.39	0.35	0.41	0.17	0.26
Mature leaves	0.35	0.42	0.48	0.48	0.39	0.52	0.68	0.61
Senescent leaves	0.25	0.31	0.67	0.20	0.35	0.47	0.28	0.43
Stem	0.03	0.03	0.05	0.04	0.06	0.05	0.08	0.05
Bark	0.06	0.13	0.09	0.03	0.14	0.05	0.09	0.10

* Each value is mean of three determinations.

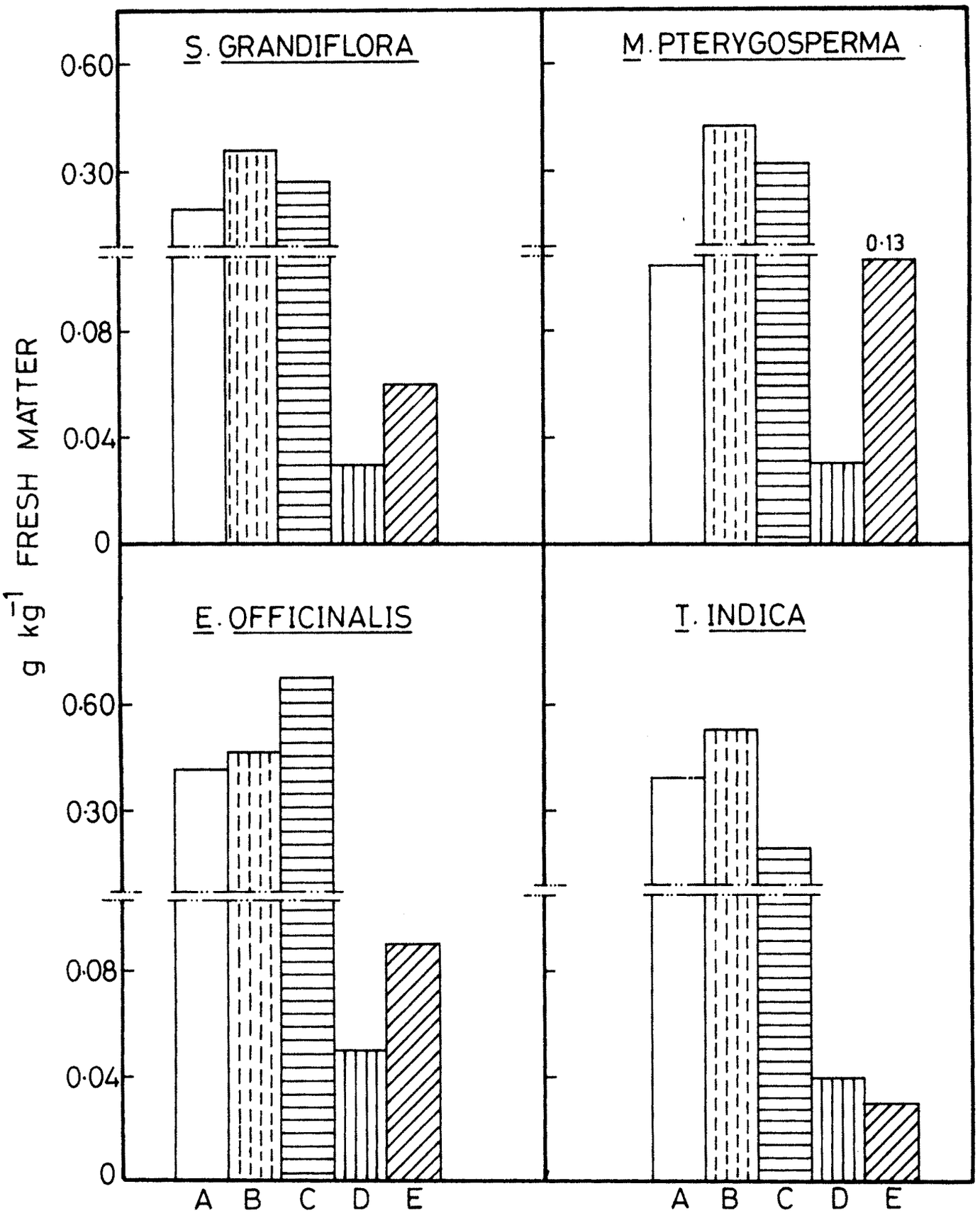

FIG. 11 CAROTENE CONTENT OF DIFFERENT PARTS OF S. GRANDIFLORA, M. PTERYGOSPERMA, E. OFFICINALIS AND T. INDICA.

A: YOUNG LEAVES, B: MATURE LEAVES, C: SENESCENT LEAVES, D: STEM, E: BARK.

A.arabica seem to be very rich in carotenoids. Young leaves of M.pterygosperma have shown the lowest value (0.11 g Kg^{-1} fresh tissue) for carotenoids. A.indica and L.leucocephala along with S.grandiflora and P.longifolia have shown a moderate to less amount of carotenoids in their young leaves. It is also observed that in most of the tree species studied there is decline in the level of carotenoids in the leaves during senescence, except that in E.officinalis, in which there is a remarkable increase in the level of these pigments during senescence. This indicates that similar to chlorophyll the carotenoids are also degraded during senescence. However, the degree of degradation of carotenoids in the leaves of these tree species varies from species to species. It can be seen that in the leaves of T.indica and P.longifolia the degree of degradation is very high. A measurable rate of degradation of carotenoids is also observed in the leaves of S.grandiflora M.pterygosperma and L.leucocephala during senescence. However, there is only a slight decrease in the carotenoid contents of A.indica and A.arabica leaves during senescence. When the rate of degradation of carotenoids in the leaves during senescence is compared with that of chlorophylls in most of the tree species, it can be seen that the chlorophylls are degraded relatively more than the carotenoids. This is quite evident in case of P.longifolia, L.leucocephala, S.grandiflora, M.pterygosperma and T.indica. This is well supported from the common

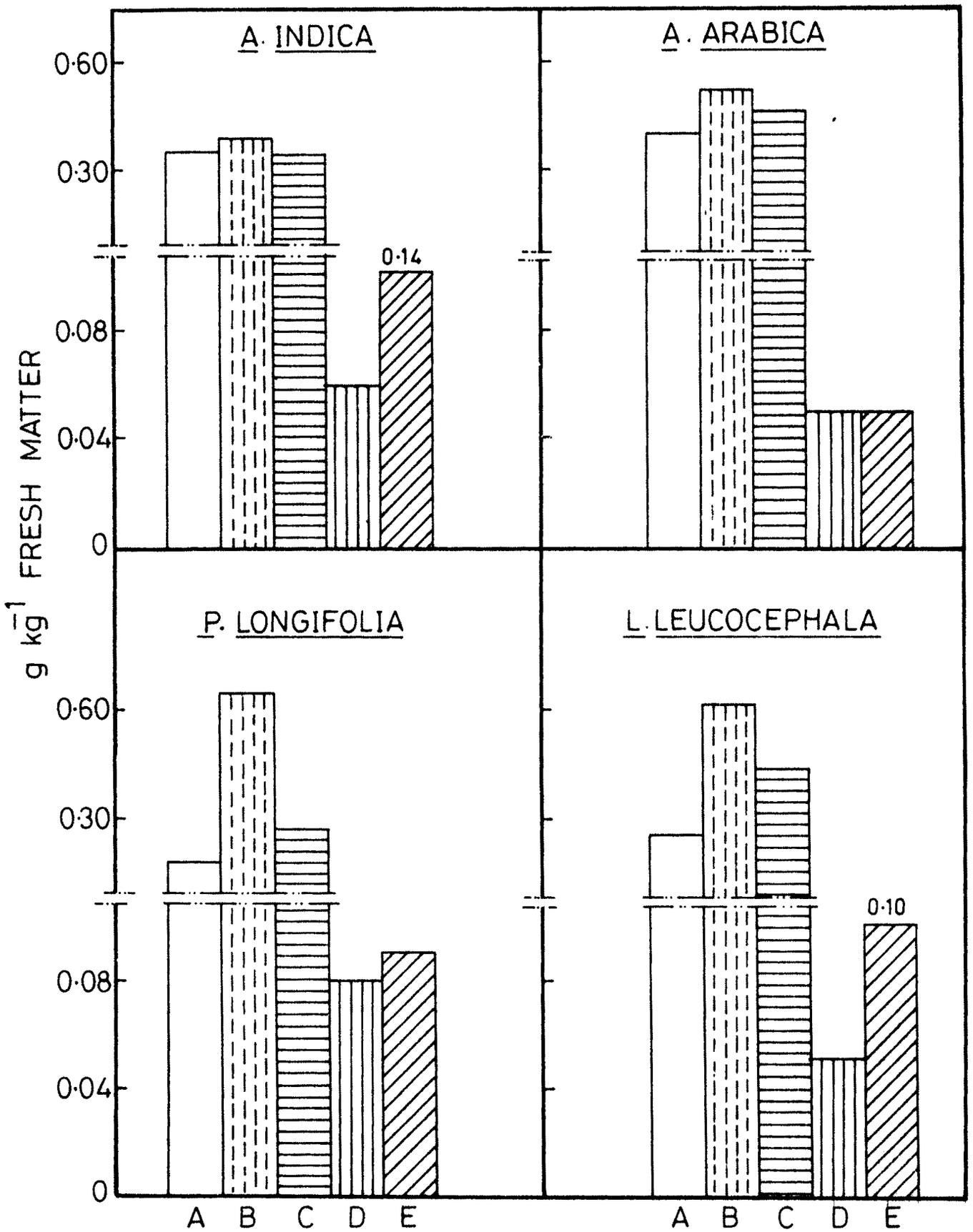

FIG. 12 CAROTENE CONTENT OF DIFFERENT PARTS OF A. INDICA, A. ARABICA, P. LONGIFOLIA AND L. LEUCOCEPHALA.
A: YOUNG LEAVES, B: MATURE LEAVES, C: SENESCENT LEAVES, D: STEM, E: BARK.

observation that the senescing leaves in the above tree species become and remain deep yellow in colour for a long time and attached with parent plant body. This is often observed in P.longifolia, S.grandiflora, E.officinalis and L.leucocephala.

As the leaves of A.arabica and L.leucocephala as well as those of T.indica contain higher amount of carotenoids, they may serve as a good source of β-carotene and hence Vitamin A. The mature leaves of P.longifolia can also be used as a rich source of β-carotene. Begum and Pereira (1977) have analysed 32 varieties of edible green leaves for their β-carotene content in different seasons of the year. They have included S.grandiflora in a group of edible green leaves with high content of β-carotene. If we consider the carotenoid content of the leaves of the tree species investigated in comparison with that of S.grandiflora, it can be suggested that almost all the species can be used as a source of β-carotene.

B) Carbohydrates :

Accumulation of a reserve of food material each growing season is essential for survival of perennial plants. This is particularly true in deciduous woody plant, where maintenance of life during the winter and resumption of growth in the spring depend on food accumulated during the previous growing season. Although starch is the main storage product in

woody plants, other substances also are stored. These include fats, nitrogen compounds, sucrose, raffinose, fructosans and hemicelluloses.

Carbohydrates reserved are accumulated largely in parenchyma cells and death of cell is accompanied by incorporation or withdrawal of reserves (Ziegler, 1964). Many studies have been made of the accumulation of starch and sugar in different tissues and organs. There are marked variations in the amounts of carbohydrates in various parts of woody plants and there are also large seasonal variations in amount and kinds of carbohydrates present. The concentration of carbohydrates usually is higher in the root than in the tops in both young and old trees. Nevertheless, in adult trees the above ground parts are the primary carbohydrates reservoir because the stem, branches and leaves make up, more of the total dry wt of a tree than that the roots do.

The leaves usually contain a high concentration of carbohydrates, but this is a relatively small proportion of the total amount in a woody plant. Foliage of short leaf pine contains 16.6% carbohydrates, a concentration about 7 times as high as that in the stem wood (Hepting, 1945). Carbohydrates (Starch + Sugars) of apple leaves amount to be 9%, a much higher value than that reported for other tissues. However, the total amount of carbohydrates in the leaves is

only about 5% of the carbohydrates reserved, of the whole tree (Murneek, 1942). In the stem and branches in the axial and ray parenchyma cells as well as pith cells comprise the major accumulation sites of starch. In the bark, starch is deposited in parenchyma and albuminous cells which are distributed in a variety of patterns. The concentration of carbohydrates in the bark is often very high but in many species the total amount of it in the bark is less than that in the wood. Wenger (1953 a) has found a higher concentration of carbohydrates in the stem bark than that in stem wood sweetgum but the wood had much more total carbohydrates.

The most obvious use of reserve carbohydrates is in maintaining respiration during growth at times when food is not supplied directly from photosynthesis. In addition to their role in maintaining respiration, reserve carbohydrates are also important for early season growth.

The total or soluble sugar and starch (total carbohydrates) contents of the developing leaves (young, mature and senescent), stem, bark, fruit and seeds of S.grandiflora, M.pterygosperma, E.officinalis, T.indica, A.indica, A.arabica, P.longifolia and L.leucocephala have been depicted in Tables 7 and 8 and Figures 13-16. It is evident that the values of starch are much higher than those of soluble sugars in all the tree species, except that in the M.pterygosperma leaves.

Table No.7 : Carbohydrate contents (Soluble sugars and starch)* of different parts of S.grandiflora, M.pterygosperma, E.officinalis and T.indica

Plant parts	Carbohydrates (g 100^{-1} g fresh matter)											
	S.grandiflora			M.pterygosperma			E.officinalis			T.indica		
	Soluble Sugars	Starch	Total carbo-hydrates	Soluble sugars	Starch	Total carbo-hydrates	Soluble sugars	Starch	Total carbo-hydrates	Soluble sugars	Starch	Total carbo-hydrates
Young leaves	0.40	2.38	2.77	1.88	1.82	3.70	1.93	3.11	5.64	0.27	2.58	2.83
Mature leaves	0.17	2.89	3.06	2.25	0.74	2.99	2.58	3.89	6.47	1.25	1.89	3.14
Sene-scent leaves	0.40	2.17	2.56	1.74	1.19	2.93	2.46	4.18	6.64	1.45	1.97	3.42
Stem	0.37	2.38	2.75	1.97	2.62	4.59	0.96	3.65	4.61	0.31	3.73	4.04
Bark	0.08	0.47	0.55	0.86	3.44	4.30	1.68	16.65	18.33	2.25	4.02	6.27
Fruit	0.45	7.13	7.58	0.04	7.79	7.83	3.52	10.80	14.32	16.29	3.40	19.69
Seed**	2.58	7.7	10.28	1.95	5.41	7.36	0.16	16.09	16.25	2.05	16.39	18.44

* Each value is mean of three determinations.

** Air-dried seeds (air dry wt).

Among the tree species, the leaves of A.arabica, E.officinalis, and A.indica seem to be highly rich in carbohydrates. On the other hand, the leaves of S.grandiflora contain, on an average, very low amount of total carbohydrates. The carbohydrate content in the remaining species is at the moderate level. It is also evident that there is no definite pattern of accumulation of carbohydrates in the developing leaves with developmental stage or with the age of a leaf. However, except in two cases, i.e. in E.officinalis and T.indica, the total carbohydrate level falls down in the leaves of remaining six tree species during senescence. It can also be seen that the leaves of A.arabica have shown the highest total carbohydrate content followed by that in E.officinalis and A.indica. S.grandiflora leaves contain the least amount of carbohydrates of all the tree species.

Starch is the major component of the total carbohydrates and it is quite clear from the values recorded in the Tables 7 and 8 and Fig.13-16 , that except in M.pterygosperma the starch content of a leaf, on an average, of all the tree species studied is higher than that of soluble sugars. The leaves of A.arabica have shown the highest level of starch, particularly in the mature leaves. This species is followed by E.officinalis and A.indica with respect to leaf starch content. The starch content of the leaves in S.grandiflora, A.arabica, P.longifolia and L.leucocephala is remarkably affected during senescence.

Table No.8 : Carbohydrate contents (soluble sugars and starch)* of different parts of A.indica, A.arabica, P.longifolia and L.leucocephala.

Plant Parts	Carbohydrates (g 100^{-1} g fresh matter()											
	A.indica			A.arabica			P.longifolia			L.leucocephala		
	Soluble sugars	Starch	Total carbo-hydrates	Soluble sugars	Starch	Total carbohy-drates	Soluble sugars	Starch	Total carbohy-drates	Soluble sugars	Starch	Total carbohy-drates
Young leaves	1.58	3.85	5.43	2.46	4.59	7.05	0.76	2.13	2.89	0.49	3.20	3.69
Mature leaves	2.89	2.83	5.72	1.50	5.08	6.58	0.74	3.69	4.43	0.78	3.28	4.06
Sene-scent leaves	1.68	3.73	5.41	0.90	3.98	4.88	1.11	2.91	4.02	0.70	2.25	2.95
Stem	2.52	8.36	10.88	0.39	6.96	7.35	0.51	2.23	2.74	1.09	3.95	5.04
Bark	2.01	5.04	7.05	1.50	3.52	5.02	0.45	3.73	4.18	0.70	2.83	3.53
Fruit	7.46	9.51	16.97	4.92	2.87	7.79	0.11	5.49	6.60	0.14	5.74	5.88
Seeds**	5.66	8.20	13.86	1.07	4.59	5.66	00.70	14.26	14.96	2.91	8.03	10.94

* Each value is mean of three determinations.

** Air dried seeds (air dry wt.)

In the remaining species, however, the starch content of the senescent leaves is higher than that of mature leaves. The young leaves of M.pterygosperma, T.indica and A.indica show the highest level of starch of all the developmental stages. It appears that in some of the tree species starch is hydrolysed during aging (particularly during senescence) and the soluble products are utilised elsewhere resulting in decreased amount of starch in the senescent leaves.

The leaves of E.officinalis and A.indica seem to be rich in soluble sugars as compared to those of remaining species investigated. M.pterygosperma leaves also contain considerable amount of soluble sugars. S.grandiflora leaves seem to contain the lowest amount of soluble sugars almost at every development stage. It is interesting to note that the soluble sugar content of a leaf in M.pterygosperma is always higher than that of starch. It can be seen that the value for soluble sugar content in the young leaf of this species is 1.88% (fresh wt) which is still slightly higher than that of starch (1.82 %). It is quite surprising to observe that the soluble sugar content of the mature leaves of this species is almost three times more (2.25%) than that of starch (0.74%). Even in the senescent leaves the concentration of soluble sugar is higher than that of starch. High level of soluble sugars may be involved in the tasty and palatable nature of the foliage of moringa (estimation of soluble sugars and starch in moringa leaves was repeated for more than 5 times).

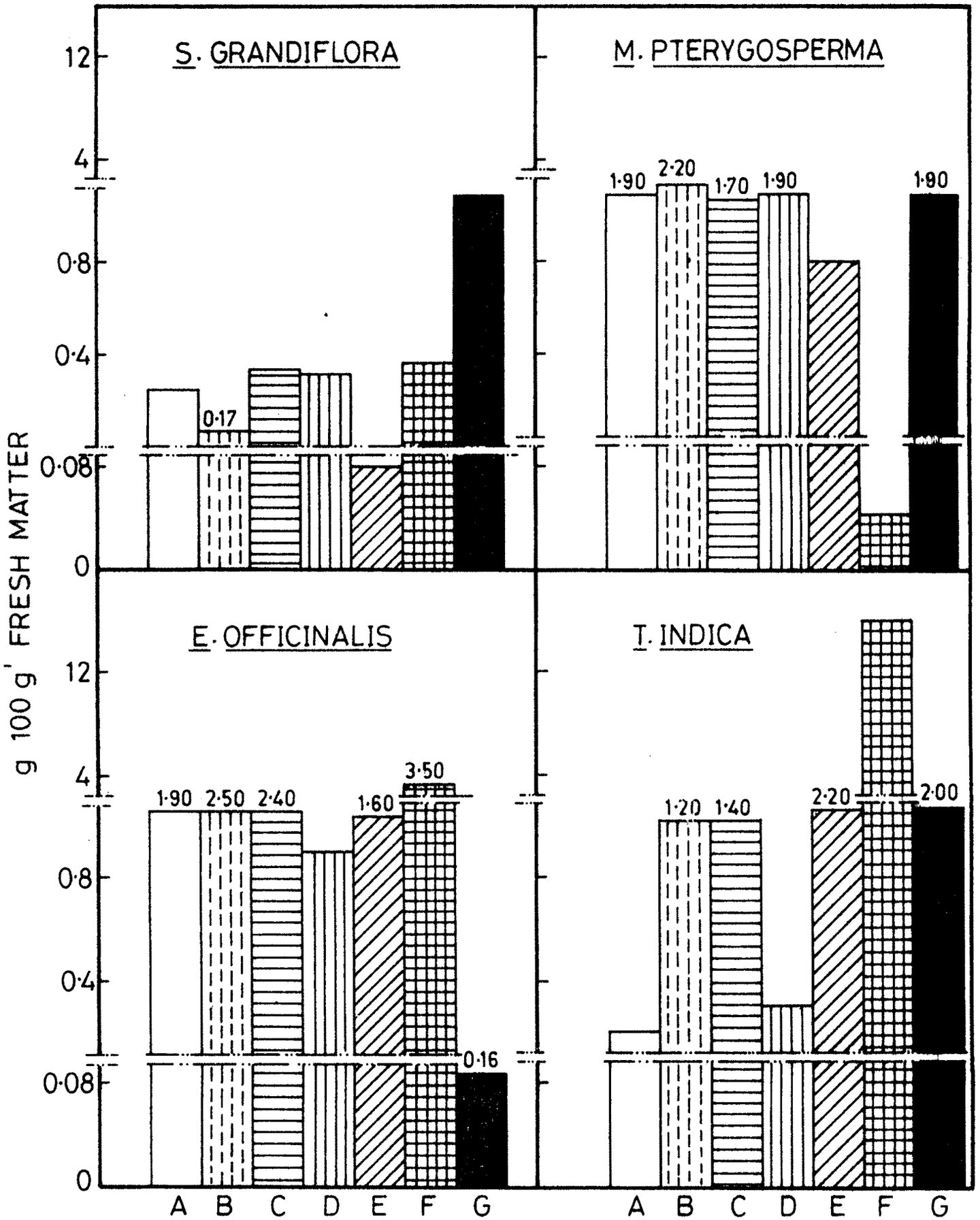

FIG.13 SOLUBLE SUGARS CONTENT OF DIFFERENT PARTS OF S. GRANDIFLORA, M. PTERYGOSPERMA, E. OFFICINALIS AND T. INDICA.

A: YOUNG LEAVES, B: MATURE LEAVES, C: SENESCENT LEAVES, D: STEM, E: BARK, F: FRUIT, G: SEED.

The level of soluble sugars in the leaves of moringa, avala, neem, babul and subabul declines during senescence. On the other hand, there is accumulation of those in the senescent leaves of S.grandiflora, T.indica and P.longifolia. The decrease in the level of soluble sugars in the senescent leaves may be due to easy translocation of the sugars. On the other hand in some species probably the soluble sugars are not translocated properly from the senescent leaves and hence remain accumulated.

The values for total carbohydrates in the other parts of the plant, namely stem, bark, fruit and seed, in all the 8 tree species have been recorded in the same tables (Tables 7 and 8). It can be seen that the reproductive parts namely fruit and seed are highly rich in carbohydrates when compared with the other parts of a plant. The stem of A.indica has recorded the highest level of total carbohydrates (10.88% free wt) of those of all the tree species. This is followed by the stem of A.arabica and then by that of L.leucocephala. The stem of P.longifolia seems to be very poor in carbohydrates as it has shown the lowest value (2.74%) for total carbohydrates. The other species have intermediate level of carbohydrates in their stem. In all cases, starch is the major carbohydrate in the stem. In A.indica and M.pterygosperma the stem seems to be rich in soluble sugars. The stem of M.pterygosperma, however, contains relatively more amount of soluble sugars when

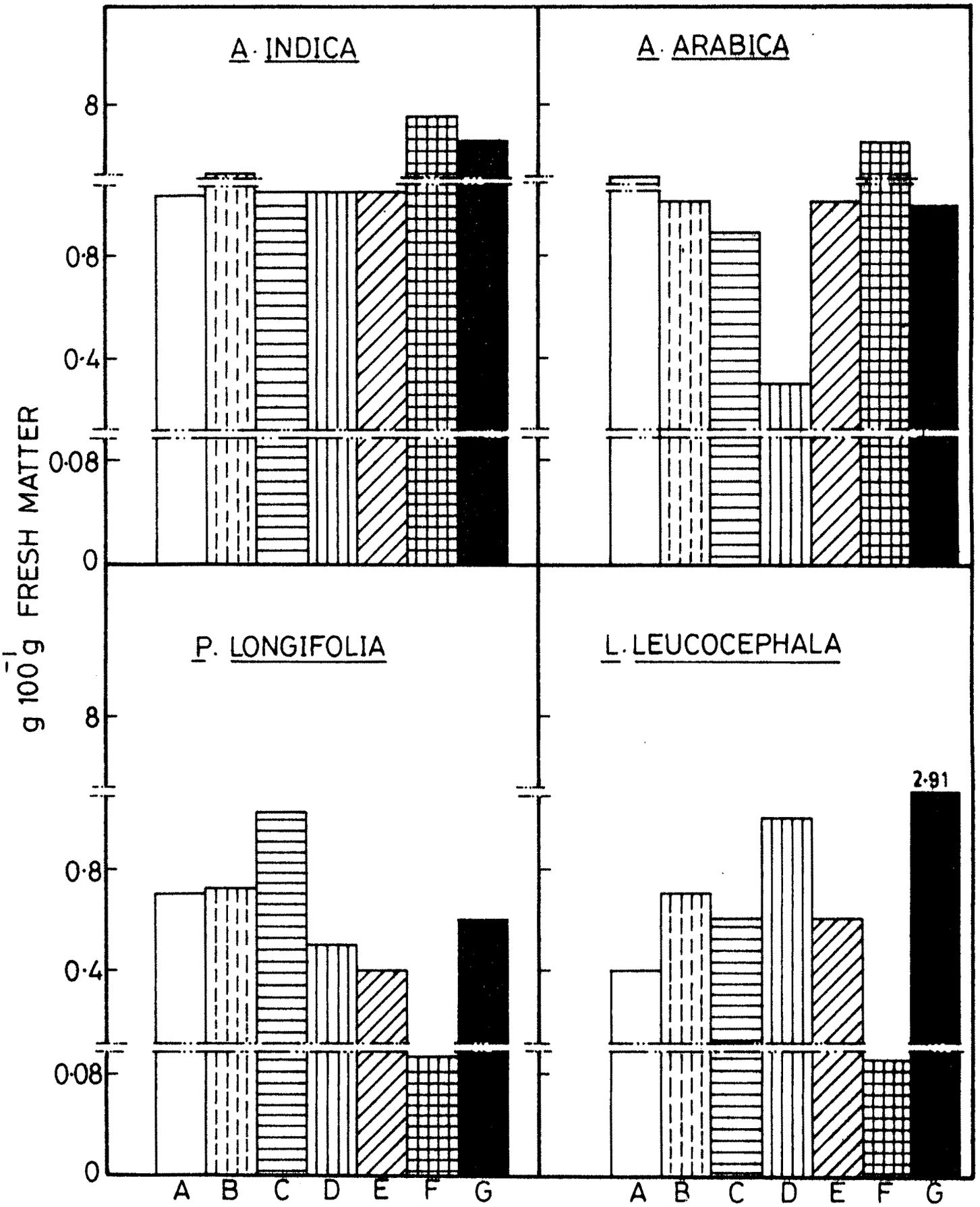

FIG. 14 SOLUBLE SUGARS CONTENT OF DIFFERENT PARTS OF A. INDICA, A. ARABICA, P. LONGIFOLIA AND L. LEUCOCEPHALA.
A: YOUNG LEAVES, B: MATURE LEAVES, C: SENESCENT LEAVES, D: STEM, E: BARK, F: FRUIT, G: SEED.

compared with that of starch. This is also an interesting feature of this species.

The bark of E.officinalis seems to be highly rich in carbohydrates. It can be seen that the bark of this species contains 18.33% carbohydrates (fresh wt). On the other hand bark of S.grandiflora is very poor in carbohydrates (0.55%). Among the tree species studied, the bark of T.indica seems to be rich in soluble sugars.

In the reproductive parts, the fruit part without seed in case of T.indica has shown the highest amount of total carbohydrates. The fruit carbohydrate level is then followed by that of A.indica and then E.officinalis. The lowest amount of carbohydrates is recorded in the fruits of P.longifolia and L.leucocephala. It is interesting to note that the fruit pulp of T.indica is very rich in soluble sugars and even the soluble sugar content in the fruit is almost five times higher than that of starch in this species. High level of soluble sugar adds probably to sweet taste of the ripe fruit. In all other cases starch is the dominant carbohydrate in the fruit.

When carbohydrate and soluble protein contents of a fruit without seed (pulp) are considered it can be said that the fruits of E.officinalis, A.arabica and L.leucocephala probably give more proteins than the carbohydrates. Thus fruit pulp in the above tree species can be considered as proteinacious

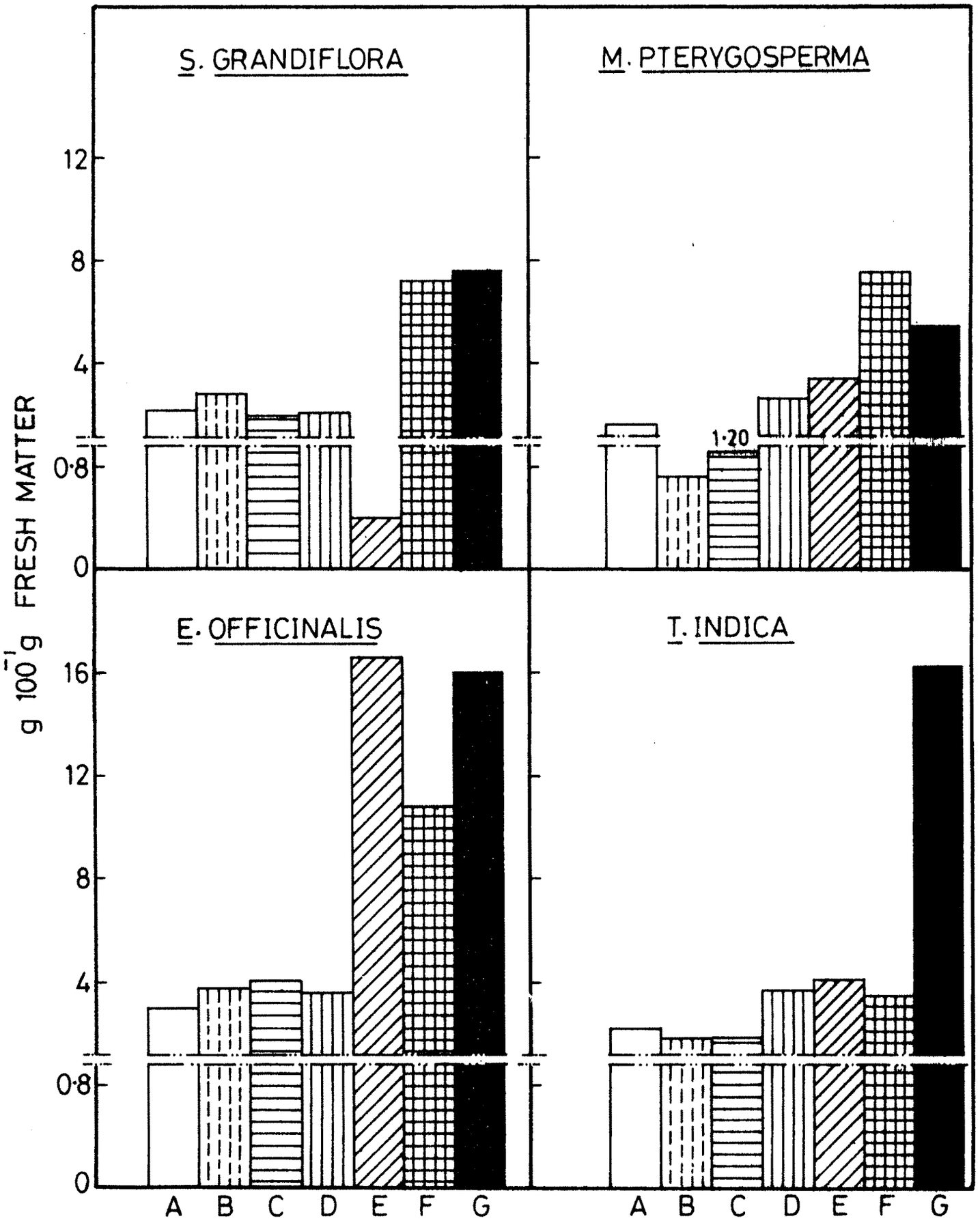

FIG. 15 STARCH CONTENT OF DIFFERENT PARTS OF S. GRANDIFLORA, M. PTERYGOSPERMA, E. OFFICINALIS AND T. INDICA

A: YOUNG LEAVES, B: MATURE LEAVES, C: SENESCENT LEAVES, D: STEM, E: BARK, F: FRUIT, G: SEED.

in nature. Fruit pulp in the remaining five tree species can provide more sugars and starch but relatively less amount of proteins. The soluble protein contents of the fruits have been depicted in Table 9.

The values for total carbohydrate contents of the seeds (air dried) of different tree species have been recorded in Tables 7 and 8. It is evident that the seed of T.indica contains the highest amount of carbohydrates among those of all the species studied. A seed of E.officinalis also contains high level of carbohydrates (16.25 g 100^{-1}g fresh tissue), little less than that in T.indica (18.44 g 100^{-1}g). These seeds have been followed by those of P.longifolia which contain 14.96% carbohydrates. The lowest amount of carbohydrates has been found in the seeds of A.arabica (5.66%).

In the seeds of all the tree species starch is the only major component of the carbohydrates. The seeds which have shown the higher level of total carbohydrates also have the high level of starch. A. arabica seed has the lowest amount of starch (4.59% air dry wt).

The soluble sugar content of the seeds clearly indicates that the seeds of A.indica and L.leucocephala seem to be rich in soluble sugars. It can be seen that the seeds of A.indica and L.leucocephala contain 5.66 and 2.91% (air dry wt) soluble sugars. The seeds of S.grandiflora also have some measurable

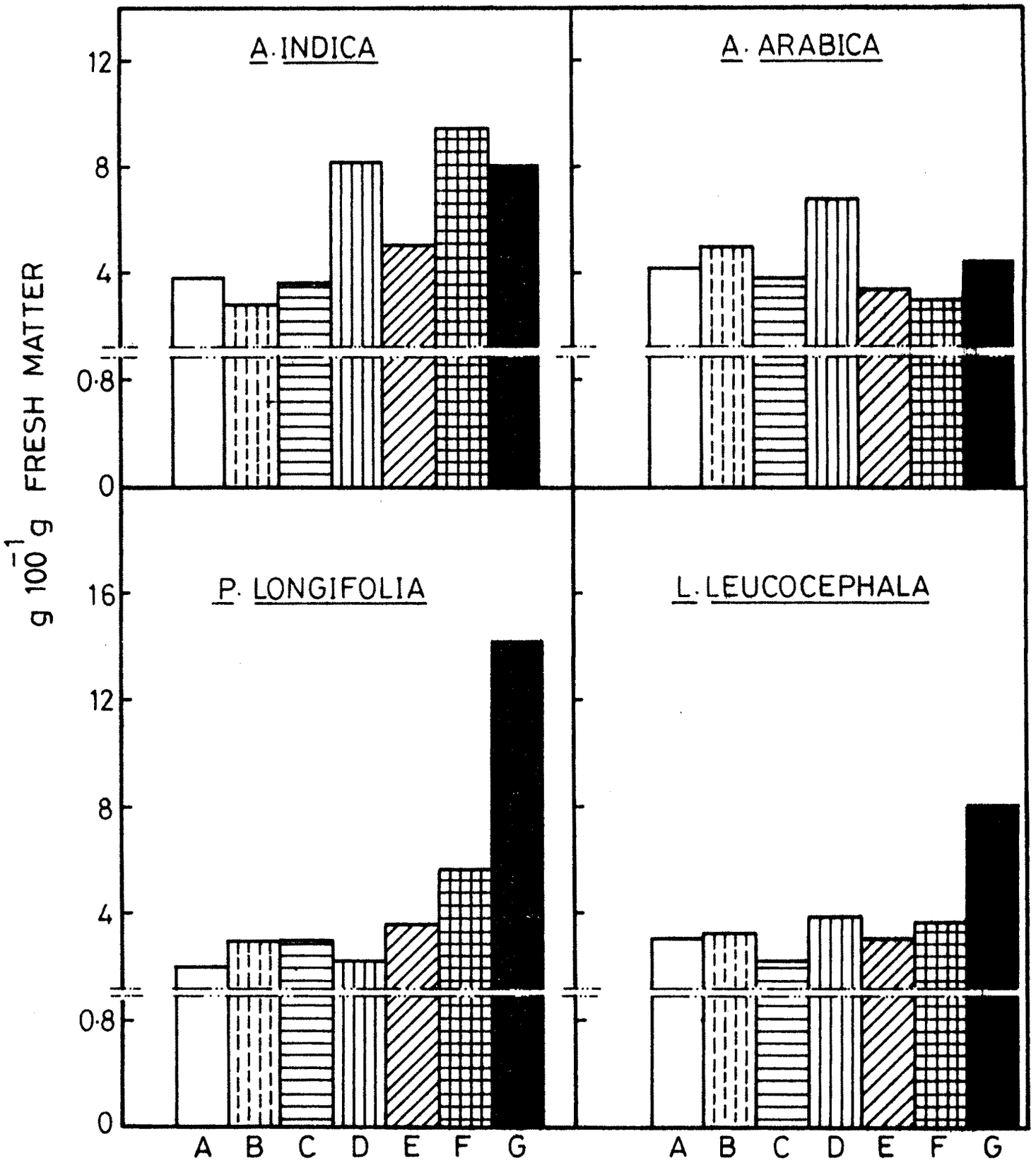

FIG. 16 STARCH CONTENT OF DIFFERENT PARTS OF A. INDICA, A. ARABICA, P. LONGIFOLIA AND L. LEUCOCEPHALA
A: YOUNG LEAVES, B: MATURE LEAVES, C: SENESCENT LEAVES, D: STEM, E: BARK, F: FRUIT, G: SEED.

quantity of soluble sugars (2.58%). The lowest value for soluble sugars (0.16%) has been recorded for the seeds of *E.officinalis*.

When the seed composition with respect to carbohydrates (starch) and protein contents is considered the seeds of *S.grandiflora*, *E.officinalis*, *A.indica* and *P.longifolia* may be considered as the starchy seeds. *M.pterygosperma*, *T.indica* and *L.leucocephala* seeds, however, can be considered for the balanced food supply with respect to carbohydrates and proteins.

Seeds contain variable quantity of food in the form carbohydrates, fats and proteins. Seed starchs are usually stored as granules. The proportion of carbohydrates, fats and proteins very greatly among seeds of different species with carbohydrates or lipids usually predominating. Seeds of white oak and sugar maple are noteworthy for their high carbohydrate content (34-47 and 62% air dry wt respectively). While, those of pines (4.5 to 4.8%) and tung (5%) have low carbohydrate contents (Mayer and Poljakoff-Mayber, 1963). There is wide variation in the seed composition of different species even in the same genus.

Haq *et al*. (1974) isolated a polysaccharide from the alcohol-extracted bark of *Litsaea chinesis*, Lamk. The fractionation of the polysaccharide using iodine solution yielded about 55% starch. Bonner (1974) found that acornes of

cherry bark (Quercus falcata var. pagodaefolia), water (Q.nigra) and willoaks (Q.phellos) grew slowly but steadly in July and August and reached maximum size in September when fats and carbohydrates, the major storage food, accumulated rapidly. He also reported that at physiological maturity in late October or early in November, crude fat levels were 15 to 20% of seed dry weight and carbohydrate totaled 45%. Three selections of traits from the state of Zulia i.e. brown, yellow and sapotae, were physio-chemically characterised by Rivas and Carmen (1979). It was found that despite of their pulp colour differences they were similar in chemical composition. 13.85% was the value recorded for total sugars. Owusw et al. (1978) have studied the seasonal changes in total sugar content of field cocoa (Theobroma cacao L.) plants. They recorded that on dry weight basis, the total sugar content of the bark (1.3 - 6.3 g 100^{-1}g) was higher than that of the wood (0.9-4.0 g 100^{-1}g). Sieckmann and Bot (1978) have found that the low temperatures increase the reducing and total sugar concentrations in the leaves of boxwood (Buxus sempervirens L.) and cranberry (Vaccinium macrocarpon Ait.). It was found that the total sugar concentration in the leaves increased from 2.2 to 5.% (fresh weight) in boxwood and from 4.4 to 7.7% in cranberry leaves after being exposed to temperature treatment of 7°C for 8 to 6 days respectively.

The values recorded for carbohydrates (total soluble

sugars and starch) in the present investigation for 8 different tree species well agree with those found for the above different plant species recently.

F) Soluble Proteins :

Soluble protein contents in different parts of S.grandiflora, M.pterygosperma, E.officinalis, T.indica, A.indica, A.arabica, P.longifolia and L.leucocephala have been recorded in Table 9 and Fig.17 and 18. Soluble proteins from the leaves have been estimated at there different developmental stages (young, mature and senescent). Stem, bark, fruit and seed are the other parts from which also the protein content has been determined.

It is evident that almost each and every plant part contains measurable amount of proteins. Among the young leaves, which are usually rich in soluble proteins, those of A.arabica, E.officinalis and L.leucocephala have shown the higher amount of soluble proteins (about 28, 26 and 22% fresh wt respectively). The young leaves of S.grandiflora, P.longifolia and M.pterygosperma, however, have exhibited lower values for soluble proteins. It can also be seen that the mature leaves of A.arabica and E.officinalis are very rich in soluble proteins (26.4 and 24.6% fresh wt respectively). The lowest amount of proteins are found again in the mature leaves of S.grandiflora (2.5%). It is observed that during the

Table No.9 : Protein contents* of different parts of S.grandiflora, M.pterygosperma, E.officinalis, T.indica, A.indica, A.arabica, P.longifolia and L.leucocephala.

Plant Part	Soluble proteins (g. kg^{-1} fresh matter)							
	S.grandiflora	M.pterygosperma	E.officinalis	T.indica	A.indica	A.arabica	P.longifolia	L.leucocephala
Young leaves	41.79	55.36	255.72	121.79	106.61	275.36	50.36	226.79
Mature leaves	25.00	46.61	246.43	127.50	54.29	263.57	71.07	88.93
Senescent leaves	38.93	80.18	227.32	74.29	61.07	273.04	91.97	67.14
Stem	13.93	12.50	151.79	170.18	26.96	173.93	7.50	133.93
Bark	16.25	14.11	194.29	194.82	63.93	249.82	37.14	81.93
Fruit	9.30	16.79	314.65	86.97	61.42	327.86	9.46	198.57
Seed**	56.25	81.96	41.96	155.00	10.89	25.54	28.93	83.93

* Each value is mean of three determinations.

** Air dried seeds (air dry wt).

maturation of a leaf the soluble protein content decreases (fresh wt basis). It can be seen that in the mature leaves of all the tree species, except T.indica and P.longifolia, the soluble protein contents have shown lower values. The soluble protein values of the senescent leaves indicate that there is slight increase in the protein content as compared to that in the mature leaves in S.grandiflora, A.indica, A.arabica and a considerable increase in M.pterygosperma and P.longifolia. In the remaining species the level of soluble proteins is declined during senescence.

Although, a variety of changes occur during aging of leaves, decreased ability of cells to synthesise RNA and protein appear to be a crucial malfunction which promotes senescence with repression of DNA, the synthesis of proteins and chlorophylls declines. This sequence of events appears to be involved in the basic mechanism of leaf senescence (Leopold, 1961; Osborne, 1962). Hardwick (1983) during his studies in leguminosae stated that leaves senesce and abscise in response to production of a senescence signal by the reproductive parts or that they senesce and abscise as a result of their proteins having been mobilised to satisfy nitrogen demands of the developing seeds. Remobilised nitrogen moves quite actively and preferentially into young and growing tissues. This mobilisation implies accelerated hydrolysis of proteins and the transport of resulting amino acids out of the

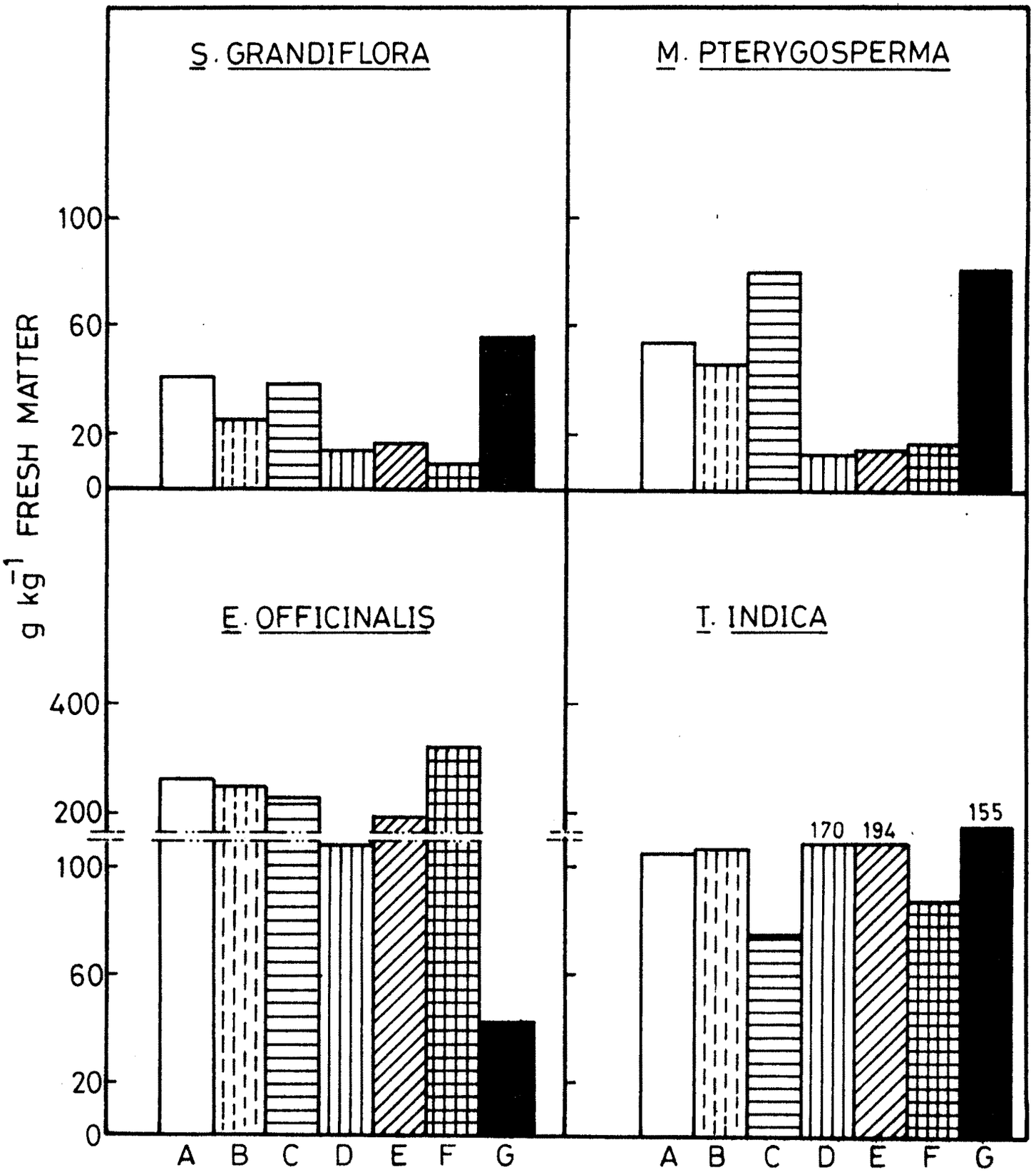

FIG. 17 PROTEIN CONTENT OF DIFFERENT PARTS OF S. GRANDIFLORA, M. PTERYGOSPERMA, E. OFFICINALIS AND T. INDICA.

A: YOUNG LEAVES, B: MATURE LEAVES, C: SENESCENT LEAVES, D: STEM, E: BARK, F: FRUIT, G: SEED.

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older leaves to young growing leaves. This may be the situation prevailing to some extent in tree species also. The high level of proteins in the young leaves and their low level in the mature and senescent leaves in most of these tree species support this.

In conclusion, it can be suggested that the leaves of A.arabica and E.officinalis at any developmental stage can be used as a good source of protein. The young leaves of L.leucocephala can also form a good source of proteins. This suggestion, however, has certain limitations as the protein values expressed are on fresh weight basis and that only soluble proteins have been considered here.

The stem of A.arabica, E.officinalis and L.leucocephala show a considerable amount of soluble proteins (about 17.4, 15.2 and 13.4 g 100^{-1}g fresh wt respectively). The stem of P.longifolia, however, contains very low amounts of proteins. The bark of A.arabica seems to be very rich in soluble proteins and that of E.officinalis and T.indica also contains considerable amount of it. The bark of M.pterygosperma, however, is very poor (1.4%) in soluble protein content.

It is quite clear that the fruit pulp of A.arabica and E.officinalis is highly rich in soluble proteins. When these values are compared with those of carbohydrates in the fruit

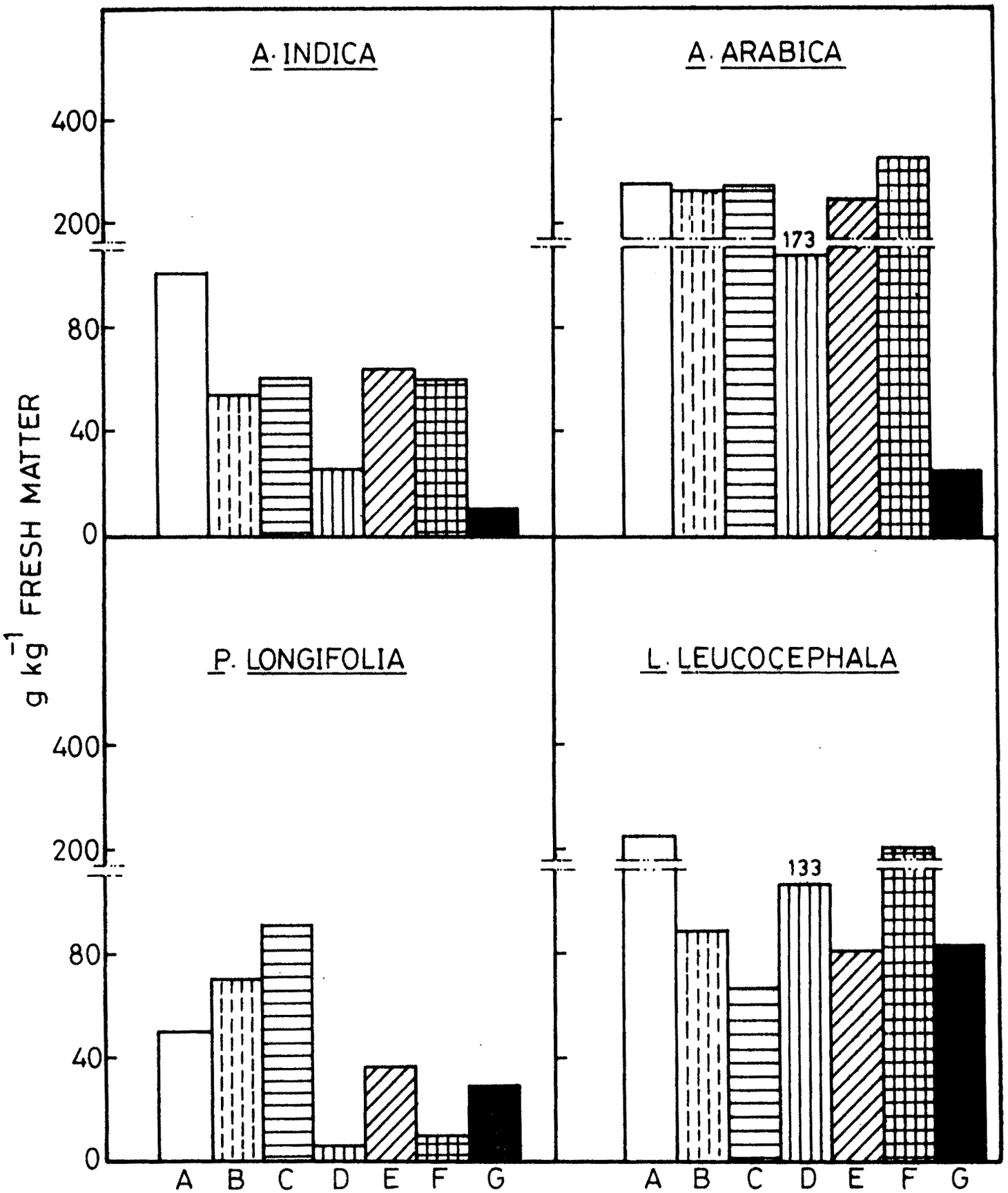

FIG. 18 PROTEIN CONTENT OF DIFFERENT PARTS OF A. INDICA, A. ARABICA, P. LONGIFOLIA AND L. LEUCOCEPHALA.
A: YOUNG LEAVES, B: MATURE LEAVES, C: SENESCENT LEAVES, D: STEM, E: BARK, F: FRUIT, G: SEED.

pulp of the respective species, the fruits of E.officinalis and A.arabica can be considered as proteinacious fruits. The fruit of L.leucocephala can also be used as a source of soluble proteins. The fruit pulp of S.grandiflora seems to be very low in protein content (0.9%).

The seed soluble protein values for different tree species have also been depicted in Table 9. It is evident that the seeds of almost all the tree species contain moderate amount of soluble proteins. The seed of T.indica seems to be relatively rich in proteins. As discussed earlier, these seeds can be used as a source of balanced food with respect to carbohydrates and proteins. Same thing is true for M.pterygosperma and L.leucocephala and also to some extent, for S.grandiflora. The seeds of A.indica seem to be very poor in soluble proteins.

Mayer and Poljakoff-Mayber (1963) have given the values of protein content in different tree species. From their observations the tree species can be grouped in two categories 1) protein rich and 2) with low protein. In the protein rich seeds the protein content varied from 27.5 to 62% air dry wt while, the species in the other group show the values ranging from 3 to 7.4%. The observations made with respect to soluble proteins in the present investigation agree with the findings described above.

G) Proline :

Proline is one of the cyclic amino acids, unique among the amino acids in it's accumulation during stress. It is considered to be stress product synthesised in response to drought (Boggess et al., 1976), salt (Cavalieri and Huang, 1979) and temperature (Chu et al., 1974, 1976) stress in plants. The investigators like vidhyasekaran (1972), Kannaiyan et al. (1973 b), Sivaprakasam et al. (1974) and Hegde and Karande (1978) are of the opinion that proline also helps the pathogen in colonising the host tissue during disease development. Proline accumulates consistently in numerous plant species and under a range of environmental conditions. It is also accumulated rather consistently during development of frost hardiness in red-osier dogwood (Li et al, 1965). It has been suggested that proline increases considerably the amount of strongly bound water in the leaf cells. However, the exact role of proline in the metabolism is not yet well understood.

The proline content of the leaves at different developmental stages (young, mature and senescent), stem, bark, fruit pulp and seeds of S.grandiflora, M.pterygosperma, E.officinalis, T.indica, A.indica, A.arabica, P.longifolia and L.leucocephala has been recorded in Table 10 and 11 and Figs. 19-22. Table 10 gives the proline values in different parts of the plants on fresh wt basis (Figs.19 and 20) while Table 11 records, the

Table No.10 : Proline content* of different parts of S.grandiflora, M.pterygosperma, E.officinalis, T.indica, A.indica, A.arabica, P.longifolia and L.leucocephala.

Plant Part	Proline (mg 100^{-1}g fresh matter)							
	S.grandiflora	M.pterygosperma	E.officinalis	T.indica	A.indica	A.arabica	P.longifolia	L.leucocephala
Young leaves	13.42	5.57	3.17	8.07	54.91	44.26	8.44	39.26
Mature leaves	11.38	6.30	2.71	8.44	60.38	11.96	10.47	9.17
Senescent leaves	22.68	11.23	6.59	9.74	11.79	24.11	12.48	8.56
Stem	11.18	44.35	5.89	5.17	36.83	6.85	8.96	6.35
Bark	1.98	1.93	2.22	13.24	113.31	4.12	7.05	3.03
Fruit	21.65	12.46	33.36	327.96	187.62	732.62	3.17	6.87
Seed**	7.37	4.93	8.54	6.54	90.96	51.31	125.46	62.43

* Each value is mean of three determinations.

** Air dry seeds.

Table No.11 : Proline content* of different parts of S.grandiflora, M.pterygosperma, E.officinalis, T.indica, A.indica, A.arabica, P.longifolia and L.leucocephala.

Plant part	Proline (mg 100^{-1}g dry matter)							
	S.grandiflora	M.pterygosperma	E.officinalis	T.indica	A.indica	A.arabica	P.longifolia	L.leucocephala
Young leaves	227.78	182.50	13.33	69.33	96.00	567.41	45.63	179.85
Mature leaves	202.59	125.00	13.93	93.33	600.60	785.20	188.82	35.26
Senescent leaves	124.07	48.51	17.78	19.85	58.67	95.70	25.19	4.74
Stem	88.15	15.18	15.70	39.11	142.52	98.37	42.67	106.67
Bark	9.26	9.99	8.30	52.44	168.30	39.41	191.71	63.11

* Each value is mean of three determinations.

proline contents of the leaf, stem and bark of the tree species, expressed on dry wt basis (Fig.21 and 22).

It is evident that the leaves of A.indica, A.arabica and L.leucocephala upto the maturity seem to be very rich in proline. The young and mature leaves of A.indica have recorded the highest amount of proline (when expressed on fresh wt basis). However, the proline content when expressed on dry wt basis, seems to be the highest in the leaves of A.arabica followed by those of S.grandiflora. The mature leaves of T.indica, A.indica, A.arabica and P.longifolia contain the maximum level of this amino acid as compared to that at any other developmental stage (dry wt basis). It can be seen that in most of the tree species investigated, proline seems to accumulate in the leaves during senescence. This is true in case of S.grandiflora, M.pterygosperma, E.officinalis, T.indica, P.longifolia and to some extent in A.arabica. However, the level of free proline is sharply declined in the leaves of A.indica during senescence. When the values for proline, expressed on dry wt basis are considered, there is always a decline in it during senescence in all the tree species except in E.officinalis where it is accumulated in the senescent leaves. Decreased level of free proline in the senescent leaves of these tree species may be due to translocation of this amino acid from those old leaves to the young growing regions. The stems of M.pterygosperma and A.indica have shown higher levels of free

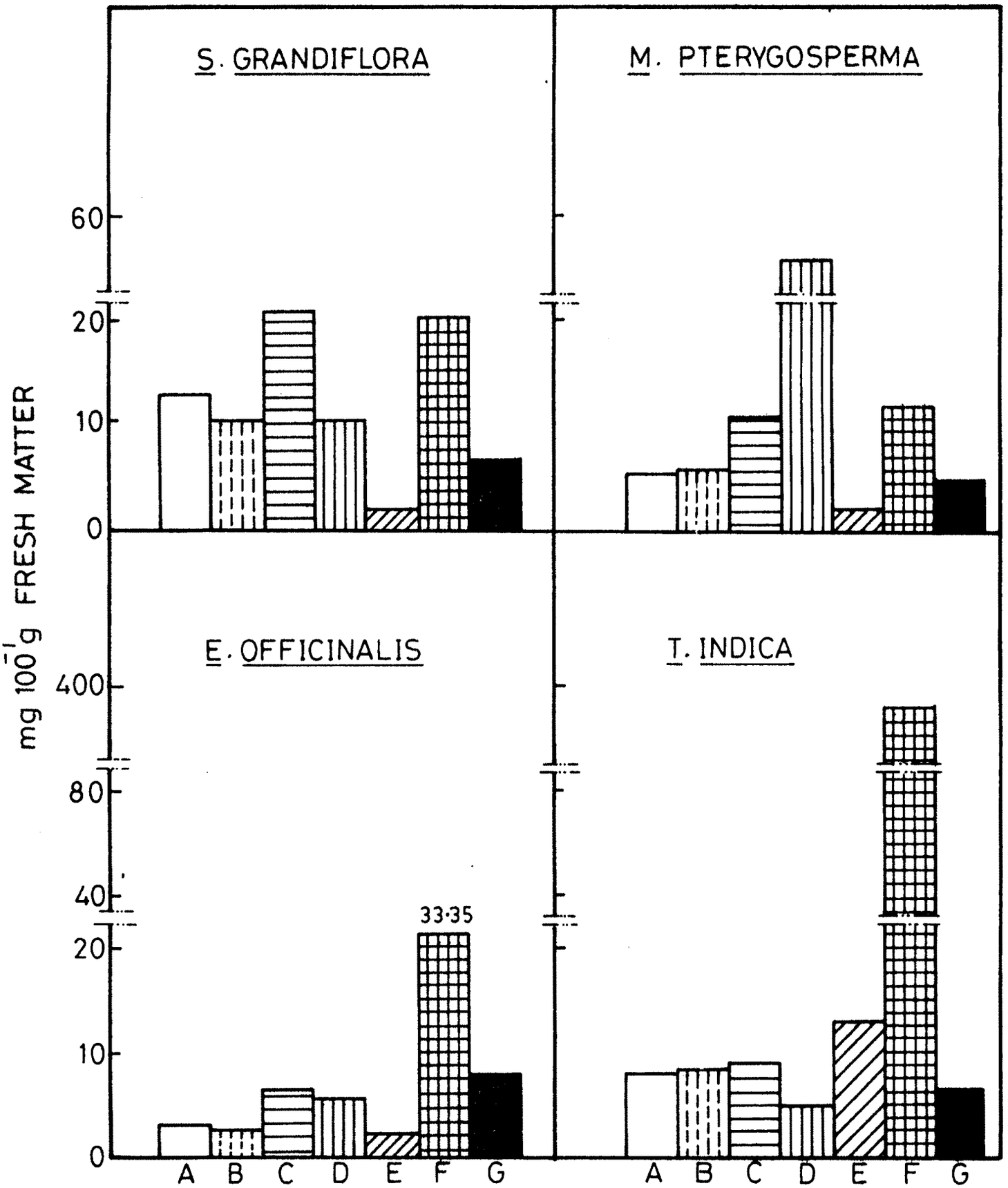

FIG. 19 PROLINE CONTENT OF DIFFERENT PARTS OF S. GRANDIFLORA, M. PTERYGOSPERMA, E. OFFICINALIS AND T. INDICA.

A: YOUNG LEAVES, B: MATURE LEAVES, C: SENESCENT LEAVES, D: STEM, F: FRUIT, G: SEED.

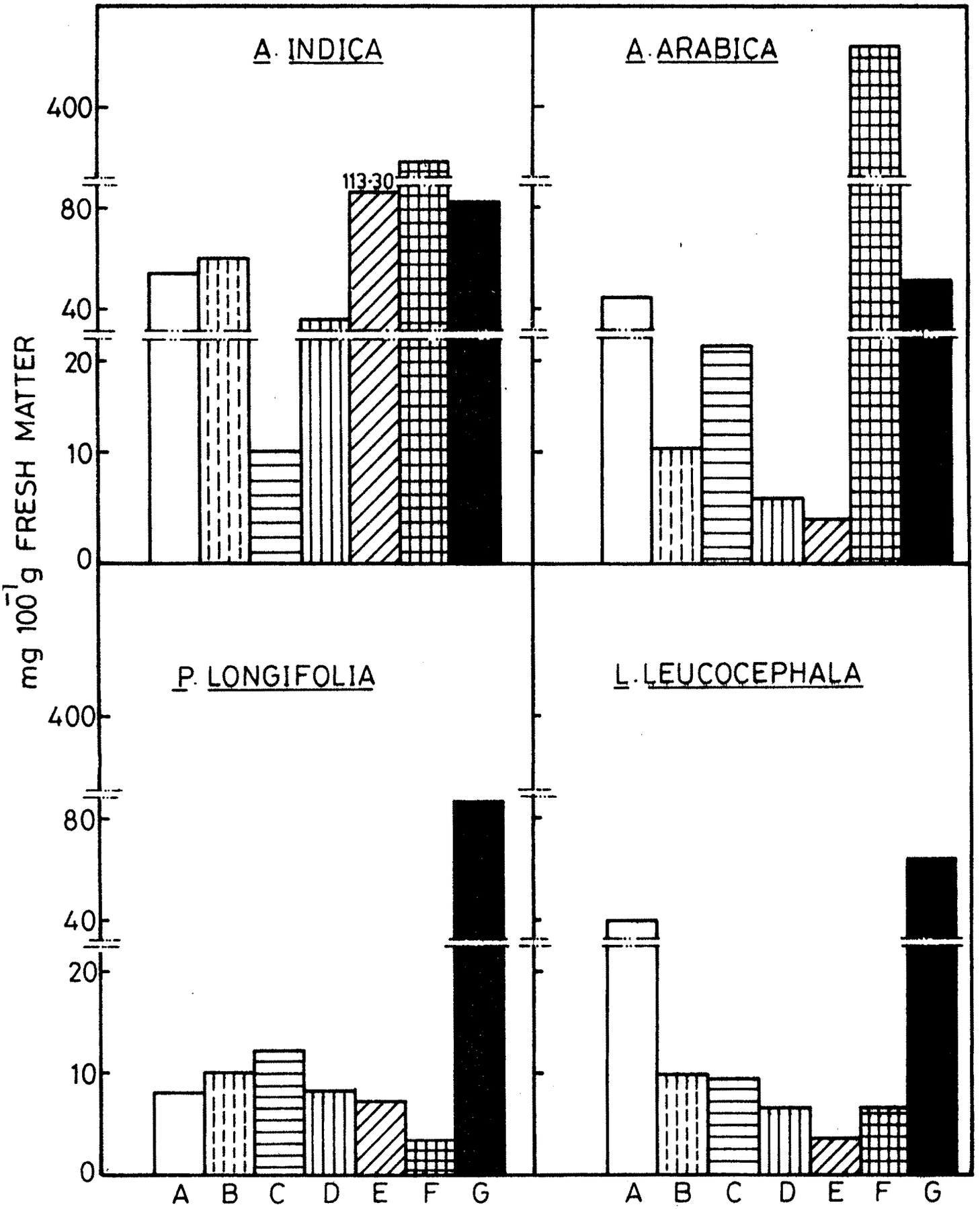

FIG. 20 PROLINE CONTENT OF DIFFERENT PARTS OF A. INDICA, A. ARABICA, P. LONGIFOLIA AND L. LEUCOCEPHALA.
A: YOUNG LEAVES, B: MATURE LEAVES, C: SENESCENT LEAVES, D: STEM, E: BARK, F: FRUIT, G: SEED.

proline as compared to that in other species. The lowest amount of proline is found in the stem of T.indica. Except in A.indica the bark of all the tree species seems to be very poor in this amino acid. The bark of M.pterygosperma and that of S.grandiflora have shown the lowest concentration of free proline. The bark of A.indica contains about 113 mg proline 100^{-1}g fresh tissue. When proline content is determined from oven dried plant material, even the stem of A.indica shows the higher amount of it. The oven dried stem of L.leucocephala also shows the accumulation of this amino acid in tremendous amounts. It can be seen that the stem of this species shows 6.35 mg of proline 100^{-1} g fresh tissue. But, when the same material was subjected to oven drying it contained 106.67 mg proline 100^{-1}g dry tissue. Such type of observations have been made in case of A.arabica also. This sudden rise of free proline level in these plants may be due to the temperature shock tor stress to the plant material. The bark of A.indica also shows the higher amount of proline even when it is determined from oven dried plant material. In case of bark of P.longifolia, however, there is tremendous rise in the level of this amino acid due to temperature treatment to the bark.

The reproductive parts, fruit and seed, also have considerable amount of free proline in their tissue. It is quite significant in the fruit pulp of the tree species. It can be seen that the fruit of A.arabica is exceptionally highly rich

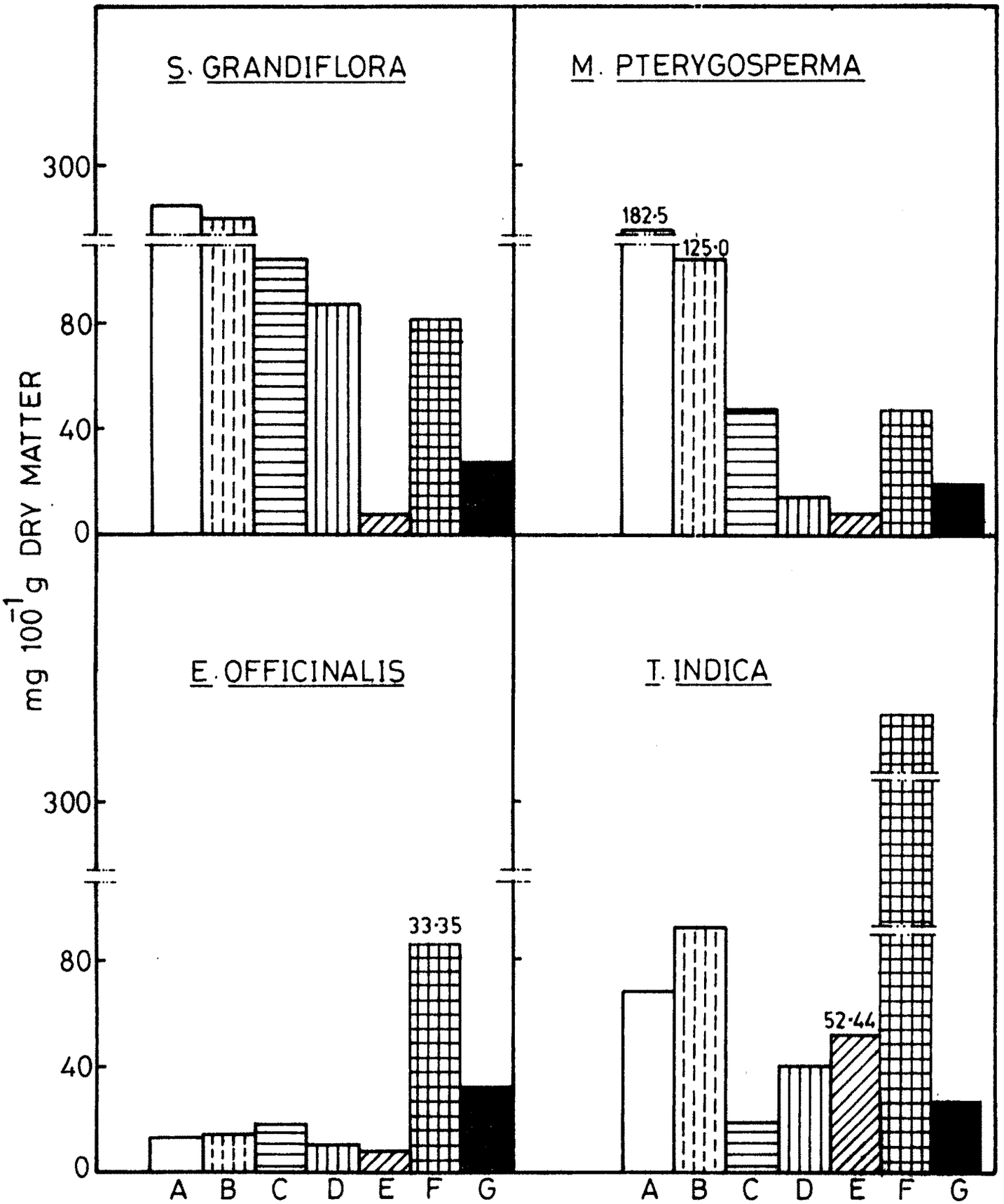

FIG. 21 PROLINE CONTENT OF DIFFERENT PARTS OF S. GRANDIFLORA, M. PTERYGOSPERMA, E. OFFICINALIS. T. INDICA.

A: YOUNG LEAVES, B: MATURE LEAVES, C: SENESCENT LEAVES, D: STEM, E: BARK, F: FRUIT, G: SEED.

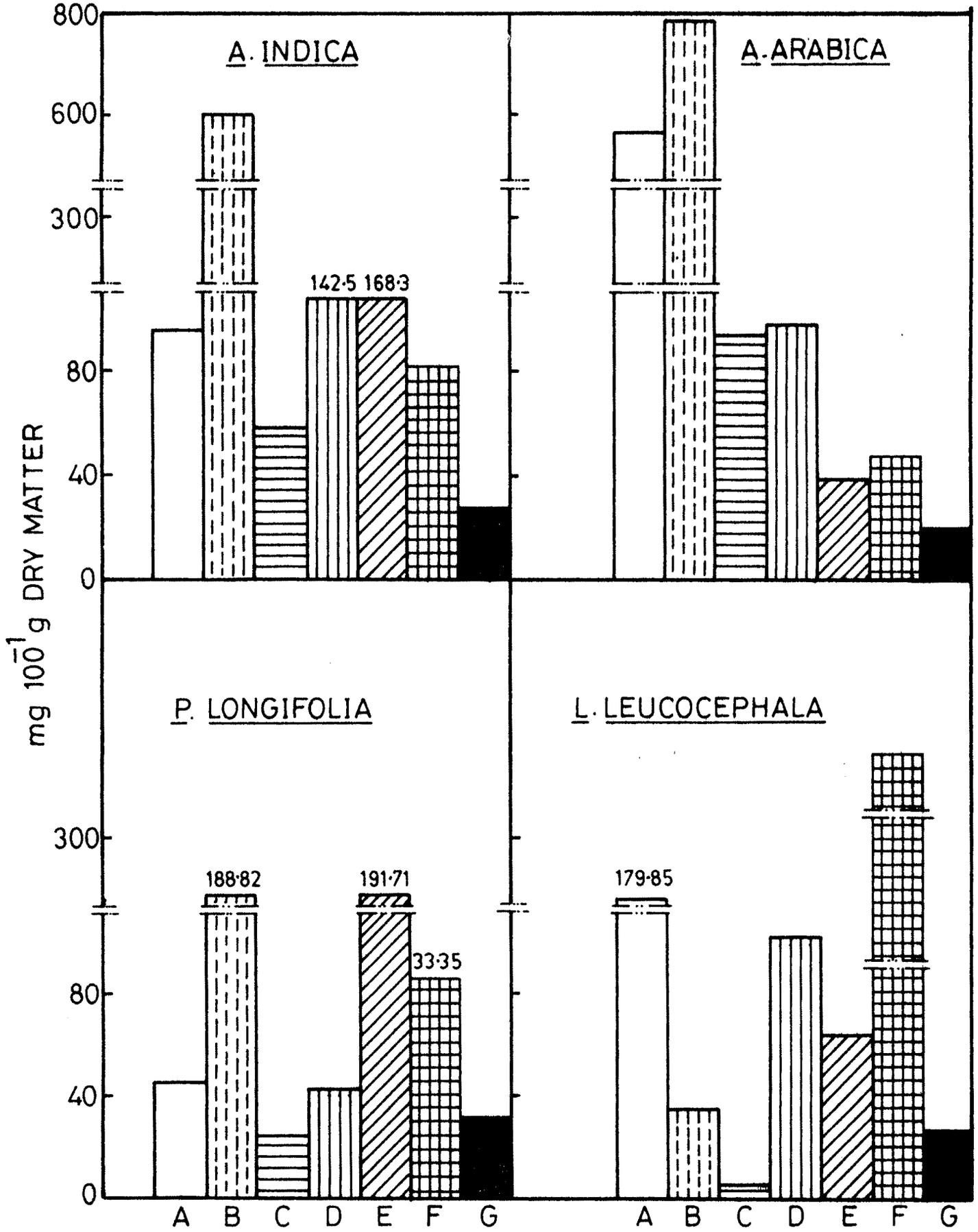

FIG. 22 PROLINE CONTENT OF DIFFERENT PARTS OF A. INDICA, A. ARABICA, P. LONGIFOLIA AND L. LEUCOCEPHALA.
A: YOUNG LEAVES, B: MATURE LEAVES, C: SENESCENT LEAVES, D: STEM, E: BARK, F: FRUIT, G: SEED.

in free proline (733 mg 100^{-1}g fresh tissue). The fruit of T.indica and A.indica also contain some measurable amount of free proline. The fruit of P.longifolia, however, seems to be very poor in this amino acid.

Seeds of tree species seem to be relatively poor in proline contents. Those of A.indica, P.longifolia and L.leucocephala appear to contain some measurable quantity of this amino acid. The seeds of M.pterygosperma, however, seem to be very poor in proline content.

The exact role of proline in the reproductive parts of a plant has not yet been clearly understood. It appears that free proline in the air dried seed may help the seedlings to develop stress tolerance. In the light of this suggestion A.arabica, A.indica, P.longifolia and to some extent L.leucocephala can be taken as stress tolerant plants.

H) Nitrate Reduction :

Most of the higher plants prefer nitrate as a nitrogen source. Assimilation of nitrate is a continuous process beginning with uptake of nitrate by the roots. The nitrate absorbed must be reduced to ammonia which is then assimilated into organic compounds, mostly amino acids and then proteins. Reduction of nitrate to ammonia takes place both in the leaves as well as in roots which is achieved in two stages involving enzymes nitrate reductase and nitrite reductase. NR (Nitrate

Reductase, E.C. 1.6.6.2) catalyses reduction of nitrate to nitrite. The enzyme from higher plants shows a specific requirement for NADH (Beevers and Hageman, 1969). $FMNH_2$ and $FADH_2$ can also act as electron donors. Aparicio et al. (1971) and Notton and Hewitt (1971) have demonstrated the molybdenum requirement for nitrogen reduction. The enzyme is present both in the leaves as well as roots. In roots, it is present in the cytoplasm while in the leaves, it is present either in cytoplasm or loosely attached with outer membrane of chloroplast.

Nitrite produced in the above reaction is further reduced to ammonia and this reduction is catalysed by yet another important enzyme system, nitrite reductase (NiR, E.C. 1.6.6.4). This enzyme is present in chloroplast, probably in thylakoids, while, in roots it is in proplastids. NiR presents a marked specificity for ferridoxin as electron donor (Vega et al., 1980).

It is generaly assumed that, at least in well-fertilized crop plant, nitrate reduction occurs chiefly in the leaves (Beevers and Hageman, 1969), the nitrate being translocated from roots to leaves in the xylem sap (Shaner and Boyer, 1976). However, in the numerous species of woody plants studied, it appears that nitrate is reduced in the roots because organic forms of nitrogen predominate in the xylem cell. Bollard (1958) found tracese or small amounts of nitrate in the xylem sap of

only one-third of 131 woody and herbacious species examined, but a variety of amino acids and amides were present in the sap of all the species.

The activity of enzyme nitrate reductase in the developing leaves (young, mature and senescent) of S.grandiflora, M.pterygosperma, E.officinalis, T.indica, A.indica, A.arabica, P.longifolia and L.leucocephala has been recorded in Table 12. It is evident that the young leaves of A.indica show the highest activity of this enzyme among the young leaves of the tree species investigated. The leaves of T.indica and E.officinalis also have shown the higher level of this enzyme during the early developmental stages. Among young leaves of all the tree species, those of A.arabica have exhibited the lowest activity of NR. The young leaves of remaining tree species show the moderate level of this enzyme in their tissue. Usually NR activity in the leaves increases with the age till maturity. This is quite evident in case of M.pterygosperma, A.arabica and L.leucocephala. However, in the remaining tree species the level of this enzyme is declined in the mature leaves. It is quite significant in E.officinalis and also in A.indica. It is also evident that the mature leaves of M.pterygeosperma have recorded the highest value among those for all the tree species, for NR activity. The mature leaves of L.leucocephala and A.indica also show quite considerable activity of this enzyme. The lowest value for NR activity has

Table No.12 : Nitrate reductase activity* in young, mature and senescent leaves of S.grandiflora, M.pterygosperma, E.officinalis, T.indica, A.indica, A.arabica, P.longifolia and L.leucocephala.

Plant Part	Nitrate reductase activity ($\mu g\ NO_2\ h^{-1}\ mg^{-1}$ protein)							
	S.grandiflora	M.pterygosperma	E.officinalis	T.indica	A.indica	A.arabica	P.longifolia	L.leucocephala
Young leaves	1.81	1.90	2.12	2.24	3.07	0.21	0.88	0.53
Mature leaves	1.02	2.88	0.80	1.50	1.80	0.26	0.73	2.09
Senescent leaves	0.78	2.69	1.36	1.80	2.11	0.39	0.52	3.13

* Each values is mean of three determinations.

been shown again by the mature leaves of A.arabica. During further usually, the activity of this enzyme in the leaves during senescence falls down almost in all the tree species investigated, except A.arabica, M.pterigosperma and L.leucocephala wherein the activity of NR increases remarkably in the senescent leaves. It appears that the enzyme is highly sensetive to phenolics as the leaves of A.arabica are highly rich in these compounds.

Various reasons have been put forth for the decrease in nitrate reductase activity during leaf senescence. Pate (1968) has correlated this decrease with decline in protein metabolism in the leaves. This decrease has also been related to decrease in the photosynthetic activity, carbohydrate metabolism, protein synthesis and inorganic nitrogen assimilation (Blahova and Segeta, 1980). Recently Doddema et al. (1986) have coincided low nitrate reductase activity with low values of soluble carbohydrates and amino acids, since there was no extra export of labelled carbon from the leaves with minimum nitrate reductase activity. It appears that low level of soluble carbohydrates in the senescent leaves of most of the tree species may be responsible for decreased NR activity in them as suggested.

The activity of enzyme nitrite reductase in the developing leaves of the tree species has been recorded in Table 13. When the values of NiR activity in the leaves are compared with

Table No.13 : Nitrite reductase activity* in young, mature and senescent leaves of *S.grandiflora*, *M.pterygosperma*, *E.officinalis*, *T.indica*, *A.indica*, *A.arabica*, *P.longifolia* and *L.leucocephala*.

Plant Part	Nitrite reductase activity ($\mu g\ NO_2\ h^{-1}\ mg^{-1}$ protein)							
	S.grandiflora	*M.pterygosperma*	*E.officinalis*	*T.indica*	*A.indica*	*A.arabica*	*P.longifolia*	*L.leucocephala*
Young leaves	5.76	1.17	4.79	15.00	6.93	0.21	2.03	2.08
Mature leaves	7.06	8.49	6.83	9.24	11.58	0.20	2.10	1.20
Senescent leaves	12.02	12.54	10.61	9.80	9.38	1.12	1.67	2.19

* Each value is mean of three determinations.

those for NR activity, the level of NiR seems to be higher than that of NR. Thus this observation is not an exception to the normal trend of higher activity of this enzyme than that of NR in plants.

It is also evident that among the young leaves of tree species, those of A.indica record the highest activity of NiR, The young leaves of S.grandiflora and E.officinalis also have remarkable activity of this enzyme. The lowest value for the activity of NiR has been recorded in the young leaves of A.arabica. Except in T.indica and L.leucocephala, in most of the tree species NiR activity is increased with the maturity of leaves. In T.indica and L.leucocephala there is more than 30 to 40% reduction in the activity of this enzyme in the mature leaves as compared to that in the young leaves. In A.arabica there is almost no change in the NiR activity upto the maturity of leaves. The mature leaves of A.indica have shown the highest level of this enzyme among those of all the tree species. This is followed by T.indica and M.pterygosperma. The lowest value being recorded for the enzyme in mature leaves of A.arabica. The activity of NiR is markedly increased in the leaves of S.grandiflora, M.pterygosperma, E.officinalis, A.arabica and L.leucocephala during senescence. In case of T.indica, however, there is only a slight elevation in the level of this enzyme during senescence. In this species, the young leaves have recorded the highest level of NiR activity.

In the senescent leaves of A.indica and P.longifolia the activity of NiR is exceptionally decreased over than in the mature leaves.

NiR activity and photosynthesis are intemately related. It is due to nature of NiR which is a chloroplastic enzyme (Miflin, 1974) and reduced ferridoxin acts as the main electron donor for the enzymatic reaction (Neyra and Hageman, 1974). The increased level of NiR in the senescent leaves of some of the tree species cannot be explained on the basis of present observations.

Very low level of NiR as well as NR in the leaves of A.arabica may be due to their high phenolic content at all developmental stages (Table 13 and 14). However, it should be mentioned that whether the phenolics in the leaf tissue affect the enzyme in vivo or in vitro cannot be explained.

I) Polyphenols :

Polyphenols are aromatic compounds, the secondary metabolic products, with one or more phenolic hydroxyl groups. Usually most phenolic substances obtained from tissues with living cells occur as glycosides or esters while, polyphenols obtained from heartwood are almost exclusively found as aglycones (organic compounds, usually phenol or alcohol, combined with the sugar portion of a glycoside). Various roles have been attributed to the phenolic compounds in plants. Mostly

these secondary metabolic products are considered to be protective in function against different type of diseases in plants (Wallace and Mansell, 1975; Lunderstadt, 1976). There are some reports which indicate that the adaptive role phenolics play an adaptive role in plants during stress conditions. Phenolics also act as inhibitors in plants e.g. cinnamic acid inhibits auxin activity. Exogenously applied monophenols increase indoleacetic acid oxidase activity and distruction of auxin but di- and polyphenols inhibit the distruction of indole acetic acid. There is rather confusing data indicating that phenols are involved in the responses of seedlings to light (Leopold and Kriedemann, 1975). The flavonoids may have some role in the response of leaves to light (Thimman, 1972), and some unsaturated lectones, such as coumarin, also have been identified as growth inhibitors. Coumarin inhibits lettuce seed germination and elongation of roots. Jacobson and Corcoran (1977) suggest that tannins are important antagonists and regulators of the gibberellins. In addition to competing for light, water and minerals, plants inhibit seed germination and growth of neighbouring plants by releasing a variety of toxic chemicals, some times called allelochems. Phenolic compounds and tannins are among such allelochems. Phenolics play a vital role in heartwood formation in tree species. The tracer studies have shown that labelled sugar moves from the phloem through the sap wood to the sapwood-heartwood boundary (Hasegawa and Shiroya, 1967). Hillis _et al_. (1962) showed that a major part

of the heart wood polyphenol was formed at the sapwood-heart-wood boundary from translocated carbohydrates that had not been utilized in growth. This is consistent with the observation that the rapid growth and efficient utilization of available carbohydrates often are associated with a low amount of heart-wood phenols (Hillis, 1968). A relationship was found between the loss of reserved starch and processes leading to the formation of phenolic substances. Cells rich in phenolic substances have few or no starch grains.

The phenolic composition of the tree species with respect to their quantity and quality has been studied. Polyphenols have been quantitatively determined from different parts of S.grandiflora, M.pterygosperma, E.officinalis, T.indica, A.indica, A.arabica, P.longifolia and L.leucocephala. While E.officinalis, A.arabica (which have shown very high level of phenolics), P.longifolia and L.leucocephala (which have shown moderate to low level of phenolics) have been investigated to determine the qualitative composition of phenolics in their different parts. The polyphenol contents of developing leaves (young, mature and senescent), stem, bark, fruit and seed in these tree species have been recorded in Table 14 and Figs.23, 24. It is evident that in most of the tree species the leaves seem to be rich in phenolics. However, bark and seed of T.indica seem to be rich in these compound as compared to the other parts, particularly, leaves, stem and

Table No.14 : Polyphenol contents* of different parts of *S.grandiflora*, *M.pterygosperma*, *E.officinalis*, *T.indica*, *A.indica*, *A.arabica*, *P.longifolia*, and *L.leucocephala*.

Plant Part	*S.grandiflora*	*M.pterygosperma*	*E.officinalis*	*T.indica*	*A.indica*	*A.arabica*	*P.longifolia*	*L.leucocephala*
	Polyphenols (g 100^{-1} g fresh matter)							
Young leaves	1.28	2.06	21.13	3.44	3.40	28.70	4.53	5.37
Mature leaves	0.84	1.29	22.51	3.84	2.08	28.09	6.33	4.77
Senescent leaves	1.64	1.34	19.32	5.78	2.04	28.43	2.06	4.67
Stem	0.44	0.37	9.84	7.59	0.93	16.85	1.02	1.10
Bark	1.40	0.39	10.33	9.69	3.26	20.55	1.42	2.92
Fruit	0.91	0.41	22.45	1.43	8.90	27.67	0.51	0.08
Seed**	1.29	0.49	1.71	13.11	1.34	0.38	0.47	1.45

* Mean of three determinations.

** Air dry seeds.

fruit pulp. In case of E.officinalis both fruit pulp as well as leaves are rich in phenols. Fruit pulp in A.indica shows the highest amount of polyphenols of all the plant parts. In A.arabica both leaves as well as fruit pulp are highly rich in phenols. Looking to over all data it is clear that almost each and every part of A.arabica has shown the highest amount of polyphenols.

It is also evident that among young leaves of the tree species studied, those of A.arabica contain significantly high level of phenolics. The young leaves of E.officinalis are also rich in polyphenols. Those of S.grandiflora, however, are very poor in phenolics. In the mature leaves, those of A.arabica again have shown the highest level of polyphenols. This is followed by those of E.officinalis. Mature leaves of S.grandiflora again have shown very less amount of polyphenols. The same trend has been observed in the senescent leaves of all the tree species. The senescent leaves of M.pterygosperma also are very poor in phenolics.

The phenolic composition (quantitative) of the leaves in the tree species have indicated that there is no uniform pattern as far as the synthesis and/or breakdown of polyphenols during development is considered. It can be seen that the level of phenolics decreases with maturity of the leaves and again increases during further stages of development i.e. during senescence. Similar trend can be observed in A.arabica and

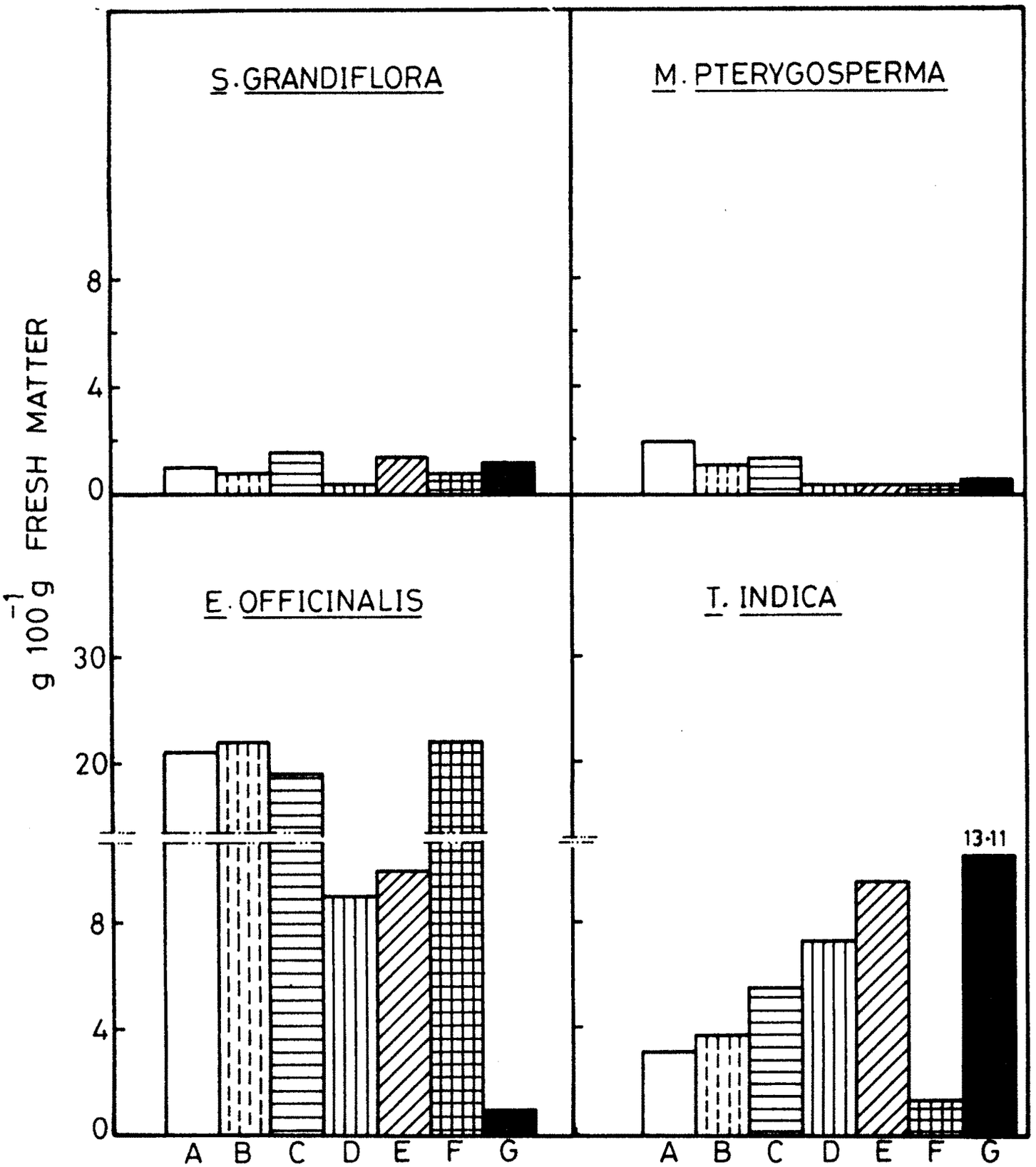

FIG. 23 POLYPHENOL CONTENT OF DIFFERENT PARTS OF S. GRANDIFLORA, M. PTERYGOSPERMA, E. OFFICINALIS AND T. INDICA.

A: YOUNG LEAVES, B: MATURE LEAVES, C: SENESCENT LEAVES, D: STEM, E: BARK, F: FRUIT, G: SEED.

M.pterygosperma leaves. On the other hand an increase till maturity and a decrease during senescence in the polyphenol content of the leaves have been observed in E.officinalis and P.longifolia. In A.indica and L.leucocephala there is concomitant decrease in the level of phenolics with an increase in the age of leaf. Thus, in these two plants the leaves during their early stages of development contain high level of polyphenols. It is interesting to note that polyphenols get accumulated in the leaves with the advancement in their age and the senescent leaves show very high level of polyphenols.

Decrease in polyphenol content during leaf senescence has been observed by a number of workers in most of the non-woody plants (Shetty, 1971; Judel, 1972; Kar and Mishra, 1976; Sable, 1983; Thombre, 1987). Jamale and Joshi (1978) have made similar type of observation in mangrove species. It has been suggested that polyphenols are probably translocated from the senescent leaves to the bark of the plant where they are stored (Jamale, 1976). So, it appears that the older leaves accumulate polyphenols and translocate them to the other parts of plant. A linear increase in the polyphenol content during leaf ontogeny has also been observed by number of worker's (Karadge, 1981; Gokhale et al., 1984; Bhivare and Nimbalkar, 1984; Thombre, 1987). According to Gokhale et al. (1984) accelerated protein catabolism in the senescing leaves

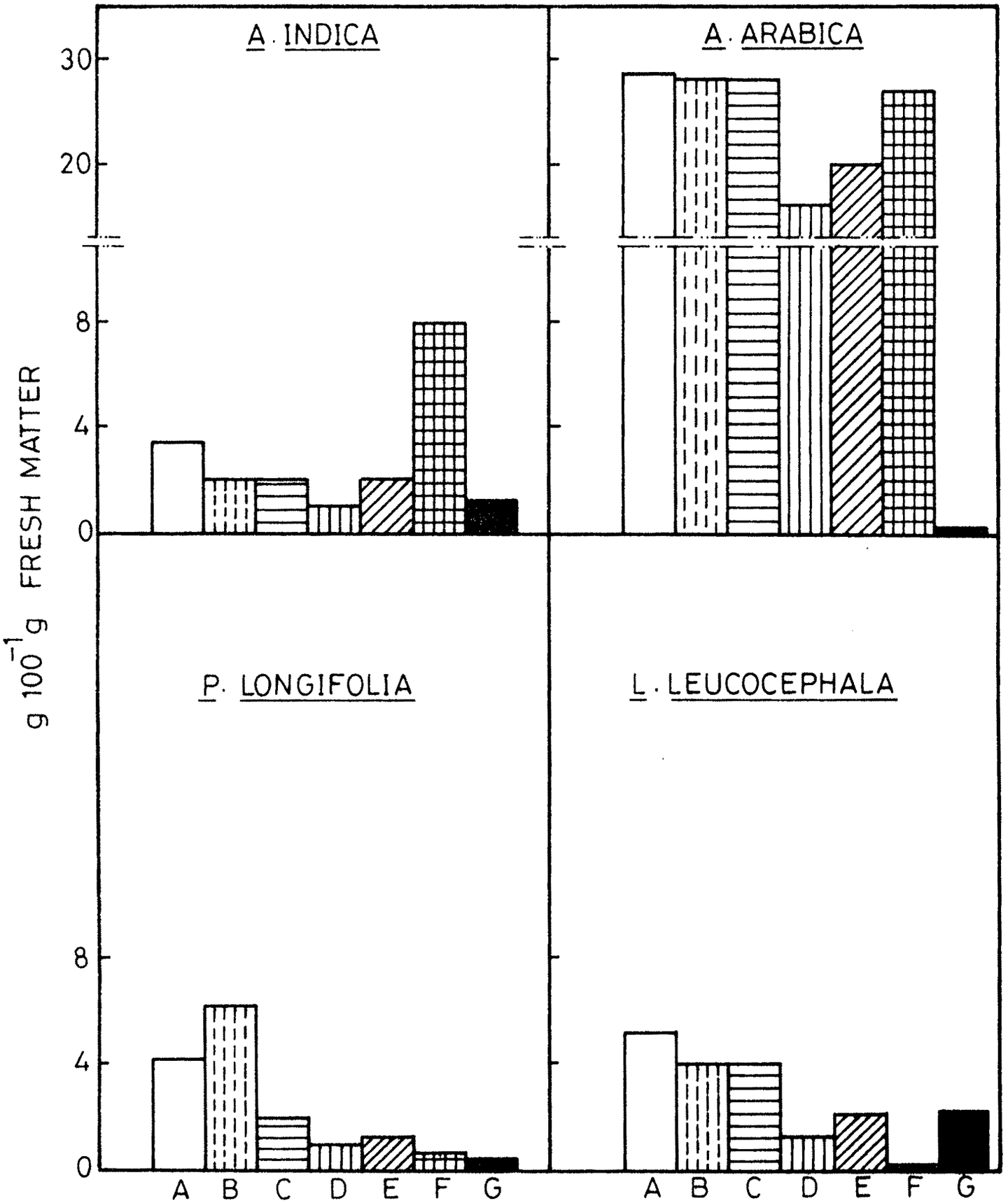

FIG. 24 POLYPHENOL CONTENT OF DIFFERENT PARTS OF A. INDICA, A. ARABICA, P. LONGIFOLIA AND L. LEUCOCEPHALA.
A: YOUNG LEAVES, B: MATURE LEAVES, C: SENESCENT LEAVES, D: STEM, E: BARK, F: FRUIT, G: SEED.

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is responsible for accumulation of metabolites containing polyphenolic compounds. The exact role of polyphenols in senescing leaves, however, is not yet clear. It may be concluded from the above discussion that the accumulation of polyphenols in the leaves not only depends upon leaf age but also upon the type of a plant.

It can be seen that stem, bark and fruit without seeds (fruit pulp along with fruit cover) of A.arabica show the highest level of polyphenols of those of other tree species. E.officinalis follows A.arabica in this respect. In E.officinalis however, the fruit pulp seems to be very rich in polyphenols. These two species are followed by T.indica in this respect. However, the fruit pulp of this species contains very low amount of phenolics. The stem and bark of M.pterygosperma have shown the lowest quantity of phenolics among all the tree species. While, the fruit pulp in L.leucocephala has found to contain neglegible amount of polyphenols. From these observations it can be suggested that almost all parts of A.arabica (except seeds), can be used as a good source of tannins. Similarly, the leaves and fruits of E.officinalis can also be used as a tannin source. Seeds of T.indica may also provide a tannin source as these have shown the highest concentration of polyphenols among those of all tree species. The seeds of most other species also contain some measurable amount of tannins. Interestingly,

the seeds of A.arabica have recorded the lowest value for phenolics.

The qualitative analysis of phenolic constituents in different parts of E.officinalis, A.arabica, P.longifolia and L.leucocephala has been depicted in Tables 15,16,17 and 18 respectively and in Fig.25 to 28, 29 to 32, 33 to 36 and 37 to 40 respectively. Among these four three species investigated for various polyphenols. E.officinalis and A.arabica, as discussed earlier, are very rich in phenolics as compared to the two other species. It is observed that the total number of phenolic compounds in the leaves and bark in these tree species varies from 17 to 28. Looking to an average number of phenolics it can be seen that there is a great diversity in L.leucocephala as, as many as 28 phenolics have been found to be present in the leaves (Table 18 and Fig.37,38,39). In the other species, the diversity of phenolics seems to be more or less identical. The bark of L.leucocephala contains as many as 25 different phenolics, which is the highest number in the bark of all the species. It should be mentioned here that due to limited number of authentic samples of phenolics and due to limited data available with respect to the Rf values of various polyphenols, we were able to identify quite a few number of phenolics on paper chromatograms.

It is evident from Table 15 and Figs.25,26,27 and 28 that the total number of phenolics present in young, mature

Table No.15 : Various polyphenols in different parts of E.officinalis

Polyphe-nol band No.	Identification	Young leaf	Mature leaf	Senescent leaf	Bark
1.	Unidentified	+	+	+	+
2.	,,	+	+	+	+
3.	,,	+	+	+	+
4.	,,	+	+	+	+
5.	,,	+	++	+	-
6.	,,	+	+	+++	-
7.	Flavan (Unidentified)	+	-	+	-
8.	Unidentified	+	-	-	-
9.	,,	+	-	-	-
10.	Flavan (Unidentified)	+	-	-	-
11.	Unidentified	+	-	-	-
12.	,,	++	+	+	-
13.	,,	++	+	+	-
13.a	,,	-	+	+	-
13.b	,,	-	+	-	-
14.	Flavan (Unidentified)	+	+	+++	-
14.a	Unidentified	-	+	+	-
14.b	,,	-	+	+	-
15.	Flavonoid	+	+++	+	+
15.a	Unidentified	+	-	-	-
16.	Caffeic acid	+	+++	++	-
17.	Unidentified	++	+++	-	-
17.a	,,	-	++	-	-
18.	,,	++	+	+	+
18.a	,,	-	+	+	++
18.b	,,	-	+	-	-
19.	,,	+	++	+	+
19.a	,,	-	+	-	-
19.b	,,	-	+	-	-

...

Table No.15 (Contd...)

Phenolic compounds	Identification	Young leaf	Mature leaf	Senescent leaf	Bark
20.	Unidentified	-	+	++	+
21.	,,	+	+	+	-
22.	,,	+	-	-	+
22.a	,,	-	-	-	+
23.	Chlorogenic acid	+	+	+	-
23.a	Flavonol	-	-	+	+
23.b	Unidentified	-	-	+	-
24.	,,	++	-	+	-
24.a	,,	-	-	+	-
A	,,	-	-	+	+
B	Chlorogenic acid	-	-	-	+
C	Quinic acid	-	-	-	+
D	Unidentified	-	-	-	+
E	,,	-	-	-	++
	Total Number of phenolics	24	26	26	17

+ Present

++ Present in appreciable amounts.

+++ Prominent

- Absent

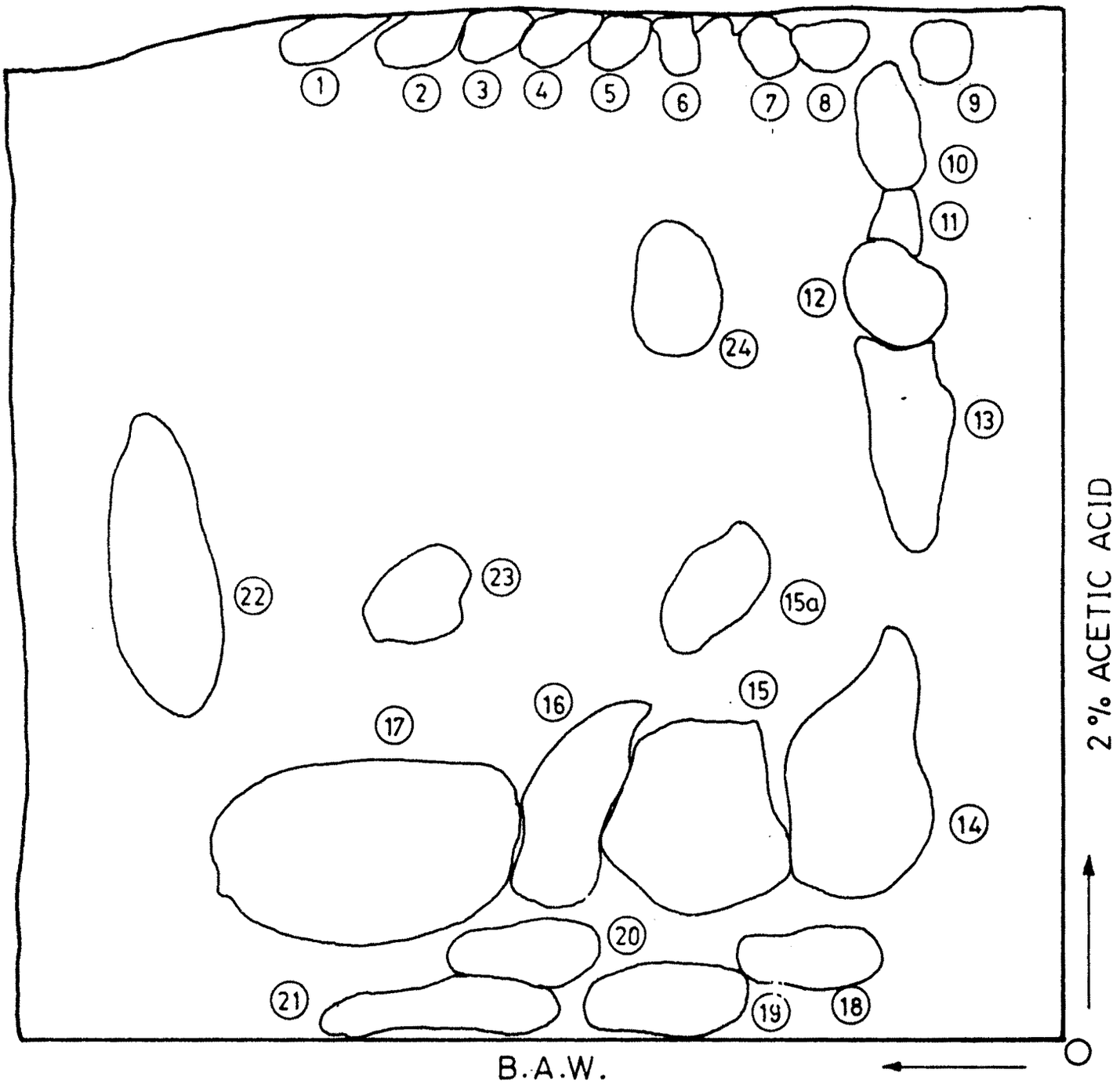

FIG. 25 POLYPHENOLS IN THE SOLUBLE FRACTION OF <u>EMBLICA</u> <u>OFFICINALIS</u> YOUNG LEAVES.

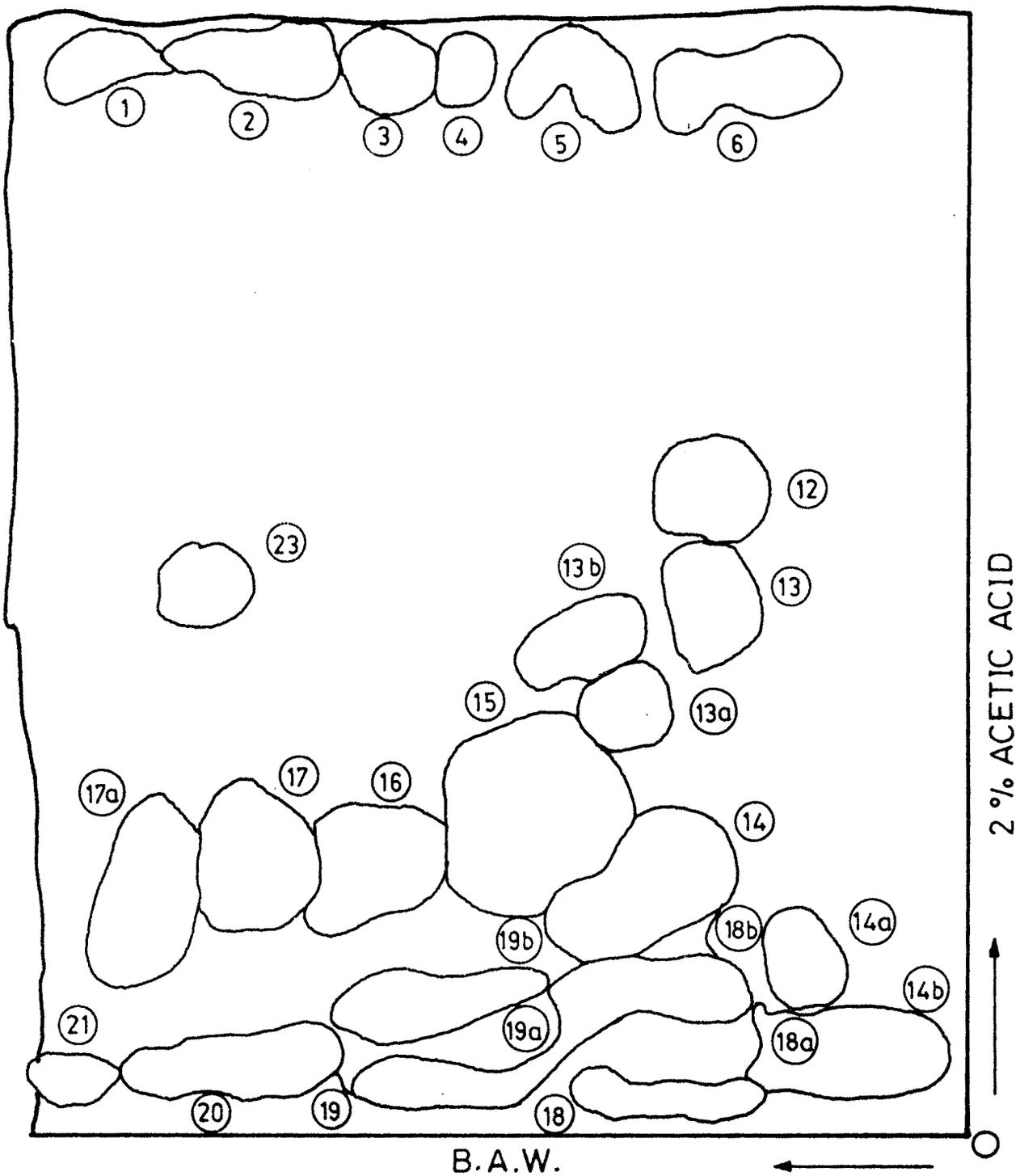

FIG.26 POLYPHENOLS IN THE SOLUBLE FRACTION OF EMBLICA OFFICINALIS MATURE LEAVES.

and senescent leaves of E.officinalis is 24, 25 and 26 respectively. While, the bark contains only 17 different type of polyphenols. Phenolic compounds bearing the numbers 1,2,3,4, 18 and 10 (unidentified), and a flavonoid, commonly occur in the leaves at all developmental stages and also in the bark. Unidentified polyphenols bearing the numbers 18 a, 20, 22 and A (unidentified) and flavonol are found to be present either in one or the other stages of leaf development and also in bark. Unidentified phenolics 5,6,8,9,11,12,13,13a,13b, 14a, 14b, 15a, 17, 17a, 23b, 24 and 24a and unidentified flavan, caffeic acid and chlorogenic acid are found only in the leaves. On the other hand unidentified phenolics 22, 22a, D, E, chlorogenic acid and quinic acid are found only in the bark of E.officinalis. It is also evident that in young leaves, unidentified polyphenols bearing numbers 12, 13, 17, 18 and 24 seem to be dominent over other polyphenols. In the mature leaves, however, polyphenols, 5, 17 and 19 and flavonoids and caffeic acid predominate. In senescent leaves unidentified phenolics 6 and caffeic acid are the concentrated phenolics. In the bark unidentified phenolics 18 a and E are more dominant. It is also clear that the level of certain phenolics increases during senescence (phenolic compounds bearing number 6,20 and flavan). The amount of unidentified phenolic compounds 12, 13 and 19 and flavonoid and caffeic acid are decreased during senescence. Even phenolics 17, 17a, 18b, 19a and 19b disappear during senescence. Some polyphenols are found only in the

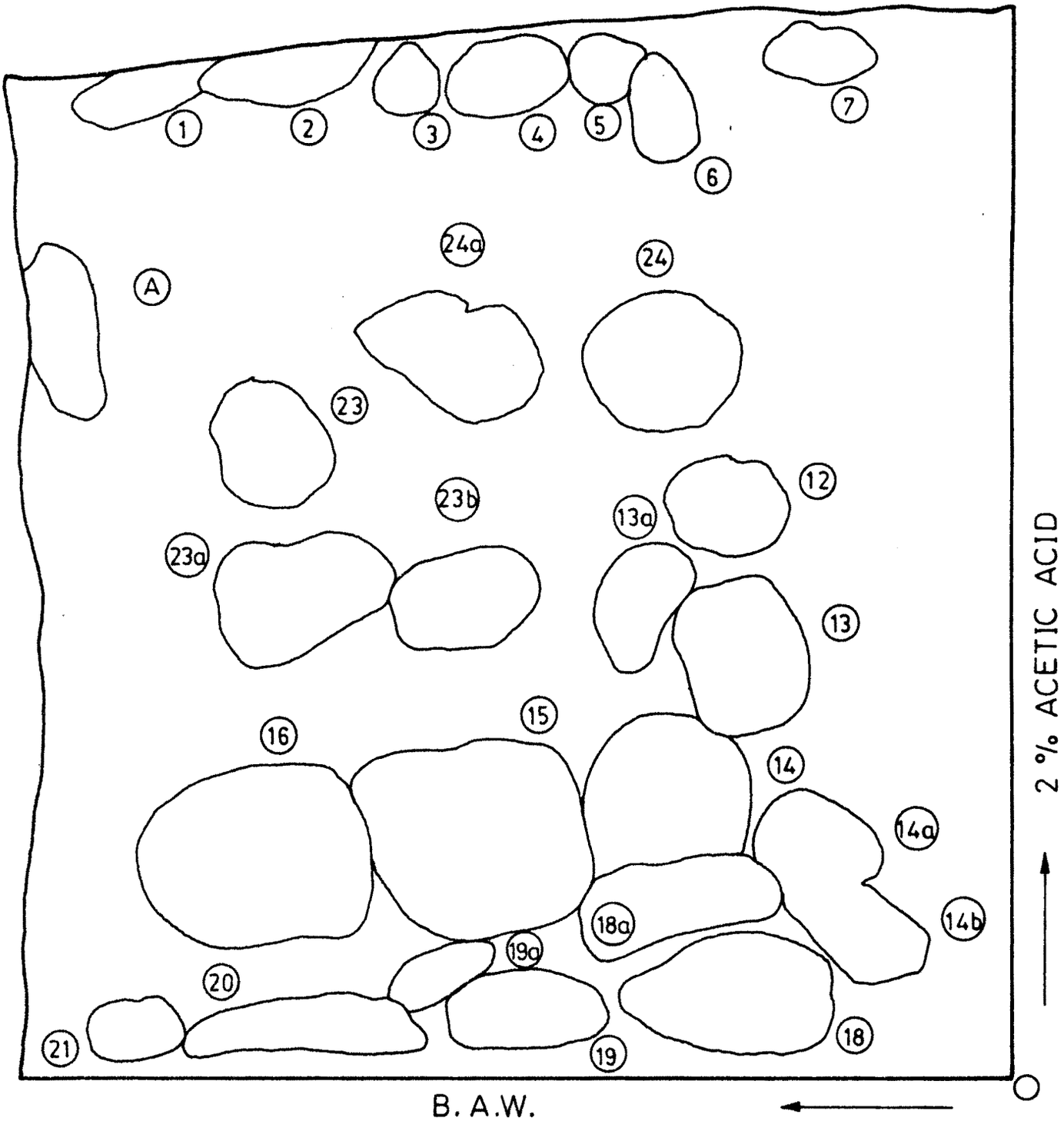

FIG. 27 POLYPHENOLS IN THE SOLUBLE FRACTION OF EMBLICA OFFICINALIS SENESCENT LEAVES.

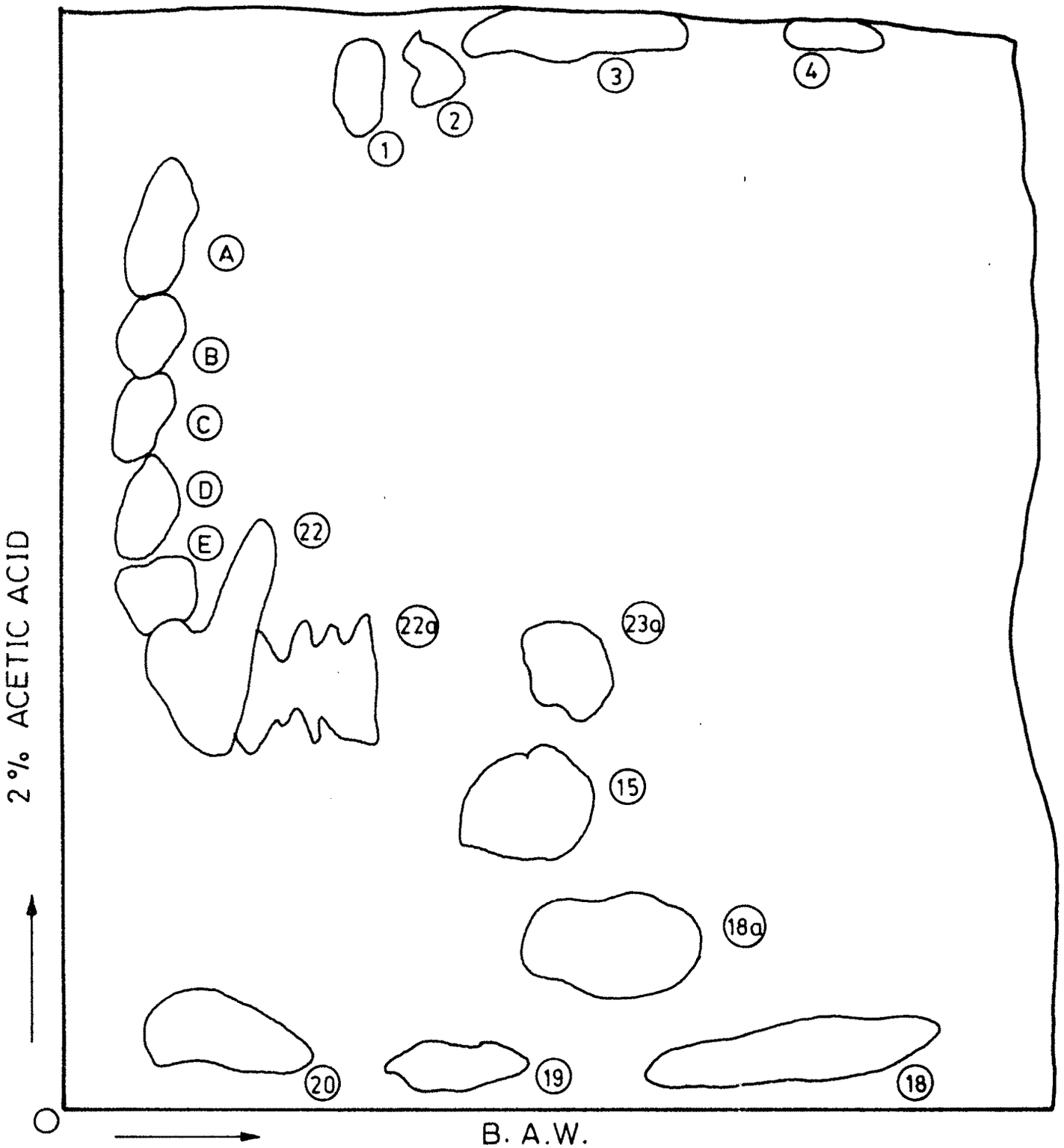

FIG. 28 POLYPHENOLS IN THE SOLUBLE FRACTION OF EMBLICA OFFICINALIS BARK.

senescent leaves. These are flavonol and some four unidentified phenolics bearing the numbers 23a, 23b, 24a and A. It can be concluded that flavonoids, caffeic acid and some unidentified phenolics (6 and 17) are more dominant over others in E.officinalis. It can also be said that not only the quantitative change but also the qualitative change is brought about in phenolic constituents of the developing leaves of E.officinalis.

Various polyphenols in the developing leaves and bark of A.arabica have been recorded in Table 16 and Fig.29,30,31 and 32. It is observed that the leaves at all developmental stages and bark contain almost the same number of phenolics. Unidentified polyphenols bearing the numbers, 1,2,3,4,5,6,7,10 and 18 and flavan, caffeic acid derivative and flavonol are the common phenolics found in the leaves at all developmental stages and also in the bark. Unidentified polyphenols 6a, 8,9,11,11a, 16 and flavonoids are found in the bark as well as in the leaves at one or the other developmental stage. Polyphenols 5b, 11c, 12, 14a, 15, 17, 17a, 17b and 20 and flavan and flavonoid are found to be present only in the leaves. While, phenolic compound 10a is present only in the bark. It is also clear that there are 21 different polyphenols present in the young leaves. Polyphenol number 9 is predominant here. In the mature leaves there are 23 different phenolics among which the compounds bearing numbers 6, 6b, 7 and 11 are at the higher concentrations as compared to that of other phenolics. In the

Table No.16 : Various polyphenols in different parts of *A. arabica*

Polyphenol band No.	Identification	Young leaf	Mature leaf	Senescent leaf	Bark
1.	Unidentified	+	+	+	+
2.	,,	+	+	+	+
3.	,,	+	+	+	+
4.	,,	+	+	+	+
5.	,,	+	+	+	+
5(a)	Flavan (Unidentified)	+	+	+	-
5(b)	Unidentified	+	+	++	-
5(c)	Flavan (Unidentified)	+	-	-	-
6.	Unidentified	+	+++	+	+
6(a)	,,	+	-	-	+
6(b)	Flavan (Unidentified)	+	++	+	+
7.	Unidentified	+	++	+	++
8.	,,	+	-	-	+
9.	,,	+++	+	-	+
10.	,,	+	+	+	+
10(a)	,,	-	-	-	+
11.	,,	+	++	-	+
11(a)	,,	-	-	+	+
11(b)	Flavonoid	-	-	+	+
11(c)	Unidentified	-	-	+	-
12.	,,	+	+	+	-
13.	Caffeic acid derivatives	+	+	+	+
14.	Flavonol (Unidentified)	+	+	+	+
14(a)	Unidentified	-	+	-	-
15.	,,	+	-	+	-

Table No.16 (Contd...) :

Polyphenol band No.	Identification	Young leaf	Mature leaf	Senescent leaf	Bark
16.	Chlorogenic acid derivative	-	+	+	+
17.	Unidentified	-	+	-	-
17(a)	,,	-	+	-	-
17(b)	,,	-	+	-	-
18.	,,	+	+	+	+
19.	Flavonoid	-	+	+	-
20.	Unidentified	-	-	+	-
	Total number of phenolics	21	23	22	20

+ Present

++ Present in appreciable amounts

+++ Prominent

- Absent

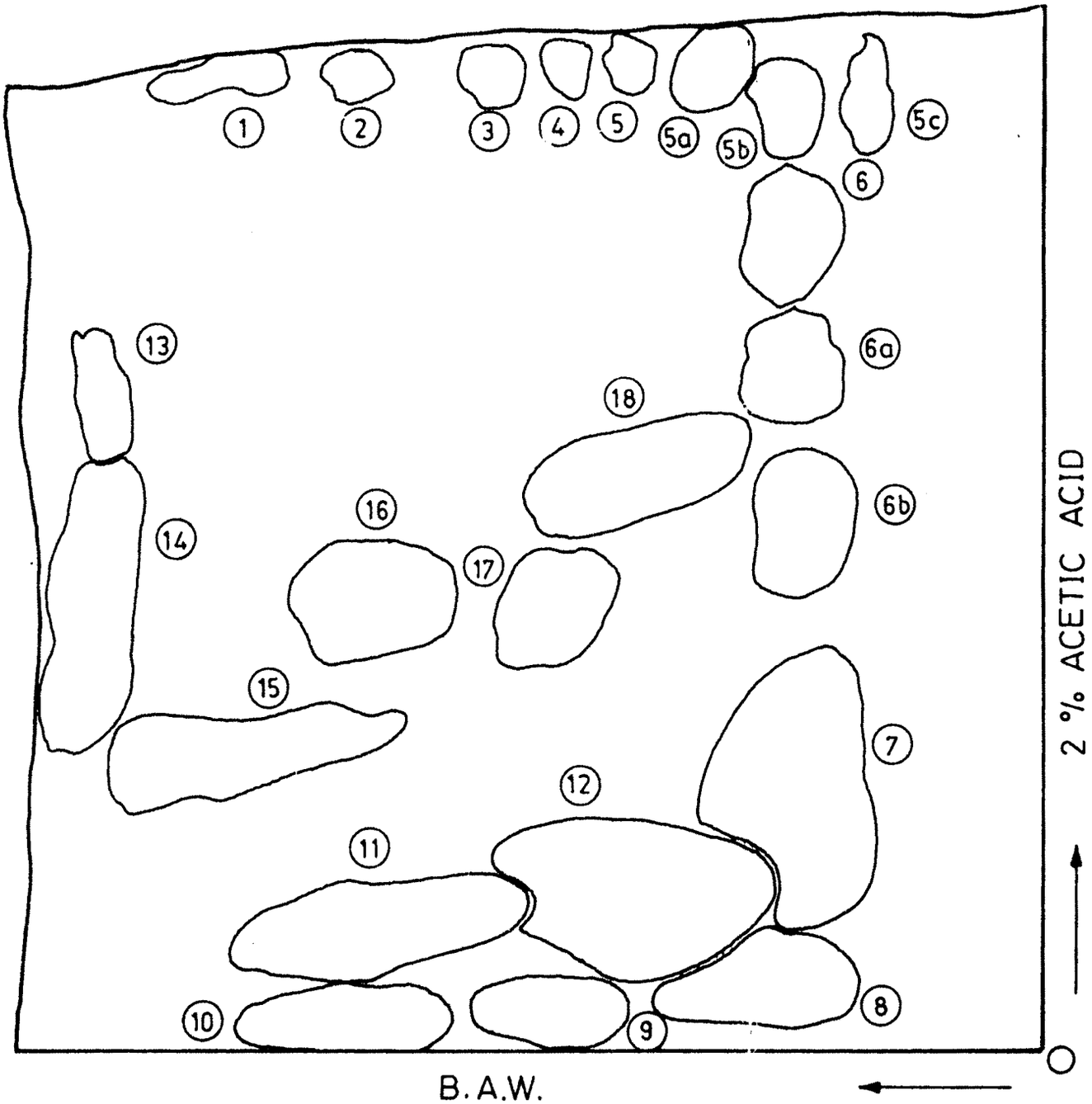

FIG.29 POLYPHENOLS IN THE SOLUBLE FRACTION OF <u>ACACIA ARABICA</u> YOUNG LEAVES.

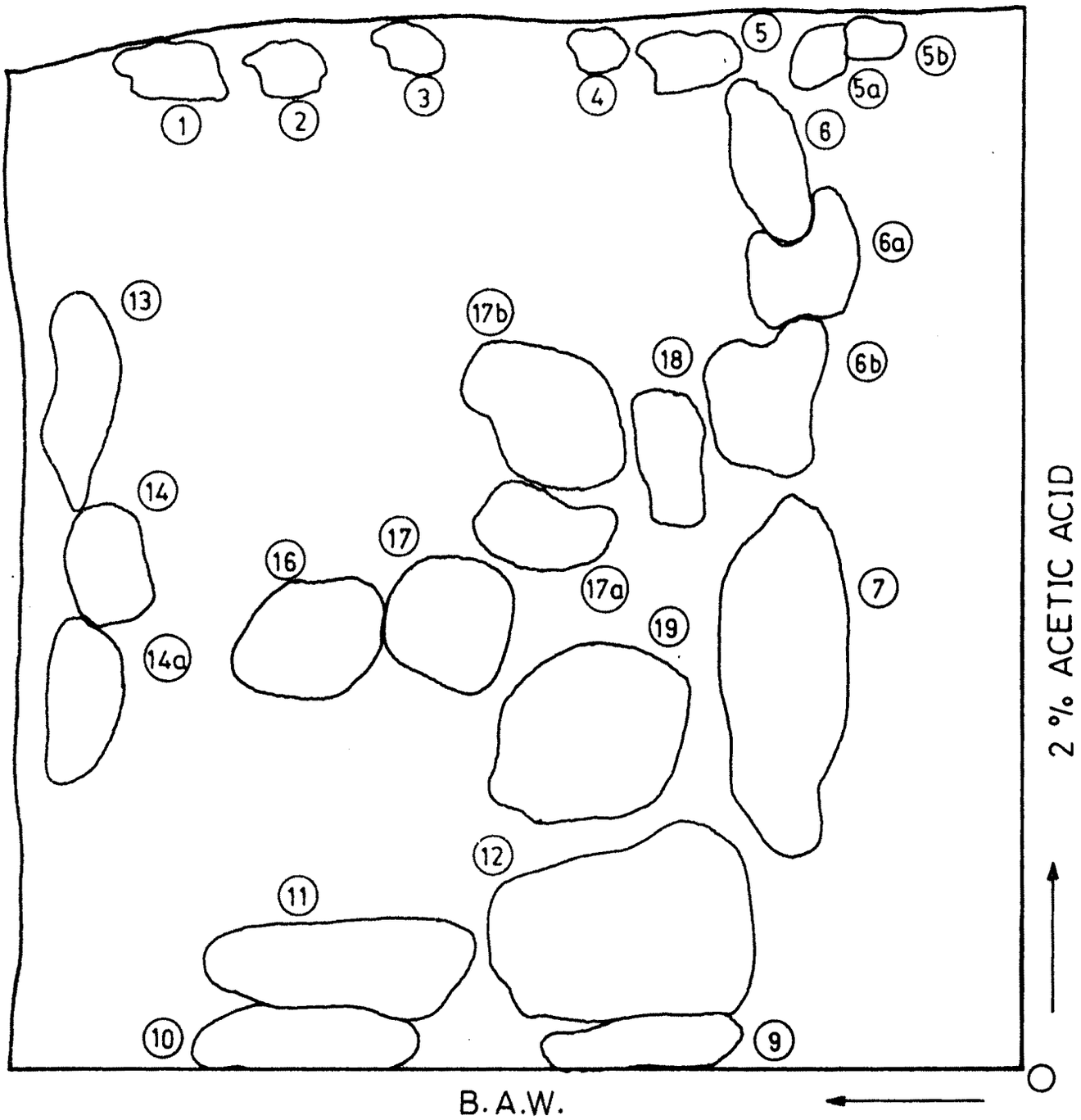

FIG.30 POLYPHENOLS IN THE SOLUBLE FRACTION OF <u>ACACIA</u> <u>ARABICA</u> MATURE LEAVES.

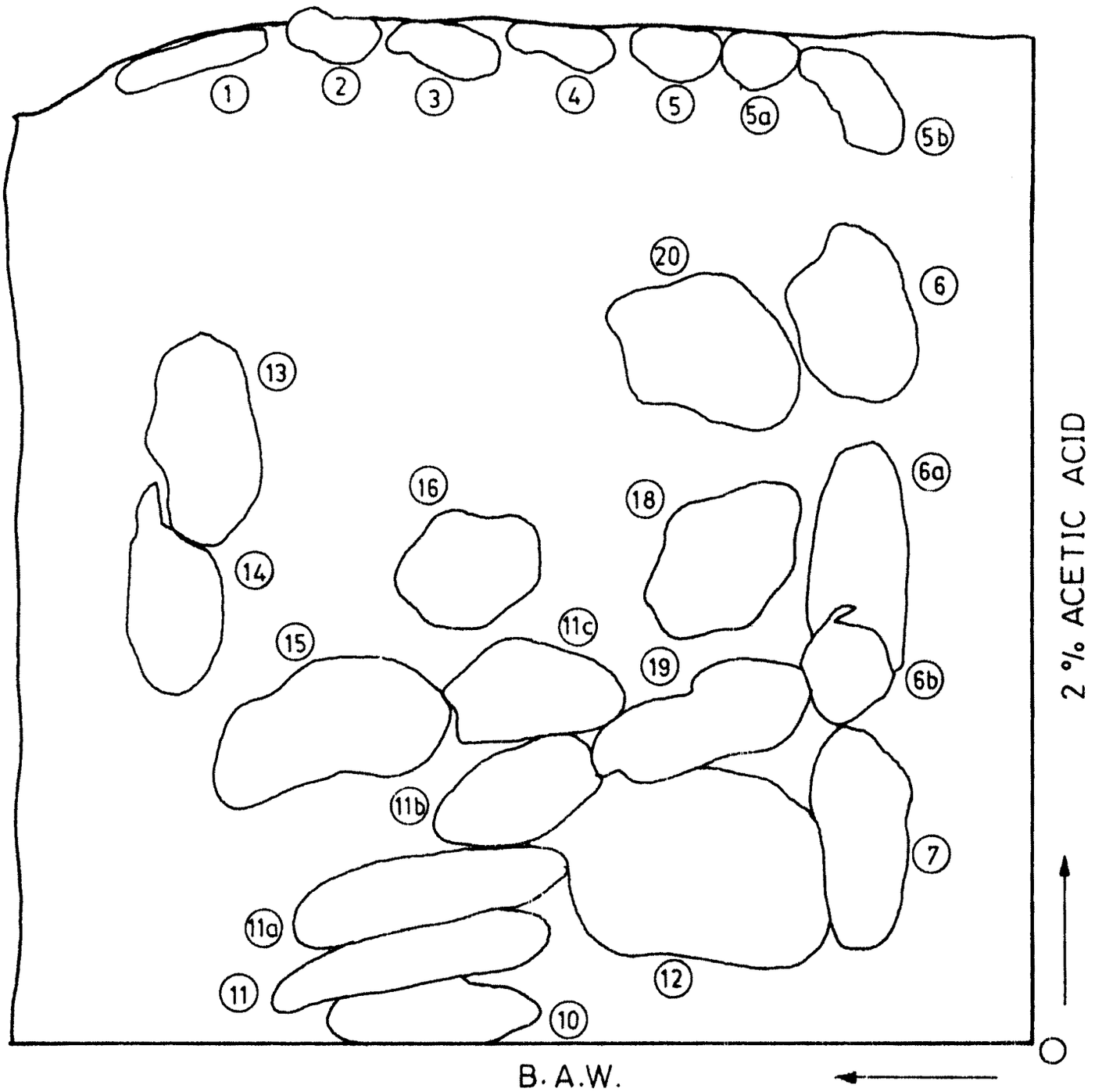

FIG. 31 POLYPHENOLS IN THE SOLUBLE FRACTION OF <u>ACACIA</u> <u>ARABICA</u> SENESCENT LEAVES.

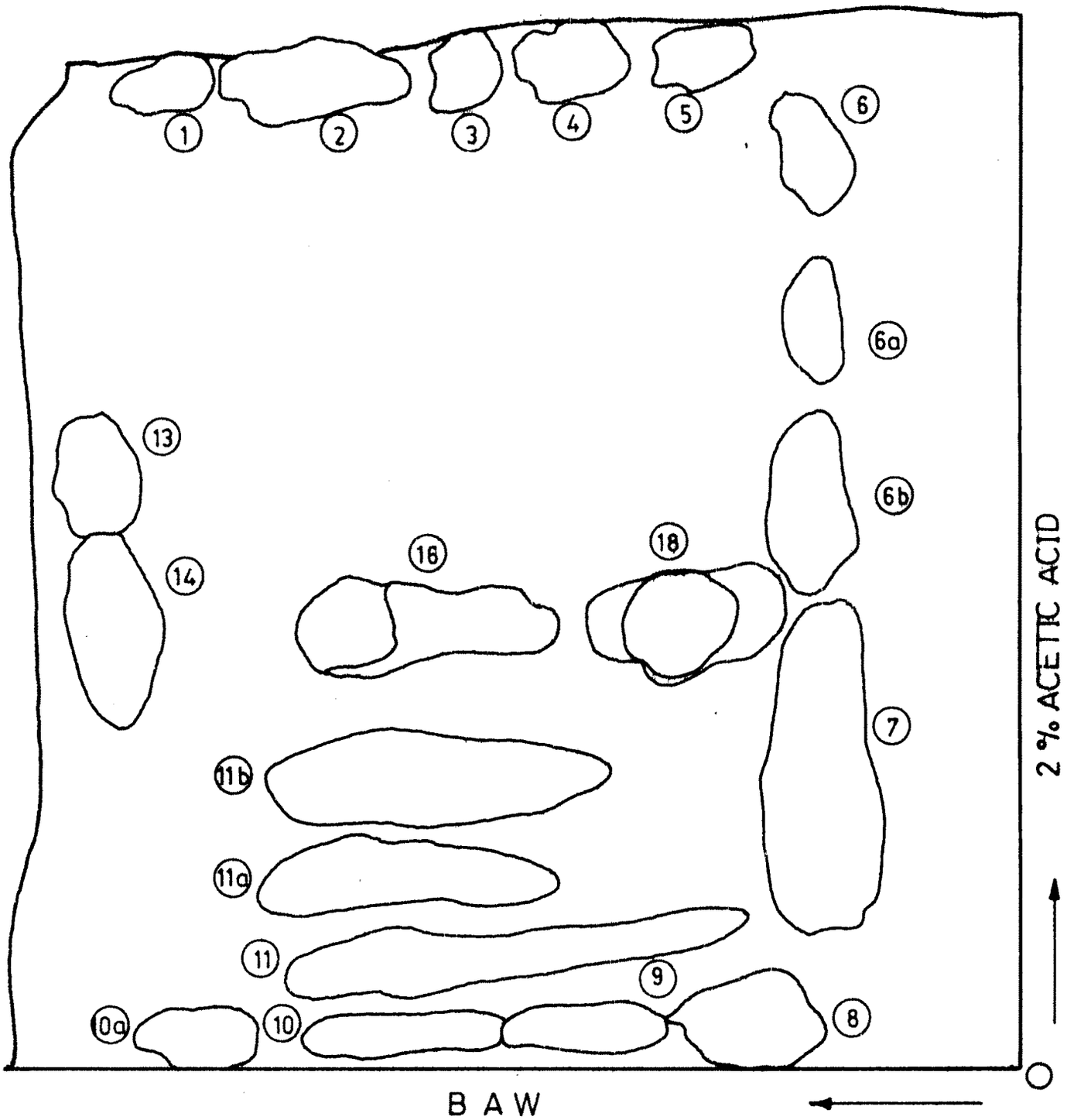

FIG. 32 POLYPHENOLS IN THE SOLUBLE FRACTION OF ACACIA ARABICA BARK.

bark no phenolic is at the higher concentration. It is evident that phenolics, 1,2,3,4,5,5a,5b, 10,12,13,14 and 18 remain almost unchanged during leaf development. However, phenolic compounds with numbers 6,7,11 and flavan seem to be accumulated in the mature leaves. There is disappearance of some unidentified flavans and the phenolics having numbers 6a,8,9,11,14a,17,17a and 17b during leaf senescence. Phenolic compounds 11a, 11c and 20 and some flavonoids appear only in the senescent leaves. In case of A.arabica also there are lot of phenolic composition changes, mostly with quality and not quantity during leaf ontogeny.

The phenolic composition of the leaves (young, mature and senescent) and bark of P.longifolia has been recorded in Table 17 and Fig.33, 34, 35 and 36. It can be seen that the young leaf of this tree species contains higher number of polyphenols as compared to that of mature and senescent leaves and bark. The young leaves have, as many as 25 different phenolics. While, mature and senescent leaves and the bark of P.longifolia contain respectively, 18, 20 and 18 polyphenols. Unidentified phenolic compounds 1,2,3,5,9,15,16 and 17 and caffeic acid derivatives and flavonol are found both in bark as well as in the leaves at every developmental stage. Phenolic compounds bearing numbers, 18a, 'd', 'e' and 'f' are also common to both bark as well as leaf. But, these are present in the leaf either at one or the other stage of

Table No.17 : Various polyphenols in different parts of *P.longifolia*

Polyphenol band No.	Identification	Young leaf	Mature leaf	Senescent leaf	Bark
1.	Unidentified	+	+	+	+
2.	,,	+	+	+	+
3.	,,	+	+	+	+
4.	Caffeic acid derivatives	+	+	+	+
5.	Unidentified	+	+	+	+
5(a).	,,	-	+	-	-
6.	,,	+	-	+	-
6(a)	,,	-	-	+	-
7.	,,	+	-	+	-
8.	Flavonol	+	+	+	+
8(a).	Unidentified	-	+	-	-
9.	,,	++	+	+	+
10.	Flavonol	++	+	-	-
10(a).	Unidentified	-	+	-	-
11.	,,	+++	+++	+++	-
12.	,,	++	+	+	+
13.	,,	+	-	-	-
14.	,,	+	-	-	-
15.	,,	+	+	++	+
16.	,,	+	+	+	+
17.	,,	+	+	+	+
18.	,,	++	-	-	+
19.	,,	+	-	-	-
20.	,,	+	-	-	-
21.	Flavonoid	+	-	-	-
22.	Unidentified	+	-	-	-
23.	Flavonoid	+	-	-	-

Table No.17 (Contd...) :

Polyphenol band No.	Identification	Young leaf	Mature leaf	Senescent leaf	Bark
23(a).	Ferulic acid	+	-	-	-
a.	Catechin	-	++	++	-
b.	Unidentified	-	+	-	-
c.	Flavan (Unidentified)	-	-	+	++
d.	Unidentified	-	-	+	+
e.	Flavonol (Unidentified)	-	-	+	+
f.	Caffeic acid	-	-	+	+
g.	Unidentified	-	-	-	+
h.	,,	-	-	-	+
	Total No.of phenolics	25	18	20	18

+ Present

++ Present in appreciable amounts

+++ Prominent

- Absent

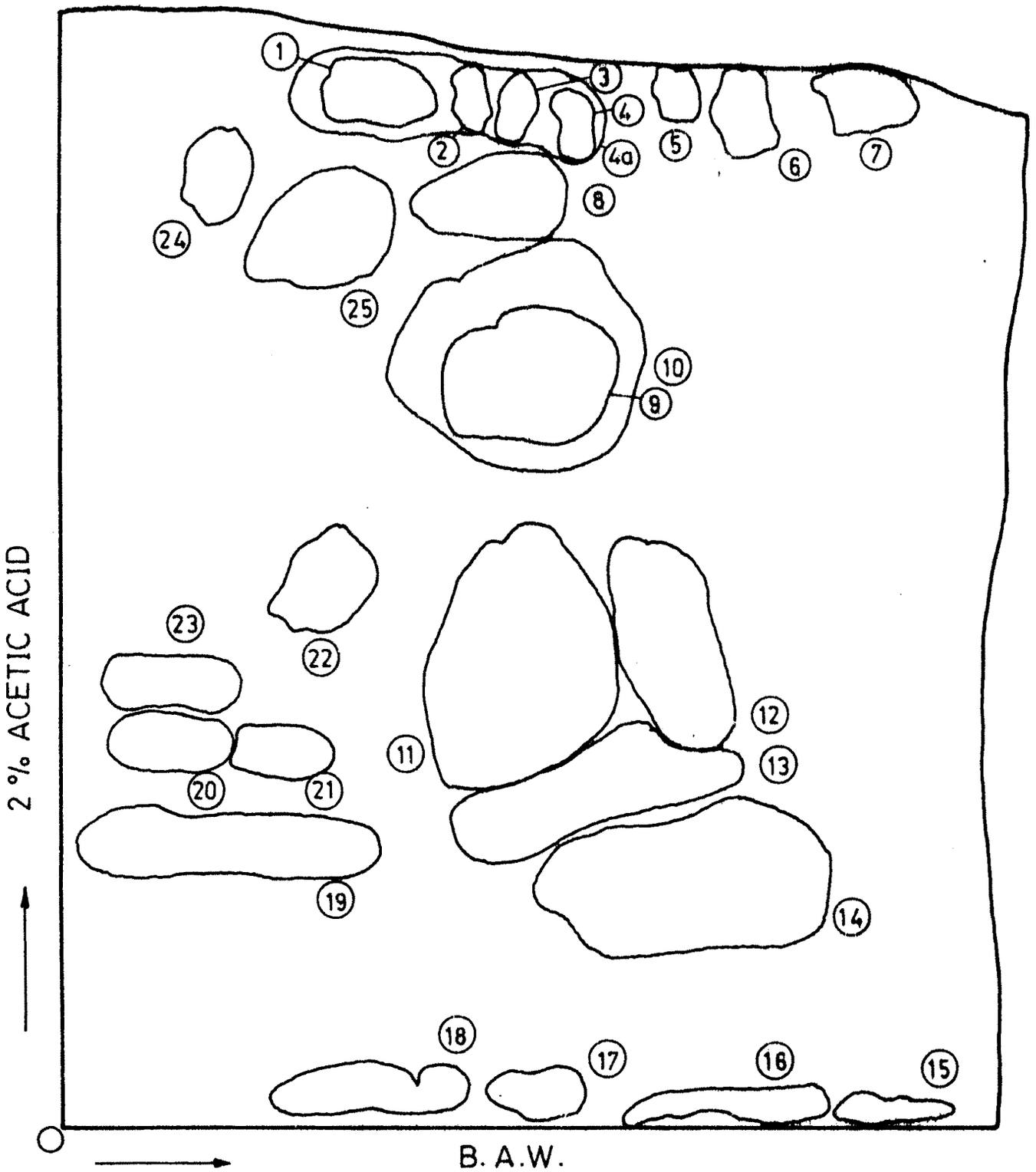

FIG. 33 POLYPHENOLS IN THE SOLUBLE FRACTION OF <u>POLYALTHIA LONGIFOLIA</u> YOUNG LEAVES.

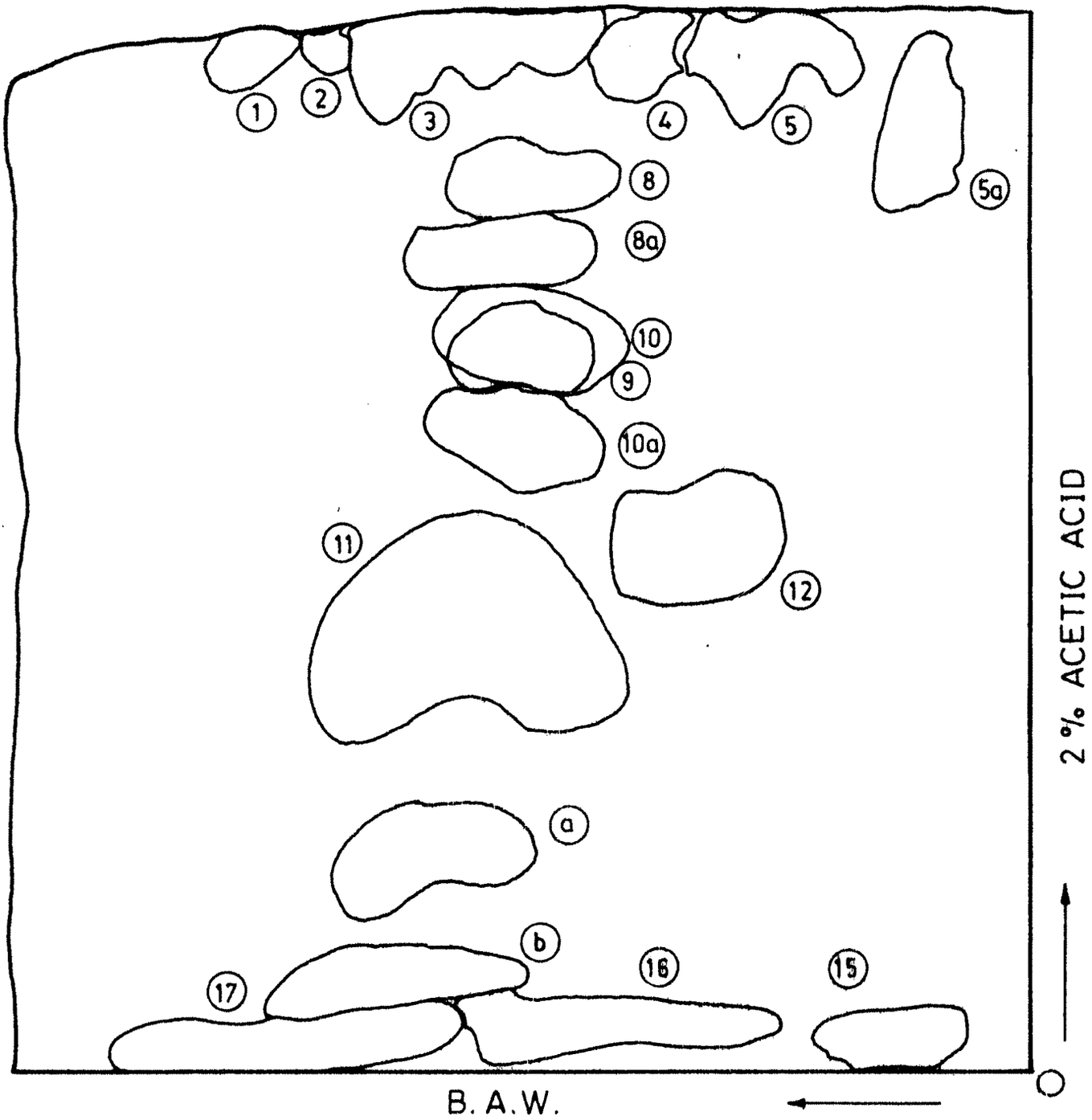

FIG. 34 POLYPHENOLS IN THE SOLUBLE FRACTION OF <u>POLYALTHIA LONGIFOLIA</u> MATURE LEAVES.

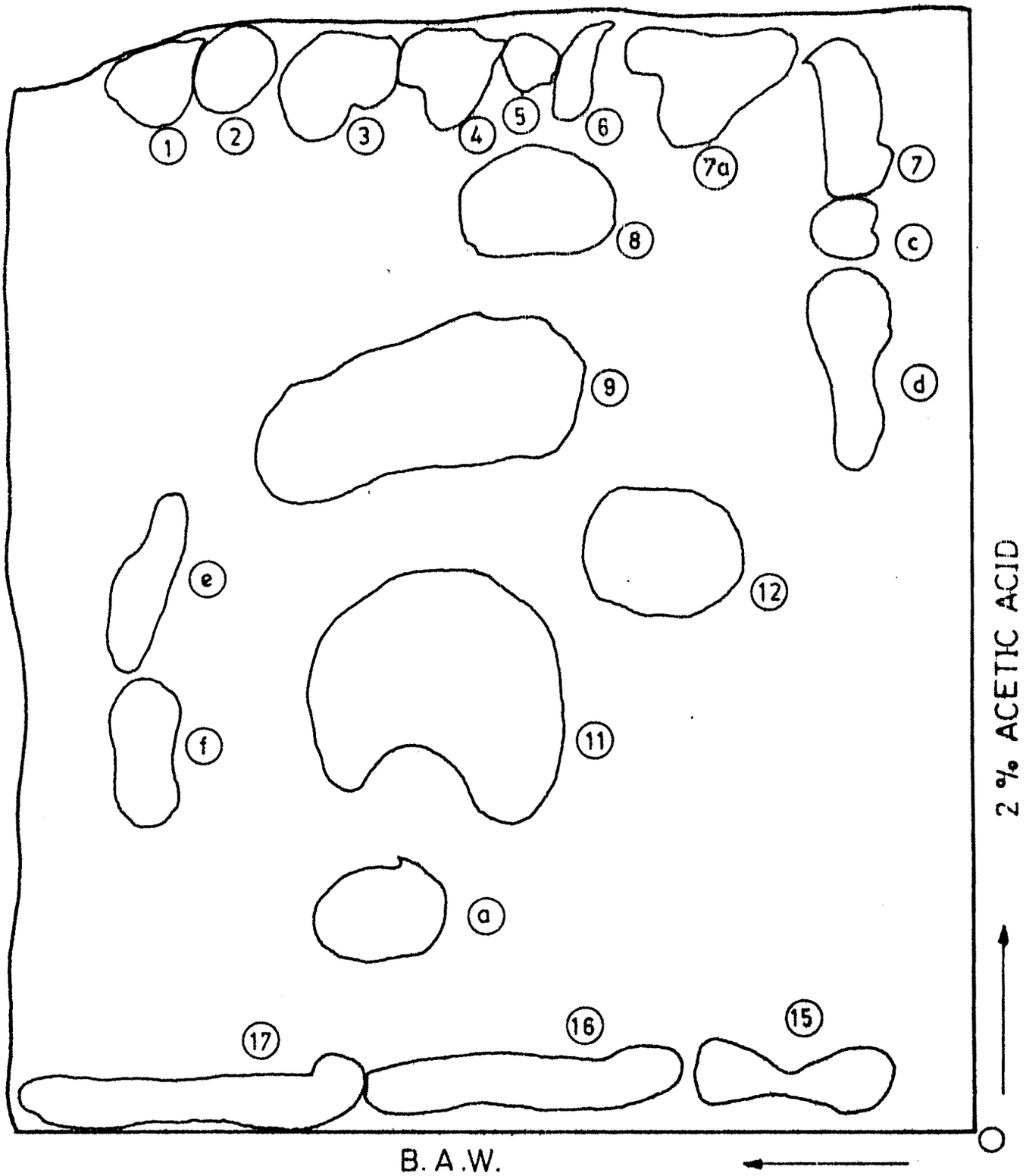

FIG. 35 POLYPHENOLS IN THE SOLUBLE FRACTION OF POLYALTHIA LONGIFOLIA SENESCENT LEAVES.

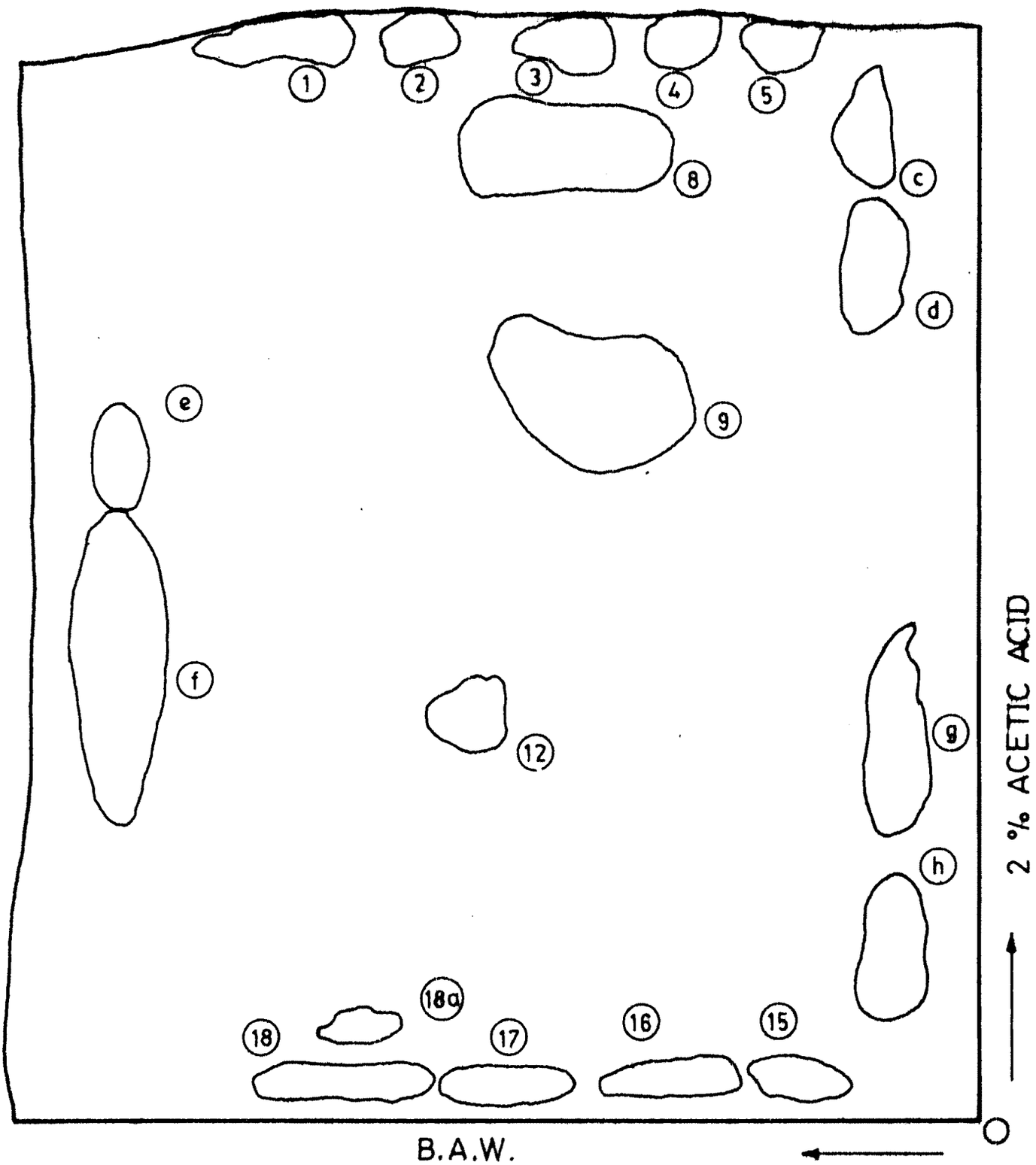

FIG.36 POLYPHENOLS IN THE SOLUBLE FRACTION OF POLYALTHIA LONGIFOLIA BARK.

development. Phenolics, 5a, 6, 6a, 7, 8a, 10a, 11, 13, 14, 19, 20, 23 'b' flavonol, flavonoids, ferulicacid, caeffeic acid and catechin are found only in the leaves and not in the bark. Unidentified phenolic compounds g and h are present only in the bark. In the leaves unidentified phenolic compounds 11, 15, 18 and catechin seem to be dominant in the leaves. In the bark it is flavan which shows the higher concentration. A remarkable change in the composition of leaves occurs during leaf maturity and senescence. It can be seen that the number of phenolics in the young leaves disappear during maturity. Phenolic compounds 6, 7, 13, 14, 18, 19, 20, 23, 24, 24a, 25 and some flavonoids which are present in the young leaves are found to be absent in the mature leaves. Even the concentration of flavanol falls down in the mature leaf and further no trace of it is observed in the senescent leaf. There is slight increase in the concentration of phenolic compound 15 during senescence. The number of phenolics those occur in senescent leaves, e.g. unidentified phenols c, d, e, f and unidentified flavan are present in mature leaves. It appears that P.longifolia leaf is also not an exception to the earlier two plants for their change in phenolic composition during leaf ontogeny. Unidentified flavans seem to dominate the other phenolics in the bark.

Table 18 and Fig.37, 38, 39 and 40 record various polyphenols in young, mature and senescent leaves and bark of

Table No.18 : Various polyphenols in different parts of *L.leucocephala*.

Polyphenol band No.	Identification	Young leaf	Mature leaf	Senescent leaf	Bark
1.	Unidentified	-	+	-	-
2.	,,	-	+	+	-
3.	,,	-	+	+	+
4.	,,	-	+	+	+
5.	,,	+	-	-	+
6.	,,	+	++	-	+
7.	,,	++	++	+	+
8.	,,	++	+	+	+
9.	,,	-	-	+	+
10.	,,	+++	+++	++	+
11.	,,	-	+	+	+
12.	,,	-	-	+	-
13.	,,	-	+	+	-
14.	,,	-	+	+	+
15.	,,	+++	++	-	++
17.	,,	-	+	+	+
18.	Proanthocyanidin	-	+	++	+
19.	Quercetin	-	+++	++	+
19(a).	Quinic acid	-	-	-	+
20.	Epicatechin + gallic acid	+++	+++	++	++
21.	Flavonoid	+++	++	++	+
22.	Unidentified	++	++	+	-
23.	,,	+	+	-	+
24.	,,	+	+	-	+
25.	,,	++	-	-	-

...

Table No.18 (Contd...) :

Polyphenol band No.	Identification	Young leaf	Mature leaf	Senescent leaf	Bark
26.	Flavan (Unidentified)	+	+	-	-
27.	Unidentified	+	+	-	-
28.	,,	+	-	-	-
29.	,,	++	-	-	-
30.	,,	++	-	++	-
31.	Quinic acid	+	+	+	++
32.	Unidentified	+	++	++	-
33.	Caffeic acid derivatives	+	+	-	+
34.	Unidentified	-	+	-	-
35.	,,	-	+	++	-
35(a).	,,	-	-	++	-
a.	Flavonol	-	-	+	+
b.	Chlorogenic acid	-	-	+	++
c.	Unidentified	-	-	+	-
d.	,,	-	-	+	-
e.	,,	-	-	+	+
	Total number of phenolics	21	28	27	25

+ Present

++ Present in appreciable amounts

+++ Prominent

- Absent

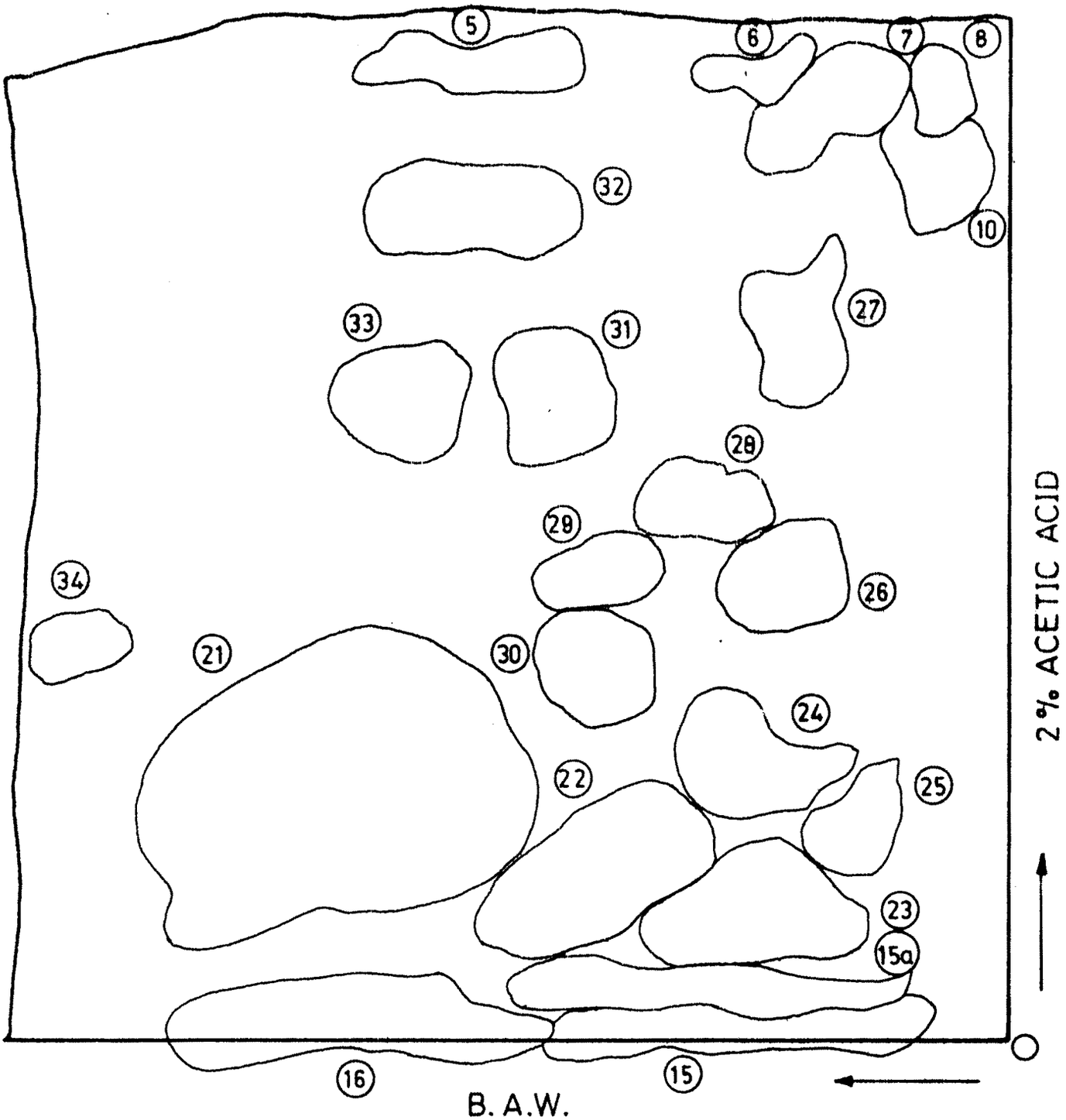

FIG. 37 POLYPHENOLS IN THE SOLUBLE FRACTION OF LEUCAENA LEUCOCEPHALA YOUNG LEAVES.

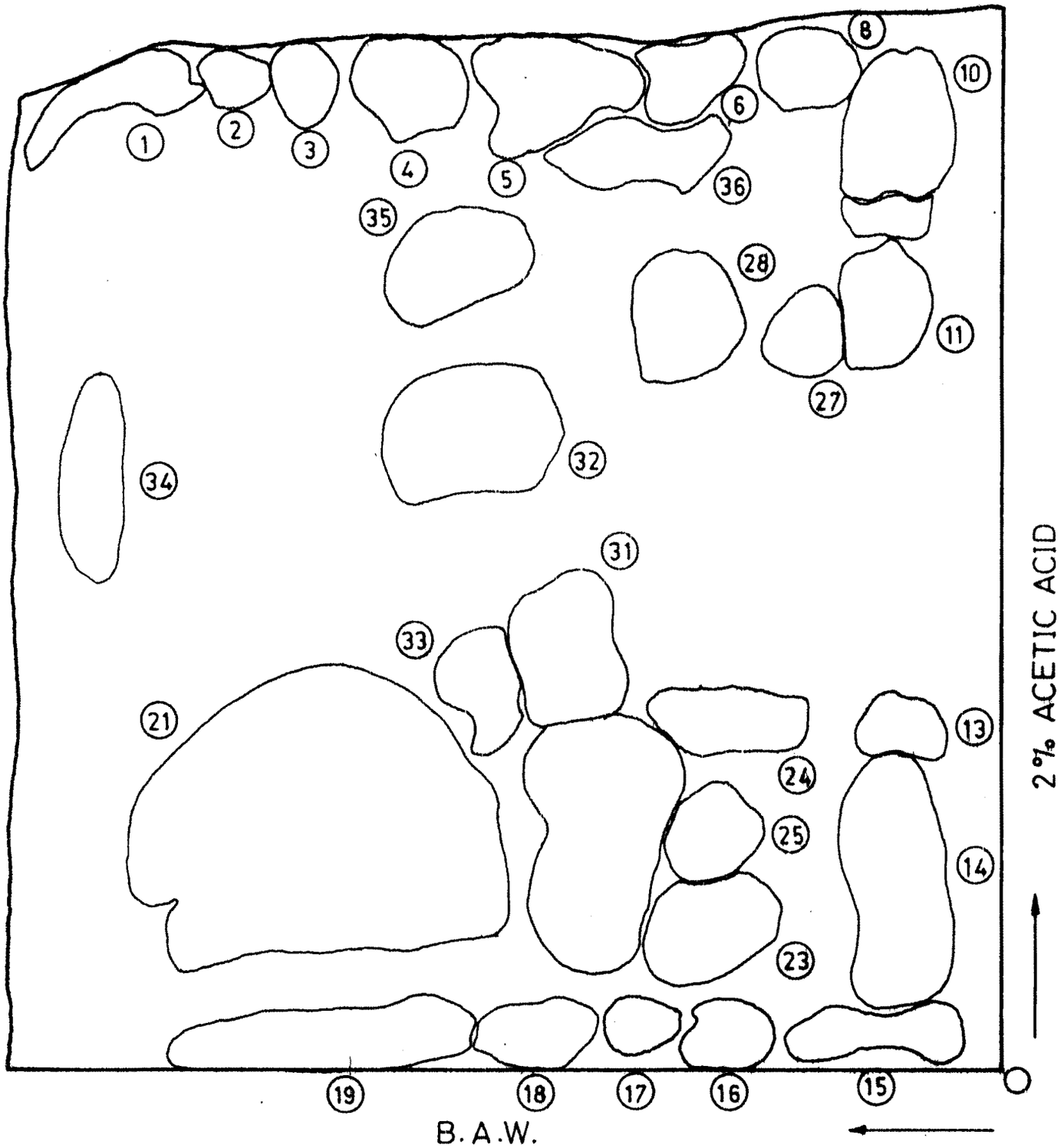

FIG.38 POLYPHENOLS IN THE SOLUBLE FRACTION OF LEUCAENA LEUCOCEPHALA MATURE LEAVES.

L.leucocephala. It is evident that there are 21, 28 and 17 phenolic compounds respectively in the young, mature and senescent leaves of L.leucocephala. The bark of this species contains as many as 25 phenolics. Unidentified phenolic compounds 7, 8, 10 epicatechin, gallic acid and flavonoids are the common phenolics occuring in young, mature and senescent leaves and bark. Unidentified phenolics 3,4,5,6,9,11, 14,15,17,24, 25'e', flavans proanthocyanidin, quercetin, caffeic acid derivatives, flavonol and chlorogenic acid are also common to leaf and bark, but are present in the leaf at one or the other stage of development. Unidentified phenolics 1,2,12,13,23,26,28,29,30,31,33,35,36,36a,c,d and e and flavans can be considered as the leaf phenolics in L.leucocephala. Quinic acid is found only in the bark of this species. It can be seen that in the young leaves, phenolic compounds, 7,8, 10, 15, 23, 26, 30, 31, flavans, epicatechin, gallic acid and flavonoids are predominant. Phenolic compounds 6,7,10,15,23, quercetin, epicatechin, gallic acid and flavonoids show the higher concentration in the mature leaves. During senescence the concentration of phenolic compounds, 10, 33, 36, 36a, proanthocyanidin, quercetin, epicatechin, gallic acid and flavonoids is kept relatively higher than that of other phenolics. Unidentified compounds 1,2,3,4,9,11,12, 13, 14, 17, 35, 36, proanthocyanidin and quercetin are found only during the later stages of leaf development. Further, flavonol,

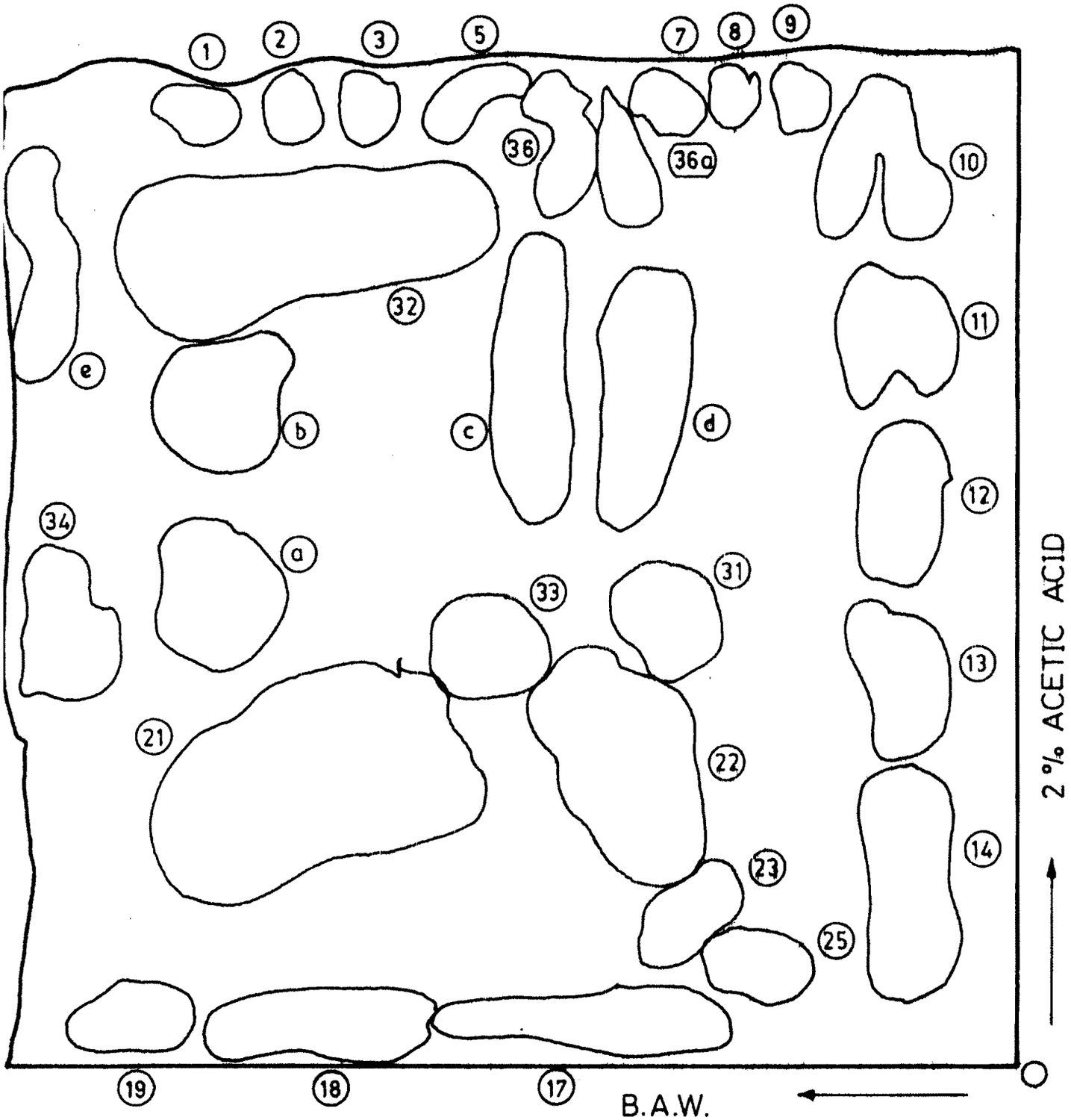

FIG. 39 POLYPHENOLS IN THE SOLUBLE FRACTION OF LEUCAENA LEUCOCEPHALA SENESCENT LEAVES.

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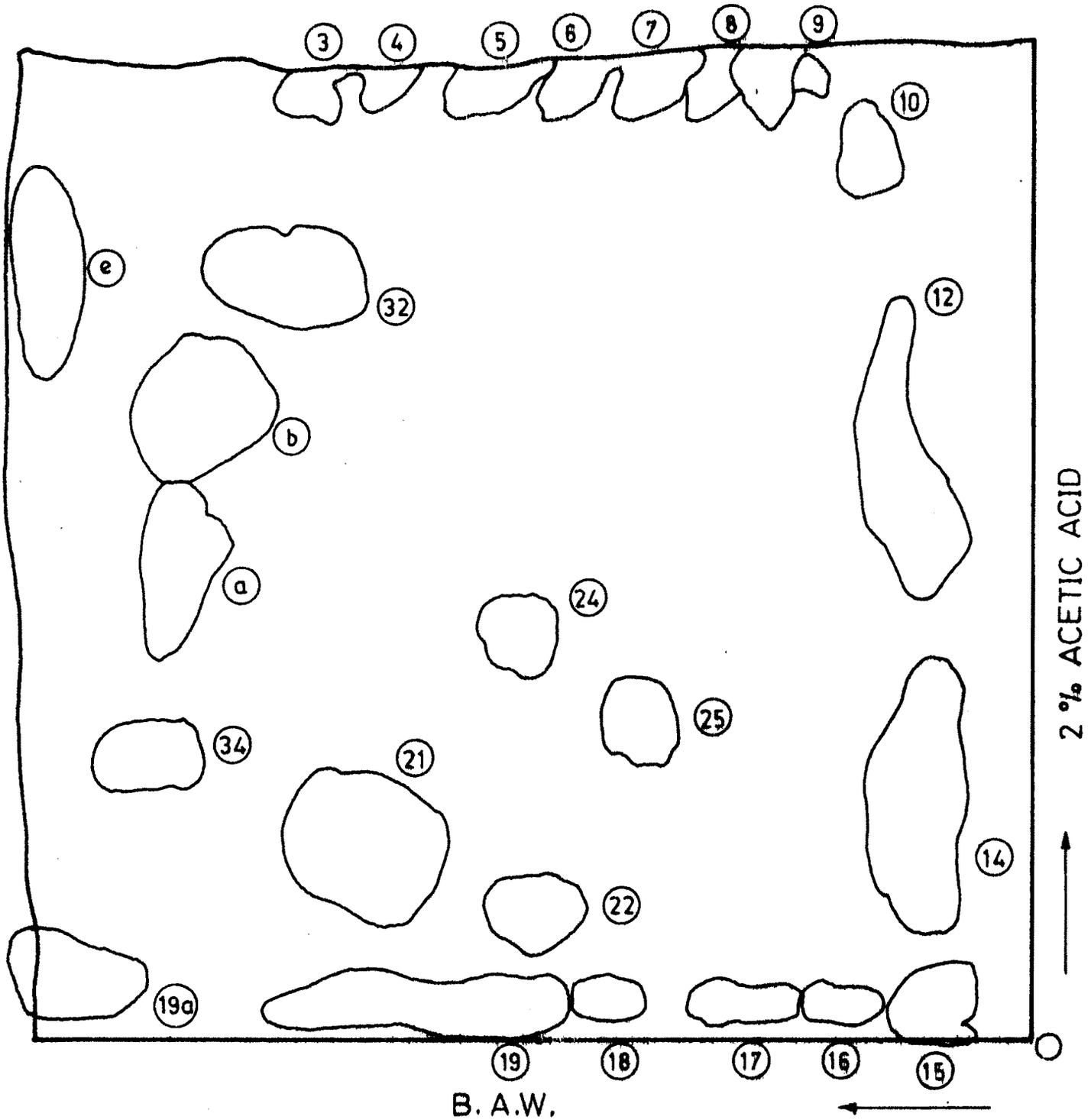

FIG. 40 POLYPHENOLS IN THE SOLUBLE FRACTION OF LEUCAENA LEUCOCEPHALA BARK.

chlorogenic acid and unidentified phenolics c,d,e, 9, 12 and 36 a appear only in the senescent leaves. Thus there are lot of changes in the phenolic composition of the leaves of L.leucocephala during their ontogeny. Epicatechin, quallic acid and chlorogenic acid are dominant in the bark of L.leucocephala.

From the foregoing discussions on polyphenols in tree species, it can be said that the polyphenol composition and concentration varies from species to species and even from organ to organ in a single species. Not only this, but also the qualitative and quantitative composition of phenolics remarkably change during leaf ontogeny. In fact, the present studies of polyphenol composition of various parts of the tree species is of the preliminary nature and hence cannot throw much light on the exact mechanism of polyphenol metabolism during leaf ontogeny. Further investigations with the help of advanced technique are highly essential, which forms a part of future investigation.