

**MINI REVIEW**

## Impact of Pyraclostrobin (F-500) on Crop Plants

Mansi Kanungo and Juhie Joshi✉

### Abstract

**Strobilurins, such as pyraclostrobin, belong to a fungicide group with preventative mode of action and are used around the world. After the launching of strobilurins, and with the evolution of this group of chemical products, the concept of disease control gained new perspectives especially when considering the advantages obtained by the action of positive physiological effects on plants. F-500 (pyraclostrobin) strobilurin, a new generation broad spectrum fungicide has been shown to cause changes in the metabolism of plants resulting in higher biomass and yield. Considering the ever increasing demand for food production with shrinking cultivable area day by day, it is necessary to go for agrochemicals which enhance the growth and development *vis-à-vis* productivity.**

**Keywords:** biomass; pyraclostrobin; strobilurins; yield

### Introduction

Strobilurins are an important class of fungicides that come from the discovery of *Strobilurus tenacellus*, the mushroom fungus that causes wood-rotting. This isolated natural fungicide is thought to be used to protect the fungus against microbes in the decomposition of the wood. The discovery of strobilurins led scientist to isolate and produce synthetic strobilurins by chemically altering the compound to be able to tolerate sunlight (Vincelli, 2002). The strobilurins are a new class of systemic fungicides

with a unique mode of action which targets the mitochondrial respiration by blocking the electron transport at the outer side of the cytochrome-bc1 complex (Balba, 2007).

After the launching of strobilurins, and with the evolution of this group of chemical products, the concept of disease control gained new perspectives especially when considering the advantages obtained by the action of positive physiological effects on plants (Venancio, Rodrigues, Begliomini, & de Souza, 2003). Thus studies so far have concentrated mainly on phytohormone-mediated effects of strobilurins on the physiology of the plant senescence process. Therefore a longer period of photosynthetic active green leaf area has been suggested to be the main factor for yield increases obtained with strobilurin fungicides, because the increased photosynthetic period would increase the quantity of assimilate available for grain filling (Bertelsen, Neergaard, & Smedegaard-Petersen, 2001). Over the past years, there has also been increasing evidence for direct influences of strobilurins on plant physiology. This physiological effect includes the so-called "greening," that is, even in the absence of challenge by pathogen attack; plants treated with strobilurins are intense green and look healthier than plants that have not been treated with strobilurin fungicides (Köehle *et al.*, 2002; Kyveryga, Blackmer, & Mueller, 2013). This suggested that, in addition to their fungicidal activity, strobilurins might also enhance the capability of plants to ward off pathogens.

### Types of strobilurins

Strobilurins are natural products isolated and identified from specific fungi. Both natural (Fig. 1) and synthetic strobilurins (Fig. 2) are available.

### Mode of action

Strobilurins are systemic fungicides and these exert their fungicidal action by blocking electron transport in the mitochondrial respiratory chain in fungi (Balba, 2007). With this unique mode of action the strobilurin is an important addition to the existing fungicides, in which

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recent broad- spectrum fungicide products have been largely based on sterol biosynthesis inhibitors (SBI).

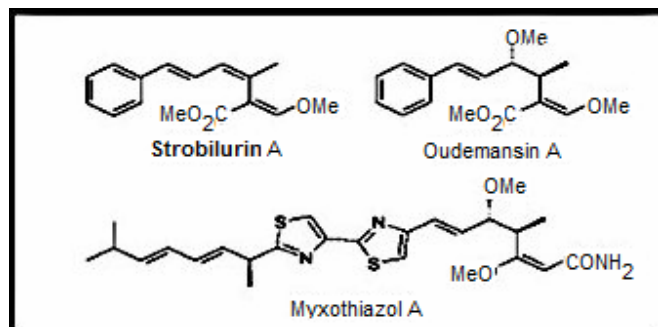


Fig. 1. Representative natural strobilurins (Bartlett *et al.*, 2002)

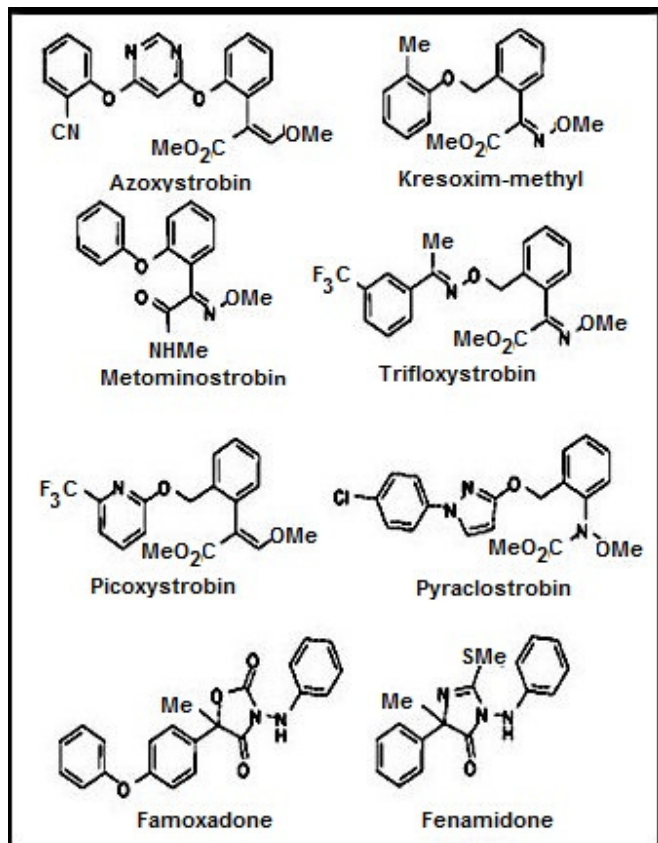


Fig. 2. The strobilurin fungicides, and famoxadone and fenamidone (Bartlett *et al.*, 2002)

The mode of action of strobilurin fungicides is the inhibition of mitochondrial respiration by binding to the ubihydroquinone oxidation center of the mitochondrial bc1 complex (complex III), thereby blocking electron

transfer (Sauter *et al.*, 1999). The strobilurins bind to one specific site in the mitochondria, the quinol oxidation (Qo) site (or ubiquinol site) of cytochrome b and thereby stop electron transfer between cytochrome b and cytochrome c, which halts reduced nicotinamide adenine dinucleotide (NADH) oxidation and adenosine triphosphate (ATP) synthesis (Brandt, Haase, Schaeffer, & von Jagow, 1993). This leads to the stopping of the energy production and the fungus will eventually die. Thus their mode of action is novel and new target-specific. They are more correctly referred to as the QoI fungicides.

**Pyraclostrobin fungicide (F500)**

Structure:

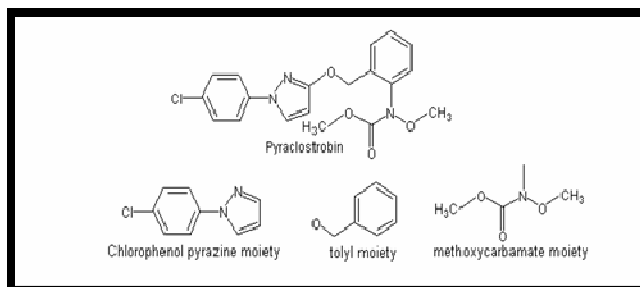


Fig. 3. Structure of Pyraclostrobin

Class: Strobilurin

Molecular-formula: C<sub>19</sub>H<sub>18</sub>N<sub>3</sub>O<sub>4</sub>Cl

IUPAC Name: methyl N-{2-[1-(4-chlorophenyl)-1H-pyrazol-3-yl]oxy]methyl} phenyl} (N-methoxy) carbamate.

Pyraclostrobin (F500) belongs to strobilurin class of agricultural fungicides (Bartlett *et al.*, 2002), used around the world, with a preventive mode of action (Grossmann, Kwiatkowski, & Retzlaff, 1999). As a fungicide family, the strobilurins all have a common mode of action. Strobilurin fungicide pyraclostrobin (F-500) initially developed to control fungal pests showed growth promoting and yield enhancing qualities under field conditions. Later field trials using F-500 on healthy plants have substantiated these observations on plants like wheat and barley (Venancio *et al.*, 2003; Köehle *et al.*, 2002). It was reported that growth of soybean is enhanced by foliar spray of pyraclostrobin (Swoboda & Pederson, 2009).

**Pyraclostrobin and biomass yield**

Strobilurins have shown some effects in boosting yields in wheat, corn, (Nelson & Meinhardt, 2011), soybean (Henry, Johnson, & Wise, 2011; Hill, Bowen, & Hartman, 2013) and in other crops. Wheat grain yields were higher in a study by Ruske, Gooding, & Jones (2003). The increased biomass had the biggest impact on grain yields. Some study revealed that fungicides applied in the absence of foliar disease did not produce non-fungicidal

physiological effect or associated yield improvement and it was concluded that environmental conditions and assessment of disease levels should be used as a guide for foliar fungicide application on soybean (Swoboda & Pedersen, 2009). Growth stimulation in plants with the strobilurin fungicides has been related to a reduction in the incidence of disease as well as increased nitrate uptake and assimilation in small grains (Köehle *et al.*, 2003). Research has shown that pyraclostrobin was important in stimulating nitric oxide, a key messenger in plants (Conrath, Amoroso, Köhle, & Sultemeyer, 2004).

### Pyraclostrobin and photosynthesis

In wheat plants strobilurins are reported to enhance the net rate of photosynthesis in the treated leaves (Köehle, Grossmann, Retzlaff, Akers, & Limburgerhof, 1997; Grossman *et al.*, 1999; Häuser-Hahn, Baur, & Schmitt, 2004; Oerke, & Dehne 2005). Strobilurin application also extends the life of flag leaf by retention of higher chlorophyll content (Habermeier, Gerhard, & Zinkernagel, 1998; McCartney, Mercer, Cooke, & Fraaije, 2007). These observations on photosynthesis indicate a higher amount of fixation of carbon by the application of strobilurin.

### Reduction and assimilation of Nitrogen

The increase in biomass and production, obtained by application of pyraclostrobin, even in plants not affected by fungi, is of special interest for agricultural practices. Since an increase in biomass also requires greater assimilation of nitrogen, the NADH-nitrate reductase that catalyzes the first stage of nitrate assimilation, is considered as the relevant target for the effect in production caused by pyraclostrobin. The reduction of nitrate to nitrite is seen as the limiting step in the assimilation of N and thus highly regulated. Nitrate assimilation in wheat plants pulverized with pyraclostrobin was increased, in comparison with control plants (Köehle *et al.*, 2003).

### Hormonal changes

Köehle *et al.* (2003) confirm the effect of pyraclostrobin in the activity of ACC-synthase and synthesis of ethylene under conditions of stress and senescence in wheat. Hormonal levels of indol-3- acetic acid (IAA) and abscisic acid (ABA) were also determined. New wheat plants (*Triticum aestivum* L. cv. *Kanzler*) were treated in leaves with pyraclostrobin for 3 hours; pyraclostrobin inhibited the activity of ACC synthase and the levels of ACC in the tissue in up to 63% at 10<sup>-4</sup> M. On the other hand, pyraclostrobin in a concentration of 10<sup>-8</sup> to 10<sup>-4</sup> M did not change the activity of *in vivo* ACC-synthase using enzymes extracted from detached buds and subjected to drying. This indicates that the fungicide may inhibit the synthesis of enzymes again. The endogenous levels of IAA may be the result of pyraclostrobin metabolism because this strobilurin breaks down to the natural precursor of IAA,

L-tryptophan in wheat (Köehle *et al.*, 2003). As another effect of pyraclostrobin, it increases concentration of endogenous levels of abscisic acid (ABA) up to a maximum of 269% on the control.

### Retarded senescence after treatment with pyraclostrobin

The detached leaves of a plant slowly lose chlorophyll, RNA, lipids and proteins, even if they are kept wet and are supplied with minerals. After exposing the wheat leaf discs to pyraclostrobin for 48 hours, the loss of chlorophyll, as a parameter of the progression of senescence, was inhibited by a growing concentration of strobilurin (Grossmann & Retzlaff, 1997). Maximum retardation of leaf senescence, with up to 82% of the higher level of total chlorophyll in relation to the control was observed at 10<sup>-4</sup> M of pyraclostrobin. The response to the dose in the retardation of senescence by pyraclostrobin had close correlation with decreasing levels of formation of ACC and ethylene and increase of IAA.

### Pyraclostrobin alleviates oxidative stress in plants

In some cereals, mainly susceptible varieties of barley, the reactive oxygen forms may induce the formation of the so-called physiological leaf spot formation (Fig. 4.) (Wu & Tiedemann, 2001, 2002a, 2002b), which causes severe losses in productivity (Baumer, Behn, Doleschel, Fink, & Wybraniec, 2001). Resistant plants respond to oxidative stress with increase in the activity of antioxidative enzymes, such as superoxide-dismutases, catalases and peroxidases (Larson, 1997). In field tests conducted in Wo Palatinat, Germany, winter barley plants treated with pyraclostrobin did not develop symptoms, while flag leaves and lower leaves of untreated plants were covered by symptoms of physiological leaf spots, indicating some blocking reactions of radicals that opposed oxidative stress. When the activity of peroxidase in the flag leaf was evaluated, the plants treated with pyraclostrobin showed almost doubled enzymatic activity, which can contribute toward tolerance to stress. It is interesting that this effect, established five days after treatment with fungicide, persisted for over four weeks (Köehle *et al.*, 2003).

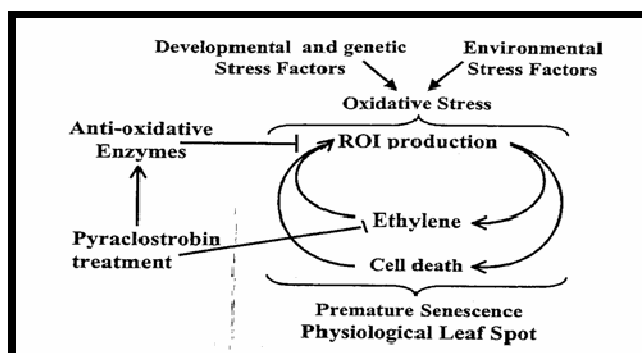


Fig. 4. Physiological and biochemical effect of pyraclostrobin

## Conclusions

The literature indicates role of strobilurin fungicide F-500:

- Enhances plant growth and biomass,
- Delays leaf senescence,
- Increases nitrate uptake, reduction and assimilation,
- Regulates phytohormonal level to overcome stress,
- Alleviates oxidative plant stress, and
- Enhances yield.

F-500 is now being used on Indian crops like soybean, fenugreek, maize, wheat. Strobilurin fungicide F-500 is thought to have an effect on plant growth and metabolism. This may be of particular significance in the tropical countries like India where various crops are largely grown without using fertilizers in the field. Even if the fertilizers are used application of pyraclostrobin can minimize the amount of fertilizers to be applied by enhancing the fixation of carbon and atmospheric nitrogen.

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