Chemistry of Natural Compounds, Vol. 33, No. 6, 1997

COMPONENTS OF COTTONPLANT LEAVES, THEIR FUNCTIONAL ROLE AND BIOLOGICAL ACTIVITY

Kh. M. Shakhidoyatov, A. M. Rashkes, and N. K. Khidyrova

UDC 633.511+581.192+578.048

This review generalizes information on the composition of the components of cottonplant leaves: hydrocarbons, organic, amino, and hydroxy acids, alcohols, triterpenes, phenolic compounds, carotenoids, sugars, pectin substances, polyisoprenoids, diols, tocopherols, sterol esters, and others. Their role in the growth and development of the plant and their biological properties are discussed.

The cotton plant (*Gossypium* L., Malvaceae), growing in tropical and and subtropical regions of Asia, America, Australia, and Africa, is represented by 35 species. One of the four cultivated species — *G. hirsutum* — grows in the republics of Central Asia, Kazakhstan, Azerbaidzhan, the USA, Mexico, Brazil, and other main cotton-planting countries.

A many-sided chemical study of the vegetative and generative organs of the cotton plant has permitted A. S. Sadykov and his students to isolate more than 100 compounds of various classes [1-3]. Cottonplant leaves (CLs) are the least used organ of the plant, although they make up 22% of the total mass of the epigeal part. Both pinched-out CLs and those gathered at the end of vegetation can be used as sources of various biologically active compounds [3]. They contain a broad set of compounds, from extremely simple to complex. Six individual saturated hydrocarbons have been isolated from the CLs and other vegetative organs and identified: tetracosane, hexacosane, octacosane, triacontane, dotriacontane, and hexatriacontane [4, 5]. The hydrocarbon composition of CLs has been characterized in [6, 7].

In addition to hydrocarbons, such high-molecular-mass alcohols as decan-1-ol, hexadecan-1-ol, heptadecan-1-ol, octadecan-1-ol, octacosan-1-ol, triacontan-1-ol, and dotriacontan-1-ol have been identified in CLs [2, 4, 5, 7].

The acid composition of CLs has been investigated in most detail. It comprises 17 [sic] organic acids [1, 2, 8, 9]: formic, acetic, valeric, oxalic, succinic, fumaric, citric, malic, isocitric, lactic, α-ketoglutaric, tartaric, pyruvic, salicylic, and *cis*-aconitic. The dynamics of the seasonal changes of such organic acids as oxalic, malic, citric, acetic, and others, have been studied. Their qualitative composition and quantitative ratio differ from variety to variety (108-F, 137-F, 2 and 3, 10964, 1306-DV) and also depend on the level at which the leaves are growing and on the vegetation period. The maximum level of organic acids is found at the end of the vegetation period, when the leaves are no longer necessary for the plant. CLs are rich in vitamins: ascorbic and nicotinic acids, riboflavin, inositol, vitamin P, and, particularly, provitamin A — carotene [2, 3]. With respect to their ascorbic acid content they approximate to tomatoes, and the ascorbic acid is present both in free and bound form. Its level scarcely changes in vegetating leaves, but falls sharply when the leaves wither, which shows its participation in photosynthesis [8]. In their citric acid content (7.5%), CLs are not inferior to lemons, pomegranates, and makhorka [3], while their level of malic acid is surpassed only by barberries and rowan berries [3]

Up to the middle 1960s there was no information in the literature characterizing the fatty acid composition of the lipids of the vegetative and the generative organs of the cotton plant, except for the seeds. Later, a substantial difference was shown between the compositions of the fatty acids in the organs and tissues of the cotton plant, which is due to their definite physiological purpose. The following fatty acids have been detected in CLs and identified (mmole-%): lauric (12:0) — 2.46; myristic (14:0) — 11.25; palmitic (16:0) — 41.47; hexadeca-6,9-dienoic (16:2) — traces; stearic* — ($18:2^{9,12}$) — 10.09; and linolenic ($18:3^{9,12,15}$) — 23.80. The amount of palmitic acid is predominating [10].

*There seems to be an omission here — Translator.

Institute of the Chemistry of Plant Substances, Academy of Sciences of the Republic of Uzbekistan, Tashkent, fax (3712) 40 64 75. Translated from Khimiya Prirodnykh Soedinenii, No. 6, pp. 773-788, November-December, 1997. Original article submitted April 28, 1997; revision submitted June 23, 1997.

0009-3130/97/3306-0605$18.00

TABLE 1. Components of Cottonplant Leaves

Name	Empirical formula	Variety, line	Lit.
	1. HYDROCARBONS		
1. Tetracosane	$C_{24}H_{50}$	108-F	4, 5, 7
2. Hexacosane	$C_{26}H_{54}$	"	"
3. Octacosane	$C_{28}H_{58}$	"	"
4. Triacontane	$C_{30}H_{62}$	108-F, L-463, L-501, L-650	4, 7
5. Dotriacontane	$C_{32}H_{66}$	108-F	"
6. Hexatriacontane	$C_{36}H_{74}$	"	"
7. Pentacosane	$C_{25}H_{52}$	108-F, L-463	7
8. Nonacosane	$C_{29}H_{60}$	L-501, L-650	"
9. Squalene	$C_{30}H_{50}$	"	"
	2. ALCOHOLS		
10. Hexacosanol	$C_{26}H_{53}OH$	108-F	2, 4, 5
11. Octacosanol	$C_{28}H_{57}OH$	108-F, L-463, L-501	2, 4, 7
12. Triacontanol	$C_{30}H_{61}OH$	108-F	"
13. Dotriacontanol	$C_{32}H_{65}OH$	"	"
14. Ceryl	$C_{26}H_{53}OH$	"	"
15. Hexadecyl	$C_{16}H_{33}OH$	"	"
16. Octadecyl	$C_{18}H_{37}OH$	"	"
17. Decyl	$C_{10}H_{21}OH$	"	"
18. Phytol	$C_{20}H_{39}OH$	L-501, L-463, L-650	7
	3. ORGANIC ACIDS		
19. Malic	$C_4H_6O_5$	108-F, 137-F	1, 2, 8
20. Citric	$C_6H_8O_7$	1306-DV	"
21 Ascorbic	$C_6H_8O_6$	"	"
22. Lactic	$C_3H_6O_3$	"	"
23. Pyruvic	$C_3H_4O_3$	"	"
24. Formic	CH_2O_2	"	"
25. Oxalic	$C_2H_2O_4$	"	"
26. Succinic	$C_4H_6O_4$	"	"
27. Tartaric	$C_4H_6O_6$	"	"
28. Fumaric	$C_4H_4O_4$	"	"
	4. FREE FATTY ACIDS		
29. Lauric	$C_{12}H_{24}O_2$	108-F	2, 10
30. Myristic	$C_{14}H_{28}O_2$	"	"
31. Palmitic	$C_{16}H_{32}O_2$	108-F L-463, L-501, L-650	7
32. Palmitoleic	$C_{16}H_{30}O_2$	"	"
33. Hexadecadienoic	$C_{16}H_{28}O_2$	"	"
34. Hexadecatrienoic	$C_{16}H_{26}O_2$	"	"
35. Stearic	$C_{18}H_{36}O_2$	"	"
36. Oleic	$C_{18}H_{34}O_2$	"	"
37. Linolenic	$C_{18}H_{30}O_2$	"	"
38. Linoleic	$C_{18}H_{32}O_2$	"	"
39 Arachidic	$C_{20}H_{40}O_2$	"	"
40. Eicosadienoic	$C_{20}H_{36}O_2$	"	"
41. Eicosatrienoic	$C_{20}H_{34}O_2$	"	"
42. Behenic	$C_{22}H_{44}O_2$	"	"
43. Tricosanoic	$C_{23}H_{46}O_2$	"	"
44. Docosadienoic	$C_{21}H_{40}O_2$	"	"
45. Lignoceric	$C_{24}H_{48}O_2$	"	"
	5. AMINO ACIDS		
46. Valine	$C_5H_{11}NO_2$	108-F	12
47 Threonine	$C_4H_9N_2O_3$	"	"
48. Serine	$C_3H_7NO_2$	"	"
49. Lysine	$C_6H_{15}NO_2$	"	"
50. Methionine	$C_5H_{11}NSO_2$	"	"
51. Tryptophan	$C_{11}H_{12}N_2O_2$	"	"
52. Histidine	$C_6H_{10}N_3O_2$	"	"
53 Arginine	$C_6H_{14}N_4O_2$	"	"
54. Leucine	$C_6H_{13}NO_2$	"	"
55. Isoleucine	$C_6H_{13}NO_3$	"	"
56. Phenylalanine	$C_9H_{11}NO_2$	"	"
	6. SUGARS		
57. Glucose	$C_6H_{12}O_6$	108-F, 1306-DV 137-F	8, 13
58. Fructose	$C_6H_{12}O_6$	"	"
59. Starch	$(C_6H_{10}O_5)_x$	"	"
60. Hemicellulose	$(C_5H_8O_4)+(C_6H_{10}O_5)_n$	"	"
61. Cellulose	"	"	"
62. Mannose	$C_6H_{12}O_6$	"	"
63. Sucrose	$C_{12}H_{22}O_{11}$	"	"
64. Maltose	$C_{12}H_{22}O_{11}$	"	"
	7. PECTIN SUBSTANCES		
	Ash elements		
65. Aluminum(III) oxide	Al_2O_3		8, 14
66. Iron(III) oxide	Fe_2O_3		"
67. Calcium oxide	CaO		"
68. Magnesium oxide	MgO		"
69. Sodium chloride	NaCl		"

TABLE 1 (continued)

Name	Empirical formula	Variety, line	Lit.
70. Potassium chloride	KCl	"	"
71. Silicon (IV) oxide	SiO_2	"	"
	8. PHENOLIC COMPOUNDS		
72. Hirsutrin	$C_{21}H_{21}O_{13}$	108-F, 152-F	16, 18
73. Hybridin	$C_{21}H_{21}O_{13}$	"	15
74. Quercimetrin (quercetin-7GL)	$C_{21}H_{21}O_{13}$	"	"
75. Isoquercimetrin	$C_{15}H_{44}O_6$	"	17
76. (+)-Catechin	$C_{15}H_{11}O_6$	"	1
77. (−)-Gallocatechin	$C_{15}H_{11}O_7$	"	"
78. Chrysanthemin (cyanidin-3-O-7GL)	$C_{21}H_{19}O_{13}$	315-F	"
79. Leucocyanidin	$C_{15}H_9O_8$		"
80. Gossypol	$C_{28}H_{26}O_4$		31
	9. TRITERPENES		
81. β-Sitosterol	$C_{29}H_{50}O$	108-F	5
82. β-Amyrin montanate	$C_{58}H_{104}O$	"	"

In the total unsaponifiable lipids of the leaves of the L-650 lines after ethylation the ethyl esters of the C_{13}, C_{15}, C_{16}, C_{17}, C_{19}, C_{21}, C_{22}, and C_{23} fatty acids have been identified [7]. Ethyl palmitate and linolenate were present in largest amount.*

At the present time, information has appeared in the literature on the presence of free fatty hydroxy acids in CLs, and 24 of them have been characterized [11]: 9-hydroxydodec-10-enoic, 9-hydroxytridec-10-enoic, a hydroxytetradecanoic, 9-hydroxytetradec-10-enoic, 9-hydroxypentadecanoic, 9-hydroxypentadec-10-enoic, a hydroxyhexadecanoic, 9-hydroxyhexadec-10-enoic, 9-hydroxydeca-10,12-dienoic, 12-hydroxypentadec-9-enoic, 10-hydroxyoctadecanoic, 12-hydroxyoctadecanoic, 9-hydroxyoctadec-10-enoic, 11-hydroxyoctadec-9-enoic, 10-hydroxyoctadec-8-enoic, 8-hydroxyoctadec-9-enoic, 9-hydroxyoctadec-12-enoic, 12-hydroxyoctadec-9-enoic, 9-hydroxyoctadeca-10,12-dienoic, 13-hydroxyhexadeca-9,11-dienoic, 9-hydroxyheptadec-10-enoic, 10-hydroxyeicosanoic, 11-hydroxyeicos-12-enoic, and 13-hydroxyoctadeca-9,11-dienoic. The composition the oxygenated fatty acids present in the healthy plant differs greatly from their composition in a plant infected with wilt, where these acids are biosynthesized in response to the infection stress. Probable routes of the formation of the oxygenated fatty acids have been proposed.

The amino acid composition of CLs has been studied. The number of amino acids found is 15 (Table 1) [12], these being present in the free form. With respect to their amino acid composition, CLs are not inferior even to the leaves of legumes, and they contain such essential amino acids as lysine, histidine, arginine, threonine, methionine, valine, phenylalanine, and leucine. CLs lack isoleucine but contain serine, which is not found in alfalfa flour, soybean oil cake, and maize leaves.

In addition, CLs are distinguished by a high protein content (about 16%) [7, 13].

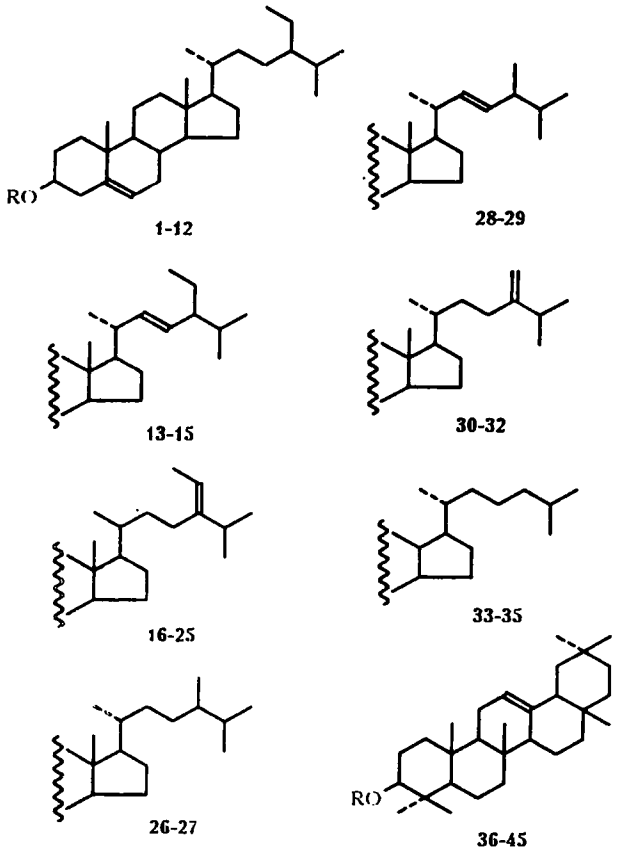
The carbohydrate composition of CLs has been studied. The maximum accumulation of sugars takes place in the period of mass flowering. With the growth of the plant, the hemicellulose content of the leaves falls and the cellulose content rises. The carbohydrates include mannose, sucrose, maltose, starch, and hemicellulose. The CLs of the higher levels contain a larger amount of reducing sugars than those of the lower levels [2].

The CLs contain 6-8% of pectin substances. Their amount in the vegetative organs decreases in the following sequence: bolls > leaves > flowers [14]. The bulk of the pectin substances of CLs consists of polygalacturonic acid.

About 27% of ash accumulates in the CLs (see Table 1), which is 3-3.5 times more than in alfalfa hay or wheat straw. It includes such trace elements as manganese, copper, molybdenum, zinc, cobalt, silver, strontium, titanium, magnesium, and zirconium. The main component of the trace elements of CLs is calcium.

At the present time there is adequate literature information on the flavonoids not only of the leaves [15-18] but also of other organs of the cotton plant. The total level of flavonoids (catechins, leucoanthocyans, proanthocyanidins) in the CLs varies from variety to variety. Thus, in *G. hirsutum* 108-F, 152-F, 8196, and 315-F, *G. barbadense* L. 5904, *G. arboreum* S-7065, and *G. herbaceum* S-7082, their level ranges from 3.15 to 4.00%, while the leaves of *G. hirsutum mexicanum* var. *nervosum watt* and *G. barbadense* L. (Paraguay and Carpylla BA-4-28) contain none [18].

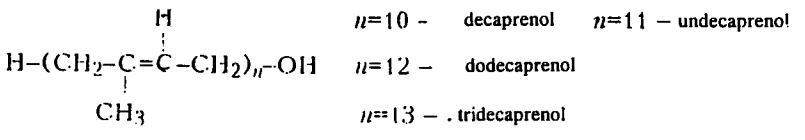
*There seems to be an omission here — Translator.



In the main, flavonoids are present in plants in the form of glycosides [16, 18]. Hirsutrin — quercetin 3-0-β-*D*-glucoside [16] — and hybridin — quercetin 3-O-[O-β-*D*-xylopyranosyl-(1→3)-O-β-*D*-glucopyranosyl-(1→3)-β-*D*-galactofuranoside] — have been isolated from the CLs of *G. hirsutum* and *G. barbadense* [15]. The tanning substances of the CLs, assigned from their chemical composition to the catechins, are represented by (+)-catechins, (−)-epigallocatechins, (+)-gallocatechins, and (−)epicatechins, with the (+)-catechins and (+)-gallocatechins predominating. As the leaves age, the (+)-catechins in them disappear and are concentrated in the roots, stems, and fruit elements. At this period, only flavonols and anthocyans remain in the CLs. It has been found that CLs contain about 1% of flavonols [2].

In order to elucidate the functional role of the components of CLs and their influence on the growth and development of the plants, a large number of investigations on the isolation and purification of secondary metabolites have been pursued in the last 15 years. As a result, about 60 compounds belonging to the isoprenoids, sterol esters, and other classes of organic compounds have been isolated and identified (Table 2).

In a study of the chemical composition of the leaves of normal-height and dwarf mutants of the cotton plant (lines L-463 and L-501; variety 108-F) a group of polyprenols (dodecaprenol, undecaprenol, tridecaprenol) was detected [19, 20], a comparative analysis of which showed that the dwarf mutation in L-501 does not affect the qualitative composition of the metabolites isolated. In the L-463 and L-501 lines the main ones are undeca- and dodecaprenols. They also predominate in the CLs of variety 108-F [19].

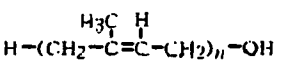


Together with isoprenols, bombiprenols with the C-2 position of the oxo group — $C_{43}H_{70}O$, $C_{48}H_{78}O$, and $C_{53}H_{86}O$ — have been identified in the CLs of variety 108-F. The bombiprenone $C_{43}H_{70}O$ has been detected previously in tobacco leaves [21]. The other two isoprenoid ketones are not known in the literature. Glycinoprenoids — products of the condensation of phytol and low polyprenols — have been found previously in soybean leaves [22].

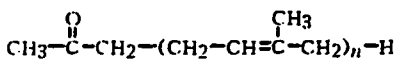
TABLE 2

1. Sterol esters

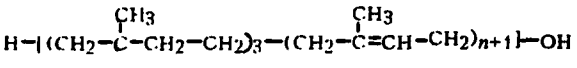
Empirical formula	MM.	Variety, line	R
1. $C_{29}H_{49}O_2C_{12}H_{21}$	594	108-F, L-501	$C_{12}H_{21}$
2. $C_{29}H_{49}O_2C_{14}H_{25}$	622	L-463, L-470	$C_{14}H_{25}$
3. $C_{29}H_{49}O_2C_{15}H_{27}$	636	"	$C_{15}H_{27}$
4. $C_{29}H_{49}O_2C_{16}H_{29}$	650	"	$C_{16}H_{29}$
5. $C_{29}H_{49}O_2C_{17}H_{31}$	664	"	$C_{17}H_{31}$
6. $C_{29}H_{49}O_2C_{18}H_{33}$	678	"	$C_{18}H_{33}$
7. $C_{29}H_{49}O_2C_{18}H_{29}$	676	"	$C_{18}H_{29}$
8. $C_{29}H_{49}O_2C_{18}H_{27}$	674	"	$C_{18}H_{27}$
9. $C_{29}H_{49}O_2C_{23}H_{43}$	748	"	$C_{23}H_{43}$
10. $C_{29}H_{49}O_2C_{28}H_{51}$	790	"	$C_{28}H_{51}$
11. $C_{29}H_{49}O_2C_{30}H_{57}$	816	"	$C_{30}H_{57}$
12. $C_{29}H_{49}O_2C_{32}H_{63}$	846	"	$C_{32}H_{63}$
13. $C_{29}H_{47}O_2C_{12}H_{23}$	594	"	$C_{12}H_{23}$
14. $C_{29}H_{47}O_2C_{16}H_{31}$	650	"	$C_{16}H_{31}$
15. $C_{29}H_{47}O_2C_{17}H_{33}$	664	"	$C_{17}H_{33}$
16. $C_{29}H_{47}O_2C_{14}H_{27}$	622	"	$C_{14}H_{27}$
17. $C_{29}H_{47}O_2C_{15}H_{29}$	636	"	$C_{15}H_{29}$
18. $C_{29}H_{47}O_2C_{16}H_{31}$	650	"	$C_{16}H_{31}$
19. $C_{29}H_{47}O_2C_{17}H_{33}$	664	"	$C_{17}H_{33}$
20. $C_{29}H_{47}O_2C_{18}H_{35}$	678	"	$C_{18}H_{35}$
21. $C_{29}H_{47}O_2C_{18}H_{33}$	676	"	$C_{18}H_{33}$
22. $C_{29}H_{47}O_2C_{18}H_{31}$	674	"	$C_{18}H_{31}$
23. $C_{29}H_{47}O_2C_{23}H_{45}$	748	"	$C_{23}H_{45}$
24. $C_{29}H_{47}O_2C_{28}H_{55}$	818	"	$C_{28}H_{55}$
25. $C_{29}H_{47}O_2C_{30}H_{59}$	846	"	$C_{30}H_{59}$
26. $C_{28}H_{47}O_2C_{15}H_{27}$	622	"	$C_{15}H_{27}$
27. $C_{28}H_{47}O_2C_{18}H_{33}$	664	"	$C_{18}H_{33}$
28. $C_{28}H_{45}O_2C_{12}H_{23}$	580	"	$C_{12}H_{23}$
29. $C_{28}H_{45}O_2C_{16}H_{31}$	636	"	$C_{16}H_{31}$
30. $C_{28}H_{45}O_2C_{15}H_{29}$	622	"	$C_{15}H_{29}$
31. $C_{28}H_{45}O_2C_{16}H_{31}$	638	"	$C_{16}H_{31}$
32. $C_{28}H_{45}O_2C_{17}H_{33}$	650	"	$C_{17}H_{33}$
33. $C_{27}H_{43}O_2C_{15}H_{27}$	608	"	$C_{15}H_{27}$
34. $C_{27}H_{43}O_2C_{17}H_{31}$	636	"	$C_{17}H_{31}$
35. $C_{27}H_{43}O_2C_{18}H_{33}$	650	"	$C_{18}H_{33}$
		AMYRIN ESTERS	
36. $C_{30}H_{49}O_2C_{12}H_{23}$	608	108-F, L-501	$C_{12}H_{23}$
37. $C_{30}H_{49}O_2C_{14}H_{27}$	636	L-463, L-650	$C_{14}H_{27}$
38. $C_{30}H_{49}O_2C_{16}H_{31}$	664	"	$C_{16}H_{31}$
39. $C_{30}H_{49}O_2C_{18}H_{35}$	692	"	$C_{18}H_{35}$
40. $C_{30}H_{49}O_2C_{20}H_{39}$	720	"	$C_{20}H_{39}$
41. $C_{30}H_{49}O_2C_{22}H_{43}$	748	"	$C_{22}H_{43}$
42. $C_{30}H_{49}O_2C_{24}H_{47}$	776	"	$C_{24}H_{47}$
43. $C_{30}H_{49}O_2C_{26}H_{51}$	804	"	$C_{26}H_{51}$
44. $C_{30}H_{49}O_2C_{28}H_{55}$	832	"	$C_{28}H_{55}$
45. $C_{30}H_{49}O_2C_{30}H_{59}$	860	"	$C_{30}H_{59}$



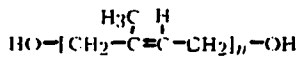
46-49



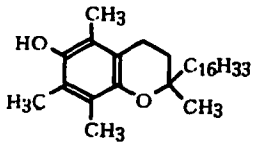
50-52



53-56



57-59



60-61

TABLE 2 (continued)

2. Polyisoprenoids

Empirical formula	MM	Variety, line	n
	1. POLYPRENOLS		
46. $C_{50}H_{82}O$	698	108-F, L-501	10
47. $C_{55}H_{90}O$	766	L-463, L-4, L-475, L-249	11
48. $C_{60}H_{98}O$	834	"	12
49. $C_{65}H_{106}O$	902	"	13
	2. BOMBIPRENOLS		
50. $C_{43}H_{70}O$	602	"	8
51. $C_{48}H_{78}O$	670	"	9
52. $C_{53}H_{86}O$	738	"	10
	3. GLYCINOPRENOLS		
53. $C_{45}H_{80}O$	636	"	5
54. $C_{50}H_{88}O$	704	"	6
55. $C_{55}H_{96}O$	772	"	7
56. $C_{60}H_{104}O$	840	"	8
	4. DIOLS		
57. $C_{50}H_{82}O_2$	714	"	10
58. $C_{55}H_{90}O_2$	782	"	11
59. $C_{60}H_{98}O_2$	850	"	12
	5. TOCOPHEROLS		
60. $C_{29}H_{50}O_2$	430	"	
61. $C_{28}H_{48}O_2$	416		

*R is a fatty acid residue, and n is the number of isoprene units

In addition to monools (polyprenols, glycinoprenols) and ketones, diols with 6-12 isoprenoid units having the hydroxy groups located on their terminal carbon atoms have been found in CLs.

It has been shown that the 1,30- and 1,35-diols, in which the numbers of isoprenoid units are six and seven, are formed when tobacco leaves are stored, while diols with n = 8-10 were first identified in CLs [21].

Some endogenous metabolites have been identified in the CLs of the lines L-501, L-650 (dwarf mutants), L-463 (tall mutants), and 108-F [7]. In the leaves of the dwarf line L-501, such metabolites as tocopherols, sterols, the triterpenoid amyrin, and phytol have been found, α-tocopherol being detected in CLs for the first time [23]. A comparative quantitative analysis for α-tocopherol in leaves of the dwarf lines L-501 and L-650 and the tall lines 108-F and L-463 in various phases of development has shown that its amounts in the individual lines differ. Its amounts are also different in the cotyledons and leaves during the maturation of all cottonplant varieties [7].

β-Sitosterol, β-amyrin montanate [4], triterpenes, and phenolic and other compounds have been isolated from CLs for the first time and identified (see Table 1). The diterpene alcohol phytol and sterols have been detected in the extractive sum of the unsaponifiable fractions [sic] from L-650 leaves.

Analysis of the fractions from the leaves of L-249, those of the leaf-shedding line L-4, which possesses the property of "self-pinching-out," and the standard variety 108-F showed the presence of phytosterols (sito-, stigma-, and campesterols and 24-ethylidenecholesterol), tocopherols, and polyprenols [24]. The free $C_{16:0}$-$C_{30:0}$ fatty acids, amyrin, esters of sitosterol, amyrin and phytol with fatty acids, and triacylglycerides were also detected in them.

The quantitative levels of tocopherols and polyprenols do not change after saponification of the fraction, which shows their existence mainly in the free form. In contrast to this, the level of sitosterol in the total secondary metabolites increases more than 20-fold, which shows its existence in the form of esters. Moreover, the amounts of undeca- and dodecaprenols in the leaves of the L-249 and L-4 lines are 2.1-2.9 times higher than in the leaves of 108-F [24].

The dynamics of the level of free phytosterols (sito-, campe-, stigma-, and cholesterols and 24-ethylidenecholesterol) have been investigated in the leaves of the breeding lines L-275 and L-470 and also of the control variety Tashkent-1 in the periods of budding-flowering and of the maturation and shedding of the leaves [25]. The amounts of β-sitosterol and stigmasterol in the laminas are greater than those of the other sterols, and the maximum accumulations of all the sterols (apart from stigmasterol) do not coincide with the vegetation phases. Thus, in the leaves of the variety Tashkent 1, the maximum occurs in the maturation phase, and for L-275 and L-470 in the budding-flowering phase.

The ratio of the levels of stigmasterol and β-sitosterol in tobacco leaves depends on the phase of development of the plant [26]; i.e., it is higher in old leaves than in young ones. In the cottonplant line L-275 this ratio behaves similarly, while in L-470 it increases sharply in the maturation phase and remains almost constant up to the leaf-shedding phase. For the standard variety Tashkent-1, the stigmasterol–sitosterol ratio decreases up to the leaf-shedding phase.

The maximum content of 24-ethylidenecholesterol in the leaves of the Tashkent-1 variety is found in the maturation phase, while in the leaves of L-275 and L-470 the minimum occurs at this time. A different pattern is observed in the dynamics of the change in the levels of free sterols in the petioles; in the case of the Tashkent-1 variety, the level of all the sterols is lowest in the leaf-shedding phase, for L-275 it falls in the last two phases, and in L-470, conversely, it rises strongly.

In early studies it was shown that the CLs of variety 108-F contain β-sitosterol and esters of sterols with lauric, myristic, palmitic, hexadeca-6,9-dienoic, stearic, oleic, linoleic and linolenic acids [10].

Subsequent investigations have revealed free β-sitosterol, stigmasterol, campesterol, 24-ethylidenecholesterol, and the triterpenoid amyrin. The CLs of the 108-F variety yielded fractions consisting mainly of mixtures of 45 esters of sterols and triterpenoids with fatty acids [27]. After the alkaline hydrolysis of the latter, the above-mentioned free sterols and amyrin were detected. Palmitic and linolenic proved to be the main esterifying acids.

Esters of sitosterol form the bulk of these compounds (Table 2), their esterifying residues consisting of unsaturated acids. Esters of a Δ^{22}-steroid (stigmasterol), however, have saturated (16:0 and 17:0) acid residues. Stigmasterol and brassicasterol are esterified by the 12:0 acid; 24-methylenecholesterol by the 12:0, 16:0, and 17:0 acids; and 24-ethylidenecholesterol by the 15:0, 16:0, and 17:0 acids. Cholesterol esters have acid moieties consisting of residues of 15:1, 17:1, and 18:1 acids. The triterpenoid amyrin is bound to acids from 12:0 to 30:0 (only the even homologs).

Thus, a comparison of the dynamics of the change in the amounts of free and bound sterols and triterpenoids over the phases of ontogenesis in the laminas and petioles of the leaf-shedding breeding lines L-275 and L-470 and the control variety Tashkent-1 show that the highest level of free sterols and their esters with saturated acids in the laminas is observed in the early phase, with, in the leaf-shedding lines, the minimum content of all the sterols analyzed in the petioles during the same phase. In the leaf-shedding period the concentration of secondary metabolites (SMs) in the petioles of line L-470 increases sharply. The results obtained are extremely useful for revealing the natural factors of the aging of cottonplant leaves, particularly the leaves of varieties which shed them at a later period (for example, Tashkent-1). For this reason, a comparison has been made of the influences of genetic and of exogenous factors on the biosynthesis of SMs [28]. The influence of an exogenous treatment was evaluated in relation to the standard defoliating agents Dropp (Schering, USA) (DSh) and DS, which, together with the active principle DSh, contains diphenylurea and carboxyphenylurea. The levels of free sterols (β-sitosterol, stigmasterol, campesterol, and 24-ethylidenecholesterol), tocopherols (α-, β-, and γ-), and β-amyrin in the laminas did not change on treatment with DSh, but with DS they rose somewhat, with the exception of 24-ethylidenecholesterol and α-tocopherol. More substantial changes in the levels of all the above-mentioned SMs take place in the petioles (1.5- to 2-fold decrease). However, the level of undecaprenol and dodecaprenol is 1.5 to 2 orders of magnitude higher than that of the other SMs. In contrast to the other SMs, the concentration of polyprenols in the petioles of control plants was approximately 4 times smaller than in the laminas. Under the action of defoliants it falls 1.6-fold, on average. In the laminas the level of polyprenols decreases 2- to 3-fold.

The laws established in the dynamics of the accumulation of SMs in the laminas and petioles of different lines of the cotton plant under the action of defoliants has permitted the conclusion of a possible influence of these compounds on the leaf-shedding process. The results of small-plot field experiments [29] have shown that treatment with the total sterols isolated from the leaves of the 108-F variety leads to the shedding of 50-60% of the leaves. The total extractive substances of the leaves of L-475 influence variety 108-F more effectively (66% shedding).

Surface lipids (SLs; 0.08% of the weight of the fresh tissue) and cell lipids (KLs; 1.3% on the weight of the comminuted tissue) are found in young leaves of the wilt-resistant variety 175-F. The KLs yield approximately 33% of neutral lipids (NLs), 27.6% of phospholipids (PLs), and 39.5% of glycolipids (GLs). The NLs identified are C_{17-23} alkanes, C_{15-23} alkenes, C_{15-23} alkylbenzenes, C_{17-23} alkenylbenzenes, squalene, fatty acid esters both with fatty alcohols and with cycloalkanols, plastoquinones, tocopherols, triacylglycerols, free fatty acids, fatty alcohols, sterols, diacylglycerols, monoacylglycerols, chlorophyll pigments, and other compounds [30]. The KLs have the following fatty acid composition (%): 12:0, traces; 14:0, 0.4; 16:0, 14.1; 16:1, 2.6; 18:0, 0.9; 18:1, 9.2; 18:2, 14.9; 18:3, 57.9. The concentration of chlorophylls is 11.78 and that of carotenoids 0.542 mg/g of moist tissue.

When CLs are infected with verticillium wilt, the amount of NLs, particularly triacylglycerols, falls. On the other hand, the level of pigments and hydroxylipids rises [30].

It must be mentioned that the smallest amount of gossypol is present in the leaves and the largest amount in the bark of the roots (1.3-3%). The level of gossypol is higher at the beginning of vegetation than in the maturation phase [31].

It has been shown for the first time that CLs contain carotenoids represented by yellow pigments [32]. The dynamics of the accumulation of such pigments as luteolin, β-carotene, violaxanthin, and others, have been studied. In the period of mass flowering the CLs contain 0.06% of carotene, in the fruit-bearing period 0.046%, and at the end of pinching-out 0.04-0.06%.

Functional Roles and Biological Activities of the Components of Cottonplant Leaves

The sharp fall in the level of ascorbic acid when the leaves wither shows that it participates in photosynthesis [8]. In Heftmann's opinion, free sterols, most frequently cholesterol, are precursors in the biosynthesis of the main types of physiologically active steroid molecules [33]. It has been shown [34] that the sterols are localized in the intracellular organelles and their interaction with phospholipids stabilizes the membranes and controls their permeability, while branching of the C-17 side-chain decreases, and the appearance of π-bonds increases, the efficacy of a steroid molecule as a membrane stabilizer.

Esters of sterols with fatty acids are also localized in the intracellular organelles [35], and they likewise act as membrane stabilizers [36]. Their role amounts to the transport of sterols [35]; however, it was shown later that these compounds regulate the level of free sterols and unsubstituted fatty acids in various periods of ontogenesis. They store these compounds and release them at the necessary moment; in addition, they bind inactive sterols [37].

Regardless of their structure, the sterols present in petioles participate mainly in the construction and destruction of membranes [25]. In addition to these processes, the sterols of the laminas participate in transformations of more diverse natures.

There is no definite information in the literature on the physiological functions of particular triterpenoids. It is known that squalene, cycloartenol, and some other compounds are biogenetic precursors of sterols [38]. Bearing in mind the nature of the activity of plant triterpenoids with respect to other biological objects (herbicidal, antimicrobial, anti-inflammatory), it may be assumed that the role of their numerous varieties consists in the protection of the host plant from various ecological factors [39].

Many representatives of the polyisoprenoids are hormones or coenzymes. Polyprenols and dolichols are of interest from this point of view. They fulfill coenzyme functions of the membrane-active participants in the transport not only of polysaccharides and peptidoglycans but also of the carbohydrate-containing biopolymers found in pro- and eucaryotes [41, 42]. Recently, a number of publications have appeared devoted to their synthesis [42-45], their isolation from natural sources [21, 27, 46, 47], and the study of their biological and physiological properties [48]. It is assumed that their broad spectrum of biological action is connected with the membrane properties of these substances and the possibility of the binding of the prenyl fragment with biologically active groups [46]. The interest in polyprenols that has arisen in recent years is due mainly to the important role that they play as lipophilic precursors of sugars in the synthesis of bacterial polysaccharides and glycoproteins [40, 49, 53]. Since the synthesis of polyprenols is a multistage process [49], such a readily available natural source of polyprenyl alcohols as cottonplant leaves [19] opens up prospects for the creation of drugs with a high penetrating capacity and also for the use of their membrane properties for the better penetration of plant-protecting agents into the plant itself. The action of the polyprenols isolated from cottonplant leaves is analogous to the action of phospholipase A_2 from the venom of the snake *Vespa orientalis* [sic] on the induction of the Ca^{2+}-conductivity channels in membrane bilayers [50].

Among the polyisoprenoids, substances have been detected that possess antiulcer and hypotensive activity [48]. These compounds, and also their derivatives, which are capable of restoring liver functions disturbed by *D*-galactosamine, have been proposed for treating diseases of the liver caused by inflammation, degeneration, and anomalies in the carbohydrate and fats metabolism. A capacity for normalizing the immune function and increasing the resistance of the organism to infection has been detected in these compounds [48].

Plastoquinones — chloroplast prenylquinones — participate in processes of photosynthesis and electron transfer in the respiratory chain just through the prenyl side-chain, since, in the majority of cases, quinones without it lose their biological activity. There are literature reports on various functions of oxidized forms of phenolic compounds. They are hydrogen acceptors in the final stages of the plant respiratory process. Such phenolic compounds as α-tocopherol and ubiquinones serve as electron carriers in the respiratory chain of mitochondria [51]

It is known that, thanks to its antioxidant properties, α-tocopherol is capable of breaking the reaction chains in the oxidation of the unsaturated fatty acid residues of the lipids of biological membranes [52]. Japanese researchers have created a preparation for accelerating the "taking" of plant grafts in which the active principles are α-tocopherol and ubiquinone [53]. There are patent claims of preparations based on α-tocopherol that are plant growth regulators [54] and preservatives [55].

The role of SMs in plant growth regulation is extremely diverse, but their influence on the aging process has not been studied. The aging of leaves is only part of the total process of the aging of the plant as a whole, which begins with a disturbance of the balance in the relative levels of phytohormones. These changes take place both under the action of the length of daylight and of a fall in the temperature and as a consequence of competition between the organs of the plant for nutrients [56, 57]. The influence of auxins, kinetins, and gibberellins on leaf aging processes has been investigated in a number of studies [58, 59]. At the present time there is no single theory of leaf shedding, which may be due to the diversity of plants and their different lifetimes. A number of authors connect it directly or indirectly with abscisic acid [60] and sometimes with an increase in the stigmasterol:sitosterol ratio [61].

About 160 compounds have been isolated from various organs of the cotton plant, some of them proving to be new. A. S. Sadykov and colleagues have shown the possibility of using cottonplant leaves as a raw material for the production of citric and malic acids [1, 3]. A technological method for their production has been developed. A plant growth stimulator including vitamins, organic acids, ash, protein, and sugar has been created from cottonplant leaves [3]. The use of this stimulator accelerates the development of cotton plants, grapes, and strawberries, and increases their yields by 5.5, 6.9, and 9-12%, respectively.

The growth-stimulating action of the preparation on ewes is shown in an increase in the weight of new-born lambs by 9.2% and an increase in fertility by 4.74% [3].

Cottonplant leaves are a valuable fodder for cattle [3]. Their quality, including their amino acid composition, is not inferior to that of many known fodders and valuable leguminous crops.

The growth of plants depends on the interaction of internal and external factors. As a rule, "internal factors" refers to compounds regulating the growth of the plant. While their concentration in plant organisms is low, they possess a high biological activity. One of such substances is the plant growth stimulator triacontanol — a higher alcohol that has also been found in alfalfa and other plants [62-64]. Under its action in a concentration of 0.001-10 mg/ml there is an increase in the crude and dry weights of seedlings of rice, barley, tomatoes, cucumbers, mung beans, maize, lettuce, potatoes, and tobacco [65-68] and a rise in the growth indices and yields of these crops [69]. An ability of triacontanol to retard the aging of the leaves of rice, barley, and oats has been detected. It exhibits a growth-stimulating effect on roses and on chrysanthemums, accelerating growth and increasing the number of buds. The treatment of rice, barley, and tomato leaves with triacontanol in a concentration of 0.01-0.1 mg/ml leads to an increase in photosynthetic activity. It simultaneously inhibits the photorespiration of plants [64], and under its action the absorptive capacity of rice roots increases.

Indian scientists have created the preparation Mixtalol, which includes aliphatic alcohols from C_{24} to C_{34} but has a high proportion of triacontanol. A number of scientists assume that its stimulating effect is connected with an increase in the absorption and transport of nutrients [70]. Others suggest its influence on photorespiration, the regulation of photosynthesis, and an intensification of the nitrogen metabolism, leading to an increase in the synthesis of nitrate reductase and of soluble proteins [70].

The total extractive substances isolated from the CLs of the self-pinching-out line L-249, and also the fractions subjected to saponification, exhibit a fairly good activity in relation to the growth and development of the standard cottonplant variety Tashkent-1 [24]. It showed a 2.7- to 3-fold increase in the number of opened bolls in comparison with the control.

The total extractive substances of CLs increase the mean weight of silkworm cocoons by 4-8%, the mean weight of the core by 2-5%, and the silk yield by about 3%; at the same time, the viability of the silkworms increases [71].

The highly effective preparation Pakhtaoi, which increases the yield of many agricultural crops, has been created from the isoprenoids of CLs [72, 73].

The biological activity of gossypol and its derivatives has been described in the literature [74, 75]. It need only be mentioned that gossypol is used in medicinal practice as an antiviral agent, and in a dose of about 1 μg/ml possesses interferon-inducing, antitumoral, antimalarial, antimicrobial, and antiulcer activities and a contraceptive effect [74]. Megosin 3% salve and batriden tablets have been created from gossypol and introduced into medical practice.

Thus, the structural diversity of the molecules of the natural compounds of CLs and differences in their physicochemical properties, especially the lyophilicity of some molecules and the hydrophilicity of others, witness a diversity of their functions in the plant organisms and of their biological properties and show the promising nature of a search for biologically active compounds.

REFERENCES

1. A. S. Sadykov and A. V. Turulov, Cottonplant Leaves — a Valuable Technical Raw Material [in Russian], Tashkent (1965), p. 9.
2. A. S. Sadykov Khimiya v Uzbekistan [in Russian], Nauka, Tashkent (1965), p. 89.
3. A. S. Sadykov, Cotton — a Wonder Plant [in Russian], Nauka, Moscow (1985).
4. A. S. Sadykov, Kh. M. Isaev, and A. I. Ismailov, Uzb. Khim. Zh., No. 2, 53 (1963).
5. Kh. I. Isaev, A Chemical Investigation of Some Substances of the Cotton Plant [in Russian], Author's abstract of Dissertation ... Candidate of Chemical Sciences, Tashkent (1968).
6. S. G. Yunusov, S. D. Gusakova, Kh. T. Mirzaazimova, A. I. Glushenkova, A. I. Usmanov, and Yu. Ikramov, Khim. Prir. Soedin., 478 (1992).
7. N. K. Khidyrova, Ya. V. Rashkes, A. M. Rashkes, U. K. Nadzhimov, and Kh. M. Shakhidoyatov, Khim. Prir. Soedin., 484 (1995).
8. A. S. Sadykov, Z. P. Pakudina, E. P. Buzitskova, A. Sh. Guli-Kevkhyan, A. Karimdzanov, and Kh. M. Isaev, Uzb. Khim. Zh., No. 6, 41 (1958).
9. S. M. Prokoshev, V. Z. Baranova, and A. I. Mednikov, Dokl. Akad. Nauk SSSR, No. 5, 985 (1955).
10. N. I. Iskhakov and A. G. Vereshchagin, Biokhimiya, **29**, No. 3, 487 (1964).
11. S. D. Gusakova, S. G. Yunusova, and A. I. Glushenkova, Khim. Prir. Soedin., 31 (1992).
12. N. N. Karavaeva, Dokl. Akad. Nauk UzSSR, No. 11, 27 (1961).
13. A. S. Sadykov and Z. P. Pakudina, Dokl. Akad. Nauk UzSSR, No. 9, 27-28 (1956).
14. E. P. Buzitskova and A. S. Sadykov, Isolation and Determination of Some of the Properties of the Pectin Substances of the Cotton Plant [in Russian], Nauch. Tr. TashGU, **1**, 263, 94 (1964).
15. B. Maksudova, Z. P. Pakudina, and A. S. Sadykov, Khim. Prir. Soedin., 322 (1969).
16. Z. P. Pakudina, V. B. Leont'ev, F. G. Kamaev, and A. S. Sadykov, Khim. Prir. Soedin., 555 (1970).
17. A. S. Sadykov, Z. P. Pakudina, and P. K. Denliev, Dokl. Akad. Nauk UzSSR, No. 6, 23 (1960).
18. A. I. Ismailov, A. K. Karimdzhanov, Sh. Yu. Isambekov, and Z. B. Rakhimkhanov, Khim. Prir. Soedin., 3 (1964).
19. A. M. Rashkes, Ya. V. Rashkes, U. K. Nadzhimov, N. K. Khidyrova, M. F. Abzalov, D. A. Musaev, and Kh. M. Shakhidoyatov, Dokl. Akad. Nauk UzSSR, No. 5, 54 (1989).
20. N. K. Khidyrova, Ya. V. Rashkes, A. M. Rashkes, and Kh. M. Shakhidoyatov, Khim. Prir. Soedin., 280 (1991).
21. W. I. Irvine, B. H. Wollen, and D. H. Jones, Phytochemistry, **11**, 467 (1972).
22. T. Suga, S. Othan, A. Narai, and K. Munesada, J. Org. Chem., **54**, 3390 (1989).
23. A. M. Rashkes, Ya. V. Rashkes, U. K. Nadzhimov, V. N. Plugar', Kh. M. Shakhidoyatov, N. K. Khidyrova, M. F. Abzalov, and D. A. Musaev, USSR Inventors' Certificate 1,398,353 (1988); Byull. Izobret., 19 (1988).
24. Ya. V. Rashkes, A. M. Rashkes, U. A. Abdullaev, M. M. Kiktev, N. K. Khidyrova, V. N. Plugar', and Kh. M. Shakhidoyatov, Khim. Prir. Soedin., 278 (1994).
25. Ya. V. Rashkes, A. M. Rashkes, M. M. Kiktev, N. K. Khidyrova, Kh. M. Shakhidoyatov, and A. A. Abdullaev, Khim. Prir. Soedin., 796 (1989).
26. C. Grunwald, Phytochemistry, **14**, 79 (1975).
27. Ya. V. Rashkes, N. K. Khidyrova, A. M. Rashkes, and Kh. M. Shakhidoyatov, Khim. Prir. Soedin., 208 (1990).
28. Ya. V. Rashkes, A. M. Rashkes, N. K. Khidyrova, M. M. Kiktiev, U. A. Abdullaev, and Kh. M. Shakhidoyatov, Khim. Prir. Soedin., 67 (1992).
29. A. M. Rashkes, N. K. Khidyrova, M. M. Kiktiev, U. A. Abdullaev, and Kh. M. Shakhidoyatov, Khim. Prir. Soedin., 113 (1997)
30. S. G. Yunusova, S. D. Gusakova, Kh. T. Mirzaazimova, A. I. Glushenkova, S. A. Usmanov, and Yu. Ikramov, Khim. Prir. Soedin., 285 (1989); 480 (1992).
31. A. I. Ismailov and A. S. Sadykov, Uzb. Khim. Zh., No. 3, 34 (1959).
32. A. S. Khodzhaev, Uzb. Biol. Zh., No. 5, 20 (1981).
33. E. Heftmann, in: Isopentenoids in Plants, W. D. Nes et al. (ed.), Dekker, New York (1984), p. 487.
34. E. Heftmann, Phytochemistry, **14**, 891 (1975).
35. R. J. Kemp, L. J. Goad, and E. Mercer, Phytochemistry, **6**, 1609 (1967).
36. C. Grunwald, Plant Physiol., **48**, 653 (1971).

37. B. D. Whitaker and D. I. Nelson, Lipids, **22**, 386 (1987).
38. P. Beneviste, L. Hirth, and G. Ourisson, Phytochemistry, **5**, 312 (1966).
39. V. A. Paseshnichenko, Itogi Nauki Tekhn., Ser. Biol. Khim., **25**, 6 (1987).
40. V. N. Shibaev, Usp. Biol. Khim., **17**, 187 (1976).
41. C. A. Rupar and R. C. Kotnapalli, Progr. Lipid Res., **24**, No. 4, 269 (1985).
42. N. Ya. Grigor'eva, V. V. Veselovskii, and A. M. Moiseenkov, Khim.-Farm. Zh., No. 7, 845 (1987).
43. L. L. Danilov, N. A. Kalinchuk, T. N. Druzhinina, V. N. Shibaev, E. V. Polunin, M. A. Novikova, S. I. Torgova, A. M. Moiseenkov, and N. K. Kochetkov, Dokl. Akad. Nauk SSSR, **271**, No. 2, 358 (1983).
44. M. A. Novikov, A. V. Lozanova, V. V. Veslovskii, V. A. Dragan, and A. M. Moiseenkov, Izv. Akad. Nauk SSSR, Ser. Khim., No. 2, 356 (1987).
45. A. M. Moiseenkov, M. A. Novikova, E. Polunin, S. I. Torgova, Izv. Akad. Nauk SSSR, Ser. Khim., No. 5, 1557 (1983).
46. V. I. Roshin, A. I. Fragina, and V. A. Sovol'ev, Rastit. Resurs., **22**, No. 4, 539 (1986).
47. T. I. Kukina, L. I. Demenkova, V. A. Raldugin, B. I. Maksimov, O. S. Chizhov, V. V. Veselovskii, and A. M. Moiseenkov, Sib. Khim. Zh., **6**, 89 (1991).
48. N. Ya. Grigor'eva and A. M. Moiseenkov, Khim.-Farm. Zh., No. 2, 144 (1989).
49. A. V. Semenovskii, N. Ya. Grigor'ev, A. M. Avrutov, V. V. Veselovskii, M. A. Novikova, and A. M. Moiseenkov, Izv. Akad. Nauk SSSR, Ser. Khim., No. 1, 153 (1984).
50. A. M. Rashkes, N. K. Khidyrova, Ya. V. Rashkes, U. K. Nadzhimov, U. Mirkhodzhaev, Kh. M. Shakhidoyatov, Positive Decision [for Inventors' Certificate] of August 21, 1992, No. 5,018,878.
51. V. A. Paseshnichenko, Itogi Nauki Tekhn., Ser. Biol. Khim., **25**, 157 (1987).
52. A. N. Erin, M. M. Spirin, L. V. Tabidze, and V. E. Kagan, Biokhimiya, **48**, 1855 (1983).
53. Kunio Hato, Kingo Jokoto, Yoshio Tsutsui, and Shoji Yamashita, Jpn. Patent No. 131,785, Biologically Active Preparation.
54. C. Sironval and Y. E. Tannir, Nature (London), **185**, No. 4716, 855 (1960).
55. Sedzi Yamashita, Jpn. Patent No. 41,827 (1973).
56. The Growth and Differentiation of Plants, F. Warring and I. Phillips [Russian translation], Mir, Moscow (1984), p. 442.
57. A. W. Galston, P. J. Davies, and R. L. Satter, The Life of the Green Plant, Prentice-Hall, Englewood Cliffs, N.J. [Russian translation, Mir, Mocow (1983), p. 313].
58. V. I. Kefeli, The Physiological Bases of Defoliation and the Production Process [in Russian], Fan, Tashkent (1991), p. 5.
59. J. Nickel, Regulation of the Growth of Plants [Russian translation], Kolos, Moscow (1984), p. 112.
60. K. Doerffling, Plant Hormones [Russian translation], Mir, Moscow (1985), p. 217.
61. Duperon, C. R. Séances Acad. Sci., Ser. D, **266**, 1658 (1971).
62. A. C. Chubnall, and E. F. Williams, Biochem. J., **27**, 1885 (1933).
63. A. P. Tulloch and L. L. Hoffman, Phytochemistry, **13**, 2535 (1973).
64. L. Z. Dolotovskaya and V. M. Krut'kov, Agrokhimiya, **7**, 138 (1970).
65. R. Hangarter, S. K. Ries, and P. Carison, Plant Physiol., **61**, 855 (1978).
66. S. K. Ries and V. F. Wert, Planta, **173**, No. 1, 79 (1988).
67. R. L. Houtz, S. K. Ries, and N. E. Tolbert, Plant Physiol., **79**, 357 (1985).
68. S. K. Ries, V. F. Wert, C. C. Sweeley, and R. A. Heavitt, Science, **195**, No. 4284, 1339 (1977).
69. A. B. Eriksen, G. Selden, D. Skogen, and S. Nilsen, Planta, **152**, 44 (1981).
70. A. Abdullaev, L. G. Gorenkova, L. D. Prusakova, and I. S. Kasparova, Fiziol. Rast., **38**, No. 6, 1181 (1991).
71. B. U. Nasrillaev, U. K. Nadzhimov, N. K. Khidyrova, A. M. Rashkes, Ya. V. Rashkes, and Kh. M. Shakhidoyatov, Ipak Zhurnali, 1-4, 7 (1993).
72. N. K. Khidyrova, N. I. Borovinskaya, A. M. Rashkes, N. N. Gazzaeva, Ya. V. Rashkes, and Kh. M. Shakhidoyatov, in: Abtracts of Lectures at a Regional Scientific Conference [in Russian], Fergana (1993), p. 18.
73. N. K. Khidyrova, N. I. Borovinskaya, N. N. Gazzaeva, A. M. Rashkes, Ya. V. Rashkes, and Kh. M. Shakhidoyatov, in: Abtracts of Lectures at a Regional Scientific Conference [in Russian], Fergana (1993), p. 19.

74. N. I. Baram and A. I. Ismailov, Khim. Prir. Soedin., 341 (1993).
75. A. I. Glushenkova and I. P. Nazarova, Gossypol and Its Derivatives and Their Uses [in Russian], Fan, Tashkent (1993), p. 14.