# BIOTIC STRESS ON LEGUMINOUS CROPS IN BULGARIA UNDER CLIMATE CHANGE

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**Abstract**

*In Bulgaria, the most widespread leguminous crop is common bean (Phaseolus vulgaris L.). Its cultivation is concentrated in Northern and Northeastern Bulgaria, which determines the regional focus of the breeding programmes. The modern approach to genetic improvement of common bean is based on the development and purposeful testing of new genetic plasma under the specific soil and climatic conditions of the respective regions. This strategy ensures high adaptability, stability and effective use of new varieties in practice. Climate change necessitates the adaptation of agronomy practices – sowing dates, mineral fertilization, use of herbicides and biostimulants, as well as evaluation of different growing systems. Dobrudzha Agricultural Institute (DAI) is Bulgaria's national centre for common bean breeding. Since the 1950s, 24 varieties have been developed, four of them released after 2015. The main breeding directions are developing varieties with habit type suitable for mechanised harvesting, improved morphological and quality traits, resistance to economically important diseases and tolerance to abiotic stress factors. In the context of global warming and changing climatic conditions, new challenges are posed to breeding, agronomy and sustainable bean production in Bulgaria. This review presents the current status of scientific research and breeding achievements in Bulgaria related to the resistance of the leguminous crops to biotic stress under conditions of climate changes.*

***Key words: adaptability, biotic stress, common bean, genetic improvement, resistance, climate change***

## INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is considered the most important leguminous crop used for direct human consumption (Uebersax et al., 2022). Global production and harvested areas in 2020 amounted to 27.5 million tonnes and 34.8 million hectares, respectively. Production has increased by approximately 60% since 1990, while harvested areas increased by only 36% over the same period (FAO, 2022).

In Bulgaria, common bean is one of the traditional and economically important crops, with a cultivation history dating more than three centuries back. During the 1990s, the average area sown with common bean was 36,800 ha (Kiryakov, 1999), but after 2000 bean production declined dramatically. At present, Dobrudzha Agricultural Institute remains the only breeding centre for common bean in Bulgaria. Breeding and improvement work at the Institute began in the 1950s of the last century.

The production systems for leguminous crops offer numerous advantages related to sustainable agriculture — low carbon footprint, short vegetative growth cycle, opportunities for crop diversification and inclusion of cover crops. Of particular importance is the symbiotic nitrogen fixation characteristic of the legume plants, which contributes to environmentally friendly cultivation by reducing the need for mineral fertilizers. Their short growing season and ability to enrich the soil with fixed nitrogen make them a preferred predecessor in crop rotations. They are also a valuable source of healthy food due to their high content of protein, dietary fibre, minerals and vitamins. They are rich in resistant and slowly digestible starch, which triggers a lower glycaemic response and has a beneficial effect on human health. Scientific studies show that certain bioactive compounds in bean seeds contribute to prevention of cardiovascular diseases, hypertension, hypercholesterolaemia and some forms of cancer.

According to the Intergovernmental Panel on Climate Change (IPCC, 2019), the global warming is leading to higher frequency of extreme weather events that negatively affect agricultural production. For Bulgaria, forecasts predict a rise in average temperatures and a decrease in summer precipitation, which will result in lower yields from the main crops. Marinova et al. (2017) found that at the beginning of the 21st century, the average air temperature in Bulgaria had increased by 0.8°C compared to the 1961–1990 period, with a noticeable shift in the seasonal distribution of rainfall. These changes affect the length of the growing season, the rate of heat-unit accumulation, and the physiological development of plants, necessitating the refinement of agronomy practices – sowing dates, fertilization, irrigation, and the selection of suitable varieties (Slavov et al., 2005). Alongside climatic challenges, global population growth and changing dietary habits require a substantial increase in agricultural output.

Diseases are among the main biotic factors influencing the productivity and quality of the leguminous crops (Allen et al., 1998). The most important diseases affecting common bean in Bulgaria are bacterial blight (Xanthomonas axonopodis pv. phaseoli and X. fuscans subsp. fuscans), halo blight (Pseudomonas savastanoi pv. phaseolicola), anthracnose (Colletotrichum lindemuthianum), rust (Uromyces appendiculatus), and white mold (Sclerotinia sclerotiorum). The the higher intensity of climate anomalies is altering the dynamics of these pathogens, leading to the occurence of new races and greater difficulties in infection control. This requires an integrated approach combining genetic resistance, agronomic measures, and monitoring of the phytopathogenic complex. Dobrudzha Agricultural Institute (DAI) plays a central role in the breeding of resistant bean varieties while being the national centre for developing and introducing genetic material adapted to the conditions of a changing climate.

The modern approach to genetic improvement of grain legumes is based on the development of new genetic plasma and its testing under the specific soil-climatic conditions of the regions for which the breeding programme is intended. This principle ensures high adaptability, yield stability and successful practical realization of new varieties. The production of grain legumes in Bulgaria (common bean, soybean, field pea, lentil and chickpea) is mainly concentrated in Northern and Northeastern Bulgaria, which also determines the regional focus of the breeding programmes. The climate changes require adaptation of agronomy practices, including sowing dates, mineral fertilization, application of herbicides and biostimulants, as well as economic evaluation of different cropping systems. At Dobrudzha Agricultural Institute, 24 varieties have been developed since the 1950s, including four registered after 2015. The main breeding directions are aimed at developing varieties with habit typet suitable for single-phase and two-phase harvesting, improved morphological and grain-quality characteristics, disease resistance, and tolerance to abiotic stress factors.

This review aims to outline the current state and trends in research on biotic stress in the leguminous crops in Bulgaria, with emphasis on breeding for resistance in common bean, and to analyze the impact of climate change on the phytopathological complex and the adaptive potential of the crop.

The review was prepared through a systematic analysis of published scientific sources related to laguminous crops and biotic stress under conditions of climate change. Data were used from peer-reviewed journals, monographs, conference proceedings and official publications of the Agricultural Academy, Dobrudzha Agricultural Institute, as well as international databases (Scopus, AGRIS, CAB Abstracts, Google Scholar). The studies were carried out at Dobrudzha Agricultural Institute – General Toshevo over the past 30 years. Bulgarian common bean cultivars and breeding lines developed through hybridisation and individual selection were subjected to investigation. Trials were carried out under field and controlled conditions to evaluate plant reactions to the main bacterial and fungal pathogens.

## I. ECONOMICALLY IMPORTANT DISEASES ON BEAN IN BULGARIA

In the lowland regions of the country, the key diseases on common bean are common bacterial blight and halo blight (Kiryakov, 1999; Kiryakov, 2018). Although of sporadic occurence, rust and anthracnose can also have a significant negative impact on yield (Beleva and Kiryakov, 2009; Kiryakov, 2009). Including bean in rotation with sunflower and oilseed rape poses a risk of epiphytotic development of the white mold pathogen (Sclerotinia sclerotiorum), due to the pathogen’s ability to survive in the soil for extended periods (Kiryakov and Zhecheva, 2019). The development and use of resistant varieties is the only economically viable and environmentally friendly approach to controlling these pathogens. The ecological conditions in the lowland and foothill areas of Bulgaria favour the development of various bacterial and fungal pathogens, whose epidemiology is changing under the variations of the climate.

**1. Bacterial diseases**

**Common bacterial blight** (*Xanthomonas phaseoli pv. phaseoli and X. citri pv. fuscans*) is one of the most important bean diseases in Bulgaria (Kiryakov, 2018). Its cause agents are characterised by high virulence and wide geographical distribution. The disease occurs annually, and its management is difficult due lack of effective chemical control agents, limited phytosanitary regulation of seed material, and, last but not least, the susceptibility of most of the varieties in the varietal structure. Studies on the strain diversity of the pathogens in Bulgaria show that their distribution across the country is almost equal, although during certain periods one of the two pathogen species predominates (Kiryakov, 1999; Kiryakov, 2018).

**Halo blight** (Pseudomonas savastanoi pv. phaseolicola) develops primarily under cool and humid conditions during the growing season. Its spread has been limited by the use of resistant varieties, but maintaining the achieved level of resistance requires constant monitoring, for at least five races of the pathogen have been identified in Bulgaria (Kiryakov, 2001).

**2. Fungal diseases**

**Anthracnose**, caused by the hemibiotrophic phytopathogenic fungus *Colletotrichum lindemuthianum*, is of economic importance in both lowland and mountainous regions of Bulgaria. In the lowland areas, anthracnose occurs sporadically and is observed mainly in years with cool and wet conditions. The pathogen populations are divided into physiological races based on the reaction of 12 differential bean cultivars included in the international differential key. To date, more than 200 physiological races have been reported worldwide. Studies on pathotype diversity of the pathogen show that ten physiological races have been identified in Bulgaria (Kiryakov, 2000, 2009). The varieties currently used in production are susceptible to the most widespread race in Bulgaria, race 81 (Kiryakov & Genchev, 2009).

**Bean rust** (*Uromyces appendiculatus*) is less frequent in the lowland parts of the country, but in years with favourable conditions it can cause serious losses (Stavely et al., 1983). According to Beleva (2010) and Kiryakov & Genchev (2004), more than 90 pathotypes have been identified in the pathogen population in Bulgaria, grouped into nine physiological races (20-0, 20-1, 20-2, 20-3, 20-19, 52-3, 29-0, 29-1, 28-1). Recent studies (Koleva & Kiryakov, 2020) reveal the occurence of pathotypes belonging to new races (20-16 and 20-18), which necessitates continued monitoring and breeding research. The disease is observed annually in mountainous regions, where conditions favour its mass distribution. At this stage, research on bean rust in Bulgaria includes: studying the virulence diversity of the pathogen (Kiryakov & Genchev, 2003; Kiryakov, 2004; Beleva & Kiryakov, 2010); identifying sources of resistance (Kiryakov & Genchev, 2004; Beleva, 2009); and investigating the genetic control of resistance in common bean against the pathogen (Beleva, 2010).

**White mold** (*Sclerotinia sclerotiorum*), caused by the ascomycete fungus *Sclerotinia sclerotiorum*, poses a serious threat in crop rotations that include sunflower and oilseed rape. The pathogen persists in the soil for many years in the form of sclerotia, resulting in a high inoculum potential (Adams and Ayers, 1979). Research on Sclerotinia in common bean currently focuses on identifying sources of resistance (Kiryakov et al., 2002) and studying the inheritance of physiological resistance in selected accessions (Genchev and Kiryakov, 2002). Most bean varieties currently grown in Bulgaria exhibit only low levels of physiological resistance to this disease. Studies conducted by Kiryakov and Zhecheva (2019) revealed considerable variation within the pathogen population, both in loci responsible for mycelial compatibility (parasexual process) and in isolate aggressiveness. This necessitates an integrated control strategy combining breeding, crop rotation and biological control, and requires testing of newly developed genetic material against a wide range of pathogen isolates.

## II. SOURCES OF RESISTANCE AND BREEDING APPROACHES

Breeding for disease resistance in common bean is a long-term and complex process, driven by the extensive racial and strain diversity of pathogens and their variability under different climatic conditions. Genetic resistance remains the most economically viable and environmentally friendly method for managing biotic stress.

### 1. Identification of donors of resistaance

Over the past decades, Dobrudzha Agricultural Institute has carried out targeted screening for sources of resistance to the major bacterial and fungal pathogens of common bean. More than 2000 accessions from national and international collections have been evaluated, resulting in the identification of numerous resistant genotypes suitable for inclusion in breeding programmes (Kiryakov et al., 2002; Stoilova & Kiryakov, 2000a, b).

Among the most effective donors of resistance to common bacterial blight are accessions G.N. Jules, G.N. Star, XAN 15, HR 45, BAC 6, VAX 3–6, A 769, as well as the Bulgarian cultivars Oreol, Beslet, Elixir and GTB Scythia (Kiryakov & Genchev, 1998, 2000; Genchev & Kiryakov, 2001; Kiryakov and Genchev, 2018). A research by Genchev and Kiryakov (2001) showed that resistance to common bacterial blight is a polygenically inherited trait, with differences in genetic control observed between leaves and pods depending on the resistance source and the virulence of the pathogen strains. Unfortunately, a large proportion of advanced-generation breeding material currently exhibits susceptibility to *X. citri* pv. *fuscans*, necessitating further intensive efforts to overcome this weakness.

Of the 17 commonbean cultivars developed at DAI – General Toshevo, only Pukliv 1 possesses resistance to 11 races of *C. lindemuthianum*. Cultivars GTB Blyan, Pirina and Pukliv 1 have resistant reaction to the majority of prevalent races, while Trakia and Pirina are resistant to the most widespread race in Bulgaria, race 81 (Kiryakov & Koleva, 2024).

As a donor of race-specific resistance to bean rust, cultivar Beslet is particularly notable, being resistant to all pathotypes of the pathogen identified in Bulgaria (Beleva, 2010; Koleva and Kiryakov, 2021, 2022). Cultivars Abritus, Trakia and Prelom exhibit resistance to the most recently identified pathotypes (Koleva and Kiryakov, 2021). Fifty sources of race non-specific resistance to *U. appendiculatus* have been identified, including . cultivars Abritus and Ustrem (Beleva, 2010; Koleva and Kiryakov, 2021)

Among the cultivars developed at DAI, Trakia, Pirina, Zlatan and 'Rodopeya possess physiological resistance to Sclerotinia (Zhecheva, K., 2025).). A considerable number of accessions showing good to moderate physiological resistance have been identified (A 195, IIRR 7585, Izabell and Ex Rico), together with accessions exhibiting variable physiological resistance grouped according to habit type (Zhecheva, K., 2025).

### 2. Inheritance of resistance and gene identification

The use of physiological races of the pathogens enables the identification of race-specific resistance loci in the studied genotypes. Analyzing 11 bean cultivars against nine races of *Colletotrichum lindemuthianum*, Kiryakov and Genchev (2016) found that resistance in cultivars Dunav 1, Tarnovo 13, Trakia and Pirina was controlled by an allele at locus *Co-1*, whereas in cultivar Elixir it was determined by the race-specific gene *Co-3*. Studies using molecular markers (SCAreoli and SQ4) revealed that resistance in cultivar Beslet is conferred by two genes located at locus *Co-2* (Genchev et al., 2010).

The inheritance of resistance to bean rust (*Uromyces appendiculatus*) has also been investigated in Bulgarian breeding materials. Beleva (2010) established that resistance in cultivar Beslet to two races of the pathogen was controlled by a single dominant gene.

### 3. Multiple resistance and modern breeding strategies

One of the strategic objectives of contemporary breeding is the development of cultivars with multiple resistance, i.e., simultaneous resistance to several pathogens. Despite the challenges related to the duration of the process and the need for multi-stage testing, Dobrudzha Agricultural Institute – General Toshevo has developed in recent years lines and cultivars combining resistance to common bacterial blight, halo blight, anthracnose and white mold (Genchev & Kiryakov, 2014).

Modern breeding programmes combine conventional methods of hybridization and individual selection with advanced biotechnological approaches, including the use of molecular markers, DNA analysis and screening for pathogen virulence. The application of these methods enables accelerated introgression of resistance genes and more precise identification of recombinant lines with high breeding potential.

## III. THE ROLE OF DOBRUDZHA AGRICULTURAL INSTITUTE

Breeding work on common bean at . Dobrudzha Agricultural Institute has been ongoing for **70 years**. It is aimed at combining high productivity, resistance to biotic and abiotic stress, and adaptability to climate change. Significant progress has been achieved in developing cultivars with enhanced resistance to common bacterial blight and halo blight, as well as in developing genotypes tolerant to drought and temperature stress. The present review includes **eight common-bean cultivars** characterised by different growth habit types and resistance to the main diseases on this crop in Bulgaria.

All cultivars exhibit a **resistant to moderately resistant phenotype** to halo blight (Table 1). With regard to common bacterial blight, cultivars GTB Scythia, Pukliv 1 and Beslet demonstrated resistant reaction, while Elixir was moderately resistant (Genchev and Kiryakov, 2001; Kiryakov and Genchev,2014).

Resistance to white mold (Sclerotinia) was exhibited by cultivars GTB Blyan, Elixir and Pukliv 1, GTB Scythia and Ustrem being moderately resistant (Zhecheva, K., 2025).

Using the method of Nunes et al. (2021), Kiryakov & Koleva (2024) determined that Pukliv 1 had the highest resistance index to anthracnose (Table 1). A high level of resistance wa exhibited by cultivars GTB Blyan, Pukliv 2, Trakia and Elixir (RI > 61). With the exception of Trakia, the remaining cultivars in this group were susceptible to race 81, which is widespread in all production areas in Bulgaria. Cultivar GTB Blyan is susceptible to races 6 and 81 but resistant to the other nine physiological races included in the study (Kiryakov & Koleva, 2024).

With respect to bean rust, cultivars Pukliv 2 and Beslet were with the highest resistance index (RI = 100%). Cultivar Beslet showed an immune to resistant phenotype against all pathotypes of *Uromyces appendiculatus* identified in Bulgaria up to now (Beleva, 2010; Koleva and Kiryakov, 2021). The resistance index of Pukliv 2 was calculated based on its reaction to six pathotypes identified in Bulgaria in 2018 (Koleva and Kiryakov, 2021). Cultivar Trakia also exhibited a high resistance index, showing a resistant reaction to 12 out of a total of 14 pathogen pathotypes (Beleva, 2010; Koleva and Kiryakov, 2021).

Table 1. Complex resistance of common bean cultivars developed at DAI to bacterial and fungal pathogens

| № | Habit type | Accession | Diseases | | | | |
|---|---|---|---|---|---|---|---|
| | | | CBB | HB | RUST (RI**) | ANT(RI**) | WM |
| 1 | IIa | GTB Scythia | R* | R | 0 | 9.1 | MR |
| 2 | IIa | GTB Ustrem | S | R | 50 | 9.1 | MR |
| 3 | IIa | GTB Blyan | S | R | 0 | 81.8 | R |
| 4 | IIIb | Elixir | MR | R | 0 | 61.5 | R |
| 5 | Ia | Trakia | S | MR | 85,7 | 69.2 | S |
| 6 | IIb | Pukliv 1 | R | R | -*** | 100 | R |
| 7 | IIb | Pukliv 2 | S | R | 100 | 75.0 | S |
| 8 | IIa | Beslet | R | R | 100 | 30.8 | S |

* – Immune; R – Resistant; MR - Moderately resistant; S - Susceptible; VS – Very susceptible
** RI = (RC x 100)/T, where RC is the number of races to which a resistant phenotype was demonstrated (I-MR), and T is the total number of races included in the study (Nunes et al., 2021).
*** - no data

A high resistance index was also recorded for Ustrem (RI = 50%), which demonstrated an immune or resistant phenotype to four of the eight pathotypes of races 20-2, 20-16 and 20-18 included in the study by Koleva and Kiryakov (2021). To date, no studies have been conducted on the response of cultivar Pukliv 1 to bean rust.

Among the eight common-bean cultivars considered here, all of them developed at DAI, cultivar Pukliv 1 stands out for its excellent combined resistance to common bacterial blight, halo blight, anthracnose and white mold, closely followed by Elixir (Table 1). All other cultivars exhibited varying levels of resistance to three of the key diseases affecting common bean in Bulgaria.

Dobrudzha Agricultural Institute also performs a coordinating role in national projects on leguminous crops, including programmes for the conservation of plant genetic resources, maintenance of gene banks, and the practical deployment of resistant cultivars. The Institute's work is closely linked to international scientific networks and consortia in the fields of plant protection and genetic resources (FAO, ECPGR, CIAT).

The activities of DAI represent a successful model for integrating conventional breeding with biotechnological methods and modern agronomic approaches. The Institute has contributed to making Bulgaria as a significant centre for research and breeding of leguminous crops in Southeast Europe.

## RESULTS AND DISCUSSIONS

The review of research on biotic stress in leguminous crops in Bulgaria outlines a clear trend toward integration of conventional and modern breeding approaches. Over the past two decades, steady progress has been made in developing bean cultivars with improved resistance to major pathogens, yet climate change demands continuous adaptation of breeding strategies.

Breeding for resistance in common bean is particularly challenging due to the extensive genetic diversity of the pathogens and the existence of numerous physiological races. Resistance to common bacterial blight and anthracnose is often race-specific, meaning that new, more aggressive strains can overcome the genetic protection of existing cultivars. This necessitates regular renewal of the breeding germplasm and the incorporation of new donors possessing combined or horizontal resistance (Genchev & Kiryakov, 2014; Koleva & Kiryakov, 2020).

Climate change is creating conditions for shifts in the epidemiology of phytopathogens. Rising temperatures and prolonged drought periods reduce the activity of some pathogens but simultaneously stimulate the development of others, particularly *Sclerotinia sclerotiorum* and bacterial pathogens on common bean. This necessitates not only traditional field studies but also modelling of the relationships between climatic parameters and disease dynamics (Marinova et al., 2017).

Contemporary breeding in Bulgaria aims at a balanced combination of resistance, yield potential and technological suitability. The results achieved at Dobrudzha Agricultural Institute confirm the effectiveness of this approach – the developed cultivars demonstrate high ecological plasticity and stable productivity. However, more active implementation of biotechnological methods is needed, such as the use of molecular markers, genomic selection and DNA-based pathogen diagnostics, which significantly accelerate the evaluation and selection process.

Furthermore, in the context of the European Green Deal and strategies for organic farming, bean breeding must also focus on improving resource-use efficiency – water, nitrogen and energy. Integrating agroecological practices with resistant genotypes will be crucial for adapting the leguminous crops to climate change and maintaining ecological balance in agricultural systems.

## CONCLUSION

Biotic stress remains one of the main limiting factors for the production of legumes in Bulgaria. Under conditions of climate change, the need for resistant and adaptive cultivars becomes of strategic importance for national food and environmental security. Common bean breeding at Dobrudzha Agricultural Institute offers a successful model for sustainable agriculture development. The developed cultivars combine high productivity, stability and resistance to major phytopathogens, making them suitable for both conventional and organic farming.

The future development of bean breeding in Bulgaria will depend on the scientific community's ability to combine genetic innovations with the application of sustainable agronomy practices that ensure stable production under changing climatic conditions.

The leguminous crops are of fundamental importance for food and environmental security. Under conditions of climate change, they offer an alternative for sustainable agriculture due to their ecological and biological specificity. Dobrudzha Agricultural Institute plays a leading role in developing new bean cultivars that combine high productivity and resistance – a key factor for the stable development of legumes production in Bulgaria. The expected scientific and practical contributions are related to the development of new leguminous cultivars with high ecological plasticity, resistance to abiotic and biotic stress factors, as well as the adaptation of cultivation technologies to specific soil-climatic conditions in both organic and conventional common bean production.

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