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Yield Comparisons of Bt and Non-Bt Corn Hybrids in Missouri in 1999

Full-season corn hybrids were evaluated in nine non-irrigated and six irrigated trials in the University of Missouri Variety Testing Program in 1999. Seed corn companies had two options for assessing the performance of Bt hybrids:

- Fifteen standard corn hybrid trials, averaging 75 hybrid entries per trial.
- Separate Bt corn trials, embedded by replication within the standard trials. These smaller trials were comprised of eight and four Bt corn hybrids in the non-irrigated and irrigated trials, respectively, and three productive non-Bt hybrids. These three were selected on the basis of high yield performance in the MU Variety Testing Program over a wide range of environmental conditions. In three of the 15 separate Bt trials, the non-Bt hybrids were artificially infested with European corn borer.

Objectives

- Evaluate yield performance of Bt and non-Bt corn hybrids under conditions of natural (endemic) European corn borer infestation in 15 standard corn trials.
- Evaluate the yield performance of non-Bt corn hybrids (under two levels of European corn borer infestation) relative to that of Bt hybrids in three artificially infested trials.
- Monitor natural levels of first and second generation European corn borer infestation in 15 standard trials located in 14 counties of Missouri.
- Assess the economic benefits of the Bt technology; i.e., determine the level of European corn borer infestation that offsets the higher seed costs associated with Bt corn seed.

Experimental procedures

Field plot design. All trials were arranged in lattice or randomized complete block designs with three replications. All plots were four rows wide and 25 feet long with a between-row spacing of 30 inches.

Agronomic practices such as planting date, seeding rate, fertility and weed control were selected and applied to optimize yields at each trial site.

The center two rows of each plot were harvested with a plot combine for yield comparisons among the corn hybrids. Yields were adjusted to a uniform moisture of 15.5% and reported in bushels per acre.

European corn borer survey. In each of the 15 standard trials, natural levels of European corn borer infestation were surveyed by dissection of 60 cornstalks of the same non-Bt hybrid (Pioneer brand 33G26) at both the late vegetative and dent stages of corn growth. Dent stage was selected for the last survey because research indicates that stalk tunneling after the grain-filling period does not reduce physiological yield.

Artificial infestation of European corn borer. The three non-Bt “check” hybrids were artificially infested with European corn borer in two non-irrigated trials (Marshall and Columbia) and one irrigated trial

(Columbia). The center rows were infested with approximately 250 neonate larvae/plant using the Davis (bazooka) technique. The larvae were applied to each plant in the leaf axil of the primary ear and in the leaf axil above and below the primary ear at the R1 (silking) stage to simulate second generation infestation.

Fifteen stalks from the center two rows of each non-Bt plot were split lengthwise to measure the following:

- Number of tunnels per plant
- Tunnel length per plant, rounded to the nearest centimeter
- Percent of tunneled plants per plot

Plants were counted as tunneled if there was an entry hole with a tunnel length of one centimeter or more in the shank of a harvestable ear or in the stalk. The top four internodes were not dissected because researchers have found no relationship between yield and level of infestation in the top three to six internodes regardless of corn growth stage infested.

Natural levels of infestation were assessed in the same three non-Bt hybrids in the adjacent standard trials by the same method, except that 10 cornstalks from the center two rows of each plot were split instead of 15 stalks.

Results and discussion – *Natural infestation*

European corn borer survey. Natural infestation levels of the pest were low at the 15 trial locations, ranging from fewer than 10% tunneled plants at six trial locations to 37% tunneled plants at the non-irrigated trials at Columbia and Chillicothe ([Figure 1](#)).

When yield comparisons were made between the top 10 Bt and non-Bt hybrids, the level of infestation did not appear to have a *consistent* effect on performance ([Figures 1-2](#)).

Yield comparisons in standard trials. Averaged over the 15 standard trials, the top 10 Bt hybrids and top 10 non-Bt hybrids were within 1.0 Bu/A of each other ([Figure 2](#)). On a regional basis, there were larger differences in yield performance when the Bt and non-Bt hybrids were compared in the four irrigated trials in the southern half of the state. Overall, the Bt hybrids yielded higher in the southwestern Missouri trials and lower in the southeastern Missouri trials than the non-Bt hybrids ([Figure 2](#)).

Yield comparisons in separate Bt trials. Eight Bt hybrids were entered at each of the nine non-irrigated trial sites, and four Bt hybrids were entered at each of the six irrigated trial sites. The results of the 12 naturally infested Bt trials closely followed those obtained in the standard trials, with the exception of the irrigated trials in southeast Missouri. The three top-yielding Bt hybrids yielded only 3.0 Bu/A more than the three non-Bt “check” hybrids when the yields of the two “Bootheel” trials were averaged ([Table 1](#)).

No evidence of “yield lag” in Bt hybrids. There was no “yield drag” or “yield lag” associated with the performance of Bt hybrids in the 15 standard trials. Although 33.9% of all corn hybrids tested possessed the Bt trait, the Bt hybrids comprised 42.3% of the hybrids that were the highest yielding or that did not yield significantly less than the top performer. The Bt hybrids accounted for 39.7% of all hybrids that yielded above the average ([Figure 3](#)).

Results and discussion – *Artificial infestation*

European corn borer infestation levels. When non-Bt hybrids were averaged across the three artificially infested trials, 100% of dissected stalks were tunneled, with an average of 5.2 tunnels per plant and a mean tunnel length of 24 centimeters per plant ([Tables 2-4](#)). In comparison, only 34% of those cornstalks from the naturally infested non-Bt hybrids were tunneled, with an average of 0.5 tunnels per plant and a mean tunnel length of 2 centimeters per plant. In the naturally infested non-Bt hybrid plots, approximately 70% of the tunnels were initiated after the tassel stage (by second or third generation corn borers). In the artificially infested non-Bt hybrid plots, over 95% of the stalk tunneling began at the blister stage (i.e., approximately one week after the neonates were applied).

Impact of infestation levels on yields. In the artificially infested trials, Burrus BX86, Mycogen 2888IMI, and Pioneer brand 33G26 yielded an average of 19.4 Bu/A or 12% less relative to the average yield of their naturally infested counterparts at the same three trial sites. Based on this comparison, the yield loss in the three artificially infested hybrids corresponded to an average of 2.5% per tunnel; however, there were notable differences in hybrid tolerance to stalk tunneling ([Tables 2-4](#)). Burrus BX86, heavily infested with an average of 5.8 tunnels per plant at the two non-irrigated trial sites, yielded only 0.4% or 3.6 Bu/A less than the naturally infested Burrus BX86 with 0.4 tunnels per plant ([Tables 2-3](#)). Burrus BX86 did not yield significantly less than the highest yielding Bt hybrid in two of the three artificially infested Bt trials.

When yields of the three top-ranked Bt hybrids were compared to the non-Bt “check” hybrids, the Bt hybrids averaged 22.2 Bu/A more than the artificially infested non-Bt hybrids and 3.9 Bu/A more than the naturally infested non-Bt hybrids ([Tables 2-4](#)). The non-irrigated trial at Columbia, the most highly infested and moisture stressed of the three sites, accounted for the greatest difference (7.0 Bu/A) between the top three Bt hybrids and naturally infested non-Bt hybrids ([Table 3](#)).

Economics of Bt corn. It is clear that there is a return on the Bt corn seed premium or technology fee when most non-Bt hybrids are heavily infested with European corn borer. However, what level of European corn borer infestation offsets the higher seed costs associated with Bt corn? Corn infested at the blister stage averages 3% physiological yield loss per borer (i.e., per tunnel) according to best estimates provided by North Central Region entomologists. Assuming the infestation began at the blister stage, the economic injury level would be one larva (tunnel) per plant based on an expected yield of 140 Bu/A, a market price of \$2.00/Bu, and a technology fee of \$8.50/A ([Figure 4](#)). The break-even point would be one larva per plant, and yield protection in excess of 4.2 Bu/A would provide a net return on the Bt technology.

This report is based on performance trials in: *Corn: 1999 Missouri Crop Performance*. University of Missouri-Columbia Special Report 521. October, 1999, by H.C. Minor, C.G. Morris, H.L. Mason, D.R. Knerr, R.W. Hasty, G.K. Stafford, and T.G. Fritts. The performance trials are also available at <http://agebb.missouri.edu.cropperf/corn/>. The full 10-page Bt corn report is available from Maureen O’Day at odaym@missouri.edu. (Harry Minor, 573-882-2001 and Maureen O’Day, 573-882-3786)

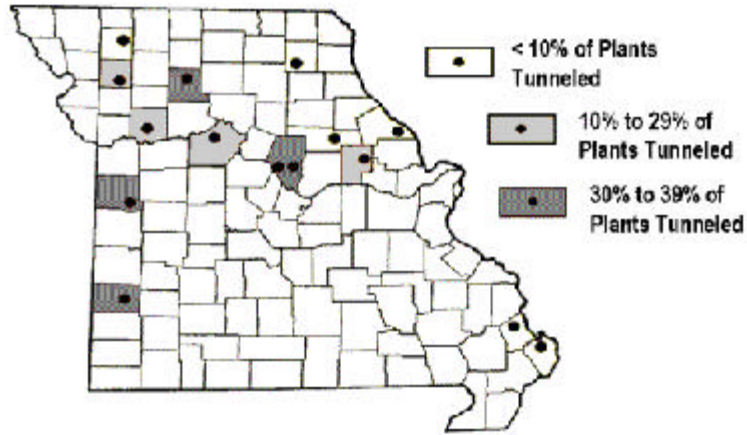


Figure 1. Natural infestation levels of European corn borer at 15 MU Variety Testing sites.

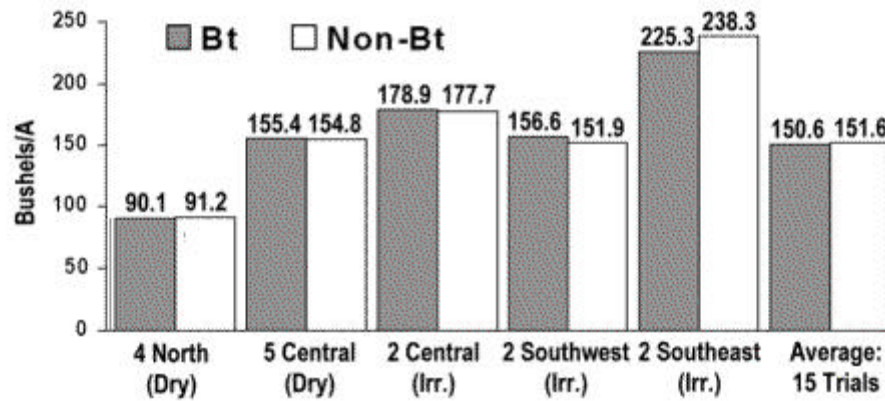


Figure 2. Yields of top 10 Bt and top 10 non-Bt corn hybrids at 15 MU Variety Testing sites, by region and irrigation.

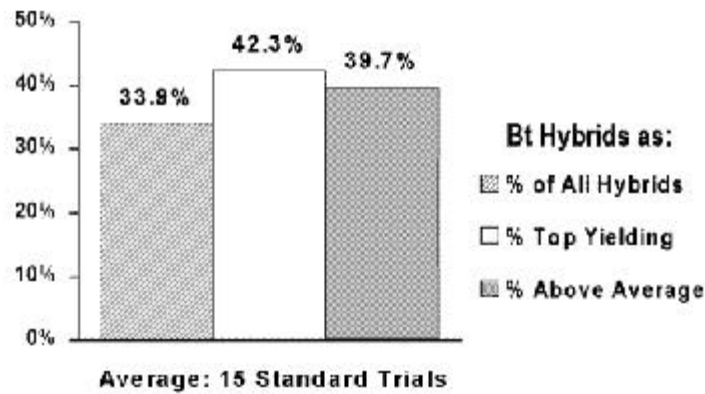


Figure 3. Bt corn hybrids rated as the percentage of top-ranked corn hybrids in the MU Variety Testing Program.

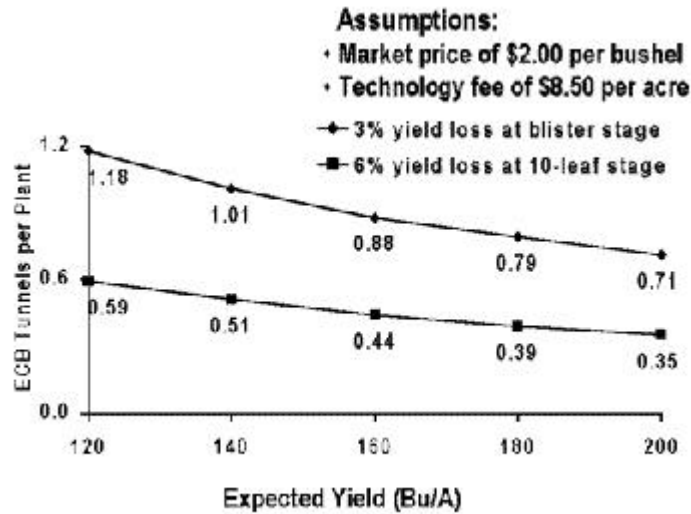


Figure 4. Minimum number of European corn borer tunnels (per plant) required to cause sufficient yield loss to cover Bt corn technology fee.

Table 1. Mean yields (Bu/A) of three top-ranked Bt corn hybrids compared to three non-Bt "check" hybrids at two irrigated trials at Oran and Charleston in southeastern Missouri.

Top 3 Bt Hybrids	Bu/A	Non-Bt Hybrids ¹	Bu/A
AgriGold A6569Bt	226.5	Burrus BX86	229.1
Terral TVX21680Bt	220.6	Pioneer brand 33G26	204.3
Terral TVX21483Bt	218.0	Mycogen 2888 IMI	222.8
Average:	221.7	Average:	218.7

¹ Natural infestation level: European corn borer tunneled 7% and 3% of non-Bt plants, respectively, at Oran and Charleston by the dent stage of growth.

Tables 2-4. Yields (Bu/A) of three top-ranked Bt corn hybrids compared to the non-Bt "check" hybrids naturally and artificially infested with European corn borer at three MU Variety Testing sites.

Table 2. Non-irrigated trial at the Frank Swisher farm near Marshall, Missouri (Saline County).

Top 3 Bt Hybrids ¹	Natural Infestation ²				Artificial Infestation ³	
	Bu/A	Non-Bt Hybrids	Bu/A	Tunnels/Plant	Bu/A	Tunnels/Plant
Asgrow RX799BT	192.2	Mycogen 2888 IMI	202.1	0.8	171.2	3.8
Garst 8366Bt/LL	191.6	Pioneer brand 33G26	192.5	0.3	165.8	5.3
Merschman M-8113	191.0	Burrus BX86	184.1	0.5	180.6	5.1
Average:	191.6		192.9	0.5	172.5	4.7

¹Not infested with European corn borer.

²90% of tunnels initiated after tassel stage.

³Artificially infested with 250 neonate larvae per plant at peak pollen shed.

Table 3. Non-irrigated trial at the Agronomy Research Center near Columbia, Missouri (Boone County).

Top 3 Bt Hybrids ¹	Natural Infestation ²				Artificial Infestation ³	
	Bu/A	Non-Bt Hybrids	Bu/A	Tunnels/Plant	Bu/A	Tunnels/Plant
Merschman M-9110	136.2	Burrus BX86	135.1	0.4	131.4	6.5
AgriPro AP9689Bt	129.3	Mycogen 2888 IMI	122.8	0.6	88.3	6.0
Garst 8366Bt/LL	125.0	Pioneer brand 33G26	111.8	0.6	98.6	7.1
Average:	130.2		123.2	0.5	106.1	6.5

¹Not infested with European corn borer.

²60% of tunnels initiated before tassel stage.

³Artificially infested with 250 neonate larvae per plant at peak pollen shed.

Table 4. Irrigated trial at the Agronomy Research Center near Columbia, Missouri (Boone County).

Top 3 Bt Hybrids ¹	Natural Infestation ²				Artificial Infestation ³	
	Bu/A	Non-Bt Hybrids	Bu/A	Tunnels/Plant	Bu/A	Tunnels/Plant
Terral TVX21483Bt	181.8	Pioneer brand 33G26	178.7	0.2	149.4	5.7
AgriGold A6569Bt	180.9	Mycogen 2888 IMI	175.6	0.5	161.5	3.6
Terral TVX21680Bt	172.0	Burrus BX86 ⁴	--	--	153.6	4.3
Average:	178.2		177.2	0.4	154.8	4.5

¹Not infested with European corn borer.

²90% of tunnels initiated after tassel stage.

³Artificially infested with 250 neonate larvae per plant at peak pollen shed.

⁴Burrus BX86 not planted in the standard irrigated trial at Columbia.