Journal of Stress Physiology & Biochemistry, Vol. 20, No. 2, 2024, pp. 144-156 ISSN 1997-0838

ORIGINAL ARTICLE

Plant Species Used for Infectious Diseases: Features of Classification Position and Chemical Composition

Popov P.L.

[1] V.B. Sochava Institute of Geography of the Siberian Branch of the Russian Academy of Sciences, Irkutsk, Ulaanbaatar 1, Russia

*E-Mail: plp@irigs.irk.ru

Received February 22, 2024

Species of medicinal plants are grouped into sets, each of which was used in folk or scientific medicine for a specific infectious disease. A total of 59 infections and species sets were taken into account. Increases in the occurrence, in such sets, of species belonging to certain families and species containing chemical compounds of certain groups (flavonoids, terpenoids, alkaloids, phenols, lactones, coumarins, iridoids, xanthones) were studied. The mathematical-statistical Student's t-test was used. As a rule, in the set of species used for infectious diseases, the occurrence of some (from 1 to 12) families is significantly increased. 67 families are characterized by a significantly increased occurrence in at least one such set. Significant differences were noted between families in the number of infections with which they are associated through their affinity for the sets of plants used. It was also revealed that, as a rule, in the set of species used for infectious diseases, the occurrence of certain (from 1 to 8) groups of compounds was significantly increased. Significant differences were noted between infections in combinations of groups of compounds that were reliably related to the plant species used. Information about the considered patterns can be used to assess the prospects of plant species, families, and chemical compounds in the study of their antimicrobial and antiviral activity.

Key words: Plant species, infectious diseases, families, groups of chemical compounds, significant increase in occurrence

Let us recall the circumstances that make the problem of infectious diseases especially relevant and connect it with the study of plants.

1. New infectious agents are discovered (non-existent or not identified, not previously studied).

2. “Old” (long-known) infectious agents develop resistance to the drugs used.

3. The importance of microscopic fungi and actinomycetes as a source of antibiotics is weakening (partly due to the factor noted in paragraph 2).

4. New technological possibilities for obtaining and using substances effective against infectious diseases are emerging. This point should be emphasized. Antibiotics, as a class of medications, appeared at one time precisely because of this factor.

5. One of the sources of drugs used for infections, not only for folk medicine, but also for scientific medicine, are plants. (At the same time, in scientific medicine, herbal remedies, in the treatment of infections, are far inferior to chemotherapy drugs). Mostly herbal preparations such as various extracts are used (including in scientific medicine). They are more important in chronic infections than in acute ones. There are still few precedents for the use of individual compounds of plant origin as highly effective agents against infectious diseases (as opposed to antibiotics from fungi and actinomycetes), but they exist. (The most significant examples are the malaria alkaloid quinine from *Cinchona officinalis* and related species, and the sesquiterpene lactone artemisinin from *Artemisia annua* (Bhattarai *et al.*, 2007)). Apparently, the potential of plants has not been sufficiently exploited.

Plant species used for various infectious diseases are numerous; often dozens or hundreds of species were used for one infection, which raises the problem of selecting the most promising species and substances as research objects.

Plant species used in infections are unevenly distributed in the phylogenetic system. There are taxa, for example families, that are rich in such species, and others that are poor.

One of the possible approaches to assessing the prospects of plant species is to establish the occurrence of species used for a certain infection (group of infections) in a certain family or other taxon of plants (Popov & Botvinkin, 2008). Cases of increased occurrence are especially important. It is unlikely that an increased occurrence of species with a particular use in a particular taxon will occur by chance (for example, species used for respiratory infections in the family *Lamiaceae*, compared with parts of the medicinal plant flora that do not belong to this family).

In cases where such an excess is detected, the question arises about the factor that determined this pattern, and it is acceptable to assume that this factor is the usefulness of using species of a given taxon for a given infection. Accordingly, taxa of increased occurrence of species with a specific application are a promising field for the search for new species with similar properties, or for in-depth study of already discovered activities. As the chemical characteristics of plant families are studied (particularly within the framework of chemosystematics), it becomes possible, or improves, to correlate relevant information with information about the affinity of species with particular medicinal applications for particular families.

Another approach is also of interest – to identify an increase in the occurrence of substances belonging to different groups and having experimentally established antimicrobial and/or antiviral activity in sets of species used for certain infectious diseases. In this case, we compare the number of species used for a certain disease, containing at least one compound of a certain group that has an antimicrobial and/or antiviral effect, with the number of such species in the flora of medicinal plants that were not used for a given disease. For example, the occurrence of plant species containing terpenoids with antiviral or antimicrobial action in the set of species used for respiratory infections can be compared with the occurrence of such species in the part of the flora of medicinal plants that were not used for respiratory infections. If such increases in occurrence are detected, the question arises about the factors that create them.

Relevant information can be taken into account to assess the prospects of certain plant species and compounds when searching for means of preventing and treating infectious diseases. Next we will look at these issues in more detail.

MATERIALS AND METHODS

The source we used (Budantsev *et al.*, 2001) contains information on the medical use of 2834 species of wild plants of the flora of the Russian Federation, but reflects the medical traditions of other countries where these species are found. The source reflects the uses of plants in both scientific and folk medicine, both in our time and in earlier eras. The names of the diseases are taken from this source and reflect mainly the knowledge that was formed in the eras when the use of these plants developed; from the point of view of modern medicine, these names are not always accurate, and may reflect groups of diseases of various etiologies, not always infectious (for example, “jaundice”). However, each such concept corresponds to a disease, if not in all, then in a significant proportion of cases, having an infectious etiology.

Another source used (Semikhov, 2001) contains information on the presence of individual compounds in certain plant species, indicating their belonging to different groups, and their biological effect.

We take into account 9 groups of compounds (ibid.): flavonoids, terpeniodes, alkaloids, coumarins, lactones, quinones, phenols, iridoids, xanthones, and four types of experimentally established biological activity: antiviral, antibacterial, antiprotozoal and antimycotic.

The Table provides information on the occurrence in sets of plants used for 59 infectious diseases, species - representatives of certain families, and species containing at least one compound belonging to one of 9 groups and possessing antimicrobial, that is, antibacterial, antiprotozoal, antimycotic or (and) antiviral activity.

We did not specifically highlight cases where the activity of a compound was established specifically in relation to the causative agent of a specific disease, the name of which is indicated in the first column of the table, due to their small number. The combination of the types of biological activity of chemical compounds under consideration in one indicator is due to the fact that these activities are in many cases statistically significantly related to each other, and a compound that has established activity against infectious agents of one type can be found to be active against infectious agents of another type. For example, according to our data (the result of calculations from the specified source), out of 1676 (presented in the source) individual chemical compounds of plant origin, 22 compounds have an antiviral effect, 188 have an antibacterial effect, 9 have a combination of these activities. The t value is 5.73, indicating a significant relationship. We have strived to avoid detail that is not achievable in the format of a single article. The purpose of this article is a generalized reflection of some patterns characterizing the chemical composition of plant species used for infectious diseases. This general picture can hopefully be useful in guiding the direction of more detailed research.

Let us give an example of a significantly increased occurrence of plant species used for a certain disease (or a certain group of diseases) in a family, in relation to the part of the flora of medicinal plants of the Russian Federation that does not belong to this family. 393 plant species have been used against respiratory infections, of which 45 species belong to the *Lamiaceae* family. In total, there are 173 species of medicinal plants in this family in the flora of the Russian Federation. The share of species with this use in the family is 45/173 = 0.26. The share of species used for respiratory infections in the part of the flora that does not belong to *Lamiaceae* is 2 times less: (393-45)/(2834-173)=0.13. The mathematical-statistical Student's t test allows us to assess the reliability of this difference (or the reliability of the relationship between family membership and application). In this case, t=4.77, which allows us to confidently reject the hypothesis of no connection; the threshold t value of 3.29, which allows us to reject the null hypothesis with a probability of 0.999, is significantly exceeded. (Note that the t value will also be 4.77 if we estimate the concentration of species of the family *Lamiaceae* in the set of species used for respiratory infections compared with the part of the medicinal plant flora not included in this set. These operations are equivalent.)

Similarly, an increase in the occurrence of species containing at least one compound of the group, for example, terpenoids (at the same time, having experimentally established antimicrobial and/or antiviral activity), is established in the set of species used for respiratory infections. There are 116 species containing at least one compound from the group of terpenoids that has an antimicrobial or antiviral effect. Of these, 48 were used for respiratory infections. In this case t=8.75; this means that plants containing terpenoids with antimicrobial or antiviral activity are found in sets of species used for respiratory infections significantly more often than among species that did not have this use.

RESULTS AND DISCUSSION

Let's look at the Table. Diseases are listed in descending order of the number of plant species used. Only diseases against which at least 5 plant species were used were taken into account. In addition, only families were taken into account, in each of which at least 5 species were represented in the flora of medicinal plants of the Russian Federation, and in which at least 2 species were used for one of the diseases taken into account. Only families in which a significantly increased occurrence of species used for the corresponding disease is noted are indicated (in the middle column). In cases corresponding to the Student's t-test value from 1.96 to 2.68, the hypothesis of no relationship is rejected with a probability of 0.95, in cases where the t values are from 2.69 to 3.29 with a probability of 0.99, and when higher t values – with a probability of 0.999 (Lakin, 1973).

At the same time, the third column of the table indicates groups of compounds characterized by both reliably and unreliably increased occurrence in the corresponding sets of plants. The number of groups of chemical compounds considered (9) allows for this possibility.

Let us note several circumstances characterizing the information presented in the Table.

Diseases vary dramatically in the number of plant species used. Apparently, this indicator is positively related to the prevalence of the disease, to the diversity of its causative agents (as we have already noted, some pathologies, the same respiratory infections, are actually groups of diseases, in practice not always accurately distinguished even by modern medicine, caused by typologically heterogeneous agents), with the danger (severity) of the disease. It is possible that the number of species in the flora of the Russian Federation, the preparations of which can have a positive effect on the disease, also influences. Without this assumption, it is difficult to explain why a number of dangerous and widespread diseases in the past, when traditional medicine was being formed, are characterized by a relatively small number of plant species used. (For example, only 5 types of plants were used for the plague; and for other especially dangerous infections, cholera, smallpox and anthrax, 13, 25 and 50, respectively). The intended effect could be to promote recovery or prevent disease, to improve the subjective state of the patient; Apparently, traditional medicine did not neglect even minimal usefulness (Popov & Botvinkin, 2008).

We also note the frequent repetition of the same families in the Table, that is, an increase in the occurrence of species used for different diseases in the same families.

The relevant information is reflected in the following list of families. In parentheses, after the name of the family, is the number of diseases reliably associated with it through an increase in the occurrence of the species used.

Solanaceae (17), *Asteraceae*, *Plantaginaceae* (10 each), *Lamiaceae*, *Scrophulariaceae*, *Rutaceae*, *Crassulaceae* (8 each), *Sambucaceae*, *Rosaceae* (7 each), *Typhaceae*, *Violaceae*, *Dipsacaceae* (6 each), *Urticaceae*, *Convallariaceae*, *Rubiaceae*, *Euphorbiaceae*, *Ericaceae* (5 each), *Betulaceae*, *Pinaceae*, *Cuscutaceae*, *Brassicaceae*, *Gentianaceae* (4 each), *Peonaceae, Hipericaceae, Oleaceae, Pyrolaceae, Ranunculaceae, Araceae, Geraniaceae, Valerianaceae, Tiliaceae, Nymphaeceae* (3 each), *Malvaceae, Cucurbitaceae, Salicaceae, Thymelaceae, Primulaceae, Polygalaceae, Ulmaceae, Fabaceae, Equisetaceae, Onagraceae, Liliaceae, Apiaceae,* *Athyriaceae, Convolvulaceae, Grossulariaceae, Campanulaceae, Poaceae* (2 each), *Hemerocalliaceae, Polygonaceae, Aspleniaceae, Trilliaceae, Fumariaceae, Limoniaceae, Ephedracae, Aristolochiaceae, Potamogetoniaceae, Alismataceae, Iridaceae, Lycopodiaceae, Tamaricaceae, Celastraceae, Orocbanchaceae, Chenopodiaceae, Alliaceae, Fagaceae* (1 each).

A significant part of the families represented in the flora of medicinal plants of the Russian Federation do not have reliable connections with any infectious disease, through the occurrence of the species used (for example, the rather large family *Boraginaceae*).

It is acceptable, in our opinion, to assume that the families leading in this indicator statistically gravitate toward chemical compounds that have (each individually) broad antimicrobial and antiviral activity, and/or chemical compounds with narrow activities of this kind, but are relatively numerous. Both situations deserve attention in the context of studying the antimicrobial and antiviral activity of plants.

The size of the family (in terms of the number of species and genera) favours its chemical diversity, and therefore the number of diseases with which it is associated. The relatively small families associated with many diseases (for example, those at the top of the list, with use for 6 diseases or more) deserve more attention: *Solanaceae, Plantaginaceae, Rutaceae, Crassulaceae, Sambucaceae, Typhaceae, Violaceae, Dipsacaceae*.

Let us consider connections of the “disease-group of compounds with antimicrobial or antiviral effect” type.

As can be seen from the Table, for a set of plant species used for a particular infectious disease, there is typically a significant increase in the occurrence of species containing compounds with antimicrobial and antiviral effects, belonging to at least one group. (The only exception is scarlet fever, which does not form reliable bonds, in the indicated sense, with any group of compounds, however, for flavonoids, it comes very close to the threshold of reliability). According to the table, there are 181 reliable positive connections “disease – group of compounds”; reliable negative – 0.

Unreliable connections, both positive and negative, also form patterns. Negative connections are not directly indicated in the table, but their number in each cell of the 3rd column is equal to the difference between the total number of substance groups under consideration (9) and the number of positive connections in it. Diseases for which from tens to hundreds of species were used (numbers 1-31 in the table) are characterized by a predominance of positive unreliable connections over negative unreliable connections (98 and 53 connections, respectively). For diseases with a smaller number of species used (numbers 32-59 in the table), the opposite pattern is characteristic (48 unreliable positive and 149 unreliable negative relationships with groups of compounds). Probably, the diversity of the chemical composition of the plant species included in the set and depending on its abundance makes a contribution to this pattern.

The number of species in the set, as well as the number of species containing a compound of a certain group, is factors that are positively associated with the severity of the statistical relationship, if any, which is reflected in the absolute value of the Student’s test.

As can be seen from the Table, in many cases, diseases differ significantly in the nature of statistical relationships with groups of chemical compounds (including combinations of reliable relationships). This also applies to diseases that are similar in the number of species used. One can compare in this regard, for example, warts, whooping cough, gonorrhoea and erysipelas (about 60 plant species in each set). Thus, in the kits used for erysipelas and whooping cough, the number of species containing terpenoids was significantly increased. In the set of species used for gonorrhoea, it is unreliably reduced. In the kit used for warts, it was unreliably increased. In the set used for erysipelas, there was a significant increase in the occurrence of 6 groups of compounds (flavonoids, terpenoids, lactones, phenols, alkaloids, coumarins) out of 9, and in the set used for gonorrhoea – in one (flavonoids). This kind of heterogeneity indicates the action of some factors specific to a particular set of species used.

As we have already said, the fact that a plant species is used for a certain disease is presumably due to the usefulness (maybe small, but practically noticeable) of its use. An increase in the occurrence of species containing compounds of a certain group in a set of species used for a certain disease is, from our point of view, a reason to consider this group of compounds as promising in the search for means of treating or preventing this disease. Bearing in mind that we are talking about infectious diseases and compounds with antimicrobial or antiviral action, it can be assumed that the usefulness is associated with the effect of the compound of this group in relation to the causative agent or causative agents of the disease. But it is necessary to take into account the following circumstance.

Chemical compounds belonging to different groups and having an antibacterial effect reliably gravitate toward the same plant species (Popov, 2021). (For example, among species containing antibacterial terpenoids, the occurrence of species containing antibacterial flavonoids is significantly increased compared to the rest of the flora). It can be assumed that similar patterns exist for species containing compounds with antiviral, antifungal, and antiprotozoal effects. The data presented in the Table are quite consistent with this assumption.

It is likely that the concentration of typologically different compounds with antibacterial action in one plant species is associated with the ecological strategy of this species and the importance of active antibacterial protection for it. Having developed, in the course of evolution, the ability to neutralize bacteria that are dangerous to it (similarly, other microorganisms or viruses), the species has become a useful means of protection against pathogens of humans and animals. Some species have developed this ability to a greater extent, other species to a lesser extent. It can be assumed, on these grounds, that if a species contains a compound that is active against the causative agent of a particular infection, then the likelihood of detecting other antimicrobial or antiviral compounds in it, including those that are not active against a given microorganism or virus, is increased.

If these patterns are real, then they contribute to the presence in the set of species used for a particular infection of many antimicrobial or antiviral compounds, including those that are not active against the pathogen (or pathogens) of this disease. These considerations are speculative; the hypothesis about the contribution of the utility factor to the formation of the statistical relationship “the set of plant species used – the group of chemical compounds in their composition” is not refuted by them.

The large number of reliable connections “disease – group of compounds” makes it difficult to select combinations that deserve the most attention (in terms of the information reflected in the table). Here it is possible to take into account additional conditions: it is quite obvious that the more pronounced of the reliable connections provide a stronger basis for attention than the relatively less pronounced ones.

If the task of the study is to find a group of compounds that are promising in terms of influencing a microorganism or virus that causes a certain infection (the study goes “from infection to substance”), then the most pronounced of the 9 connections of a given disease across groups of compounds deserve increased attention. In our study, the strongest connections correspond to the highest values of the Student's test. For example, this is the connection “respiratory infections – terpenoids”, “pulmonary tuberculosis – flavonoids”. In the table, the names of compounds in each cell of the third column are ranked by the magnitude of these values.

If the objective of the research is to study the antimicrobial or antiviral properties of a certain group of compounds (the study goes “from substance to infection”), then attention should be paid to the most pronounced of the 59 connections formed by each group of substances with diseases. For example, these are the connections “sepsis – alkaloids”, “dysentery – flavonoids”.

Both conditions in the given examples coincide, but they can also be separated, for example, the connection “rabies-iridoids” corresponds only to the first condition, the connection “respiratory infections-coumarins” - only to the second.

In addition, situations deserve increased attention when a plant species belongs to a family that is reliably associated with an infectious disease through intersection with a set of species used against it, and at the same time, contains a chemical compound of a group that gravitates towards this set.

Table. Plant families and groups of chemical compounds occurring with increased frequency in sets of plant species used for major infectious diseases

Diseases (number of plant species)	Plant families (number of medicinal plant species in the family as a whole; in its part that has a given application; **Student's t test**)	Groups of substances (number of species containing a compound of this group in the flora of medicinal plants; in its part having this application; **Student's t test**)
1. Respiratory infections (393)	*Lamiaceae* (173;45;**4,77**). *Solanaceae* (14;8;**4,71**); *Pinaceae* (19;9;**4,24**). *Rutaceae* (8;5;**3,99**). *Ephedracae* (5;3;**2,99**). *Athyriaceae* (8; 4; **2,96**). *Rosaceae* (147;29;**2,11**). *Dipsacaceae* (12;4;**1,96**). *Sambucaceae* (7,3,**2,22**).	Terpenoids [116;48; **8,75**] Phenols [59;27;**7,16**] Flavonoids [246; 71; **7,12**] Coumarins [124;38;**5,53**] Alkaloids [49;14;**3,0**] Iridoids [62;16;**2,75**] Lactones [29;7;**1,61**] Quinones [36;8;**1,46**] Xanthones [18;3;**0,34**]
2. Pulmonary tuberculosis (313)	*Polygalaceae* (10;7;**5,96). ***Dipsacaceae* (12;7;**5,24**). *Plantaginaceae* (10;6;**4,95**). *Pinaceae* (19;8;**4,33**). *Trilliaceae* (7;3;**2,69**). *Urticaceae* (7;3;**2,69**). *Violaceae* (26;7;**2,20**). *Betulaceae* (29;7;**2,26**). *Araceae* (9;3;**2,14**). *Scrophulariaceae* (85;15;**1,97**).	Flavonoids [246;72;**9,54**] Terpenoids [116;32; **5,80**] Iridoids [62;19**;4,98**] Coumarins [124;28;**4,19**] Phenols [59;16;**3,98**] Alkaloids [49;10;**2,11**] Xanthones [18;3;**0,76**] Lactones[29;4;**0,47**] Quinones [36;4;**0,01**]
3. Jaundice, hepatitis (224)	*Hemerocalliaceae* (5;4;**5,98**). *Solanaceae* (14;7;**5,85**). *Nymphaeceae* (7;4;**4,83**). Aspleniaceae (8;4;**4,42**). *Cuscutacae* (7;3;**3,43**). *Rutaceae* (8;3;**3,11**). *Crassulaceae* (26;6;**2,88**). *Gentianaceae* (40;8;**2,86**). *Fumariaceae* (10;3; **2,59**). *Peonaceae* (6;2;**2,3**). *Asteraceae* (372;40; **2,19**). *Cucurbitaceae* (7;2;**2,03**).	Alkaloids [49;19;**8,08**] Flavonoids [246; 41;**5,33**] Coumarins [124;25;**5,17**] Iridoids [62;12;**3,38**] Phenols [59;27;**3,02**] Terpenoids [116;15; **2,05**] Lactones[29;4;**1,18**] Quinones [36;4;**0,72**] Xanthones [18;2;**0,51**]
4. Dysentery (203)	*Limoniaceae* (8;4;**4,71**). *Typhaceae* (5;3;**4,59**). *Geraniaceae* (17;6;**4,51**). *Rosaceae* (147;23;**4,1**). *Oleaceae* (8;3;**3,33**). *Plantaginaceae* (10;3;**2,81**). *Lamiaceae* (173;21;**2,62**). *Polygonaceae* (49;8;**2,51**). *Urticaceae* (7;2; **2,2**).	Flavonoids[246; 62;**11,48**] Terpenoids [116;28; **7,24**] Coumarins [124;23;**5,03**] Phenols [59;14;**4,99**] Iridoids [62;9;**2,27**] Quinones [36;5;**1,57**] Alkaloids [49;6;**1,39**] Lactones[29;3;**0,67**]
5. Scrofula (190)	*Rubiaceae* (24;8;**5,24**). *Betulaceae* (29;7;**3,77**). *Malvaceae* (17;5;**3,75**). *Scrophulariaceae* (85; 14;**3,66**). *Grossulariaceae* (8;3;**3,49**). *Violaceae* (26;5;**2,57**). *Ulmaceae* (8;2;**2,07**). *Valerianaceae* (23; 4; **2,06**).	Flavonoids[246; 42;**6,8**] Iridoids [62;16**;6,08**] Terpenoids [116;19; **4,25**] Coumarins [124;17;**3,19**] Phenols [59;8;**2,13**] Alkaloids [49;6;**1,56**] Quinones [36;4;**1,06**] Xanthones [18;2;**0,76**]
6. Pneumonia (157)	*Plantaginaceae* (10; 6; **7,54**). *Geraniaceae* (17;6;**5,37**). *Polygalaceae* (10;4;**4,77**). *Iridaceae* (17;4;**3,25**). *Peonaceae* (6;2;**2,98**). *Asteraceae* (372;32;**2,77**). *Urticaceae* (7;2;**2,67**). *Oleaceae* (8;2;**2,41**). *Rutaceae* (8;2;**2,41**). *Rubiaceae* (24;4;**2,39**). *Violaceae* (26;4;**2,2**). *Pinaceae* (19;3;**1,96**).	Iridoids [62;14**;5,93**] Flavonoids[246; 33;**5,65**] Terpenoids [116;18; **4,80**] Alkaloids [49;10;**4,59**] Phenols [59;8;**3,87**] Coumarins [124;16;**3,67**] Xanthones [18;3;**3,10**] Quinones [36;3;**0,74**] Lactones[29;2;**0,32]**
7. Malaria (148)	*Aristochlochiaceae* (6;2;**3,1**). *Asteraceae* (372; 31; **2,89**). *Gentianaceae* (40;6; **2,8**). *Cucurbitaceae* (7;2;**2,78**).	Flavonoids[246; 44;**9,34**] Terpenoids [116;24; **7,64**] Coumarins [124;18;**4,76**]

	Sambucaceae (7;2;**2,78**). *Valerianaceae* (23;4;**2,63**). *Betulaceae* (29;4;**2,09**).	Alkaloids [49;8;**3,52]** Phenols [59;9;**3,50**] Quinones [36;5;**2,35**] Xanthones [18;3;**2,19**] Iridoids [62;7**;2,17**] Lactones[29;2;**0,41**]
8. Angina (135)	*Campanulaceae* (27;6;**4,28**). *Tiliaceae* (9;3;**4,03**). *Asteraceae* (372;29;**2,96**). *Sambucaceae* (7;2;**2,96**). *Solanaceae* (14;3;**2,93**). *Scrophulariaceae* (85;8;**2,04**).	Flavonoids[246; 36;**7,6**] Terpenoids [116;19; **6,0**] Iridoids [62;11**;4,83**] Coumarins [124;12;**2,63**] Phenols [59;6;**1,97**] Alkaloids [49;5;**1,80**] Xanthones [18;2;**1,27**] Quinones [36;2;**0,22**]
9. Purulent wounds (114)	*Pyrolaceae* (10;4;**5,8**). *Ulmaceae* (8;3;**4,83**). *Rubiaceae* (24;5;**4,21**). *Typhaceae* (5;2;**4,1**). *Scrophulariaceae* (85;9;**3,13**). *Ericaceae* (38;5;**2,89**). *Lamiaceae* (173;14;**2,81**). *Plantaginaceae* (10;2;**2,58**). *Ranunculaceae* (135;10;**2,05**). *Hipericaceae* (13;2;**2,09**). *Crassulaceae* (26;3;**1,96**). *Violaceae* (26;3;**1,96**).	Iridoids [62;16**;8,83**] Phenols [59;12;**6,45**] Quinones [36;8;**5,59**] Flavonoids[246; 23;**4,5**] Lactones[29;4;**2,69**] Alkaloids [49;5;**2,22**] Terpenoids [116;9; **2,09**] Xanthones [18;1;**0,33**] Coumarins [124;5;**0,01**]
10. Abscesses (113)	*Araceae* (9;2;**2,8**). *Convallariaceae* (17;3;**2,89**). *Dipsacaceae* (12;2;**2,23**). *Liliaceae* (20;6;**6,0**). *Pinaceae* (19;4;**3,81**). *Potamogetoniaceae* (8;4;**6,66**). *Scrophulariaceae* (85;8;**2,6**). *Thymelaceae* (9;3;**4,51**). *Typhaceae* (5;2;**4,12**).	Iridoids [62;9**;4,28**] Flavonoids[246; 18;**2,79**] Terpenoids [116;8;**1,64**] Coumarins [124;8;**1,43**] Phenols [59;4;**1,11**] Xanthones [18;1;**0,34**] Alkaloids [49;2;**0,03**]
11. Rabies (98)	*Alismataceae* (6;3;**6,25**). *Euphorbiaceae* (41;8;**5,67**). *Solanaceae* (14;4;**5,16)**. *Convolvulaceae* (9;3;**4,91**). *Convallariaceae* (17;4;**4,54**). *Gentianaceae* (40;6;**4,02**). *Lycopodiaceae* (6;2;**4,01**). *Cuscutacae* (7;2;**3,64**). *Sambucaceae* (7;2;**3,64**). *Dipsacaceae* (12;2;**2,51**).	Iridoids [62;8;**4,12**] Flavonoids[246; 18;**3,47**] Xanthones [18;3;**3,08**] Coumarins [124;8;**1,87**] Terpenoids [116;7; **1,55**] Alkaloids [49;2;**0,24**] Lactones[29;1;**0,00**]
12. Dermatomycoses (87)	*Celastraceae* (6;3;**6,67**). *Solanaceae* (14;4;**5,55**). *Rutaceae* (8;2;**3,6**). *Thymelaceae* (9;2;**3,34**). *Hipericaceae* (13;2;**2,58**). *Crassulaceae* (26;3;**2,51**).	Alkaloids [49;7;**4,59**] Flavonoids[246;18;**4,04**] Quinones [36;5;**3,78]** Coumarins [124;10;**3,30**] Iridoids [62;6;**3,05**] Phenols [59;2;**2,43]** Terpenoids [116;7; **1,89**] Lactones[29;2;**1,20**] Xanthones [18;1;**0,61**]
13. Syphilis (84)	*Dipsacaceae* (12;5;**7,92**). *Orocbanchaceae* (11;4;**6,55**). *Tamaricaceae* (9;3;**5,38**). *Solanaceae* (14;3;**4,08**). *Cuscutacae* (7;2;**4,0**). *Euphorbiaceae* (41;5;**3,51**). *Onagraceae* (17;3;**3,58**). *Convolvulaceae* (9;2;**3,41**).	Flavonoids[246;15;**3,03**] Alkaloids [49;4;**2,16**] Lactones[29;2;**1,26**] Quinones [36;2;**0,92**] Iridoids [62;3**;0,88**] Terpenoids [116;5; **0,87**] Coumarins [124;5;**0,72**] Phenols [59;2;**0,19**]
14. Nephritis (83)	*Athyriaceae* (8;2;**3,71**). *Hipericaceae* (13;2;**2,67**). *Primulaceae* (31;3;**2,24**). *Rutaceae* (8;2;**3,71**). *Sambucaceae* (7;2;**4,03**). *Scrophulariaceae* (85;8;**3,6**). *Solanaceae* (14;2;**2,53**). *Tiliaceae* (9;3;**5,42**). *Typhaceae* (5;2;**4,92**). *Urticaceae* (7;2;**4,03**).	Flavonoids[246;24;**6,54**] Phenols [59;8;**4,89**] Iridoids [62;7**;3,95**] Coumarins [124;10;**3,47**] Quinones [36;3;**1,94]** Alkaloids [49;3;**1,58**] Terpenoids [116;6;**1,46**] Xanthones [18;1;**0,66**]
15. Cystitis, cystourethritis (78)	*Solanaceae* (14;5;**7,56**). *Typhaceae* (5;2;**6,0**). *Tiliaceae (9;3;**5,62**).* *Plantaginaceae* (10;3;**5,28**). *Ericaceae* (38;5;**3,95**). *Equisetaceae* (10;2;**3,34**).	Phenols [59;8;**5,08**] Iridoids [62;8**;4,94**] Flavonoids[246;18;**4,58**] Coumarins [124;11;**4,26**]

	Pyrolaceae (10;2;**3,34**). *Primulaceae* (31;3;**2,37**). *Rosaceae* (147;8;**2,04**).	Alkaloids [49;4;**2,33**] Terpenoids [116;4;**0,47**] Lactones[29;1;**0,23**] Quinones [36;1;**0,01]**
16. Laryngitis (69)	*Campanulaceae* (27;5;**5,45**). *Sambucaceae* (7;2;**4,49**). *Solanaceae* (14;2;**2,88**). *Gentianaceae* (40;3;**2,09**).	Coumarins [124;11;**4,76**] Flavonoids[246;14;**3,47**] Terpenoids [116;8; **3,18**] Phenols [59;4;**2,19**] Iridoids [62;3**;1,24**] Quinones [36;2;**1,22**] Lactones[29;1;**0,36**]
17. Warts (64)	*Euphorbiaceae* (41; 24;**24,43**). *Dipsacaceae* (12;3;**5,31**).	Lactones[29;5;**5,46**] Flavonoids[246;16;**4,69**] Coumarins [124;5;**1,36**] Terpenoids [116;4; **0,88**] Alkaloids [49;2;**0,87**] Phenols [59;2; **0,59**]
18. Whooping cough (63)	*Solanaceae* (14;6;**10,24**). *Plantaginaceae* (10;3;**5,97**). *Urticaceae*(7;2;**4,37**). *Araceae* (9;2;**4,08**). *Liliaceae* (20;2;**2,37**). *Lamiaceae* (173;8;**2,21**).	Terpenoids [116;11;**5,42**] Coumarins [124;11;**5,13**] Phenols [59;6;**4,18**] Flavonoids[246;13;**3,41**] Iridoids [62;4**;2,28**] Lactones[29;2;**1,72**] Quinones [36;2;**1,36**] Alkaloids [49;2;**0,89**]
19. Gonorrhea (61)	*Plantaginaceae* (10;3;**6,08**). *Equisetaceae* (10;3;**6,08**). *Typhaceae* (5;2;**5,84**). *Nymphaeaceae* (7;2;**4,82**). *Oleaceae* (8;2;**4,46**). *Malvaceae* (13;7;**4,42**). *Convallariaceae* (17;3;**4,42**). *Onagraceae* (17;3;**4,42**). *Chenopodiaceae* (48;3;**1,97**). *Crassulaceae* (26;2; **1,96**).	Flavonoids [246;10;**2,16**] Coumarins [124;5;**1,48**] Iridoids [62;3**;1,47**] Alkaloids [49;2;**0,94**] Phenols [59;2;**0,66**] Lactones[29;1;**0,48**]
20. Erysipelas (60)	*Solanaceae* (14;6;**10,62**). *Crassulaceae* (26;3;**3,35**). *Convallariaceae* (17;2;**2,77**). *Rosaceae* (147;7; **2,29**).	Flavonoids [246;17;**5,47**] Lactones[29;4;**4,39]** Coumarins [124;9;**4,07**] Terpenoids [116;8; **3,65**] Alkaloids [49;4;**2,62**] Phenols [59;4;**2,51**] Iridoids [62;3**;1,51**]
21. Gastroenteritis (51)	*Valerianaceae* (23; 4; **5,06**). *Ericaceae* (38;4;**3,58**). *Fabaceae* (171;9;**2,89**). *Alliaceae* (18; 2; **2,63**). *Scrophulariaceae* (85;5;**2,41**). *Crassulaceae* (26;2;**1,96**).	Flavonoids [246;12;**3,8**] Iridoids [62;4;**2,79**] Phenols [59;3;**1,92**] Terpenoids [116;4; **1,36**] Coumarins [124;4;**1,22**] Alkaloids [49;2;**1,21**] Quinones [36;1;**0,44**]
22. Anthrax (50)	*Solanaceae* (14; 3; **5,6**). *Plantaginaceae* (10; 2; **4,39**). *Euphorbiaceae* (41;4;**3,92**). *Convallariaceae* (17;2;**3,14**). *Asteraceae* (372; 12; **2,3**).	Flavonoids [246;12;**3,88**] Terpenoids [116;7;**3,57]** Phenols [59;4;**2,96**] Iridoids [62;4;**2,83**] Coumarins [124;5;**1,96**] Alkaloids [49;2;**1,24**] Lactones[29;1;**0,69**] Quinones [36;1;**0,46**]
23. Leprosy (36)	*Rutaceae* (8;3;**9,16**). *Cuscutacae* (7;2; **6,46**). *Rubiaceae* (24;2;**3,1**). *Apiaceae* (140; 5; **2,49**)	Flavonoids [246;11;**4,69**] Terpenoids [116;6; **3,83**] Coumarins [124;6;**3,63**] Alkaloids [49;3;**3,06**] Phenols [59;3;**2,64**] Iridoids [62;2;**1,39**]
24. Enteritis (34)	*Plantaginaceae* (10;2;**5,47**). *Salicaceae* (24;3;**5,11**). *Rosaceae* (147;8;**4,85**).	Flavonoids [246;11;**4,93**] Iridoids [62;4;**3,84**] Terpenoids [116;4;**2,27**] Phenols [59;2;**1,56**] Coumarins [124;3;**1,28**] Alkaloids [49;1;**0,54**]
25. Smallpox	*Solanaceae* (14;2;**5,38**). *Ranunculaceae* (135; 4;	Alkaloids [49;2;**2,42**]

(25)	**2,65**).	Quinones [36;1;1,**22**] Iridoids [62;0;**0,62**] Flavonoids [246;3;**0,59**]
26. Measles (25)	*Sambucaceae* (7;2;**7,84**). *Ranunculaceae* (135; 4;**2,65**).	Terpenoids [116;5;**4,03**] Alkaloids [49;3;**3,96**] Flavonoids [246;7;**3,44**] Phenols [59;2;**2,08**] Lactones[29;1;**1,48**] Quinones [36;1;1,**22**] Coumarins [124;2;**0,89**]
27. Diphtheria (24)	*Solanaceae* (14;3;**8,42**).	Alkaloids [49;4;**4,07**] Coumarins [124;5;**3,96**] Quinones [36;2;**3,10**] Flavonoids [246;4;**1,4]** Terpenoids [116;2;**1,05**] Iridoids [62;1;**0,67**]
28. Scarlet fever (19)	*Solanaceae* (14;2; **6,26**).	Flavonoids [246;4;**1,92**] Quinones [36;1;**1,56**] Coumarins [124;2;**1,32**] Alkaloids [49;1;**1,18**] Iridoids [62;1;**0,92**] Terpenoids [116;1**;0,26**]
29. Pharyngitis (19)	*Lamiaceae* (173;4; **2,73**).	Terpenoids [116;9;**9,55**] Phenols [59;5;**7,42**] Iridoids [62;3;**4,06**] Coumarins [124;2;**1,32**] Flavonoids [246;3;**1,1]**
30. Intermittent fever (18)	*Rutaceae* (8;2;**8,45**). *Salicaceae* (24;2;**4,93**). *Crassulaceae* (26; 2; **4,71**). *Rosaceae* (147;4;**3,42**). *Lamiaceae* (173;3; **1,99**).	Flavonoids [246;8;**5,41**] Coumarins [124;5;**4,87**] Alkaloids [49;2;**3,06**] Phenols [59;2;**2,69**] Lactones[29;1**;1,92**] Terpenoids [116;2;**1,51**]
31. Lupus (17)	*Peonaceae* (6;2;**10,4**). *Geraniaceae* (17;2;**5,98**). *Scrophulariaceae* (85;2;**2,13**).	Alkaloids [49;2;**3,18**] Flavonoids [246;5;**3,05**] Iridoids [62;2;**2,71**] Phenols [59;1;**1,10**] Terpenoids [116;1;**0,37** Coumarins [124;1;**0,30**]
32. Sepsis (16)	*Fabaceae* (171;4;**3,2**). *Brassicaceae* (93; 2; **2,08**).	Alkaloids [49;5;**9,08**] Flavonoids [246;3;**1,43]** Phenols [59;1;**1,17**] Coumarins [124;2;**1,16**] Iridoids [62;1;**1,11**]
33. Urethritis (14)	*Plantaginaceae* (10;2;**8,81**).	Lactones[29;1;**2,28**] Alkaloids [49;1;**1,56**] Phenols [59;1;**1,33**] Iridoids [62;1;**1,27**] Coumarins [124;1;**0,51**]
34. Encephalitis (14)	*Peonaceae* (6;2;**11,49**).	Terpenoids [116;3;**3,28**] Phenols [59;1;**1,33**] Coumarins [124;1;**0,51**]
35. Gangrene (13)	*Brassicaceae* (93;2;**2,45**).	Terpenoids [116;2;**2,06**] Flavonoids [246;3;**1,85]** Alkaloids [49;1;**1,65**] Coumarins [124;1;**0,59**]
36. Cholera (13)	*Fagaceae* (11;2;**8,72**). *Poaceae* (83;2;**2,67**).	Terpenoids [116;4;**4,87**] Coumarins [124;3;**3,30**] Flavonoids [246;4;**2,84**] Phenols [59;1;**1,42**]
37. Bone tuberculosis (13)	*Pyrolaceae* (10;2;**9,16**). *Solanaceae* (14;2;**7,68**). *Lamiaceae* (173;3;**3,19**).	Iridoids [62;2;**3,26**] Flavonoids [246;4;**2,84** Alkaloids [49;1;**1,65**] Coumarins [124;1;**0,59**]
38. Typhus	*Ericaceae* (38;2;**4,63**).	Phenols [59;3;**5,57**]

(12)		Terpenoids [116;2;**2,2**] Flavonoids [246;3;**2,01**] Iridoids [62;1;**1,46**]
39. Pyelonephritis (12)	*Brassicaceae* (93;2;**2,61**).	Terpenoids [116;5;**6,58**] Flavonoids [246;6;**5,09**] Coumarins [124;2;**2,09**] Phenols [59;1; **1,52**]
40. Herpes (12)	*Asteraceae* (372; 4; **2,08**).	Xanthones [18;1;**3,36**] Terpenoids [116;2;**2,2**] Coumarins [124;2;**2,09**] Flavonoids [246;3;**2,01**] Iridoids [62;1;**1,46**]
41. Trichomonas colpitis (11)	*Nymphaeceae* (7;2;**12,01**).	Alkaloids [49;2;**4,19**] Terpenoids [116;3;**3,89**] Coumarins [124;3;**3,72**] Flavonoids [246;1;**0,05]**
42. Typhoid fever (10)	*Lamiaceae* (173;3;**3,19**).	Alkaloids [49;2;**4,44**] Lactones[29;1;**2,83**] Terpenoids [116;2;**2,54**] Flavonoids [246;2;**1,27]** Coumarins [124;1;**0,87**]
43. Trichophytia (10)	*Betulaceae* (29;2;**5,97**).	Alkaloids [49;2;**4,44**] Coumarins [124;2;**2,42**] Flavonoids [246;3;**2,4**] Terpenoids [116;1;**0,94**]
44. Chicken pox (10)	*Apiaceae* (140;2;**2,2**).	Flavonoids [246;4;**3,52**] Coumarins [124;2;**2,42**] Phenols [59;1;**1,76**] Terpenoids [116;1;**0,94**]
45. Tuberculosis of lymph nodes, glands (9)	*Asteraceae* (372;4; **2,79**). *Grossulariaceae* (8;2;**12,43**). *Violaceae* (26;2;**6,71**).	Terpenoids [116;4;**6,12**] Phenols [59;1**;1,90**] Coumarins [124;1;**0,99**] Flavonoids [246;2;**0,26**]
46. Pyelitis (9)	*Ericaceae* (38;4;**11,26**).	Phenols [59;3;**6,58**] Iridoids [62;2;**4,12**] Flavonoids [246;4;**3,82**] Coumarins [124;2;**2,62**] Terpenoids [116;1;**1,06**]
47. Candidal stomatitis (9)	*Crassulaceae* (26;2;**6,71**).	Flavonoids [246;3;**2,63**] Coumarins [124;2;**2,62**] Phenols [59;1**;1,90**]
48. Amoebic dysentery (8)	*Rosaceae* (147;3; **4,13**). *Rutaceae* (8;2;**13,20**). *Violaceae* (26;2;**7,16**).	Flavonoids [246;5;**5,41**] Alkaloids [49;2;**5,06**]
49. Lung abscess, lung gangrene (8)	*Brassicaceae* (93;2;**3,45**).	Iridoids [62;1;**2,00**] Quinones [36;1;**2,84**] Flavonoids [246;1;**0,38**]
50. Giardiasis (7)	*Asteraceae* (372;4;**3,45**). *Betulaceae* (29;2;**7,25**).	Phenols [59;2;**4,91**] Terpenoids [116;2;**3,27**] Flavonoids [246;2;**1,87**] Coumarins [124;1;**1,28**]
51. Mumps (7)	-	Phenols [59;1;**2,26**] Flavonoids [246;2;**1,87**] Coumarins [124;1;**1,28**]
52. Meningitis (7)	*Poaceae* (83;2;**4,03**).	Alkaloids [49;2;**5,46**] Coumarins [124;2;**3,13**] Flavonoids [246;1;**0,53**]
53. Dermatomycoses of the scalp (6)	-	Quinones [36;1;**3,37**] Phenols [59;1;**2,26**] Terpenoids [116;1;**1,56**] Flavonoids [246;1**;0,7**]
54. Tetanus (6)	*Solanaceae* (14;3;**17,31**).	Coumarins [124;2;**3,47**] Terpenoids [116;1;1,**56**]

		Flavonoids [246;1;**0,7**]
55. Plague (5)	*Asteraceae* (372;3;**3,11**).	Quinones [36;1;**3,74**] Terpenoids [116;1;**1,8]** Coumarins [124;1;**1,71**] Flavonoids [246;1;**0,89**] Flavonoids [246;1;**0,89**]
56. Brucellosis (5)	*Rubiaceae* (24;2;**9,56**).	Iridoids [62;2;**5,79**] Coumarins [124;1;**1,71]** Flavonoids [246;1;**0,89**]
57. Infectious-allergic polyarthritis (5)	*Asteraceae* (372;3;**3,11**).	Terpenoids [116;2;**4,06**] Coumarins [124;1;**1,71**]
58. Leishmaniasis (5)	*Euphorbiaceae* (41;4;**14,72**).	Flavonoids [246;3;**4,08**] Alkaloids [49;1;**3,14**]
59. Foot and mouth disease (5)	-	Phenols [59;1;**2,81**] Terpenoids [116;1;**1,8**] Coumarins [124;1;**1,71**]

CONCLUSIONS

1. In the set of species used for infectious diseases, as a rule (for 56 diseases out of 59), the occurrence of representatives of a certain family or families of plants is significantly increased.

2. Families, including those close in the number of species in the flora of medicinal plants, differ sharply in the number of diseases (from 0 to 17) reliably associated with them through an increase in the occurrence of the species used.

3. In a kit used for an infectious disease, as a rule, there is a significant increase in the occurrence of species containing at least one compound that has an experimentally established antimicrobial or antiviral effect, and belonging to one of 9 groups (flavonoids, terpenoids, alkaloids, phenols, coumarins , lactones, iridoids, xanthones, quinones). As a rule, such compounds from more than one group (up to 8) reliably gravitate towards the set of species used.

4. Infectious diseases differ significantly in combinations of groups of chemical compounds, which reliably gravitate towards the sets of plant species used.

5. Information about the increased occurrence in kits used for infectious diseases of species of certain families, and species containing antimicrobial or antiviral compounds of certain groups, can be used to assess the prospects of families, plant species, and chemical compounds when studying their antimicrobial, antiviral properties properties.

CONFLICTS OF INTEREST

The author declare that he has no potential conflicts of interest.

REFERENCES

Bhattarai, A., Ali, A. S., Kachur, S. P., Mårtensson, A., Abbas, A. K., Khatib, R., ... & Björkman, A. (2007). Impact of artemisinin-based combination therapy and insecticide-treated nets on malaria burden in Zanzibar. *PLoS medicine*, 4(11), e309.

Budantsev, A. L., Lesiovskaya, Ye. Ye., Abysheva, L. N., Belenovskaya, L. M., Bobyleva, N. S., Bykova, O. P., ... & Ulicheva, G. M. (2001). Dikorastushchiye poleznyye rasteniya Rossii. SPb. 663 p. [In Russian]

Lakin G.F. (1973). Biometriya. M.: Vysshaya shkola, 343 p. [In Russian]

Popov, P. L., & Botvinkin, A. D. (2008). Analiz svedeniy o primenenii rasteniy dlya profilaktiki i lecheniya beshenstva. *Sibirskiy meditsinskiy zhurnal (Irkutsk)*, 78(3), 91-95. [In Russian]

Popov, P. L. (2021). Svyaz' antibakterial'noy aktivnosti vida rasteniy s khimicheskimi soyedineniyami raznykh grupp: statisticheskiy podkhod. *Vestnik Biomeditsina i sotsiologiya*, 6(3), 28-36. [In Russian]

Semikhov V.F. (2001). Biologicheski aktivnyye veshchestva rastitel'nogo proiskhozhdeniya, v trekh tomakh, M.: Nauka, 349, 763 p. [In Russian]