SUMMARY

Headline® fungicide improves Plant Health through inhibition of mitochondrial respiration in both fungal diseases and plants.

In fungi, inhibition of mitochondrial respiration prevents the breakdown of carbon required for production of energy to fuel fungal growth. This results in death of the fungi.

In plants, the inhibition of mitochondrial respiration causes a cascade of positive events that can result in improved tolerance to stresses and increased efficiency of plant physiological processes. Inhibition of mitochondrial respiration by Headline results in:

- Less CO₂ lost by the plant resulting in more carbon available for plant growth and yield.
- Increased activity of nitrate reductase, the enzyme that is important for making a form of nitrogen that can be used by plants. This results in more nitrogen available for plant growth and yield.
  - The activation of nitrate reductase increases levels of nitric oxide. Nitric oxide triggers plant defense mechanisms. Plant defense mechanisms are important not only in defending against fungal diseases, but also bacterial and viral diseases.
  - Nitric oxide inhibits enzymes involved in the production of ethylene, a plant hormone produced in response to stress. Ethylene can cause a plant to drop energy containing leaves, to mature earlier than normal, and abort flowers, seed and/or pods in response to stress.
- Increased activity of enzymes like superoxide dismutase and peroxidases that remove harmful activated oxygen species. This can result in reduced oxidative stress in response to environmental disorders, such as physiological leaf spot, ozone damage, cold stress, and heat stress.

Headline improves Plant Health, not just through superb, broad spectrum control of fungal diseases, but also through improved tolerance to stress and increased efficiency of plant processes. This enables plants to better withstand disease and a multitude of environmental stresses resulting in improved crop harvestability, quality and yield.
Yield

Seed Quality • Healthier Plants • Stalk Strength

Growth Efficiency
- Better use of nitrogen fertilizer
- More efficient photosynthesis

Disease Control
- Excellent control of major foliar diseases
- Increased tolerance to bacterial and viral infections

Stress Tolerance
- Drought
- Hail
- Ozone
- Frost
- Heat

HEADLINE® FUNGICIDE DISEASE CONTROL AND PLANT HEALTH
INTRODUCTION

When crops are able to put nearly all of their energy into growth and grain/seed fill, yield potential is maximized. To achieve this, crops must make the best use of inputs like carbon and nitrogen while limiting energy wasted on fending off stresses caused by weather, environment, diseases and other factors. Changing agronomic practices that create higher yield situations, like increased planting density, can also add stress to a crop. Newer hybrids, with added traits, have been bred for higher yields. Breeding for high yields can be at the expense of other traits that provide more tolerance to disease and stress. To maximize crop yields profitably, growers focus on controlling factors that they can impact to create an ideal environment for crop growth and yield. These factors include agronomic practices to reduce stress, improve crop growth, and manage pests and disease.
Pyaclostrobin, the active ingredient in Headline, belongs to the strobilurin class of fungicides. In addition to excellent, broad spectrum disease control, research has shown that Headline also provides additional Plant Health benefits. Headline controls foliar fungal diseases by inhibiting respiration in the fungal mitochondria. This inhibition prevents the breakdown of energy rich carbon compounds that the fungus needs to produce energy for growth. Headline also has activity on the plant mitochondria and reduces respiration in the plant. Since the plant’s primary source of energy comes from sunlight through photosynthesis, this decrease in respiration can have a positive effect on growth. Decrease in respiration allows the plant to keep more stored carbon compounds for growth and triggers a chain reaction of positive physiological changes in the plant. These positive physiological changes may include an increase in nitrate reductase activity, elevated levels of antioxidants and defense signaling compounds, and a decrease in the stress hormone ethylene. The combination of disease control, stress reduction and increased growth efficiency lead to the Plant Health benefits of Headline described in this report (Figure 1).

Figure 1: Headline Disease Control and Plant Health

Proposed model of Plant Health benefits

* red lines indicate inhibition of pathway or process
** blue arrows indicate activation of pathway or process
† Increased tolerance to bacterial and viral infections
Today’s growers seek to maximize yields and profitability of their farming operation as production costs continue to rise. With these rising costs, growers want to know that when they invest money into inputs like nitrogen, the crop is able to make the best use of those inputs to achieve the highest yield potential. Laboratory and field research has demonstrated that Headline can improve nitrogen utilization in crops and can also improve photosynthetic efficiency. The result is that Headline treated crops may keep more carbon for growth, development, and yield potential.

Headline Improves Crop Utilization of Nitrogen

Nitrate reductase is an enzyme in plants that is required to convert nitrate to nitrite so that it can be used by the plant for growth and development. The activity of Headline on plant mitochondria results in a reduction of respiration. This reduction in respiration activates the nitrate reductase enzyme. This activation results in more rapid conversion of nitrate into nitrite for the plant to use. Thus nitrogen utilization is improved and plant biomass can be increased to provide more photosynthesis and carbon for grain fill (Figure 2).

Greenhouse and laboratory results
A research study was conducted to determine the effect of Headline on the enzyme, nitrate reductase. Within a few hours after Headline application to wheat leaves, the activity of nitrate reductase increased by more than 70%. The increased nitrate reductase activity was maintained for more than three nights after a single application of Headline (Graph 1a, next page).

Nitrate uptake in vivo increased approximately 40% seven days after Headline treatment. The increased nitrate reductase activity and nitrate uptake was followed by enhanced plant growth, with an increase in plant biomass of about 20%, two weeks after the Headline application (Graph 1b, next page).
Field observations and research
Research studies were conducted in corn and soybeans in Brazil to determine if Headline® fungicide activates the nitrate reductase enzyme under field conditions. In corn, the active ingredient in Headline was compared to azoxystrobin. Azoxystrobin is the strobilurin active ingredient in Quilt® and Quadris® fungicides. Across all nitrogen rates, nitrate reductase activity increased on average by 47% one day after application of a product containing the same active ingredient in Headline (data not shown). At the highest nitrogen rate used, the product containing the active ingredient in Headline increased nitrate reductase activity by 20% more than azoxystrobin (Graph 2).

In soybeans, the active ingredient in Headline was compared to azoxystrobin. Two applications of each product were made, and nitrate reductase activity was measured 8 days after the last treatment. The product containing the active ingredient in Headline increased nitrate reductase activity by 89% more than the untreated and 55% more than azoxystrobin (Graph 3).

Graph 2: Headline Increased Nitrate Reductase Activity in Corn Greater Than a Competitive Strobilurin

Graph 3: Headline Increased Nitrate Reductase Activity in Soybeans Greater Than a Competitive Strobilurin
To determine the effect of Headline® fungicide on corn growth and yield in the field, research trials were conducted by the University of Illinois under a low disease environment. Nitrogen rates ranged from 0 to 300 lbs/ac. At all nitrogen rates, Headline-treated corn out-yielded untreated corn, indicating that more grain was produced per unit of nitrogen (Graph 4). The result is potentially more efficient utilization of nitrogen.

**Headline Improves Photosynthetic Efficiency**

Increasing the efficiency of photosynthesis also allows a crop to make best use of available inputs. The activity of Headline on plant mitochondria reduces respiration in crops. This reduction in respiration reduces the amount of CO₂ given off when stored carbon compounds are broken down. Reducing the amount of CO₂ given off can mean more carbon remains available for growth, development, and eventually yield potential (Figure 3).
Field Observations and Research
Field research studies were conducted in corn and soybeans in Brazil to determine the effect of Headline® fungicide on plant photosynthetic efficiency and respiration. In corn, a single treatment of the same active ingredient in Headline was made to corn at the V8 growth stage. Three rates of nitrogen were used. In the treated corn, six days after application, respiration was significantly decreased by an average of 28% and net photosynthesis was significantly increased an average of 73% across all nitrogen levels (data not shown). A comparison to azoxystrobin was included in this trial. At the highest nitrogen rate used, the product containing the active ingredient in Headline decreased respiration by 25% and increased net photosynthesis by 58% more than azoxystrobin (Graphs 5 a&b). For soybeans, two applications of the same active ingredient in Headline were made. Seven days after the second application, respiration was significantly decreased by 49% and net photosynthesis was significantly increased by 26%. A comparison to azoxystrobin was included in this trial. The product containing the active ingredient in Headline decreased respiration by 16% and increased net photosynthesis by 8% more than azoxystrobin (Graphs 5 c&d).

Graph 5 a&b and c&d: Headline Fungicide Reduced Respiration and Increased Net Photosynthesis, Improving Stress Tolerance and Yield Potential

Dr. Durval Dourado Neto, ESALQ/USP, application to 8 leaf corn; measured 6 days after treatment
* The strobilurin in Quilt

Neto and Alzemberg ESALQ/USP; 7 days after 2nd application
* The strobilurin in Quadris
Disease control is important for maintaining maximum yield potential. Disease control is especially important with current agronomic practices like increased plant population and reduced tillage practices that often create conditions favorable for disease. A crop with a higher plant population per acre is more likely to have increased disease pressure, increased stress on each plant, and reduced stalk strength. Disease control maintains green leaf area and reduces the amount of energy used by the plant to fight the disease. Headline® fungicide is widely recognized as a fungicide with excellent control of major foliar fungal diseases in a wide variety of plant species. The Plant Health benefits of Headline can also increase tolerance to bacterial and viral infections, another part of plant defense.

**Headline Pre-treatment Activates Plant Defenses**

Faster and/or improved defense responses by plants to pathogen attack reduce the impact of disease. Faster response helps reduce yield losses even when a crop can fight off the disease. Headline has been shown to activate plant defenses so that a crop is better prepared to defend itself when pathogen attack occurs. One way that plants respond to disease is by producing nitric oxide which triggers plants to defend against the disease. Headline promotes the production of nitric oxide by reducing respiration in the plant mitochondria. The reduction in respiration activates nitrate reductase enzyme, which in turn increases the amount of nitrite. Together, activated nitrate reductase and increased levels of nitrite produce nitric oxide (Figure 4).

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**Figure 4: Activation of Plant Defense Responses, Proposed Model**
**Greenhouse and laboratory results**

The increased production of nitric oxide was shown in a research study by treating intact tobacco leaves and soybean cell suspension cultures with **Headline®** fungicide. **Headline** treatment of soybean cells caused a **Headline** dependent production of nitric oxide which was greatest 5 hours after treatment and remained essentially unchanged for the next 19 hours (Graph 6a). **Headline** treatment of tobacco leaves caused an immediate emission of nitric oxide that could still be detected the fifth day after treatment (Graph 6b) (**Headline** is not registered for use on tobacco in the U.S.). The production of nitric oxide after application is an important step in the Plant Health effects of **Headline**.

The impact of increased nitric oxide production on plant disease was demonstrated in a wheat research study (Figure 5). Only the first leaf of a wheat seedling was treated with **Headline** in this study. The second leaf, though not treated, had a reduction in disease of 25%. Since **Headline** does not move out of one leaf into another, it was concluded that the **Headline** pre-treatment may have activated a plant defense signal that moved to the second leaf.
Headline® Fungicide Increases Tolerance to Bacterial and Viral Infections

Systemic acquired resistance (SAR) is another type of plant defense response. One example of a SAR response is when a plant has been infected by one pathogen and then can respond faster to the same or different pathogen later. SAR is called systemic because even parts of the plant that were not originally infected are activated for defense. SAR plays an important role in reducing the impact of disease on a crop and helps protect yield potential. Many plants produce a pathogenesis-related (PR) protein to activate SAR. PR proteins can act like antimicrobial compounds. In tobacco, the major PR protein is PR-1. Build-up of PR-1 is part of the tobacco plant’s resistance to tobacco mosaic virus infection.

Greenhouse and laboratory results
To determine if Headline would activate plant defenses against viral diseases, tobacco was selected as a model crop due to its susceptibility to viruses. Generally, fungicides do not have activity on viral pathogens. In the studies, tobacco plants were pre-treated with Headline and then infected with tobacco mosaic virus. The viral lesion sizes in plants pre-treated with Headline were reduced by more than 50% (Graph 7, Figure 6). Headline pre-treatment did not directly cause the build-up of PR-1 protein. Instead, Headline activated the plant to more rapidly build-up the PR-1 protein (data not shown). Tobacco leaves pre-treated with Headline also had better resistance to bacterial infection (Graph 8).

Figure 6: Headline Pretreatment Activated Plant Defense Against Tobacco Mosaic Virus (TMV)
BASF research results, Brazil
** Inoculation 24 Hrs. after treatment

Graph 7: Headline Activated Plant Defense Against Viral and Bacterial Infection

Graph 8: Headline Activated Plant Defense Against Viral and Bacterial Infection

INCREASED TOLERANCE TO ENVIRONMENTAL STRESS

A growing season is never perfect for the entire season. Even short periods of mild stress can reduce the yield potential of a crop. Reducing the impact of these stresses allows a crop to better maximize its yield potential. When a crop experiences stress, it produces several compounds in response. Two of these compounds are ethylene and activated oxygen species.

Headline® Fungicide Improves Tolerance to Drought

Ethylene is a hormone that plants produce in response to many stresses, including drought stress. Plants also produce ethylene in response to injury, when plants mature, prior to leaf, flower, or pod loss, and before pathogen triggered cell death. Reducing the production of ethylene can limit the natural response to stress, which is to sacrifice important contributors to yield like leaves, flowers, or pods in an attempt to reduce the effects of stress on the plant. Nitric oxide inhibits the enzymes involved in the production of ethylene. The more nitric oxide, the less ethylene produced. Since nitric oxide levels in a plant are often increased after Headline application, the amount of ethylene in Headline treated plants is also reduced (Figure 7).

Figure 7: Headline Reduces Plant Stress by Inhibiting Ethylene Production and Increasing Antioxidative Capacity, Proposed Model

* red lines indicate inhibition of pathway or process
** blue arrows indicate activation of pathway or process
**Greenhouse and laboratory results**

To study ethylene reduction and improved tolerance to drought, young wheat plants were treated with Headline® fungicide. After treatment, leaves were removed and allowed to wilt to simulate drought stress. The activity of one of the major enzymes, 1-aminocyclopropane-1-carboxylic acid (ACC) synthase, involved in production of ethylene was then measured. ACC synthase activity was decreased 61% by Headline compared to the control. The amount of ACC produced by the enzyme was reduced by about 31% compared to the control (Graphs 9 a&b). The inhibition of ethylene production by Headline was compared to other strobilurins. Forty-five hours after the stress started, Headline reduced ethylene production by 33% more than trifloxystrobin and by 67% more than azoxystrobin (Graph 10).

**Graph 9 a&b: Headline Inhibited ACC Synthase Activity**

**Graph 10: Headline Inhibited the Production Ethylene in Wheat After Stress**

* Azoxystrobin – strobilurin in Quilt
† Trifloxystrobin – strobilurin in Stratego

BASF Global Ag Research

Wheat plants treated with Headline, Köhle et al. 2002 in Modern Fungicides and Antifungal Compounds III, Eds. Dehne, Gisi, Kuck, Russell and Lyr
When crops experience drought stress, leaves begin to senesce and die. This premature senescence is triggered by an increase in the production of ethylene. Losing green leaves means limiting a crop’s ability to carry out photosynthesis for maximum yield. Corn and soybeans were studied in the greenhouse to determine if an application of Headline® fungicide reduced the negative impact of drought stress. Plants were grown to the four leaf or trifoliate stage, treated with Headline, and then watering was stopped. Drought stress symptoms were rated on a 0-10 scale. In the soybean study, 13 days after watering was stopped, there was a 24% reduction in the effect of drought on plants treated with Headline compared to the untreated (Graph 11a, Photos 1 a&b). In the corn study, 10 days after watering was stopped, there was an 8% reduction in the effect of drought on plants treated with Headline compared to the untreated (Graph 11b). Greenhouse research studies were also conducted on wheat to determine the effect of Headline on water use efficiency. Water use efficiency is a measure of how much grain is produced with a known amount of water. Wheat treated with Headline required less water to produce a bushel of grain. As increasing drought stress was applied, wheat treated with Headline required increasingly less water than the control (Graph 12).

Photo 1 a&b: Headline Improved Crop Tolerance to Drought Stress

BASF Research Trial

Graph 11 a&b: Headline Improved Crop Tolerance to Drought Stress

Graph 12: Less Water Needed to Produce a Bushel of Grain With Headline Treatment

BASF research results: wheat
Field observations and research
Field research studies on corn were conducted to determine if Headline® fungicide reduced the impact of drought under field conditions. These studies were done with Headline and controlled irrigation at the BASF Research Station in Dinuba, California. This station was selected because little natural rainfall occurs there in the summer and disease pressure is low. Three different irrigation levels were used, optimum, 75% of optimum and 50% of optimum. Percent green leaf tissue and yield were measured to determine the health of the crop. Headline treated corn plants had improved leaf greenness and yield at all irrigation levels. In treatments that were subject to low to moderate drought stress, yield was increased by 20% (Graphs 13 a&b). With increased drought stress, Headline treated corn increasingly had better leaf greenness and yield over the untreated corn. These results indicate that Headline can improve photosynthetic capacity and yield by helping the plant to maintain healthy leaf tissue under drought stress.

Graph 13 a&b: Headline Improved Corn Yield Under Drought Stress

Application made at VT, leaf health evaluated at R2, Dinuba, CA, 2007. No foliar disease present during trial.
BASF Research Trial
**Headline® Fungicide Improves Tolerance to Hail**

Hail is another stress that triggers the production of ethylene because of crop wounding. Hail can reduce yield potential by destroying green leaf tissue and making a way for certain pathogens to enter the plant. **Headline** applications reduce ethylene that signals crop stress and protect wounded crops from disease.

**Field observations and research**

In a simulated hail trial conducted in Ontario, Canada, **Headline** applications either 7 days before or 7 days after simulated hail stress in corn helped maintain green leaf tissue and increased yield (Graphs 14 a&b).

**Graph 14 a&b: Headline Improved Plant Tolerance to Hail Damage**

*Simulated hail damage, Headline applied at early tassel, London, Ontario, Canada, 2008*  
*BASF Research Trial*
On-farm corn and cereal trials where hail events were reported also show that Headline® fungicide helps protect the crop leaf tissue from disease after a hail event and keeps green leaf tissue to maximize yield potential (Graphs 15 and 16).

*Results from 2006 Headline Corn On-farm testing program (15 locations): Headline applied at or near VT*

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**Graph 15: Headline Improved Crop Tolerance to Hail Damage**

**Graph 16: Headline Improved Crop Tolerance to Hail Damage**

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*Castleford, ID, 2008*
Headline® Fungicide Improves Tolerance to Ozone

In addition to ethylene, activated oxygen species are produced when a crop experiences stress. The production of activated oxygen species causes oxidative stress in the plant. Oxidative stress occurs with stresses such as drought, desiccation, flooding, freezing, chilling, ice encasement and ozone. Improved tolerance to these environmental stresses occurs when a crop can reduce the activated oxygen species. A number of enzymes are involved in reducing activated oxygen species, including superoxide dismutase (SOD), catalases, and peroxidases.

Field observations and research

Oxidative stress is involved in the formation of Physiological Leaf Spot (PLS). PLS is a disorder that is noted by necrotic spotting or areas of dead cells in leaves. PLS is an environmental disorder and is not caused by a fungal, bacterial, or viral infection. The effect of the active ingredient in Headline on PLS has been studied in a barley field research trial. Treatment prevented development of PLS symptoms by about 80% in one variety and about 55% in another (Graphs 17 a&b). In another trial, application of a product containing the same active ingredient in Headline significantly protected barley by more than 90% from oxidative stress injury due to ozone treatment (Graph 18).

This tolerance to ozone damage has also been demonstrated on corn (Photo 2).

Graph 17 a&b: Headline Reduced Physiological Leaf Spot (PLS) Symptoms in Barley

Graph 18: Headline Improved Tolerance to Ozone Damage


Photo 2: Headline Improved Tolerance to Ozone Damage

Salisbury, MD, 2004

Greenhouse and laboratory results

The harmful effects of activated oxygen species can be reduced by increasing the activity of enzymes that remove them, like superoxide dismutase (SOD). SOD enzyme activity in leaves is the most important scavenger for removing superoxide radicals, a type of activated oxygen species. Research trials were conducted to determine the effect of a Headline® fungicide treatment on activity of this protective enzyme. SOD activity significantly increased by 20% in barley plants treated with Headline, resulting in a 44% reduction in the amount of activated oxygen species and superoxide produced (Graphs 19 a&b). Another type of enzyme that removes activated oxygen species is peroxidases. The peroxidase activity in flag leaves of barley was measured. Plants treated with Headline showed nearly a two-fold increase in peroxidase activity (Graph 20).

Graph 19 a&b: Headline Increased Anti-oxidative Capacity to Protect Wheat Plants

Graph 20: Headline Increased Peroxidase Activity to Protect Wheat Plants
Headline® Fungicide Improves Tolerance to Cold Temperatures and Frost

Increased SOD activity is also linked to tolerance of other stresses and includes plant re-growth after freezing stress.

Greenhouse and laboratory results
In growth chamber studies, corn was exposed to low temperatures to determine the effect of Headline on crop response to cold temperature. Headline treated corn exposed to 50°F for 14 hours maintained a higher chlorophyll content for seven days after cold treatment than untreated corn. The Headline treated corn was also significantly taller by 2.0 cm after the cold stress (Graphs 21 a&b).

Headline can help a crop tolerate extremely low temperatures for a period of time. In a growth chamber and greenhouse study, immediately after Headline treatment, wheat plants were exposed to 14°F for two hours. The health of the plants was rated after a recovery in the greenhouse. The plants pre-treated with Headline were significantly healthier than untreated plants (Graph 22).

Graph 22: Headline Improves Crop Tolerance to Frost Stress

Wheat exposed to 14°F for 2 hours, ratings made later the same day after recovery in the greenhouse
BASF Research Trial

Graph 21 a&b: Headline Improved Crop Tolerance to Cold Stress

Corn exposed to 50°F for 14 hours, measurements taken 7 DAT, height was statistically significant p=0.05
BASF Research Trial

SPAD Units

Height (cm)

Number of Plants Per Pot

Visit our website at HeadlinePlantHealth.com
Field observations and research

Frost tolerance after Headline® fungicide application is also seen in the field. Two sugar beet field sites that received Headline applications were rated for vigor and frost damage after several frost events. The frost events happened after Headline application (Photo 3). At the Idaho location, the plant vigor with Headline treatment was significantly better across all application dates. The vigor was on average 1.6 units greater than untreated using a 1-10 rating scale (Graph 23a). At the Minnesota location, the plant vigor with Headline treatment was significantly better across all application dates. The vigor was on average 5.3 units greater than untreated using a 1-10 rating scale (Graph 23a). Frost damage was also measured at the Minnesota location (1-5 rating scale). Headline treated plants showed half as much frost damage to their leaves compared to the untreated (Graph 23b).

Graph 23 a&b: Headline Improved Crop Tolerance to Frost – Sugar Beet

Photo 3: Headline Improved Crop Tolerance to Frost – Sugar Beet
In Nampa, ID, three mint field locations that received Headline® fungicide applications were rated for frost damage after several frost events. These frost events occurred after Headline application. The frost tolerance ratings at the three fields were on average 4.1 units greater than untreated using a 1-10 rating scale (Graph 24, Photos 4 a&b).

**Graph 24: Headline Improved Crop Tolerance to Frost - Mint**

![Graph showing frost tolerance ratings on a 1-10 scale. M&S Farms, Christiansen Farms, and Ernest Farms are compared.](image)

**Photo 4a: Headline Improved Crop Tolerance to Frost – Mint**

![Photo showing untreated and treated mint fields.](image)

**Photo 4b: Headline Improved Crop Tolerance to Frost – Mint**

![Photo showing untreated and treated mint fields.](image)
Headline® Fungicide Improves Tolerance to Heat

Like cold stress, heat stress is linked to increased SOD activity. Nitric oxide is also linked to increasing tolerance to heat. As discussed earlier, Headline applications increase SOD activity and increased the production of nitric oxide by increasing the activity of nitrate reductase. So it is reasonable that Headline applications can improve tolerance to heat.

Greenhouse and laboratory results
This improved tolerance to heat with Headline application was studied in the growth chamber and the field. In the growth chamber, wheat plants treated with Headline were able to withstand 14 hours at 104°F significantly better than the controls (Photo 5).

Field observations and research
Field trial work in Syria with the International Center for Agricultural Research in Dry Areas studied the result of Headline applications on canopy temperature of wheat. Reduced canopy temperature means less water lost and less heat stress. The canopy temperature was measured using thermography. Thermography is a type of imaging that allows differences in temperature to be visualized. Headline treatment reduced the canopy temperature compared to the control in 11 of the 12 wheat varieties tested (Graph 25 & Photo 6).

Graph 25: Headline Reduced Canopy Temperatures That Cause Drought Stress in Plants

Photo 5: Headline Improved Crop Tolerance to Heat Stress

Photo 6: Thermal Image of Canopy Temperatures

International Center for Agricultural Research in the Dry Areas (ICARDA), 2007
**HEALTHY® FUNGICIDE IMPROVES PLANT HEALTH AND HARVESTABILITY**

The combination of disease control and physiological effects that lead to the Plant Health benefits of **Headline** have been described in this report. These positive physiological changes include an increase in nitrate reductase activity, elevated levels of antioxidants and defense signaling compounds, and a decrease in the stress hormone ethylene. These **Headline** Plant Health benefits may reduce stress on the crop and allow the crop to stay healthy longer. Healthier crops do not prematurely dry down (Photo 7). **Headline** allows the crop to complete grain fill and reach natural physiological maturity. In crops like corn, wheat, and sunflower, this can also mean an increase in stalk health (standability) that allows one to harvest the crop when they are ready. Rather than chasing corn fields before they lodge, growers can plan and harvest on their timetable in the most efficient manner.

Stalk lodging is the breakage of the stalk below the ear or seed head like in cereals. Improved stalk and stem strength has been associated with a reduction in stalk rots. Stalk rots affect the movement of nutrients in the plant. Also, stalk lodging can result after stresses such as extreme weather that is too wet or too dry, hail or frost, or poor soil conditions. Crops under stress use proportionally more resources for grain production than for plant growth. Thus they commonly rob resources from the stalk to complete grain fill. This reallocation of resources results in a weaker stalk that is more susceptible to lodging and stalk rot diseases. **Headline** improves crop standability which ultimately means an easier harvest.

*Photo 7: Headline Improved Growth Efficiency and Overall Plant Health*

*Boody, IL, August 15, 2007*

*Untreated*  
*Headline*

*Seymour, IL, August 26, 2008*

*Untreated*  
*Headline*
Field observations and research

Lodging data were recorded from 175 on-farm corn trials in 2005 and 2006. The trials were separated into moderate and severe lodging situations. Trials with moderate lodging had less than 10% lodging in the untreated section and trials with severe lodging had more than 10% lodging in the untreated section. In both situations, Headline® fungicide reduced lodging. Where lodging was severe, lodging averaged greater than 25% in the untreated, but less than 10% in plots treated with Headline (Graph 26).

Photo 8: Headline Treated Corn Stands Better at Harvest

Graph 26: Headline Treated Corn Stands Better at Harvest, On-farm Results

![Graph showing lodging percentage comparison between untreated and Headline treated plots](Graph_26)

$n = 175$ on-farm comparisons, 2005 and 2006
Reduced lodging after Headline® fungicide application is also seen in other crops. Headline application reduced storm induced lodging in wheat in a grower field in NC (Photo 9). In an on-farm grower sunflower field, Headline treated sunflowers had 0% lodging and yielded 152 lbs/ac more than untreated. The untreated sunflowers had 40% lodging (Photo 10).

Photo 9: Headline Improved Straw Strength and Reduces the Risk of Lodging

![Untreated](Freemont, NC, 2007)

![Headline](Freemont, NC, 2007)

Photo 10: Headline Improved Stalk Strength – Sunflower

![Untreated](Bismark, ND, 2007)

![Headline](Bismark, ND, 2007)
For years, growers have reported that Headline® fungicide use allows for a faster and less fatiguing harvest. The benefits often have a monetary value. Decreased lodging results in less grain loss at harvest time. Faster harvest also reduces labor, fuel, and equipment costs. For example, it would require an additional 55 hours to harvest 1000 acres of corn if a lodged crop required the operator to slow down just 2 mph (utilizing a combine with an eight row head). Not only would this delay completing harvest by potentially a week or more, but would also increase labor costs since often 2 or more persons are required to operate the combine and haul the grain. In addition to labor costs, the additional 55 hours of operating a combine would require an estimated $2,310 of fuel (14 gal/hr at $3/gal) and $6,600 in equipment costs ($120/hr lease).

Headline provides healthier, less diseased stalks that efficiently transport water and nutrients to leaves and grain. Healthy, less-diseased stalks at harvest result in decreased crop lodging and enable a more efficient harvest.
Always read and follow label directions.

For more information about Headline and other BASF products please visit: www.agproducts.basf.us

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