# OWERVIEW ON THE MANAGEMENT OF POWDERY MILDEW IN WHEAT (*BLUMERIA GRAMINIS* F. SP. *TRITICI* D. C. SPEER) IN THE CONTEXT OF CLIMATE CHANGE

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## ABSTRACT

*Powdery mildew (Blumeria graminis f.sp.tritici) is one of the most important wheat diseases that farmers claim first in cereals field in Romania. The incidence of powdery mildew in Romania varies from year to year depends on climatic conditions, cultivar susceptibility and inoculum amount. Most of winter wheat cultivars grown in Romania are moderate resistant and sensitive to powdery mildew therefore the risk of yield losses, especially during wet springs increases significantly without proper management strategies. The highest losses occur when the disease affects flag leaf, respectively 16% when the infection affects flag leaf after heading and 25% when the infection affects flag leaf before heading. In the context of climate change which impact host-pathogen relationship one of the best strategies to control powdery mildew in Romania is chemical control applied at stem elongation stage GS39 (flag leaf blade all visible) to booting stage GS43 (flag leaf sheath visibly swollen) and GS 59 (spike completely emerged above flag leaf ligule). However, changes in plant growth and physiology resulting from higher atmospheric $CO_2$ concentration associated with changes in temperature and precipitation conditions can affect the efficacy of systemic fungicides altering their penetration, translocation and mode of action into the plants, which can determine a new fungicide application calendar.*

## INTRODUCTION

Etiologic agent responsible for the disease of the winter wheat by powdery mildew is the fungus *Blumeria graminis (D. C.) Speer (syn. Erysiphe graminis D. C., f. c. Oidium monilioides (Nees.) Link. Blumeria graminis.* The species produces powdery mildew on wheat, barley, oat and many spontaneous grasses. According with Eugenia Eliade (1990) the polyphagia of this fungus species is only apparent, in reality in the framework of *B. graminis* taxon are special forms (*f. spec*) and physiological races or pathotypes strictly specialized.

The fungus *Blumeria graminis (D. C.) Speer* produces in the wheat plants anatomic changes (cytological and histological), physiological (biochemical, by growth) and morphological that are exteriorizing in fact as disease symptoms typical of powdery mildew. The *Erysiphaceae* species are microscopic fungi strictly parasite, they represent a homogenous group of ascomycetes both as morphological structure and as development, life cycle and the diseases produced in the infected plants. They are known from past times and have aroused the interest of the plant pathologists worldwide both from theoretical point of view and as economic importance [C. SANDU - VILLE, 1967; EUGENIA ELIADE, 1990]. Many pathogenic fungi as setting a long-term nutritional relationship with the living cells of the host plant instead to killing them. Those pathogens were named *biotrophic* (*bios* – life, *trophy* – feeding). This type of parasitism can lead to important harvest loses in crops, and in the natural environment can diminish the competitional capacity of the host. Thus, this parasitism type is sophisticate, respectively keeps the host alive as food-source for long time, that determined the scientists to suggest that the biotrophic parasitism is an evolutionary way.

In literature are considered the biotrophic pathogens by the type of the fungi that causes diseases named rusts (*Basidiomycota - Uredinales*) and powdery mildews (*Ascomycota - Erysiphales*) - J. W. DEACON (1997, 2006). In 1958 GOLOVIN proposes the genus *Blumeria* for *Erysiphe graminis*, that becomes ***Blumeria graminis*** this name being used until nowadays.

Biochemical and functional changes produced by the fungus on the attacked wheat plants were the object of many researches along the time. In the wheat leaves attacked by *Blumeria graminis*, A. L. KLECAN *et al.*, (1986) have noticed the decrease of the fructose content and the enrichment of the cells with fructose 2-6 biphosphate, a metabolite that stresses the plants. During the night the concentration of this metabolite is the same, both in diseased and in healthy leaves too. During the daylight the content in 2-6 biphosphate in the diseased leaves increases a lot (10% in the second day after the infection to 150% in the $15^{th}$ day) instead of fructose. From the hydro-carbonated substances of the plant the fungus *Blumeria graminis f. sp. Tritici* intake only glucose instead of sucrose [J. M. MANNERS, J. L. GAY, 1983]. *Blumeria graminis f. sp. tritici* uses the nutrient resources of the host without leading to a rapid death of the infected plant. In wheat is well known the role of the stem in the synthesis of the organic substances that will be deposited in grains. In fact, that is the role of the chloroplasts, of the chlorophyll from the stem cells without omitting the role of the chloroplasts from leaves. F. T. LAST (1962) – cited by EUGENIA ELIADE (1990) notices that due to the mycelian network that is developing on leaves as patches or on the stem as a sleeve is determining the decrease of the chlorophyll content, respectively less organic substances in grains this fact leading to the shrivelling of the grains with negative influence to the panification and capacity of the wheat germs to penetrate the soil at germination.

Regarding the enzymes the researches have leaded to the conclusion that in the powdery mildew diseased plants are increasing the ferments from the group of hydrolases and desmolases (oxidase, peroxidase and reductases). According with W. E. MCKEEN *ET AL*. (1969) the fungus *Blumeria graminis* enter into the cells by destroying the membrane of these disk-shape cells with the help of the enzyme cellulase. D. R. WALTERS ET AL. (1986) demonstrates that around the disks or the entering gates of the fungus haustoria the plants are intensifying the activity of arginine-decarboxylase and ornithine-decarboxylase, this activity amplifies in the cells adjacent to the mycelium patches from the plant. G. VIZAROVA *et al.* (1981) and G. VIZAROVA (1987) have noticed in the powdery mildew diseased cereals the presence of the cytokines, e.g. the zeatin and its derivates, substances implied in the provision of the plant resistance to the attack of *Blumeria graminis*. KUNOH H. *et al.* (1969) notices that under the action of the enzyme hydrolase produced by the fungus in the halo of the membranes perforations of the epidermal cells appear substances from the aldehydes group, pentoses, possible uronic acid and perhydrole [C. DER MARDIROSIAN, G. M. BLOCHT, 2001; E. ONO *et al*., 2001]. BUSHNEL W. R. *et al.* (1975) observed important chemical changes both in the epidermal cells in that has entered the fungus and in the cells from the mesophyll from the adjacent area. There are abundant the mitochondria that determinate the rapid increase of the respiration intensity, the endoplasmic reticulum, Golgi apparatus, polyribosomes for massive synthesis of DNA and RNA, leuco-plastids and others.

Through these syntheses specific to the wheat varieties resistant to powdery mildew the plants transform these cells in a toxic environment that kills the fungus through toxicity and impossibility to form new haustoria. In the wheat plants infested with *Blumeria graminis* the respiration is more intense in comparison with the healthy plants [PRATT, 1938; LAST, 1962; W. R. BUSHNEL *et al.*, 1975, cyted by Eliade E., 1990]. Complex researches indicate that the increased respiration comes from the affected host plant tissue. The affected tissues of the host plant are manifesting a slightly increase of the temperature as a result of the infection. This fact is associated with the increase of the oxygen and an increased activity of the respiratory enzymes [J. W. Deacon, 1997]. According with several authors, transpiration intensifies and the photosynthesis decreases [ALLEN *et al*., 1938; LAST, 1962, cited by EUGENIA ELIADE, 1990].

The roots of the infected wheat plants are less developed due to the parasitism of the fungus, diminishing the capacity of absorption of the nutritive substances. There was noticed a delay in the plant growth due to the development of the mycelium that comprises the leaves and stems surface. Due to the parasitism the spikes are smaller and often the drying of the superior half of the spike where the spikelets are atrophying due to the coverage with mycelium. Due to the attack the grains can be absent in spike and if they are present, they can be shrivelled [LAST, 1962; MINARCIC *et al.*, 1979; FRIC, 1964, cyted by Eliade E., 1990].

The manifestation at the exterior of the plants specific to the fungus *Blumeria graminis f. sp*. *tritici* becomes severe, generalised, respectively has mass or epidemic character or even pandemic if the environmental conditions are favourable to the development of the pathogen, if there are present sensitive wheat varieties and physiologic virulent races [J. M. PRESCOTT *et al.*, 1986; GH. POPESCU, 1998; E. J. BAILEY *et al*., 1996; SUZANE BISSONETTE, 2002].

There is well known that powdery mildew is one of the main diseases of wheat from the semi-continental or maritime climate areas and can affect seriously the harvest. It can be found on large areas in every year being widely spread on all the continents, mainly in humid regions. The loses determined by this disease varies from a year to other depending mainly by the weather conditions. The harvest loses are due mostly to the shrivelled grains and to the diminishing of the amount of grains produced [E. KLUGE,1992; E. WILIAMS, L. J. LITTLE FIELD, 1995; E. LIPPS PATRICK, 1996; W. GAZAWAY, 1997; M. KELLER *ET AL.*, 1999; D. MICLUŢA, 2003]. According with F. J. ZELLER *et al.* (2002) the fungus *Blumeria graminis f. spec. tritici* can produce in wheat quantitative harvest loses to 45%, but also it can produce qualitative loses that affects the panification features mainly the shrivelling of the grains. E.g. in U.S.A. the total harvest loses due to powdery mildew are between 13% and 50%, mainly where isn't applied well the diseases control [C. A. GRIFFEY *et al*., 1994]. According with K. L. EVERTS *et al*. (2001), powdery mildew affects the ripening of the wheat grains and the quality of the processed products. Thus, the non-treated susceptible varieties can have loss of 16% when the flag leaf is infected before the spike appearance. When the infection reaches to the flag leaf the potential losses can reach to 25%. In contrast, the resistant varieties can lose from 5% to 8% from the harvest if powdery mildew goes up from the basal leaves to the flag leaf [E. LIPPS PATRICK, 1996; P. HART, R. WARD, 2000; C. E. DRYE, 2002].

The attack of the fungus *Blumeria graminis* on wheat in Romania was intensified mainly after the year 1960, the fungus being present in all the cereal cultivated areas (ANA HULEA *et al.*, 1975). The powdery mildew of the wheat was present in all the wheat crops from the country with values of the attack degree comprised between 2.5 % to 100% during the period 1987-1990 [AL. BĂRBULESCU *et al*., 1990].

During the researches developed on a long period of time, in some crops even over 20 years at S.C.A. Suceava (Romania) there was noticed a time evolution of powdery mildew that in the past years was covering the basal and medium level leaves and in present has extended in the superior level or even on spikes. The loses determined by powdery mildew were oscillating between 322 - 2128 kg/ha (9.3 – 34.8%), in average 1063 kg/ha, when is compared with the non-treated control with the variant where were applied two treatments and between 214 - 1040 kg/ha (3.9 – 23.5%), in average 805 kg/ha when there was applied one treatment. These great variations in losses from a spike to other is due to the climatic conditions that determinate in a great measure that determinate in a great measure the evolution of the pathogens and of the different resistance of the varieties [I. IGNĂTESCU, V. BRUDEA, 1999]. Generally, the harvest losses caused by powdery mildew and other foliar diseases in the non-treated crops were 1500 - 2800 kg/ha [V. BRUDEA, 2002].

In the last years there was noticed in all the wheat and barley cultivating countries worldwide an increase of the attack of the fungus *Blumeria graminis*.

On the background of the climate changes, cooler and rainy springs powdery mildew gain ground it manifesting a high frequency and intensity in the crops from areas where the disease was almost unobservable. In the context of climate changes there is necessary the upgrade of the control strategies applied to wheat powdery mildew and to the other specific pathogens.

## CLIMATE FACTORS AND THEIR INFLUENCE ON WINTER WHEAT POWDERY MILDEW

Capacity of the fungus *Blumeria graminis f. spec. tritici* to attack the wheat plants and their disease by powdery mildew is due to the features of pathogeny, virulence, aggressivity, nutrition and production of enzymes and toxins. Due to these features there is manifested the pathogeny or disease of wheat by powdery mildew. There are added the climatic conditions that has to be favourable to the development of the pathogen.

Pathogeny is the feature of a germ to be pathogenic, respectively to infect the plant determining the disease and the appearance of the symptoms [EUGENIA ELIADE, 1990]; it is the feature that confer to the fungus *B. graminis f. spec. tritici* the capacity to attack or infect only the wheat. The infection is realised by the germinative filaments of the spores, respectively the conidia and ascospores.

Germination represents the totality of the morphological, physiological and biochemical processes by passing of the spores from the inactive condition to the active phase from the life-cycle. Generally, the conidia are able to germinate as soon as they have been releases, thus they don't need a postmaturation period. Thus, there germinate only detached conidia, dispatched from the chain or from the conidiophore [JHOOTY, 1967; PAULECH, 1969, cited by Eliade E., 1990].

Low temperature stimulates the germination of the conidia, these keeping their germination capacity even after they were kept 6-8 hours at -17$^0$C – SCHAFNIT (1929), cited by EUGENIA ELIADE (1990).

Temperature is an extremely important factor that exerts its influence both on the germination rare and duration. Regarding the influence of the temperature on the germination duration in *Blumeria graminis f. sp. tritici,* MZHARANADZE (1976) had noticed 91.5% germinated conidia after 24 hours and 85 -96.4% after 48 hours at the maximal temperature of 19 - 21$^0$ C and at a moisture of 90 - 100%. The conidia germinate from a minimum temperature of 0 - 10$^0$ C.

Moisture has a very important role for the spore germination. According with YARWOOD (1936, 1950), DELP (1954), DRANDAREVSKI (1969), cited by Eliade E. (1990), high water content of the conidia of *Blumeria* gives them the possibility to germinate in a dry atmosphere. PAUL *et al.* (1986) shows that conidia germinate at air moisture of 70 - 100%.

The damaging action of the water on the conidia can be demonstrated by spraying a colony with water [HIRATA, 1967]. When *Blumeria* conidia are sprayed with water there are forming small water drops every of it being supported by a number of conidia chains. If the drops have the possibility to evaporate the conidia chains that were in contact with the water drops adhere one to other and the conidian mass changes its colour. Thus, the rapid rainfalls that are falling important water amounts are disturbing the germination of the conidia and many times they are stopping the evolution of the pathogen.

The colour change of the mycelium is a sign for the colony death. The conidia mass seen at microscope appears as a crust that seems to be composed mainly from broken conidia that adhere one to other, having among them still living conidia. After several days at the colony edges start to appear new conidiophores with conidia.

The light has also influence on the germination of the conidia. Under the influence of this factor takes place the physiological maturation of the conidia, phenomenon that takes place during the day-light.

The fact that in the absence of light the conidia didn’t germinate or germinate in a low rate is explained by the fact that the conidia developed in dark are poorer in carbohydrates, their nutrition is reduces and because of that their vitality is lower.

The influence of the climate conditions on the dispersion of the powdery mildew spores in winter wheat crops was studied in Germany with the intention to develop a simulation model of the conidia dispersion of *Blumeria graminis f. sp. tritici* considering the entire vegetation period, the dispersion of the spores was measured in parallel with the disease development. During the night the dispersion of the spores was lower, thus the calculated sporulation indicating that the conidia produced in this period aren’t disseminated until the conditions for it are favourable. The most important factors that influence the dispersion of the spores are: wind speed, vapours pression in the canopy and rainfalls. Once with the increase of the wind speed and beginning of rain the number of the conidia in air measured at every 30 minutes was considerably higher compared with the values obtained previously. The greatest number of conidia in air can be determined also by the passing through the powdery mildew infected canopy. A model for the calculation of the dispersion course of the conidia from an infected field plot infected naturally is done by using the variable meteorological data [S. FRIEDRICH, 1995].

The environmental conditions that are influencing the formation of the perithecia are temperature, air moisture and light, those factors being very well observed. There is considered that their influence cannot be precisely delimited regarding the parasite fungus only because the react simultaneously and in the same measure on the host. Generally, many scientists give a great significance to the high temperature values in the role of the perithecia formation in *Blumeria graminis.*

In *Blumeria graminis f. sp. tritici,* perithecia differ from air moisture greater than 60%. The importance of the host plant in the formation of the perithecia is greater. Thus, in many resears show that in *Blumeria graminis f. sp. tritici* the first perithecia appear on the basal leaves, respectively the senescent ones. The maturation of the perithecia and the production of ascospores is favoured by the high humidity and mainly the free water, the temperature of 1 - $27^{0}$ C, optimum 11 - $15^{0}$C, pH limits between 3 - 9, optimum 5 - 7, the hydrogen ions concentration [GRAF-MARTIN, 1934; TURNER, 1956; MOSEMAN *et al.*., 1957; ARYA, 1964; SMEDEGARD-PETERSEN, 1967; HE *et al.*, 1968 – cited by EUGENIA ELIADE, 1990]. PEDALINO *et al.* (1970) have obtained the germination of the ascospores at the temperature of 20 - $22^{0}$C, after 5 - 6 days on agar water in Petri plates.

In the case of mature perithecia the walls crack under the pression of the asci from inside or due to moisture, thus the asci are projected at a distance of several centimetres. The asci with ascospores can be released also by the decay of the perithecia wall.

The infection as pathogeny phase is influenced by the environmental factors' temperature and humidity (dew, relative air moisture and rainfalls), light, nebulosity, wind speed and even the pollutant factors. The fungus *Blumeria graminis f. spec. tritici* realises the infection of the wheat and manifests its pathogeny in wide temperature limits. Regarding the moisture, the fungus is more aggressive and virulent at lower values (37 - 56%) instead of an atmosphere with hygroscopicity of 9 - 97%. Relative air moisture and rainfalls interfere positively with the fungus attack degree, but with a low intensity at half comparative with dew. The pathogeny features of the fungus are influenced by light and dark, e.g. the oidial chains are longer, with low vitality and a low infection capacity due to the low content in carbohydrates, the nebulosity of 3 - 6 being the significance limit. Thus, between the wind speed and fungus virulence is a negative correlation [C. SANDU - VILLE, 1967; F. KOCOUREK, L. VECHET, 1984; EUGENIA ELIADE, 1990; J. S. YANG *et al.*, 1992; S. FRIEDRICH, 1995 a şi b; J. W. DEACON, 1997, 2006; L. CHET, 2003; OTILIA COTUNA, GH. POPESCU, 2004, 2005].

After POPESCU G. (1998) powdery mildew epidemy in wheat crop has an evolution in that are succeeding several phases, respectively: 1 – logarithmic growth phase; 2 – exponential or synergic growth phase in that the disease progresses very rapidly and becomes pandemic; 3 – transition phase in that the disease starts to decrease; 4 – stationary lag phase. Thus, in the case of epidemy and pandemic is a progress, an evolution in time determined as amplitude by the aggressive and virulent activity of the fungus and that can be measured and expressed by the *r* rate, important for the mathematic modelling of this process. E.g. the influence of the climatic factors on the dispersion of powdery mildew in winter wheat was studied in Germany. The results and data from literature were applied to a mono-dimensional mathematic model for the estimation of the probability of the infection with powdery mildew of the winter wheat. With the data collected at every hour (temperature, air moisture in canopy at 1 m height and rainfalls) there was possible the simulation of the different phases of the infection cycle (sporulation, dispersion of the spores and incubation period).

Using this model there can be estimated the course of the dispersion of the spores in the naturally infected crops under the influence of the various weather conditions can be simulated. After the setting of the conidia the appearance of the rainfalls, windspeed and pressure of the deficit of vapours from air have a negative effect on the probability of the calculated infection. Using this infection model the events that appear at the beginning of the epidemy during the infection are detectable and can be used for the initiation of the control measures at the proper moment [S. FRIEDRICH, 1995].

The factors implied in epidemy and pandemic can be climatic, technological and intrinsic, respectively dependent both by the host plant (wheat) and pathogen (*Blumeria graminis*). Among the climatic factor have great importance temperature and air moisture. E.g. powdery mildew is highly expansive in cooler conditions (17.7 – 22.2$^0$C, UR = 85 - 100%) and moisture [J. M. PRESCOTT *et al*., 1986; E. WILLIAMS, L. J. LITTLEFIELD, 1995]. The high moisture of 85 - 99% (in the presence or absence of the rain) and low temperatures (15 – 26$^0$C) favours the development of the diseases, the disease is remarkably slowed in evolution at 25$^0$C [J. E. BAILEY *et al*., 1995; E. P. LIPPS, 1996].

According L. CHET (2003) the development of the disease is rapid, acute in warm and humid weather. The fungus is unique regarding the production of spores and infection, these processes developing in low moisture conditions. Hard and rapid rainfalls aren't favourable to the production of the spores or the growth of the mycelium on the leaves surface.

On the other side there is known that every condition that lead to the low provision with water of the leaves as is a high density of the plants is favourable to the development of the disease. The disease is very susceptible to special conditions of temperature, but warm weather with cool nights diminishes considerably the evolution of the disease, instead the warm and sunny weather without dew in the morning stops suddenly the powdery mildew epidemy or pandemy [A. TENUTA, 1999, 2002; R. M. DAVIS *et al*., 2002; W. M. jr. BROWN, 2001; GH. POPESCU, 2005].

BISSONNETTE SUZANNE (2002), shows that is very important the monitoring of the climate factors as it is coming the appearance of the flag leaf (growth stage 8). If the weather is warm and humid (15.5 – 21.1$^0$C) the disease appears and spreads to the upper leaves.

In Romania *Blumeria graminis* of the wheat was a pathogen that was appearing in crops every year without creating important problems. The climate changes from the last years have changed slightly this situation. The spring of 2019 was characterised by a humid and cool climate in many locations, these conditions being favourable to the infection with *Blumeria graminis* in the cereal crops in many areas from the country. There were situations when on the background of stresses plants, without tillers and with a low hight powdery mildew had reached the spike determining harvest losses.

## MANAGEMENT OF POWDERY MILDEW IN WHEAT IN THE CONTEXT OF PRESENT CLIMATE CHANGES

Present climate changes related with the absence of the rotation, the reduced number of species cultivated in a farm, the excess of nitrogen fertilizers and the high densities that are now applied in wheat crops have leaded to the increase of the incidence and severity of the attack of the fungus *Blumeria graminis* in wheat. To the climatic and technologic factors are added the intrinsic factors that are represented in the case of wheat by the sensitive varieties and in the case of pathogen by the physiological races [GH. POPESCU, 2005].

In the context of the climate changes at that we are assisting in the last years there is necessary a revision of the present integrated control systems focused mainly on chemical control measures and less or none on prevention. The neglection of the preventive measures by the farmers has leaded to the excessive multiplication and spread of the pathogens and pests in agricultural crops and the increase of their aggressivity supported also by the climate in continuous change.

**Technological measures** have an important role in the prevention of the powdery mildew in wheat that is realised by respecting crop rotation, correct executed soil works, seeding at optimal and date and densities, use of resistant varieties, rational use of the fertilizers, correct irrigation if is applied. [M. HATMAN *et al*., 1986, 1989; V. FLORIAN, 1988; VIORICA IACOB *et al*., 1998; VIORICA IACOB, 2003]. These are the cheapest preventive methods (prophylactic). Many cereal producers use cultural methods for the powdery mildew control. They are using modern varieties with high productivity, crop rotation, balanced fertilisation and proper technological works that are limiting the harvest losses due to powdery mildew.

**Monoculture** practiced for long time permanentize the attack of powdery mildew, instead the rotation disturbs the spread of the pathogen [M. HATMAN, I. BOBEŞ *et al*., 1989].

**Summer and autumn ploughing** contribute to the creation of the optimal conditions for the morphological, physiological and biochemical development of the plants and to the diminishing and destruction of the resistance organs of the pathogens [V. FLORIAN, 1988]. Superficial ploughing in summer applied immediately after harvesting favours the germination of the grans lost on soil the new appeared plants serving as transitional host for the pathogen from the harvested crops to the winter crops [GH. POPESCU *et al*., 1985; T. BAICU, A. SĂVESCU, 1986]. The infected biological material is introduced in soil and destroyed by autumn ploughing works. The deep autumn ploughing has a very important phytosanitary role because applying this work there are buried the perithecia of *Blumeria graminis*, respectively the winter resistance forms, contributing to the diminishing or elimination of the attack in the following year [GH. POPESCU *et al.*, 1985; M. HATMAN, I. BOBEŞ *et al*., 1989; GH. POPESCU *et al*., 1991; GH. SIMERIA, 2002; VIORICA IACOB, 2003].

**Excess or deficiency of nutrients** and the unilateral applying of the fertilisers sensitize the plants to the attack of the pathogen [T. BAICU, A. SĂVESCU, 1986; ANETA ELENA DRĂCEA *et al*., 1980; GH. POPESCU *et al*., 1981, 1991; VIORICA IACOB, 1998; GH. SIMERIA, 2002; E. ULEA, 2003; AGAPIE A. L. *et al*., 2018]. Chemical fertilisers being pollutant is recommended to be used rationally as complex NPK forms with a balanced rate of every element. This action of pollution diminishing becomes more obvious if the chemical fertilisation is mixed with the organic one, only the organic fertilisation balanced application means non-pollutant fertilisation [GH. POPESCU, 1997]. Using this method there was partially diminished the attack of *Blumeria graminis*, but not at the expected level in the case of wheat [GH. POPESCU, 2005].

SHANER G., R. E. FINNEY (1977), T. BUSCHBELL and G. M. HOFFMANN (1992) have show that the development of *Blumeria graminis* was dependent by the nitrogen application, thus the first intervention was necessary in all the nitrogen doses applied (40, 80, 160 kg/ha) and the second and third were necessary in the plots fertilised with 160 kg/ha N, followed by the plots fertilised with 80 kg/ha N and 40 kg/ha N. The severity of the attack of powdery mildew is increased in the conditions of fertilisation with high doses of nitrogen [D. K. TOMPKINS *et al*., 1992; R. M. DAVIS *et al*., 2002].

By respecting the **optimal seeding moment** is realised the phenomenon named “run by disease”, factor by prophylactic importance because it provides a normal growing and development rate of the plants [GH. POPESCU, 1998].

BĂRBULESCU A. e*t al*. (1988) have highlighted the fact that the powdery mildew attack was favoured in a certain measure by the late seeding of wheat.

In some researches from Canada developed to determinate the influence of the agricultural practices on the development of powdery mildew considering the soil factor, nitrogen fertilisation, seed amount and distance between rows on the disease severity. Thus, the distance between rows of 36 cm and the amount of seeds of 140 kg/ha compared with the distance between rows of 9 cm and 350 kg/ha of seeds has demonstrated an increase of the disease severity. In this way, the great distance between rows favours the dispersion of the disease that climb progressively in plant, while the high amount of seeds has created a microclimate favourable for the development of powdery mildew after the installation of the pathogen on leaves [D. R. TOMPKINS *et al*., 1992]. In dense canopies the pathogens find better development conditions because there is realised the humidity and temperature favourable for the pathogeny and epidemiology [A. TENUTA, 1999; W. GAZAWAY, 1997; R. M. DAVIS *et al*., 2002]. **Optimal density** contributes to the elimination of the possibilities of the fungus *B*. *graminis f. sp. tritici* to initiate the pathogeny and in the case that it is already initiated it limits the expansion of the infection or of the epidemy [GH. POPESCU, 2005]. BĂRBULESCU A. *et al*. (1988), mentions a similar evolution of the powdery mildew attack in conditions of irrigated and non-irrigated crop.

**Harvesting** at the proper moment prevents the falling of the grains on soil and their germination that allows the passing of the infection from the past crops to the new ones [V. FLORIAN, 1988; VIORICA IACOB *et al*., 1998; E. ULEA, 2003].

From the integrated production the complex system that provides quantitative and qualitative constant harvests, the subsystem extremely economic and non-pollutant is the **genetic control** [T. BAICU, 1992; 1996; GH. POPESCU, 2005]. In this case the indicated measure is the cultivation of resistant varieties to powdery mildew. The cultivation of the resistant variety doesn't mean biological control, it is a technological measure. In this way GH. POPESCU (1997) specifies what it means biological control, respectively determining the resistance in a plant by using an organism against another organism. There exist wheat varieties that are manifesting resistance, immunity or tolerance to powdery mildew, totally distinct features [GH. POPESCU, 1998]. There is recommended the use of mixtures of varieties that were highlighted by reducing the powdery mildew attack and that had higher yields in comparison with pure plots [R. MANTHEY, H. FEHRMANN, 1993].

Regarding the genetic resistance there exist oligo-genic genetic resistance determined by major genes (e.g. Pm – powdery mildew), specific resistance of short duration that is manifesting against some physiological races of the fungus, and the poly-genic genetic resistance determined by minor genes, non-specific, of long duration and that is manifesting against all the races of the pathogen [N. CEAPOIU, FLOARE NEGULESCU, 1983]. This classification isn't unanimously accepted.

The plants avoid disease or attenuate the virulence of the pathogens through two categories of mechanisms: **structural** and **genetic**.

***Structural mechanisms*** in conception of E. J. PARLEVLIET and J. C. ZADOKS (1977) provides the plants a pseudo-resistance or false reaction, apparent, respectively a physical reaction passive and indirect. The pseudo-resistance of the interaction forms the pathological-system *Blumeria graminis – wheat* is provided by the presence in the varieties and hybrids of plants of pre-existent structures (pre-infection) or new structures („*de novo*"), respectively post-infection.

Non-specific resistance or conservative is realised by resistance genes of tat antifungal proteins appear in the plant cells both in the presence of infection pathogen and non-infection (physio-pathic pathogen). The defensive ways or anti-microbial activity (**AMP)** or anti-microbial proteins or anti-fungal are mediated by:

- **oxidative explosion of the cells** or hyper-sensitive resistance [J. T. GREENBERG, 1997; X. DONG, 1998; C. A. FRYE et al., 2000 a.o.].

- **SAR (Systemic acquired resistance)** is realised with three hormones of the plants, respectively salicylic acid (SA) – C. J. LAMB *et al*. (1989); J. A. RYALS *et al*. (1993); B. J. STASKAWICZ *et al.* (1995); X. DONG (1998); S. XIAO (2001) a.o.; iasmonic acid (JA) and etylene – K. H. KOGEL *et al*. (1994); J. GORLACH *et al*. (1996); PEER M. SCHENK *et al*. (2000) a.o.; calmodulin – $Ca^{2+}$ (**CaM)** and perhydrol – M. C. KIM *et al*. (2002 a, b); P. PIFFANELLI *et al*. (2002) a.o.

**- ISR (Induced Systemic Resistance)** – C. M. J. PIETERSE *et al*. (1996); S. C. M. VAN WEES *et al.* (1997); X. DONG (1998) – a new resistance form of answer of the plants at the level of roots.

The answer of the plants in the non-specific resistance are given by the action of the genetic factors conserved by the fungus *Blumeria graminis* in evolution, respectively **PAMP$_{(S)}$ – (**Pathogen associated molecular patterns) and are long time active, respectively there is maintained the horizontal action of the defence genes.

The specific resistance or evolutive is provided by resistance genes that are inducing in the plant cells defensive proteins **(AMP)** when they are attacked by pathogens. E.g. in the wheat varieties the resistance is provided by Pm– powdery mildew genes.

Implication of the specific resistance genes, singular or multiple (allele) or of those with mixed action and non-specific that are manifesting in the wheat variety phenotype a defensive synergism superior to the one induced by the non-specific or specific genes, but not with total protection [J. W. WILSON *et al*., 2001].

Genetic control will have an efficiency of 100% in control when from the membrane of the epidermal wheat cells from leaves will be eliminated the proteins, respectively the receptor genes, this elimination blocks the cause of the present powdery mildew disease, respectively **AVR (evolutive pathogeny genes) and PAMP$_{(S)}$** or conservative genes [S. XIAO *et al*., 2001; F. S. WEI *et al*., 2002; T. ASAI *et al*. 2002; R. PANSTRUGA, P. SCHULTZ – LEFERT, 2002].

In the framework of a system for the diseases management, biological measures represent an important part of the integrated control. The present trend of the humankind is to diminish as much as possible pollution, translated in agriculture by reducing the number of chemical treatments and their replacement with some bio-treatments. The biotherapy of the pathogens is quite difficult to be applied and the results in control are often oscillates and depend by various factors.

In Romania have an important contribution in this field the experimental result published in more than 100 scientific works by TATIANA SEŞAN in collaboration with T. BAICU (1993). A synthesis in this field has appspikeed in the paper „*Combaterea non-poluantă a patogenilor plantelor prin măsuri biologice şi culturale* (en. *Non-pollutant control of the plant pathogens by biological and cultivational measures*)" – GH. POPESCU (1997).

From the variants of biotherapy described by GH. POPESCU (2005), are referring to the control of the fungus *Blumeria graminis f. sp. tritici:* premunition, myco-parasitism or hyper-parasitism, antibiosis and mycorrhizae.

Premunition in the mycotic variant, respectively „fungus against fungus" was used in the control of the fungus *Blumeria graminis* parasite on barley by H. E. NELSON (2005) that has noticed that the barley plants colonized by the fungus *Fusarium oxysporum f. sp. Radicis – lycopersici* are resistant to powdery mildew.

In **myco-parasitism** *Blumeria graminis* is infested by the saprophyte fungi *Trichoderma viride*, *Trichothecium roseum* and *Ampelomyces,* first two species being frequently mentioned in this way. In **antibiosis** the success in the control of powdery mildew is due to the metabolites of the abovementioned species, respectively trichodermin, trichothecene and ampelomycin [TATIANA SEŞAN, T. BAICU, 1993, 1995]. On the background of the antagonist variant, respectively hyper-parasitism and antibiosis there have been obtained bio-products necessary for the Romanian agriculture for the control of the pathogens in plants as is *B. graminis f. sp. tritici* respectively: Trichodermin 3, 4, Trichodermicin, Trichodermicin 4, Trichosemin, Trichodex and Ampelomycin [GH. POPESCU, 1997]; from those Trichosemin and Trichodex aren't used in wheat and trichothecene (trichodermin) was used in practice for powdery mildew control [TATIANA SEŞAN, 1987].

In present exist commercial bio-products for the bio-control of powdery mildew in wheat that are containing mycelia fragments and conidia of a selected genotype of the antagonist fungus *Ampelomyces quisqualis*. The fungus acts as a bio-fungicide preventively, by attacking the pathogen before it penetrates the tissues. There is important to know that bio-products must to be applied prophylactic. The recommendation of the specialists is to be applied as foliar spraying in sufficient water to provide a uniform film on plants. Depending by the infection degree of the fungus there can be applied 2 – 3 spraying or even more. The bio-fungicides are environmentally friendly, they aren't determining the resistance phenomenon and they aren't creating problems regarding the residues from the vegetal products.

The expression „**biological control product”** today is wider, there being included minerals, sulphurs, algae, compost, plant extracts or lecitine a.o. [H. PFLEIDERER, 1993; N. HABER, 1993]. According with the first author there wasn't efficient any biological control product in the control of fungus *Blumeria graminis f. sp. tritici* comparable with a fungicide.

HABER N. (1993) has experimented bio-control products with lecithin and plant extract – Bio – Blatt Mehltaumittel, with plant extract – Milsana, Neudo-vital and Cosan 80 (sulphur) as etalon and obtains a diminishing of the losses caused by the strong powdery mildew attack on leaves, but none product hasn't controlled powdery mildew on spike. The biological product wit soybean extract (phospholipids 75%) – ”L 1700” helped the fungicide based on sulphur Thiovit to have efficacy on the control level desired by the farmer [F. A. CULSHAW, 1992].

Biological fungicides registered at E.P.A. tries to compete with the synthetic fungicides from the market. The farmers must to use for the control of powdery mildew synthesis fungicides and performant technological measures because there weren't perfectioned biological fungicides with high efficiency in the control of the leaf's pathogens, respectively wheat powdery mildew, thus they have to determinate an increased vigour to the wheat plants [H. PFLEIDERER, 1993; J. D. FROYD, 1997; GH. POPESCU, 1998].

A less know control method is the action of the mycorrhizal fungi, respectively an association at the level of the plant roots with fungi following the symbiosis principle advantageous for both sides was discovered by H. W. DEHNE and F. SCHONBECK (1978) in wheat in Germany where the association with a endo-mycorrhiza had conferred a high resistance to the wheat against powdery mildew; the success of control is provided by the antibiotics produced by the symbiotic fungi. This observation determined the researcher N. C. SCHENK (1981) to assume that mycorrhiza is a new way of biological control. Arbuscular mycorrhiza is used today in the biological control more in combination with other antagonist fungi. Thus, the bio-products are used mainly to the seed treatment and of the planting material.

The present trend in diminishing the air and soil leads the ecological agriculture gain more ground. Also, the consumers are more interested in keeping their health and are focused more and more on the ecological vegetal products free of pesticides residues.

The chemical control of powdery mildew is applied worldwide with the purpose to limit the damages produced by this fungus that sets on leaves and spike. For the chemical therapy of this disease are used a series of systemic or contact fungicides with specific or polyvalent action. Because very few pesticides accomplish all the features usually are used mixtures of 2 or 3 fungicides with different action mode and activity spectre. The fungicides mixture is preferred on one side because it prevents or delay the appearance of the resistance phenomenon of the fungus for these products, and on other side the efficacy is high because of the synergism phenomenon.

The fungicides used in the control of wheat powdery mildew are belonging to the following chemical groups: inorganic, piperidines, strobilurines, benzophenones, triazoles, benzoylpyridines, imidazoles, acetamides, thiophanates, amines, pyrozoles, spiroketalamines and mixtures. The range of the chemical substances used for the control of powdery mildew in wheat is very wide. In Romania are authorised more many fungicides: fenpropidine, flutriafole, azoxystrobine, cyflufenamid, cyproconazole, difenoconazole, metconazole, metrafenone, piriofenone, prochloraz, prothyoconazole, sulphur, tebuconazole, tetraconazole, thiophanate - methyl, triadimenol and mixtures of bixafen + prothyoconazole, epoxiconazole + kresoxime - methyl, fenpropimorph + metrafenone + epoxiconazole, prothyoconazole + trifloxistrobine, spiroxamine + tebuconazole + triadimenol, prochloraz + tebuconazole + proquinazide, tebuconazole + prothyoconazole *etc*.

The fungicides from the triazoles group are very used alone or in mixtures because they provide a control quite long as time duration and the Maximal limit allowed of toxic residues remains without values after 30 or 42 days. There weren't surpassed in efficacy by any biological product assumes H. PFLEIDERER (1993) in its work entitled „*How efficient are biological fungicides?*”.

The chemical treatments used for the control of powdery mildew can be applied with terrestrial or aerial spraying methods, the last one having a greater efficiency.

***When is recommended to spray?***

T. BAICU, SESAN TATIANA (1996) recommends the treatments to be applied depending by the economic damaging level or in the phenophase of spikelet's initiation, flowering and 50% flowered.

The control is economic if after tillering on the last three leaves or before anthesis on the flag leaf are more than 25% powdery mildew parches, respectively has accomplished economical damaging level and the climatic factors (temperature, air moisture, rainfall, fog and dew) continue to fulfil in the optimal limits for the disease development [GH. POPESCU, 1998].

The spraying applied in the one node stage (growing stage GS 31) have controlled early the powdery mildew, but the best control and the best yield response was associated with the sprayings applied at the emergence of the flag leaf (GS 39 – 43) or the spikelet initiation (GS 59), growth stages before to the increase of the attack. Treatments applied at the spikelet appearance and the ones from the beginning of the flag leaf growth have determined a good protection of the spikelet [N. V. HARWICK *et al.*, 1994].

In Czech Republic the applying of the treatment in autumn hasn't stopped the appearance of the powdery mildew that was maintained in vegetation too. When the treatment was applied early in spring the attack of the fungus was stopped before to reach at the level of the damaging infection; in the case of late spring treatment the infection level was superior to the early spring treatment, but the powdery mildew was controlled[L. TVARUZEK and K. KLEM, 1995].

HART PAT (1997) recommend the applying of treatment for the control of powdery mildew these being justified if the disease is visible on the flag leaf or if the lesions produced by the fungus cover 1% from the surface from the proximity of the flag leaf. The flag leaf is very important because it produces 60-70% from the carbohydrate translocated in spikelet. Because the flag leaf is important it dies when 20% from the surface is covered with lesions, thus the chemical treatment is very important mainly for the diminishing of the infection on the flag leaf [P. HART, R. WARD, 2000].

Regarding the diminishing of the fungicides dose as method for the diminishing of the chemical pollution of the environment is a much discussed and risky problem due to the favouring of the resistance to fungicides, but a diminishing with 10% from the recommended dose that provides a satisfactory control of the disease but this doesn't satisfies the farmer [M. JAHN, U. BURTLES, 1994].

In present we are assisting to growths of the treatments number, there existing situations when are applied even 5 - 6 sprayings. Beneath this aspect there are farmers that aren't respecting the optimal control moments by applying treatment late in the vegetation season. The late application of the fungicides can lead to the presence of the toxic residues in grains. Usually are necessary more many treatments where the preventive measures aren't respected or aren't applied. The reasons that motivate these decisions are numerous. The broad range of cultivated plants in a farm, the minimal soil works, climate in continuous change have favoured increases of the populations of harmful organisms in agro-ecosystems that are difficult to control.

## CONCLUSIONS

Management of powdery mildew in the present context of climate changes shall bring the preventive measures on the first position of disease control in cultivated plants. The correct application of some control strategies based on technological measures and control shall diminish a lot the chemical pollution of the agro-ecosystems. There is known that the intensive agriculture practiced nowadays by the plant protection works pollutes the environment and the vegetal products. In the vegetal products from nowadays are found many times pesticides over the allowed levels. In the conditions that consumers are demanding vegetal products free of pesticides the agronomists should to revise the control systems practiced and recommended today, based almost totally on chemical treatments.

The management of powdery mildew and of the other specific pathogens can be realised by respecting the prophylactic measures, application of the treatments only following phyto-sanitary checks and in the case of surpassing of the economic damaging level of the pathogens, the compliance the optimal moments for disease control, the compliance of the timing between treatment and harvesting, diminishing of the chemical treatment number, replacement at least of one chemical fungicide with a bio-fungicide.

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