The concept of the phytogenic field: theory, research experience and practical significance

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Abstract. The aim of this study was to analyze the theoretical foundations of the concept of the phytogenic field, to show the fruitfulness and practical feasibility of studying the phytogenic field of plants, especially edificatory species, using the example of studies carried out in various ecological and phytocenotic conditions and to determine the effect of uneven-aged black saxaul plants on wormwood-ephemeral vegetation by studying phytogenic field of this edificator species. The phytogenic field of black saxaul was studied by the phytometer method in the Karnabchul desert. It was found that the phytogenic effect of the edificator on the wormwood-ephemeral vegetation is observed at a distance of 90-150 cm outside the crown, depending on the age state of black saxaul. The average crown radius of black saxaul in the studied phytocenosis is 115 cm, and the average radius of its phytogenic field is 235 cm. To create a continuous integral phytogenic field in the entire phytocenosis, 434 black saxaul individuals per 1 ha are required evenly.

1. Introduction
Knowledge of the structural and functional organization of phytocenoses is one of the main tasks of modern phytocenology. The most promising in this respect is the study of the relationships of plants that make up phytocenoses, because the relationship of plants is a factor in the organization of a phytocenosis, the spatial distribution of cenopopulations and even individuals. “With the appearance of this trait, phytocoenosis appears, phytocenotic selection appears. As long as there is no such trait, there is no phytocenosis, but there is only a set of individuals and plant species conditioned only by ecotopic selection”[1].

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The ability of plants to change the environment and influence others was noted by VN Sukachev back in 1915 in his work "Introduction to the doctrine of plant communities": "Each plant itself changes ... the climate, transforming it in a certain direction" [2] and thus “plants in the community influence each other and are closely related to each other” [2].

An important direction of research in studying the interaction of plants in a community is the study of their phytogenic fields. The study of the phytogenic fields of edificatory species is of particular importance. This is due to the fact that the appearance of a phytocenosis is largely determined by edificator species, since these plants play a leading role in creating special environmental conditions around individual individuals and throughout the cenosis [3, 4].

1.1. Theoretical foundations of the phytogenic field concept

The theoretical foundations of the concept of the phytogenic field were developed and scientifically substantiated by Professor Uranov [5]. In his opinion, each plant, in its life activity, changes the environmental conditions within a certain part of the space around itself and this changed environment affects the growing plants nearby in different ways. He called this part of the environment the phytogenic field of this individual. Thus, due to the presence of an individual of a particular species, part of the space acquires new properties that differ from the general background.

According to Uranov [5], plant specimens are an elementary source, the causative agent of changes in the environment. Further research, carried out under the leadership of A.A. Uranov, showed that in relation to various life forms of plants, an elementary source of the phytogenic field can be an individual (annual, single-stemmed tree), part of an individual (root suckers that are part of one individual; partial formations) or a set of individuals (compact clones of dense sod grasses, bulbous, etc.), since each of them in relation to the environment acts as a single, further non-dividing "center of influence" [6].

The phytogenic field in principle (by analogy with the fields existing in physics) has no boundaries, however, "the practical boundary of the field can be considered the area of space where the effect of a given plant on the environment becomes less than the effect of other plants or agents of a different nature" [7].

The phytogenic field of plants, according to Uranov [5], has two dissimilar parts: internal, lying within the general contour of plants, external - outside it; when passing from the inner to the outer part, the phytogenic field strength changes abruptly, suddenly. This indicator is used to determine the boundary of the inner part of the phytogenic field.

Studies carried out in various ecological-geographical zones have established that in some cases, the quantitative indicators of phytometer species change dramatically in the transition from the inner to the outer part [4, 8-17], in others – gradually [18-20]. To isolate the inner part of the phytogenic field, abrupt changes in one intensity indicator are sufficient [21].

Uranov [7], once again returning to the theory of the phytogenic field, developed the concept of the minimum phytogenic field. In his opinion, the space most tightly controlled by a plant individual is the minimum phytogenic field. Within this part of the phytogenic field, the individual carries out the strongest interaction with the environment and it is limited by the contours of the individual itself and the immediate vicinity to it. Based on this, we can say that the minimum phytogenic field corresponds to the inner part of the phytogenic field. The study of the phytogenic field of various species by many researchers made it possible to determine their minimum phytogenic field, the average radius of which in herbaceous plants ranges from – 3-6 cm to 10-12 cm [21, 22], in trees: pine - about 6 m from the trunk [23], larch - 1-2 m [20], single oaks - 3 m [9], black saxaul - up to 2 m [14, 20]. The average radius of the minimum phytogenic field varies depending on the age state of the active species. For example, in virginial individuals of black saxaul it is 0.65 m; young generative – 1.12 m; middle-aged generative – 1.67 m [14, 15]. According to Zaugolnovaya et al. [21], the boundary of the outer part of the phytogenic field can be limited by the space where the living and dead plant parts are physically present. It actually corresponds to the zone occupied by the plant root system and its rhizosphere.
study of phytogenic fields using the phytometer method showed that the boundary of the outer part of this field can be established by the behavior of phytometer species [15-17, 20].

An important property of the phytogenic field is its change over time. Studies have shown that the intensity of the phytogenic field of the edificator species changes during the day and during the growing season, i.e. its influence changes in connection with the daily and seasonal changes in external factors [14]. The structure and intensity of the phytogenic field changes depending on the ontogenetic moment of plant development, which is confirmed by the change in the environment-forming role of Shrenk's spruce [24], the environment-forming ability of black saxaul in ontogenesis [14, 17]. The intensity of the phytogenic field changes by the hereditarily fixed rhythm of plant development [5].

An essential property of a phytogenic field, in contrast to a physical one, consists not only in the nature of the change in the field strength, but also in the fact that the effect of the phytogenic field continues to exist even after its source disappears. Traces of plant life in the soil can persist for several decades [10].

At a certain density of individuals of dominants, an overlap of their phytogenic fields is observed, and a continuous field of phytocenosis [25] or a cenogenic field [26], is created, due to which a cellular network of interactions is formed in space, which determines the structural and functional organization of the phytocenosis.

1.2. The state of knowledge of the phytogenic field of plants
Each plant, to one degree or another, changes the ecological environment in its environment, and those individuals that change it to the greatest extent in comparison with their neighbors and in such a way that this is reflected in the abundance or condition of the latter, and will be edificators [4]. Therefore, the leading role in creating special environmental conditions around individual individuals and throughout the cenosis belongs to edificator species, the environment-forming effect of which largely determines the appearance of the phytocenosis. In this regard, the study and determination of the phytogenic field of edificatory species is of particular importance.

Questions of the phytogenic field of plants were studied in the steppe zone near Ioanna's feather grass and Becker's fescue by Uranov and Mikhailova [22], Mikhailova [8], Zaugolnova and Mikhailova [27], in meadow cenoses in the soddy pike Galanin et al. [19, 28], in the field thistle Galanin [18], in the forest cenoses near the forested forest and the dream of Toropova [6], in the northern forest area near the Gmelin larch Dem'yanov [20], in a lichen pine forest in sheep's fescue by Samoilov [29], single oaks by Samoilov [9], herbaceous plants (lily of the valley and spotted probes) by Samoilov and Tarkhova [30], various woody plants in forest communities by Kotov, Kuzmina [31], in the pine forest of the Kivach reserve, Paal et al. [32], in the grassy forests of the Lower Angara region, Lashchinsky [23], Scots pine on the dumps of the coal industry by Ufimtsev et al. [33] and others.

These studies have confirmed the theoretical concepts developed by prof. Uranov [5, 7] on the phytogenic field: plant individuals, changing environmental conditions, affect the redistribution of a number of growing plants. The data obtained by these authors showed that different species change environmental conditions in different ways and create phytogenic fields of different parametric characteristics. If the field of influence of an edificator species on a plant of herbal cenoses is limited to centimeters, then the phytogenic field of woody plants is measured in meters.

Research conducted by Uranov's students [6, 8, 21, 27] and his followers [9, 11-20, 29-33], when studying the phytogenic fields of many plant species belonging to different life forms, confirmed the fruitfulness of the theoretical provisions on the phytogenic field in solving scientific and applied issues of phytoecology and ecology. The analysis of these works gives the main to say that the definition of the phytogenic field, especially of the edificator species, “is of paramount importance in the study of the structure of the phytocenosis, since functional relationships in the plant community depend on this value” [23] and “will allow a more accurate and specific assessment of the nature and degree of interspecific relationships” [34].
Pointing out the importance of studying the phytogenic field of plants, Uranov [5] wrote: “Penetration into the essence of the internal environment of a community through the study of phytogenic fields should give a biologist important information necessary both for forecasting and planning directed human intervention in the structure and life of the community”.

“The concept of a phytogenic field, proposed and substantiated by Uranov, is of fundamental conceptual significance for the systemic approach of phytocenology, because it forces us to consider a phytocenosis as not a simple sum of individuals, but as something whole, in which due to the interaction and interference of phytogenic individuals create an integral phytogenic field, an integral mode of closure” [35].

1.3. Manifestations of the environment and cenosis-forming ability of desert plants

In the botanical literature, there is an opinion that in desert conditions during the formation and dispersal of plants in space, external environmental factors play a decisive role, and the relationship between species as a result of the sparseness of the grass stand is weak or completely absent [36, 37]. To a certain extent, these statements ignore the role of edificators of desert plant communities.

In the conditions of the deserts and semi-deserts of Central Asia, a number of works have been carried out to study the environment-transforming role of shrubs and semi-shrubs, in particular, the tree-like shrub of black saxaul. Studies have shown that black saxaul has a significant effect on the soil [10; 38; 39], on the redistribution of atmospheric precipitation and, as a consequence, on the nature of the water regime of the soil [10, 38, 40-42], as a result of which the species composition changes and a sub-crown plant microgroup is formed [38, 43].

Black saxaul protects undercrown vegetation from high solar radiation), reduces air and soil temperatures, and increases air humidity [40, 41, 44]. As a result, favorable microclimatic conditions are formed for the growth and development of undercrown vegetation.

At present, the opinion has been established that black saxaul is a powerful cenosis-forming agent in deserts. It is distinguished by significant longevity, large volume of phytomass, which gives a lot of organic matter and, as a result, creates a kind of ecological environment for a large number of plant species. These qualities determine its cenosis-forming ability [39].

The presence of black saxaul in phytocenoses creates a mosaic structure of vegetation (phytogenic mosaicism), it enriches desert pastures with well-eaten plants and increases the diversity of desert food [43].

Studies carried out in the sandy desert have shown that black saxaul significantly affects the change in the species composition of vegetation and the accumulation of aboveground phytomass by them [10, 38]. Moreover, the degree of influence of this shrub on vegetation depends on its age and state of life. Summarizing the above, we can conclude that black saxaul has a high environment-transforming power, which is expressed in a change in ecological regimes and, as a consequence, vegetation of a different composition, structure and productivity is formed in pasture ecosystems. At the same time, from the analysis and assessment of literary sources, it follows that all the authors who studied the environment-transforming and cenosis-forming abilities of black saxaul limited themselves to the study of the minimum phytogenic field of this treelike shrub. In other words, the study mainly studied the influence of black saxaul on the undercrown air and soil environment, undercrown vegetation.

There is a basis for judging that, based on the concept of a phytogenic field, the sphere of influence of black saxaul on the environment and vegetation is not limited to its minimum phytogenic field, this influence, as we see it, covers a wider area. At the same time, special studies aimed at understanding the phytogenic field, its parameters, structure and properties of edificatory plants, including black saxaul, have not yet been carried out in desert pasture ecosystems.

In the conditions of desert pastures, this issue is of particular importance in connection with the improvement of natural pasture ecosystems through their phytomelioration. Black saxaul Haloxylon aphyllum (Minkw.) Ilijin., as a powerful violent species with a large environment and cenosis-forming ability, high potential and seed productivity, a significant duration of complete ontogenesis, ecological
plasticity and high adaptive potential to stressful environmental conditions, is widely used in the creation of shrub-grass pastures and pasture shelter belts. The study of the phytogenic field of black saxaul will make it possible to determine the relationship of this tree-like shrub with other species in the phytocenosis. Knowing the relationship of black saxaul, the edificator of black saxaul pastures, with other neighboring species, we can judge the internal life of the phytocenosis. Knowledge of the phytogenic effect of this edificator species on plants experiencing these influences is essential in the development of effective technologies for the creation of highly productive, multicomponent artificial pastures with the participation of black saxaul, as well as for the knowledge of the structural and functional organization of black saxaul forests and the development of ways of purposeful accommodation in life. These communities to increase and maintain their productive state, increase the stability of the composition, structure, etc. The study of the phytogenic field of this tree-like shrub will make it possible to establish the size, nature and direction of its influence, to find out the structure of the distribution of subordinate species and to determine the productivity of pasture ecosystems. Therefore, the problem of studying the phytogenic field of desert fodder plants, in particular, the tree-like shrub - black saxaul, is very relevant in scientific and practical terms.

2. Methods
The aim of the study is to analyze the theoretical foundations of the concept of the phytogenic field, to show the fruitfulness and practical feasibility of studying the phytogenic field of plants, especially edificatory species, using the example of studies carried out in various ecological and phytocenotic conditions and to determine the effect of uneven-aged black saxaul plants on the productivity of wormwood-ephemeral vegetation through studying the phytogenic field of this ephemeroid species. Studies of the phytogenic field of black saxaul in the wormwood-ephemeral desert of Karnabchul were carried out by the phytometer method developed by Uranov [22]. Determination of the abundance, linear growth, and annual growth of the aboveground phytomass of wormwood was carried out around 36 individuals (12 virginal, 12 young generative, and 12 middle-aged generative) black saxaul with the sampling, which consisted of a series of annular areas. The size of these areas, starting from the trunk, was equal to the average diameter of the wormwood and was 30 cm. In the ring plots, the annual increase in the aboveground phytomass was determined by the age states of the phytometer species (j – juvenile, v – virginal, q1 – young generative, q2 – middle-aged generative, q3 – old generative, s – senile) by cutting off the forage part of plants with subsequent drying and weighing.

To determine the aboveground phytomass of herbaceous plants, 9 model individuals of black saxaul were selected: 3 virginal, 3 young generative and 3 middle-aged generative. Around these individuals, transects were laid in four directions (north, south, west, east) 50 cm wide, the length of which slightly exceeded the radius of the crown of black saxaul. These transects, starting from the trunk of the saxaul, were divided into 50x30 cm areas. The number of transects in each age group was 12, total - 36. The vegetation found in these areas was mowed and divided into 3 groups: bulbous bluegrass, thick-stemmed sedge and forbs. After that, the number, indicators of linear growth of bulbous bluegrass and thick-columnar sedge were determined. Then the air-dry mass of herbaceous plants was determined.

The control was a natural wormwood-ephemeral pasture, where black saxaul was absent. During office processing, the data obtained were recalculated per 1 m². The materials were processed by the method of mathematical statistics [45].

3. Results and Discussion
Research carried out in Karnabchul showed that under the phytogenic influence of black saxaul, sharp fluctuations in abiotic environmental factors significantly decrease and become more moderate. In the saxaul phytogenic field, the illumination is much lower than outside it. In the minimum phytogenic field, especially in the northern and western directions, the illumination is 20-40% of the total value in
the open pasture. The temperature of the soil and air of the phytogenic field is low during the day and higher at night compared to the control, where black saxaul is absent. Due to this, the daily amplitude of temperature fluctuations in the phytogenic field decreases. At the same time, the humidity of soil and air in the phytogenic field of black saxaul is much higher, especially in its inner part. As a result, in the phytogenic field of black saxaul, a more favorable ecological situation is created, characterized by less tension. At the same time, the nature of its impact on the environment changes depending on the season of the year, and during the growing season, a milder microclimate is created in the phytogenic field of this treelike shrub [13, 14].

Black saxaul has a significant effect on the mineral composition of the soil. As a result of leaching of black saxaul litter, salinization occurs mainly in the inner part of the phytogenic field, where sodium predominates, which indicates the beginning of the formation of solonetzicity, and the presence of soda, toxic for a number of plants, in the upper soil horizons [14]. Thus, the effect of black saxaul on environmental conditions, on the one hand, is positive: a more moderate microclimate is created in the phytogenic field, which contributes to better growth and development, the accumulation of high yields of the fodder mass of plants in the lower tiers; on the other hand, it is negative, which is expressed in soil salinization and a decrease in the illumination of the phytogenic field.

A comparative study of the influence of black saxaul individuals of different ages showed that the degree of their impact on environmental conditions is not the same. The highest habitat-transforming ability is possessed by middle-aged generative individuals of black saxaul, the lowest - virginal and old generative ones. The degree of salinity of the under-crown soil also depends on the age state of this tree-like shrub. Insignificant soil salinity is observed in the minimal phytogenic field of virginal plants of black saxaul. With the transition to the next age states, the degree of salinity increases. The highest degree of salinity is observed in the inner part of the phytogenic field of a middle-aged generative plant of black saxaul [14].

A change in environmental conditions under the phytogenic influence of black saxaul have a significant effect on other plants growing in this phytocenosis and is primarily expressed in the redistribution of vegetation of the lower tiers. In the minimum phytogenic field, the dominants of wormwood-ephemeral vegetation are displaced - wormwood, bulbous bluegrass and sedge. Sedge is absent in such a place of middle-aged generative plants of black saxaul; wormwood is represented mainly by old generative, subsenile and senile individuals. Bluegrass is found in small quantities. With the transition to the outer part of the phytogenic field, the number of bulbous bluegrass shoots increases abruptly and gradually decreases with further distance from the center of the phytogenic field. The abundance of sedge and wormwood, on the contrary, increases as the intensity of the phytogenic field decreases. The influence of black saxaul outside the crown on the placement of phytometer species is observed at a distance of 90-150 cm, depending on the age of the edificator species; therefore, the radius of the phytogenic field, taking into account the average radius of the crown, is 155 cm in v saxaul individuals, and in g1 individuals - 232 cm and in g2 individuals - 317 cm, on average 235 cm. With a further distance from the center of the phytogenic field, the nature of distribution and the number of phytometer species do not differ from the control (open wormwood-ephemeral pasture).

The influence of the phytogenic field is reflected not only on the distribution, but also on the indicators of the linear growth of plants of phytometer species. In the minimum phytogenic field, their growth processes are noticeably suppressed. Wormwood specimens are undersized here, and rare plants of bluegrass and sedges often dry out in a vegetative state, without forming generative shoots.

With the transition from the inner to the outer part of the phytogenic field, the rapid development of bulbous bluegrass is observed, the height of the shoots of which is 1.5-2.0 times higher than the control. With further distance from the center of the phytogenic field and, accordingly, with a decrease in the intensity of the phytogenic field, the linear growth indices of bluegrass decrease and gradually approach the control. At the same time, the indicators of linear growth of other phytometer species - wormwood and thick-stemmed sedge - gradually increase with distance from the center of the
phytogenic field and approach the control at a distance of 90-150 cm outside the crown, depending on the age state of black saxaul.

The reason for the deceleration of growth processes in some species and acceleration in others is, apparently, the expression of ecological originality and their competitiveness. Different degrees of ecological specificity of species, in turn, are manifested in the degree of differentiation of ecological niches [46].

In the minimal phytogenic field, due to changes in the habitat of the dominant species of wormwood-ephemeral communities, wormwood, bluegrass bulbous and thick-stemmed sedge are displaced, and as a result, ecological niches are freed. Under changed environmental conditions, salt and shade-tolerant plants settle.

An integral consequence of the differentiation and packing of ecological niches in the saxaul phytogenic field is the nature of the annual growth of the aboveground phytomass of wormwood-ephemeral vegetation. The largest values of the annual increase in the aboveground phytomass of plants in the lower tiers are observed at the crown periphery and in the near-crown space. Depending on the age status of black saxaul, they are 1.6-3.2 times higher than those on the natural wormwood-ephemeral pasture. Here, the aboveground phytomass of bulbous bluegrass is especially high, which accumulated on the crown periphery and in the near-crown space in virginal saxaul plants 44.65-54.49 g/m², in young generative plants - 83.05-155.35 g/m², in middle-aged generative - 54.27-162.61 g/m², in the control - 23.01 g/m².

A high aboveground phytomass is also formed in forbs. At the same time, in the phytogenic field of saxaulacherny, a low level of annual growth of the aboveground phytomass is observed in the wormwood and sedge pachystylis.

Such a distribution of the aboveground phytomass of wormwood-ephemeral vegetation is observed at a distance of 90-150 cm outside the crown, depending on the age state of black saxaul. If we take into account that the average crown radius of the saxaulacher phytocenosis studied is 115 cm, then the average radius of its phytogenic field is 235 cm. Therefore, in order to create a continuous integral phytogenic field in the entire phytocenosis, 434 individuals of black saxaul per 1 ha are required.

4. Conclusions
1. The theoretical position of prof. A.A. Uranov on the phytogenic field turned out to be the most applicable in the study of the relationship of plants by determining the phytogenic field of plants, especially edificatory species, which confirms the results of numerous studies carried out in various ecological-geographical and phytocenotic conditions.
2. Black saxaul as the most powerful edificatory species of desert phytocenoses has a significant impact on the environment. The impact of black saxaul on environmental conditions, on the one hand, is positive: a more moderate microclimate is created in the phytogenic field, which contributes to better growth and development, the accumulation of higher yields of fodder mass of plants in the lower tiers; on the other hand, it is negative, which is expressed in soil salinization and a decrease in the illumination of the phytogenic field.
3. The impact of black saxaul is observed not only within the minimum phytogenic field (under the crown), but also outside the crown at a distance of 90-150 cm, depending on the age of the edificator species, therefore, the radius of the phytogenic field, taking into account the average radius of the crown, is in v individuals of saxaul 155 cm, in g1 individuals - 232 cm and in g2 individuals - 317 cm, on average 235 cm. With further distance from the center of the phytogenic field, the phytogenic effect of black saxaul on wormwood-ephemeral vegetation decreases to a minimum.
4. Analysis of the data showed that it is with a more uniform diffuse distribution of black saxaul individuals, not exceeding 434 individuals per 1 ha, that the optimal intensity of the phytogenic field of this edificator species is created throughout the phytocenosis, which contributes to a more complete development of the ecological niche by species that make up ephemeredoid-wormwood-black saxaul community, weakening of competition between species, better use of the material and energy resources of the environment and, as a consequence of all this, the formation of the aboveground eaten
phytomass, which is 1.5 times higher (excluding the annual increase in the aboveground phytomass of black saxaul) than the natural wormwood ephemeral vegetation.

5. The foregoing allows us to say that the study of plant relationships from the standpoint of the concept of the phytenic field has not only theoretical, but also significant practical value.

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