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STRUCTURE AND BIOLOGICAL SIGNIFICANCE OF THE SOYBEAN PLANT

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Abstract
This article presents scientific information on soybean plant characteristics, morphology, anatomy, biological classification, cultivation, and the work that should be done to increase its importance and productivity in agriculture.

Keywords: Soya, protein, oil, nodule bacteria, manure, feed, technical, product, nitrogen, phosphorus, potassium, soil.

Introduction

As well as providing an alternative to animal-based protein (being relatively rich in the amino-acids Lysine and Methionine unlike most other legumes currently grown in Europe) there are several other benefits to growing soybeans in the UK. First, as a leguminous crop soybean can fix nitrogen reducing the need for fertilizer and increasing system-level N use efficiency. Second, with increasing resistance of weeds, slugs, insect-pests and diseases to chemical control agents, and the loss of active ingredients due to more stringent legislation, diverse crop rotation, including a spring sown protein crop such as soybean is becoming of increasing agronomic interest to UK farming. A key question facing farmers, however, is what is the likelihood that the crop will grow successfully, and can this crop be a profitable part of a diverse crop rotation now and in the future? Research trials can help answer these questions in part, but they are both expensive and time consuming and questions related to the effects of climate change become infeasible to test: therefore, we turn to models.

In this study, we set out to determine the spatial extent over which soybean is a viable crop in the UK based on the current climate, and to determine how this is likely to alter under climate change. For this we consider both the probability that early maturing varieties of soybean will mature, and the yield that could be expected. To achieve this we used data from field trials designed to test the viability of growing earlier maturing varieties of soybean in the UK to calibrate and validate the crop model in the Rothamsted Landscape Model (Coleman et al., 2017) for soybean. Once the model was validated, we used it with simulated weather data based on current and future climates for 26 sites across the UK to determine the probability that soybean crops would mature, and how this is affected by location and climate change.

The Main Part

Chemical and Biological Advantages of the Soybean Plant

Soybean is a genus of annual herbaceous plants belonging to the legume family (Fabaceae), classified as both a leguminous grain and an oilseed crop. Its homeland is China, and it was first cultivated in Uzbekistan in 1975. The stem is coarse and upright, although some varieties are prostrate. The plant height ranges from 15 cm to 2 m, with 2–8 lateral branches. The leaves are hairy, with petioles 8–20 cm long. The flowers are small, white or pink, and arranged in raceme-like inflorescences. The fruit is a pod that may be yellow, black, or brown, and covered with fine hairs. Each pod contains 2–6 seeds, which consist of 24–45% protein, 13–37% oil, 20–32% carbohydrates, and essential vitamins [3].

Soybean contains a complete and valuable protein, comparable in nutritional quality to animal protein. It also includes biologically active compounds, such as lecithin, choline, and various macro- and microelements, along with other essential nutrients. Soybean naturally contains no lactose or cholesterol, which makes it especially beneficial for dietary and medical use. It is noteworthy that in terms of caloric content, nutritional balance, and biologically active substances, soybean products are highly balanced and serve as valuable food sources.

The main products obtained from soybeans are soy flour and soybean oil. Soy flour is used in the production of confectionery products, fillers, and substitutes for meat, milk, and cheese. Soybean oil is widely used in food preparation, particularly in the production of mayonnaise and margarine.

According to the Institute of Nutrition of the Russian Academy of Medical Sciences (RAMS), soy-based products are recommended for the prevention and treatment of the following diseases: atherosclerosis, hypertension, ischemic heart disease, post-myocardial infarction recovery, chronic cholecystitis, diabetes mellitus, chronic constipation, obesity, musculoskeletal disorders (such as arthritis and arthrosis), and allergic diseases.

In animal husbandry, feeding livestock with soybean meal significantly increases productivity — daily weight gain can double when soybean-based feed is included in their diet [4].

When livestock are fed with soybean-based feed, the feeding period required to achieve a 100 kg live weight gain is reduced by 10–15 days, and the quality of the resulting products improves significantly. For feed purposes, soybean meal, cake, flour, and green mass are widely used. Soybean cake contains about 38.7% protein and 5.5% oil. Both soybean cake and flour can effectively replace milk in calf diets.

From 1 ton of soybeans containing approximately 40% protein and 1.4% oil, it is possible to obtain 750–800 kg of soybean meal, which is a valuable concentrated feed for livestock. The green mass of soybean is also an excellent forage crop. Its highest nutritional value is observed when harvested during flowering or pod-filling stages. Each feed unit of green soybean mass contains 145–301 g of protein. In addition, its content of carotene, protein, and calcium is considerably higher than that of cereal forages [9].

Soybean hay is another valuable feed resource: 1 kg of soybean hay contains 0.47–0.54 feed units and 110–150 g of protein. Soybean straw can also be used as fodder, containing 2–4.8% protein and 1.5–2.9% oil.

In industry, various products are produced from soybean processing residues that are not suitable for food or feed use. These include construction boards, fabrics, artificial fertilizers, and by-products from soybean oil processing such as paints, soaps, black lacquers, and rubber goods.

As a technical crop, soybean is used in the soap-making, paint and varnish, textile, chemical, and industrial sectors. From soybeans, materials such as plastics, films, linoleum, technical oils, and many other products can be produced.

Despite its high quality, rich in protein and oil, soybean cultivation in Uzbekistan is not yet widely applied in agriculture. Some soybean varieties contain up to 57% dietary protein, easily digestible unsaturated oils, and up to 30% carbohydrates (mainly mono- and disaccharides). They are also rich in biologically active substances and vitamins such as A, B_1, B_2, B_3, B_6, E, C, D, Q, and PP, as well as trace elements like Mn, Mo, Mg, and V.

Soybean grains are used to prepare dietary foods for diabetic patients. The main protein of soybean — glycinin — is easily digestible, water-soluble, and capable of fermentation, forming yogurt-like products. It is also rich in essential amino acids [8].

Effects of Soybean on the Human Body

Today, soybean is mainly cultivated in Asia, South America, and North America. Soybean is considered a high-quality source of protein, and consuming one or two servings of soy products per day can be beneficial for human health.

Soybean improves bone health and helps reduce the risk of cardiovascular diseases, strokes, and certain types of cancer.

1. Protection Against Diabetes

As a source of fiber and protein, soybean contributes to healthy weight gain and helps manage diabetes effectively, despite its relatively high fat content, because it contains no cholesterol. Consuming soybeans is one of the most effective natural ways to prevent and manage diabetes. Several studies have shown that soy has the ability to increase insulin receptors in the body, which helps prevent the onset of diabetes or assists in controlling the condition in those already affected. Moreover, soybeans are low in carbohydrates, making them particularly suitable for diabetic diets.

2. Treatment of Anemia

Soybean is effective in treating anemia, as it is rich in iron and copper, two essential minerals required for the production of red blood cells [10].

3. Cardiovascular Health

A soy-rich diet helps protect against stroke and heart disease. Soybeans reduce key risk factors by lowering total cholesterol and bad cholesterol (LDL) levels, while also reducing blood pressure and improving vascular function.

Soybeans produce oil belonging to the oleic-linoleic group and are rich in protein. Both ripe and immature pods (edamame) are used in food. Soy flour is utilized in making sausages, milk, cottage cheese, and confectionery products.

In addition, soy straw, hay, green stems, and silage serve as nutritious animal feed. Soy is widely used in cooking because it is nutritious and highly beneficial. Its mature seeds, oil, and immature pods are consumed in various forms.

From soybeans, flour, groats, oil, and protein are produced, which are further processed into soy milk, tofu, cheese, sausages, bread, cookies, cakes, candies, chocolate, coffee, sauces, canned goods, pasta, and many other food products. Canned products made from immature soy pods are especially tasty, nutritious, and beneficial [12].

4. Promotion of Brain Development

Regular consumption of soybean oil contributes to brain development because it is rich in soy lecithin, B vitamins, and vitamin E. These substances are essential for the normal growth and function of the human brain. They not only nourish neurons, but also stimulate the renewal and metabolism of brain cells. Continuous consumption helps improve memory and supports intellectual development.

5. Eye Protection

Soybean oil provides rich nutrition for the human body. It contains plant proteins, palmitic acid, stearic acid, linoleic acid, and other beneficial components, as well as being rich in carotene and vitamin A [11].

These compounds play an important role in eye health, enhancing retinal function and protecting the eyes from harmful substances. Regular consumption of soybean oil can improve vision and help prevent eye diseases.

Conditions and Agrotechnics of Soybean Cultivation

Germination Period

Soybean seeds begin to germinate when their moisture content reaches 90–150% of the dry matter weight. After the seeds swell, 2–3 days later, the embryonic root breaks through the seed coat and begins to develop. As the main root grows, lateral roots and root hairs start to form.

Root hairs are extremely small and rich in protein within the growth zone. The roots continue to grow until seed formation begins. The development of the root system depends on the physical properties of the soil, temperature, moisture, and nutrient availability. The rate of root growth is considered an important indicator of soil fertility and is usually higher in early-maturing varieties.

Branching Stage

Branching typically begins when 3–5 compound leaves have formed. During this stage, the main stem grows rapidly until flowering begins, after which the rate of growth slows down. Simultaneously, leaf formation also decreases. Lateral branches develop from the lower parts of the stem. However, there are varieties that are weakly branched or unbranched [5].

Budding Stage

The budding stage begins immediately after or simultaneously with the branching stage. During budding, the plant reaches its maximum leaf formation, which accounts for 30–40% of total foliage. At this stage, the demand for soil moisture increases sharply [6].

Flowering Stage

In early-maturing varieties, flowering begins after the formation of 5–6 leaves, coinciding with the development of lateral branches. In late-maturing varieties, flowering begins about 30 days after germination. The flowering period is prolonged, lasting 14–40 days, depending on the variety.

Flowering coincides with a period of intensive vegetative growth, meaning that plants must be continuously supplied with adequate water and nutrients. After the onset of flowering, soybeans experience rapid growth. The rate of this growth depends on environmental conditions and varietal characteristics [6].

Pod Formation and Environmental Requirements of Soybean

Pod Formation

About 10–15 days after flowering begins, pods start to form on the lower nodes of the plant, and pod formation gradually moves upward in the same sequence as flowering. The flowering and seed-filling stages are considered the critical phases in soybean development, during which the plant's water requirement is at its highest [6].

Light Requirements

Soybean is a short-day plant, and light plays a decisive role in its development. The plant is particularly sensitive to day length from emergence to full flowering. During this period, soybeans absorb mostly short-wavelength solar radiation ranging from 380 to 720 nanometers (nm), which promotes the formation of vegetative organs.

In contrast, during the reproductive stage, especially pod and seed formation, soybeans require longer-wavelength light, which supports the accumulation of nutrients and seed maturation [6].

Temperature Requirements

Soybean is a thermophilic (heat-loving) crop. Its geographical distribution depends largely on the availability of sufficient warmth and sunlight.

The total amount of effective heat required for soybean growth varies by variety and ranges from 1600°C to 3000°C.

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Early-maturing varieties: 1700–2200°C
Mid-season varieties: 2400–2700°C
Late-maturing varieties: 3000–3500°C
The minimum germination temperature is 6–7°C, but under such conditions, germination is slow, taking 25–30 days. The optimal temperature for germination is 20–22°C, and when soil moisture is sufficient, seeds germinate within 4–5 days [7].

Moisture Requirements
Soybean is native to monsoon climates and is a moisture-loving crop. It consumes a large amount of water to produce biomass and yield — approximately 3200
5500 m³ of water per hectare during its growing season.
The transpiration coefficient of soybeans is very high, ranging from 400 to 500 under humid conditions and 500 to 700 under fluctuating humidity.
Despite its high water consumption, soybeans can withstand moderate drought and are considered more drought-tolerant than common beans (Phaseolus vulgaris) [7].

Soil Requirements
Soybean is not highly demanding in terms of soil type and can grow well in soils with a pH ranging from 5.0 to 6.0, while the optimal pH for its growth is around 6.5.
The plant grows successfully in almost all soil types except saline, acidic, and waterlogged soils.
Soybean requires well-aerated soil, as proper soil porosity (around 20–22%) enhances the formation of root nodules, which play an essential role in nitrogen fixation. Conversely, in compacted or excessively moist soils, nodule bacteria do not develop properly, leading to reduced nitrogen assimilation and weaker plant growth [7].
Industrial and Livestock Applications of Soybean: Processing and Nutritional Products Soybean holds a significant place in global oilseed production.
Its superiority stems from various factors, including favorable agronomic characteristics, high profitability for producers, a rich source of high-quality protein feed for livestock, nutritionally valuable food products, and the abundant and reliable availability of soybeans even under competitive market conditions.
Moreover, properly processed soybean oil is regarded as a high-quality edible oil, comparable to the most widely consumed vegetable oils [2].
Soybean is considered a high-quality protein source, being one of the few known plant-based foods that contain all essential amino acids typically found in meat. In addition to its high protein content, soy is characterized by low levels of saturated fat, absence of cholesterol, and lactose-free composition, making it ideal for healthy diets.
Another category of soy-based food products is referred to as "second-generation soy foods." These include tofu sausages and burgers, soy breads, soy noodles, soy-based yogurt, and cheeses. Furthermore, numerous processed products contain soy-derived ingredients such as lecithin, commonly found in chocolates and baked goods.

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Soybean is the most common dietary source of isoflavones; however, the amount of isoflavones varies depending on the type of soy product, processing method, and brand. Among the richest sources are soy flour and soy nuts [13].

Because of its high-quality protein and digestible energy content, much of the soybean crop is processed into protein-rich meal after the oil is extracted, which is then used as animal feed. The remaining soy flour is used to produce tofu, soy milk, and other soy-based products.

The residual soybean oil obtained after processing is utilized for various purposes, including cooking oil, biodiesel, bioheat fuel, and as a non-toxic industrial material in products such as paints and cleaning agents. Waste materials from soybean oil production are also recycled and processed into feed for poultry, cattle, and fish. More than half of the processed soybean meal used in animal husbandry is consumed by poultry, while a portion is used in aquaculture as fish feed.

The rising global demand for soybeans can be attributed to several reasons. Primarily, the soybean seed contains up to 50% protein and up to 28% oil, making it an essential raw material in the food industry. Furthermore, soybean plays a vital role in the industrial, technical, and livestock sectors, being used in the production of soap, varnish, paint, plastics, films, and in the chemical and textile industries.

Soybean is also a valuable feed crop, as soy meal and cake (oilcake) are produced from it, while the green stems serve as nutritious forage for animals. In total, over 400 types of products can be derived from soybeans, with protein being the most valuable among them. Globally, about 32% of protein resources come from animal sources, while 68% originate from plants — 55% of which come from soybeans.

Thus, soybean plays a critical role in addressing the global protein deficiency problem, highlighting its increasing industrial, nutritional, and economic importance [15].

The Importance of Soybean in Livestock and Rural Development

Soybean plays an indispensable role in animal husbandry. Soy meal contains 40–48% protein, making it a highly nutritious feed for livestock. Using soybean as animal feed helps develop local livestock farming and reduces dependence on imported feed [14].

A study by Johnson and Smith (2023) highlighted that soybean cultivation plays a critical role in ensuring stable agriculture under climate change conditions. In particular, soybeans are capable of producing higher yields under water-limited conditions compared to many other crops.

In Uzbekistan, soybean cultivation can increase employment opportunities for youth and women, especially in rural areas, and can boost household incomes. Additionally, soybean cultivation and processing create new jobs in the agricultural sector, contributing to overall rural economic development [16].

Conclusion

Based on the literature review, it can be concluded that soybean, a member of the legume family with a prominent global significance, contains essential amino acids in its seeds, which determine its nutritional value. These proteins were traditionally considered characteristic only of animal proteins, but research has shown that soy proteins can effectively replace animal proteins in terms of amino acid composition.

Furthermore, the economic importance of soybean is evident. In Uzbekistan, the development of high-yielding and abiotic stress-resistant varieties is essential for enhancing agricultural productivity and ensuring a stable supply of this valuable crop.

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