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Crop rotation – a guarantee for sustainable yields

Author(s): проф. д-р Щелияна Калинова, Аграрен Университет Пловдив
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The need for crop rotation has been established since the early stages of agricultural development. The first artefacts date back to Roman times, when *Virgil* wrote in his works that higher yields from cereal crops are obtained after leguminous crops and that proper crop rotation provides “rest” for the land. Later, *Pliny* recommended that wheat crops be alternated with lupine, vetch and other leguminous crops.

At the beginning of the 19th century, with the rapid development of the natural sciences, the first attempts were made to provide a scientific justification for the causes determining the negative impact of continuous and multi-year cultivation of crops on the same area. According to the Swiss botanist *De Candolle*, plants extract from the soil both the substances they need and those they do not need. These very substances are released back into the soil, accumulate, and inhibit the

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development of repeated and subsequent crops of the same species. This understanding was later modified in the sense that plants excrete through their roots organic compounds harmful to subsequent crops of the same species, which are not harmful to crops of other plants and even serve them as food. At the beginning of the 20th century, American scientists discovered toxic substances excreted by plant roots. It turned out that they are harmful to plants of the same botanical species, less harmful to biologically related plants, and harmless to biologically unrelated plants.

With the emergence and development of the theory of crop rotation, the need for alternation of crops has been explained by the corresponding theories of soil nutrition of plants. Based on the theory of **humus nutrition** of plants, *scientists* divided cultivated plants into two opposing groups – ***exhausting*** and ***enriching*** the soil with humus. The first group includes cereal crops with a closed stand, and the second – broad-leaved crops (row crops, legumes, perennial forage crops, etc.). At that time the nitrogen-fixing capacity of leguminous plants and their beneficial effect on the subsequent crop were still unknown.

According to the theory of **mineral nutrition**, cultivated plants are classified depending on which nutrient element most depletes the soil – nitrogen, phosphorus, potassium or calcium. It is considered that the negative effect of monoculture is due to the unilateral depletion of the soil in the same mineral nutrients. Therefore, in practice, the alternation of crops that deplete the soil in different nutrient elements is recommended.

Later research in England and France showed that this concept of unilateral soil depletion is untenable. In many cases, even with heavy fertilization, some crops (flax, clover, etc.) give unsatisfactory yields.

The discovery of the **symbiosis between leguminous crops and nodule bacteria** is revolutionary for agriculture and provides a new explanation for the positive effect of alternating leguminous and non-leguminous crops. Under monoculture cultivation of leguminous crops, the nitrogen fixed by the nodule bacteria and accumulated in the soil is not only not used in subsequent years by the same plant, but also suppresses its development. The nitrogen accumulated in the soil after leguminous crops is used by plants from other families, which increase their yields.

At the same time, *A. Kostichev* and *V. R. Williams* developed a completely new direction in the theory of crop alternation. According to these two authors, when cultivating annual cereal crops, the chemical composition of the soil does not change, but its physical properties deteriorate; the soil structure is sharply destroyed, which in turn worsens the water and nutrient regime and reduces soil fertility. According to this theory, the structure can be improved only by growing perennial mixtures of grasses and legumes, and their inclusion in the crop rotation is recommended, giving rise to the so-called **grass-field crop rotations**.

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A common shortcoming of the crop rotation theories considered is their limited and one-sided character. Numerous later studies aimed at identifying the causes of the negative effect of monoculture and the positive effect of rotation have proven that these causes are diverse and interrelated.

In modern agriculture, the reasons for crop rotation are grouped into the following four categories:

1. ***Biological causes***, which are expressed in the different response of cultivated plants to weeds, diseases and pests; lower organisms – fungi and bacteria parasitizing on the roots or excreting toxic substances; metabolic products, etc. Depending on the degree of intensification of agriculture and the level of supply of cultivated plants with water and nutrients, the importance of biological causes increases and, along with it, the phytosanitary role of crop rotation. Moreover, in organic farming the role of crop rotations is of primary importance.

2. ***Chemical causes*** – these are the different requirements of plants for nutrients and their varying ability to absorb them from the soil, and others.

3. ***Physical causes*** – these reflect the different effects of plants and their cultivation practices on the physical properties and water regime of the soil.

4. ***Economic causes*** – these demonstrate that accurately designed, scientifically based crop rotations enable proper soil tillage, fertilization, irrigation, reduction of production costs, and others.

The main reason for yield reduction is the cultivation of crops as repeated or continuous stands, regardless of the different soil and climatic conditions, the technology applied, and their biological characteristics.

Depending on the degree to which plants react to continuous cultivation, crops are divided into the following three groups:

1. ***Crops that do not tolerate continuous cultivation***, even repeated sowing in the same place (**sunflower, lucerne, clover, pea, sugar beet**, **pepper, flax etc.**).

2. ***Crops that to some extent tolerate repeated sowing after themselves*** (**wheat, barley, early tomatoes, etc.**). Short-term monoculture in their case can be successfully applied under high-level agronomic practices.

3. ***Crops that tolerate longer-term continuous cultivation*** (**maize, Oriental tobacco, cotton, hemp, potatoes, rice, rye, oats, etc.**).

This grouping of crops raises the question of the **limits of saturation of crop rotations with one and the same crop**.

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For cereal crops (wheat, rye, barley), according to some authors, the limits are 75% (Vorobyov, Dospekhov), for Germany – 75% (Könecke), for England – up to 80%, and for our country – 50% (Dzhumalиeva). If the relative share of cereals increases to 75%, it is necessary to apply additional measures so that yields do not decline. Such measures include fertilization, soil tillage, the use of suitable varieties and hybrids, intensifying the crop rotation with preceding crops or with second crops – where possible and economically feasible – the use of highly effective pesticides, and others.

The saturation of crop rotation with maize and soybean can reach 80%. This is the practice in many regions of North America, Argentina, China, Russia, Romania, and others.

Agronomic practices and the biological requirements of plants necessitate giving preference to crop rotation over monoculture. In practice, when choosing the method of crop cultivation – continuous or in crop rotation – economic conditions, specifically the specialization and concentration of production, should be primarily taken into account. Therefore, in order to avoid possible negative consequences arising from the intolerance of crops, modern intensive factors must be used as a priority (fertilization, effective plant protection chemicals, irrigation, high-yielding and resistant varieties and hybrids, etc.).