[Kansas Agricultural Experiment Station Research Reports](https://newprairiepress.org/kaesrr)

Volume 3
Issue 6 *Kansas Field Research*

Article 6

2017

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Recommended Citation

Adee, Eric and Duncan, Stu (2017) "Timing of Strobilurin Fungicide for Control of Top Dieback in Corn," *Kansas Agricultural Experiment Station Research Reports*: Vol. 3: Iss. 6. https://doi.org/10.4148/2378-5977.7423

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Abstract

Significant yield losses can result from top dieback (TDB) in dent corn, which is caused by infection by the fungus, *Colletotrichum graminicola*, causing anthracnose. Research is limited on the effectiveness of fungicide application because of the unpredictable nature of the disease. Three field studies were established to assess the timing of fungicide application on foliar diseases that developed TDB, one in Illinois (2010) and the other two in Kansas (2015 and 2016). Fungicide applications at tasseling and later were effective in reducing the incidence of TDB by greater than 20% and increasing yield greater than 14 bu/a, or greater than 7%, while earlier applications (V5 to V8) did not reduce TDB or increase yield compared to the untreated check.

Keywords

top dieback, corn, fungicide, anthracnose, strobilurin

Timing of Strobilurin Fungicide for Control of Top Dieback in Corn

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Summary
Significant yield losses can result from top dieback (TDB) in dent corn, which is caused by infection by the fungus, *Colletotrichum graminicola*, causing anthracnose. Research is limited on the effectiveness of fungicide application because of the unpredictable nature of the disease. Three field studies were established to assess the timing of fungicide application on foliar diseases that developed TDB, one in Illinois (2010) and the other two in Kansas (2015 and 2016). Fungicide applications at tasseling and later were effective in reducing the incidence of TDB by greater than 20% and increasing yield greater than 14 bu/a, or greater than 7%, while earlier applications (V5 to V8) did not reduce TDB or increase yield compared to the untreated check.

Introduction
Top dieback (TDB) of dent corn *(Zea mays*) is caused by an infection of the upper part of the corn plant by the fungus causing anthracnose (*Colletotrichum graminicola)*. Anthracnose can infect the corn plant early in the season, causing foliar lesions, and/or stay dormant in the plant until stress conditions cause the infection to result in stalk rot and/or TDB symptoms. Infections later in the season, under the right environmental conditions, have been reported when the infection occurs in the pre-tassel whorl or on the leaf sheaths. Spores of the pathogen are dispersed by wind and rain, and infection is favored by warm, humid, and overcast conditions. The symptoms of TDB can be diagnosed when leaves in the top part of the plant, primarily the flag leaf, start to become reddish/purple, then yellow and then necrotic, while the lower leaves around the ear remain green. The formation of black lesions and fungal fruiting bodies on the stalk near and under the leaf sheath confirm the diagnosis and distinguish TDB from other causes of the top of the corn plant dying prematurely.

Management practices to reduce losses to anthracnose in corn include hybrid selection, crop rotation, controlling insect damage, and reducing stress from low fertility and moisture as much as possible. Strobilurin fungicides are effective at controlling the leaf blight phase of anthracnose, primarily in the early growth stages. However, there is little information on the effectiveness of strobilurins against the TDB phase of anthracnose. Strobilurins applied at tasseling or later reduced TDB, but did not affect yield in a one-year fungicide study in Iowa (Robertson, et al., 2010). Furthermore, reproducing the conditions that result in TDB is difficult, hindering experimentation. Similarly, repeating the same study for controlling TDB at multiple locations or years has not been very effective. The authors have observed TDB in only 3 of 9 corn fungicide studies. The results presented in this paper are from these three fungicide-timing studies that became infected with anthracnose causing the TDB symptoms on corn.

Procedures

Fungicide timing application studies on corn that developed TDB symptoms were conducted in 2010 at the University of Illinois' Northwestern Illinois Agricultural Research and Demonstration Center (NWRC), near Monmouth, IL, and in 2015 and 2016 at Kansas State University's Kansas River Valley experiment fields (KRV), near Topeka, KS (Table 1). The dryland study at NWRC was in corn following soybeans, while the studies at KRV were under sprinkler irrigation in second-year corn. Nitrogen fertilizer was applied at recommended levels at all locations (Table 1). Due to the sandy soils and 10.31 inches of rain in May 2015 at KRV, an additional 130 lb/a of nitrogen (N) was sidedressed at V5 (five leaves with collars visible), which alleviated some of the N deficiency symptoms. In all studies, the corn was planted in 30-inch rows. The hybrid DeKalb 61-69 was planted at NWRC. Golden Harvest 11U58-3111 and Golden Harvest G12J11-3111 were planted at KRV in 2015 and 2016, respectively. The plots were 10 ft wide (4 rows) by 100 ft long at NWRC and 40 ft long at KRV. The experimental design was a randomized complete block with 4 replications for all studies. Additional crop management details are listed in Table 1. The irrigation scheduling at KRV was assisted by the KanSched2 K-State Research and Extension Mobile Irrigation Lab scheduling program (www.bae.ksu.edu/mobileirrigationlab/kansched2).

The fungicide treatments were applied with a CO_2 backpack sprayer equipped with Spraying Systems TJ 8002VS nozzles, 30 psi, 19 gal/a, to the middle two rows of a 4-row plot. The fungicide applied at NWRC was Headline SC at 6 oz/a. At KRV, several different fungicides with strobilurin as the active ingredient, along with some strobilurin and conazole were included as well. At KRV, multiple fungicide treatments applied at the same time were grouped for analysis because there were no significant differences in TDB, foliar disease, and yield between strobilurin treatments that were applied at the same time. The growth stages of the corn at treatment applications were: V5-8 (five to eight leaves with collars emerged), tasseling (VT), seven days after tasseling (VT+7 days), and 14 days after tasseling (VT+14 days).

Data Collection and Analysis

Foliar disease severity was quantified at R5 (dent), evaluating the severity of foliar disease from the ear leaf and above as a percent of the leaf area with symptoms in the middle two rows of each plot. Gray leaf spot (GLS), *Cercospora zeae-maydis* (Tehon and W.Y. Daniels), was the predominant leaf disease at NWRC. Gray leaf spot and common rust, *Puccinia sorghi* (Schwein.), were present at KRV. Plants with the top two to four leaves with purple or yellow coloration or necrotic, while the lower leaves remained green, occurred in the studies (Figure 1). Observations of black lesions and fungal fruiting bodies on the stalk near and under the leaf sheath below the lowest leaf that expressed symptoms confirmed that the TDB symptoms were caused by *C. graminicola*. Additionally, the absence of any insect feeding into the stalk, such as European corn borer, showed there was not an additional factor causing TDB. The number of plants exhibiting TDB symptoms were counted in the middle two rows of each plot and converted to a percentage of all plants. The middle two rows of the plots were harvested for yield, and yields were calculated from plot weights adjusted to 15.5% grain moisture. Return on fungicide investment for an application at different growth stages was calculated by multiplying the yield increase over the check treatment by corn price, then subtracting an estimated cost of foliar fungicide and application. A range of corn prices and costs of fungicide application were used to include possible value/cost ratios a grower might encounter.

Effect of Fungicide Application on Top Dieback in Corn

The early season fungicide application at the V5 to V8 growth stages did not reduce foliar disease, TDB, or increase yield when compared with the untreated check (Tables 2, 3, 4, and 5). As a result, fungicide application did not result in a positive economic return (Table 6). The lack of effectiveness of fungicides against TDB indicates the infection occurred after the V5 to V8 application, and near VT when the environmental conditions were very favorable for the disease.

The foliar application of fungicides to corn at VT or up to 14 days after VT reduced the incidence of TDB to less than half of the incidence in the untreated checks, and resulted in increased grain yield up to 10% (Tables 2, 3, 4, and 5). The reduction in TDB and foliar leaf disease by the fungicide applications were very similar at all locations (Table 2, 3, and 4), with greater reduction in the diseases with the VT and later timing of fungicide application. Due to the variability within the experiment at KRV in 2015, the effect of timing of fungicide application was not significant for yield (Table 3), but the relationships between treatments were similar to those at NWRC (Table 2). The lower incidence of TDB in 2016 resulted in no difference between yields as well (Table 4). The combined analysis showed differences between timing of fungicide application in yield, with the application at VT or later resulting in greater yields than with the untreated check (Table 5).

Foliar disease level, due to GLS and common rust, was reduced from 5% in the untreated checks, to 3% or less (Tables 2, 3, 4, and 5), but at a level of severity that had little impact on yield, as demonstrated by previous research. Applying a strobilurin fungicide up to 2 weeks after VT also resulted in a positive return on investment of the foliar fungicide application (Table 6). The rate of return for the investment in fungicide application can be influenced by ratio between the value of corn and the cost of the fungicide application. The effect of the timing of strobilurin fungicides on TDB agrees with the results from a study conducted in Iowa, where TDB was reduced by the VT or later application of fungicides.

The yield potential was much lower at KRV in 2015, averaging 131 bu/a, compared to 237 and 195 bu/a, respectively, at NWRC and KRV in 2016. Excessive rainfall in May caused a loss of N in the KRV soil for which sidedressed N could not fully compensate. Additionally, the incidence of TDB in the check treatment was 65% at NWRC compared to 37% at KRV in 2015 and 8.9% at KRV in 2016. However, the response of TDB to the fungicide applications was very similar at all locations (Tables 2 and 3). While there were many differences between the three locations, the period of several days of rain and overcast conditions just prior to or at VT was a common factor (Figures 1 and 2) linking the occurrence of TDB.

Anthracnose is favored by warm, wet, and overcast conditions (Figures 1 and 2). The onset of TDB in these studies is probably attributed to several days of rain and overcast conditions around tasseling. In 2012 through 2014, the solar radiation was relatively high and rainfall low in the days just prior to and after VT at KRV (Figure 3), resulting in no observable TDB. Irrigation was probably not a very significant factor since most irrigation occurs when the solar radiation is relatively high (Figures 2 and 3). At KRV in 2015, corn reached VT in the period of July 6 to 10 under overcast conditions which resulted in below average solar radiation recorded (Figure 2), resulting significant incidence of TDB. For the week around VT for 2015 and 2016, the average solar radiation was 15.8 and 17.6 mJ/m^2, respectively, compared to the VT week average of 26.4, 23.7, 22.5 mJ/m^2 for 2012, 2013, and 2014, respectively, with several days greater than 30 mJ/m^2. No TDB was observed in the corn fungicide trials at KRV in 2012, 2013, and 2014. No anthracnose lesions were observed at any location at the V5 to V8 growth stages.

Additional factors that favored TDB development at KRV were crop rotation, tillage, and possible N stress. The studies at KRV were planted into cornstalks that had been vertical tilled in the fall, leaving ample corn residue on the soil surface to serve as an inoculum source. Additionally, the N deficiency experienced early in the 2015 season and into the growing season could have been an additional stress factor that could have made the corn more susceptible to TDB. The conditions at NWRC were favorable for high yield potential, and there were no other factors other than the warm and humid weather conditions that increased the risk of TDB.

Practical Applications

Relative to TDB, the positive benefit to fungicide application for up to two weeks after VT demonstrates a relatively wide window of application time that will still result in a positive return on investment for fungicide application. Delays to fungicide application at VT could be attributed to weather or scheduling a commercial applicator. A two-week window gives growers some flexibility when faced with potential delays. With foliar fungal diseases, such as GLS and rust, the observation of the symptoms on the lower leaves can be an early indicator that a fungicide could be warranted if the environmental conditions are favorable for foliar disease to progress up through the crop canopy. However, with TDB, there may be no early symptoms to alert a grower to a potential problem. A key factor in determining if TDB will be an issue is periods of rainy/overcast conditions just prior to and at VT.

Confirming that fungicides containing strobilurin are effective in reducing TDB and increasing yield of corn could be a significant factor in reducing yield losses to TDB. The difficulty will be in predicting when the environmental conditions are most conducive for TDB. If other foliar fungal diseases are at the threshold to apply a fungicide at VT, then there could be the added benefit of control of TDB. However, if the foliar disease level is below the threshold at VT, it may be more difficult to guarantee a positive return for the investment in the fungicide application. Much more attention should be paid to the timing of overcast periods and rainfall/irrigation events in coordination with VT. Additionally, better understanding of the hybrid, crop rotation, and/or tillage interaction with rainfall at VT will help improve the success rate of a fungicide application in improving yield in the event that TDB is expressed.

Results

These data have demonstrated the effectiveness of strobilurin fungicides in reducing the severity and yield loss to TDB in corn. Additionally, there is a relatively wide window, up to two weeks after VT, for fungicide application that can result in an increase in corn yield and a positive return on investment for the fungicide application if the conditions warrant the application of a fungicide. It appears TDB is favored by periods of rainy/overcast conditions for several days right around VT.

Reference

Robertson, A.E., Peckinovsky, K., and Liu, L. 2010. Effect of foliar fungicides on anthracnose top dieback, and frost injury of corn in Iowa, 2009. Plant Disease Management Report, 4:FC087.

Table 1. Study details for corn fungicide studies on top dieback (TDB)

	NWRC 2010	KRV 2015	KRV 2016
Soil type	Muscatune silt loam	Eudora sandy loam	Eudora sandy loam
Previous crop	Soybeans	Corn	Corn
Tillage	Chisel in fall, field cultivate in spring	Vertical tillage in fall	Vertical tillage in fall
Nitrogen fertilizer	160 lb	200 lb followed by 130 lb side-dressed	200 lb
Planting date	April 20	April 16	April 16
Hybrid	DK 61-69	GH 11U-58-3111	GH G12J-11-3111
Seeding rate	37,800	32,000	32,000
V5-8 application	June 1	June 8	May 31
VT application	July 8	July 8	July 1
VT+1 application	July 15	July 15	July 8
VT+2 application	July 22	July 22	July 15
Plant disease rating	August 23	August 6	August 1
TDB rating	August 23	August 14	August 1
Harvested	September 8	September 14	September 20

Corn growth stages: V5-8 = 5 to 8 leaf collar visible, VT = tasseling.
University of Illinois' Northwestern Illinois Agricultural Research and Demonstration Center (NWRC), near Monmouth, IL, and the Kansas State University's Kansas River Valley experiment fields (KRV), near Topeka, KS.

Table 2. Effect of timing of fungicide application to corn on top dieback (TDB) at Northwestern Research Center, Monmouth, IL, in 2010

	Yield		Top dieback		Foliar disease severity	
Timing of fungicide application	bu/a[z]		Percentage of plants[z]		Percentage ear leaf and above[z]	
Check	228	b	65.5	a	4.5	a
V5-8 [y]	233	b	64.3	a	4.5	a
VT	252	a	32.1	b	1.3	b
VT+7 days	251	a	25.5	b	1.5	b
VT+14 days	246	a	33	b	3.8	a
Pr>F*	<0.0001		<0.0001		<0.0001	

[y] Corn growth stages: V5-8 = 5 to 8 leaf collar visible, VT = tasseling.
[z] Means followed by the same letter within a column are not significantly different at Pr>0.05.
*The lower the Pr>F value, the greater probability that there is a significant difference between yields.

Table 3. Effect of timing of fungicide application to corn on top dieback (TDB) at Kansas River Valley, Topeka, KS, in 2015

	Yield	Top dieback		Foliar disease severity	
Timing of fungicide application	bu/a	Percentage of plants[z]		Percentage ear leaf and above[z]	
Check	128	37.0	a	6.2	a
V5-8 [y]	128	33.1	a	3.3	b
VT	143	12.6	b	2.3	b
VT+7 days	140	14.9	b	2.3	b
VT+14 days	144	18.4	b	1.7	b
Pr>F*	0.50	<0.0001		<0.0001	

[y] Corn growth stages: V5-8 = 5 to 8 leaf collar visible, VT = tasseling.
[z] Means followed by the same letter within a column are not significantly different at Pr>0.05.
*The lower the Pr>F value, the greater probability that there is a significant difference between yields.

Table 4. Effect of timing of fungicide application to corn on top dieback (TDB) at Kansas River Valley, Topeka, KS, in 2016

	Yield	Top dieback	Foliar disease severity
Timing of fungicide application	bu/a	Percentage of plants[z]	Percentage ear leaf and above[z]
Check	192	8.9 a	3.4 a
V5-8 [y]	188	5.6 b	2.2 b
VT	194	4.1 bc	0.9 c
VT+7 days	199	1.1 c	0.7 c
VT+14 days	203	1.9 c	1.0 c
Pr>F*	0.27	<0.0001	<0.0001

Corn growth stages: V5-8 = 5 to 8 leaf collar visible, VT = tasseling.
[z] Means followed by the same letter within a column are not significantly different at Pr>0.05.
*The lower the Pr>F value, the greater probability that there is a significant difference between yields.

Table 5. Combined data on effect of timing of fungicide application to corn on top dieback (TDB) at Northwestern Research Center (NWRC), Illinois, in 2010, and Kansas River Valley (KRV), KS, in 2015 and 2016

	Yield	Top dieback	Foliar disease severity
Timing of fungicide application	bu/a[z]	Percentage of plants[z]	Percentage ear leaf and above[z]
Check	183 b	37.1 a	4.5 a
V5-8 [y]	184 b	34.6 a	3.2 b
VT	196 a	16.4 b	1.6 c
VT+7 days	197 a	13.8 b	1.4 c
VT+14 days	197 a	17.8 b	2.0 c
Pr>F*	0.008	<0.0001	<0.0001

[y] Corn growth stages: V5-8 = 5 to 8 leaf collar visible, VT = tasseling.
[z] Means followed by the same letter within a column are not significantly different at Pr>0.05.
*The lower the Pr>F value, the greater probability that there is a significant difference between yields.

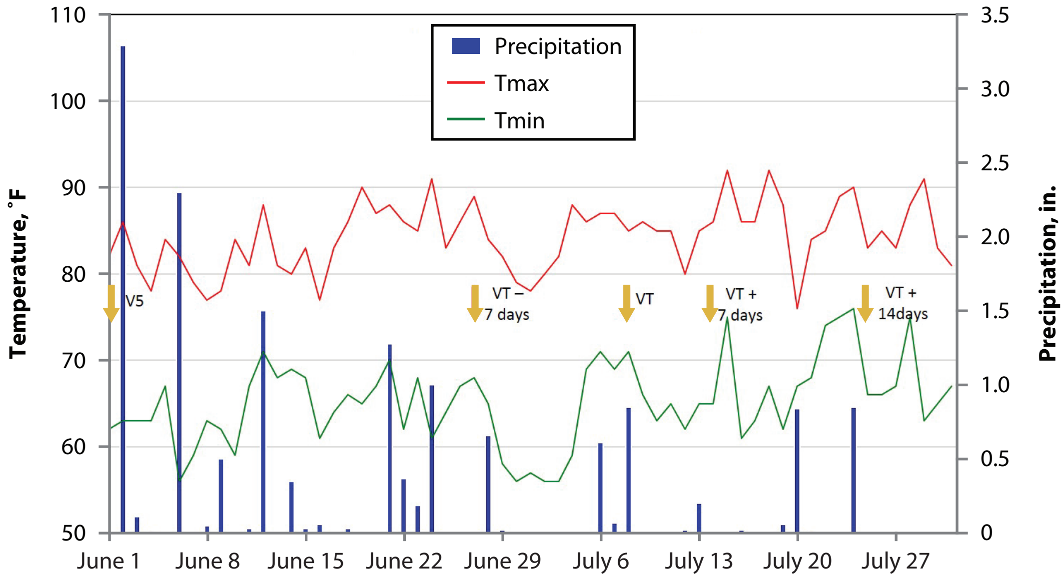

Figure 1. Rainfall and temperature from University of Illinois' Northwestern Illinois Agricultural Research and Demonstration Research Center, Monmouth, IL, for June and July 2010. National Climate Data Center (2016).

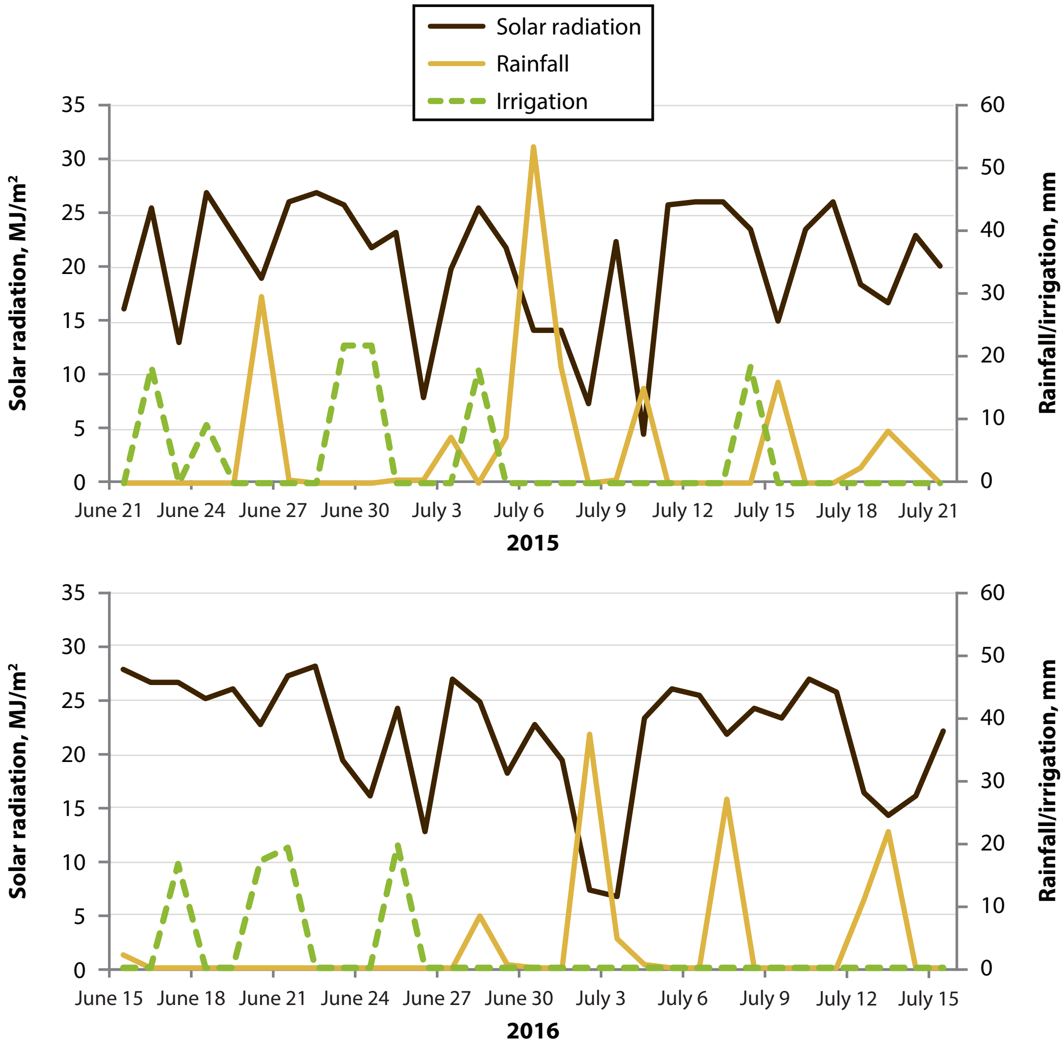

Figure 2. Solar radiation, rainfall, and irrigation for the Kansas State University Kansas River Valley experimental fields, Topeka, KS, for two weeks before and after tasseling of corn (VT) in 2015 and 2016, corresponding to development of top dieback. Weather Data Library, Kansas State University, 2016.

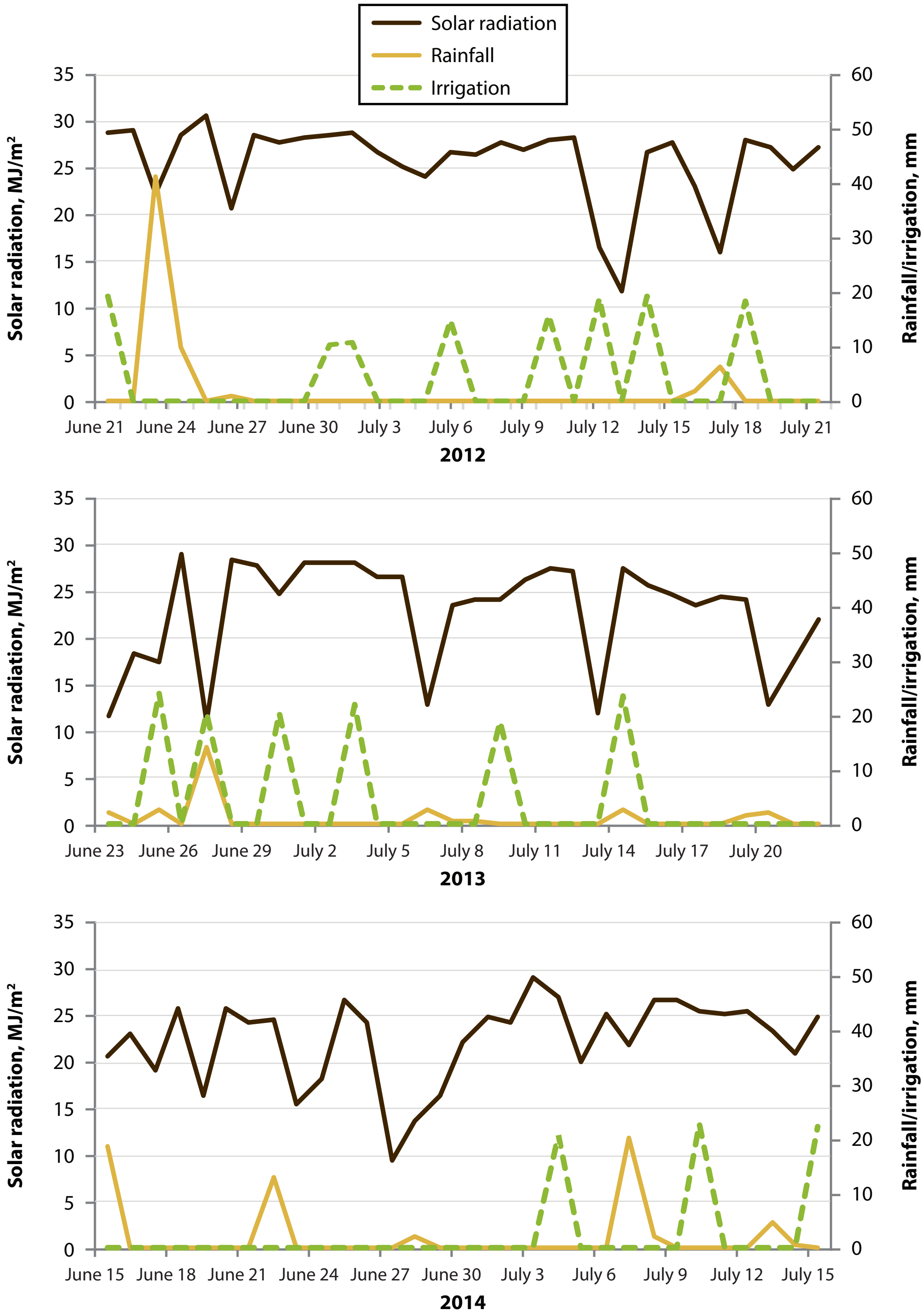

Figure 3. Solar radiation, rainfall and irrigation for the Kansas State University Kansas River Valley experimental fields, Topeka, KS, for two weeks before and after tasseling of corn in 2012, 2013, and 2014, corresponding to no observed top dieback. Weather Data Library, Kansas State University, 2016.