Martin-Gatton
College of Agriculture, Food and Environment
*Cooperative Extension Service*

**Plant Pathology Research Report** **PPRR-08**

# Leaf Spot Disease Development and Its Effect on Yield of Essential Oil-Producing Hemp Cultivars in Kentucky

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Since the modern hemp (*Cannabis sativa*, THC <0.3%) production era began in 2014 (Agricultural Act of 2014; Agricultural Improvement Act 2018), several diseases and insect pests have been confirmed, and yield losses have been documented. Regions with high rainfall, particularly in the southern U.S., are optimal for disease development. Kentucky's climate is a key factor in the large number of diseases that affect hemp. During summer months, high temperatures average 82° to 91°F, with humidity above 75%, and monthly rainfall ranges from 3 to 4 inches. (kymesonet.org). Wet conditions and high humidity are favorable for many plant pathogens, including those causing leaf spot diseases.

Hemp leaf spot diseases have been known to result in losses due to extreme blighting and plant death or by harvests being rejected by processors. The most common leaf spot diseases include Bipolaris leaf spot (*Bipolaris gigantea*), Cercospora leaf spot (*Cercospora flagellaris*), and Septoria leaf spot (*Septoria cannabis*). In 2020 and 2021, the development of these three leaf spot diseases were investigated in multi-cultivar hemp plots in two different Kentucky locations: the UK Spindletop Research Farm in Lexington (LEX) and the UK Robinson Center for Appalachian Resource Sustainability in Quicksand (APP). In this study, disease progression, cultivar susceptibility, and relationship between leaf spot diseases and yield were examined.

**Disease progression.** Variation in disease progression was observed among the three leaf spots in trial fields. In general, Septoria leaf spot appeared early in the growing season (6 weeks after planting or earlier), reached peak severity at mid-season (9 to 12 weeks after planting), and declined in severity at the end of growing season (13 to 15 weeks after planting) (Figure 1). Bipolaris leaf spot was observed early in the growing season (7 to 8 weeks after planting) with increasing severity through the end of the growing season (Figure 1). Finally, Cercospora leaf spot emerged mid-season (9 to 12 weeks after planting) and reached peak severity at the end of the growing season (Figure 1). Overall, severities of the three leaf spot diseases were higher in the mid-canopy compared to the upper canopy (Figure 1).

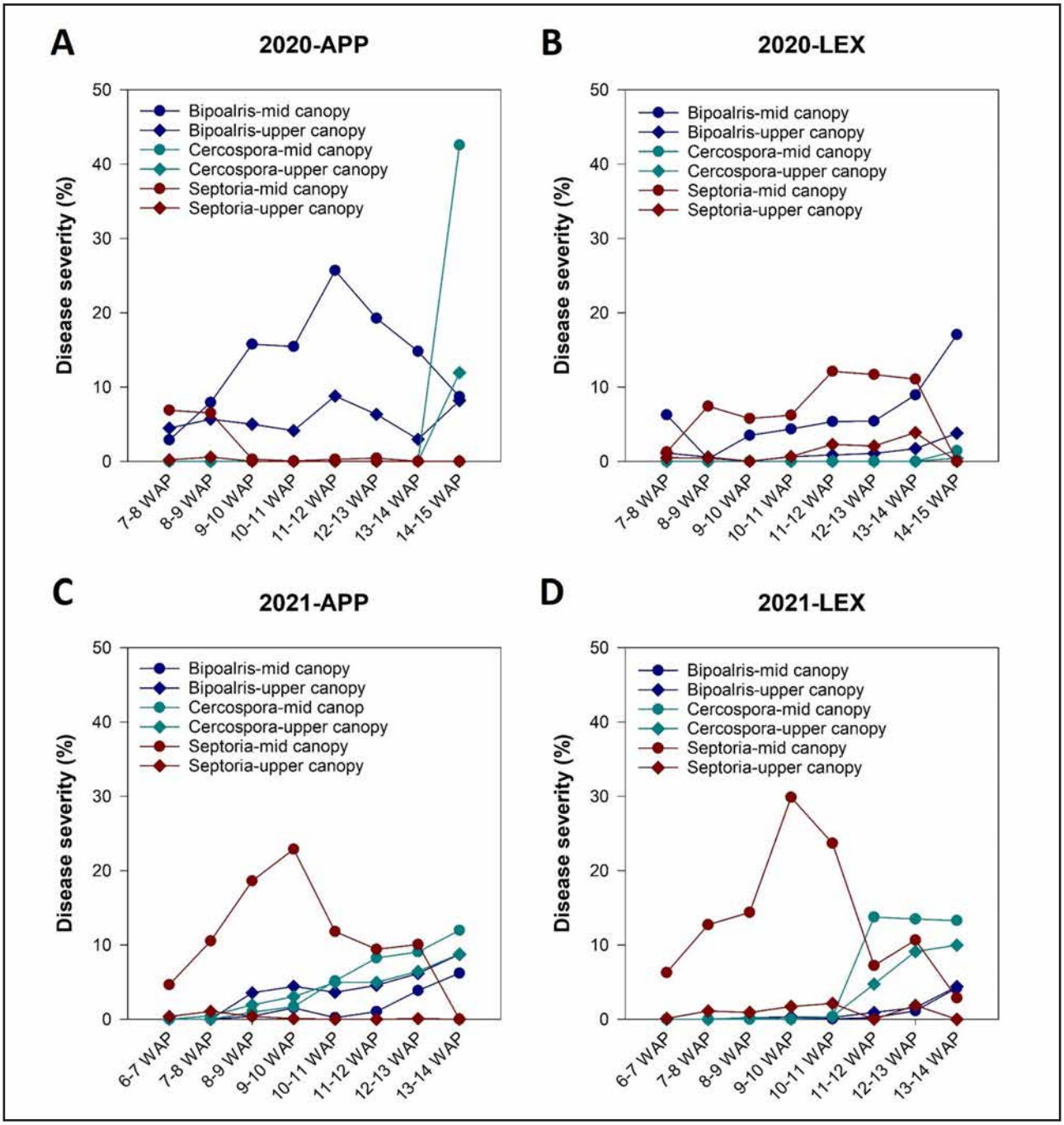
**Cultivar susceptibility.** Variation in leaf spot severity was observed among four CBD hemp cultivars (representing four different relatedness groups) planted in two different fields in 2 years. This indicated differences in susceptibility among cultivars to each of the leaf spot diseases (Table 1, Table 2). Included in the trial fields were BaOx group (cv BaOx), Cherry group (cv Cherry Citrus), Otto II group (cvs Otto II or Endurance), and Trump group (cvs T1 or Wife). In general, Trump group cultivars were the most susceptible (showed highest disease severity), while Otto II group cultivars were the least susceptible (showed lowest disease severity) to the three leaf spot diseases (Figure 2).

**Yield and its relationship with disease.** Variation in both floral dry weight (biomass) and CBD (cannabidiol) was observed among cultivars (Figure 3, Table 2, Table 3). Even though Trump cultivars had higher leaf spot severity compared to Otto II, floral dry weights (biomass yield) of Trump cultivars were relatively equal to floral dry weight of Otto II cultivars (Figure 3). No reverse-relationships between leaf spot diseases and yield suggested that there was no relationship between disease severity and yield. While floral dry weight of Trump and Otto II cultivars were relatively equal, Trump cultivars consistently had higher CBD yield than Otto II cultivars (Figure 3). This indicated that floral dry weight is independent of CBD yield.

**Conclusion.** In Kentucky, Bipolaris, Cercospora, and Septoria leaf spots are the most common diseases of hemp and the most concerning for growers, particularly as they result in defoliation and blighting. This study

documented no relationship between severities of leaf spot diseases (or defoliation) and yield and suggested a reduced need for disease management. However, the importance of foliar disease can shift over time, and future cultivars may again include susceptibilities that result in yield losses. Cultural practices can be important tools for managing diseases on hemp, especially as resistant cultivars and synthetic fungicides are still limited. While selection for disease resistant traits is still in its infancy, findings of this study suggested potential and prospective disease management strategies through cultural practices such as cultivar and planting date selections. In addition, variation in susceptibility among cultivars used in this study can be beneficial for breeding programs.

**Figure 1.** Weekly progression of disease severity (percent leaf area) for Bipolaris, Cercospora, and Septoria leaf spots in the mid and upper canopy at the (**A**) APP (Quicksand, KY) and (**B**) LEX (Lexington, KY) locations in 2020 and (**C**) APP and the (**D**) LEX locations in 2021 from 7 to 15 weeks after planting.




WAP = weeks after planting

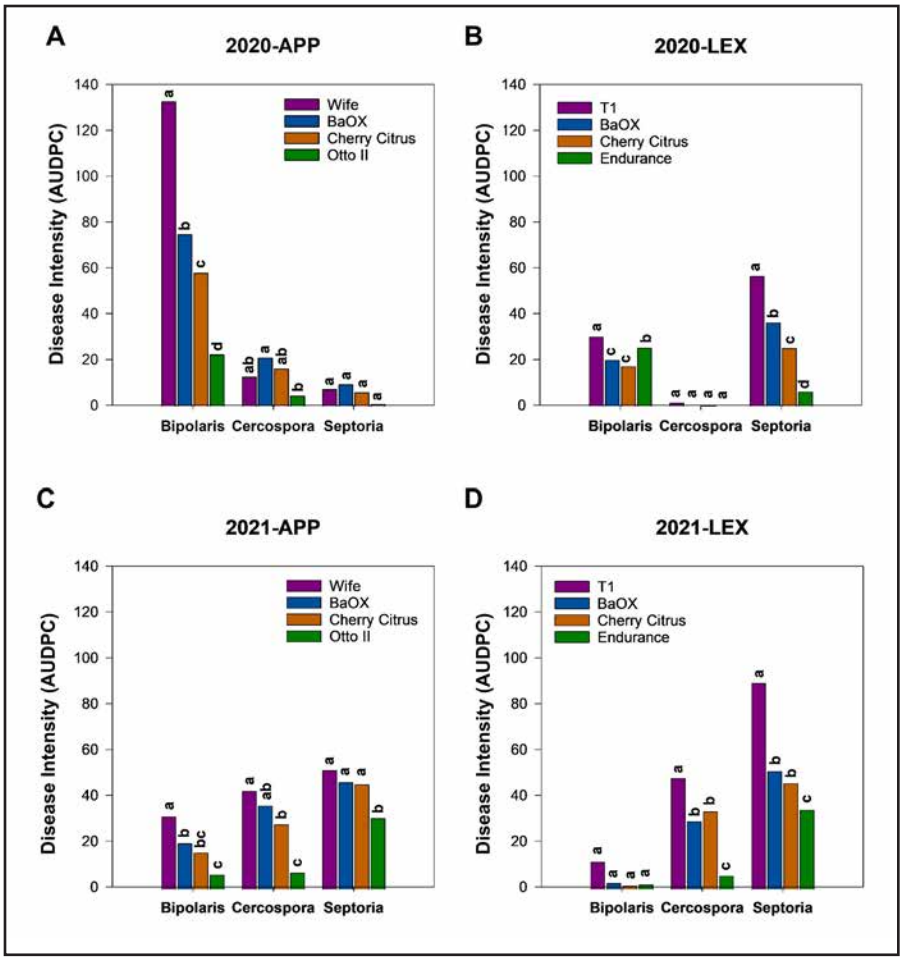



**Figure 2.** Summary of disease severity for Bipolaris, Cercospora, and Septoria leaf spots for cultivars BaOx, Cherry Citrus, Otto II, and Wife at APP (Quicksand, KY) in (**A**) 2020 and (**C**) 2021 and cultivars BaOx, Cherry Citrus, Endurance, and T1 at LEX (Lexington, KY) in (**B**) 2020 and (**D**) 2021 at 15 weeks after planting. Disease severity for each disease within each year-location with the same letters are not significantly different.

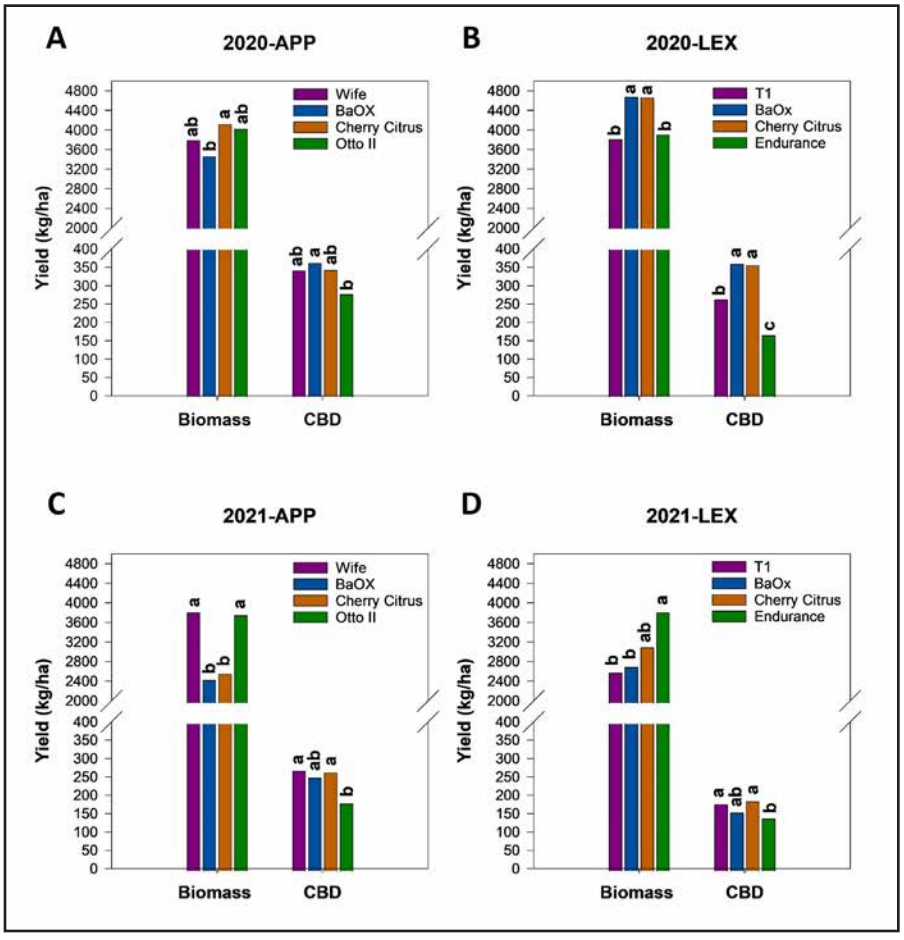



**Figure 3.** Total biomass and CBD yield (kg/ha) for cultivars BaOx, Cherry Citrus, Otto II, and Wife at APP (Quicksand, KY) in (**A**) 2020 and (**C**) 2021 and cultivars BaOx, Cherry Citrus, Endurance, and T1 at LEX (Lexington, KY) in (**B**) 2020 and (**D**) 2021 at 15 weeks after planting. Yield within each year-location with the same letters are not significantly different.

| Cultivar[1] | 2020 Disease intensity of all foliar diseases[2] | | 2021 Disease intensity of all foliar diseases[2] | |
|---|---|---|---|---|
| | APP | LEX | APP | LEX |
| **Trump group (T1 or Wife)** | 50.9 a | 29.5 a | 42.0 a | 50.0 a |
| **BaOx group (BaOx)** | 35.1 b | 18.9 ab | 34.2 a | 27.8 b |
| **Cherry group (Cherry Citrus)** | 26.8 b | 14.2 ab | 29.9 a | 23.8 b |
| **Otto II group (Endurance or Otto II)** | 9.2 c | 10.6 b | 14.7 b | 14.1 b |
| *P-value* | <0.0001 | <0.0001 | <0.0001 | <0.0001 |

**Table 1**. Disease intensity of all foliar diseases for each cultivar at each location and in each year.

[1]Cultivar significantly affected disease intensity in all location-year combinations, P value <0.0001.
[2]Average disease intensity of combined foliar diseases at all canopy positions on each cultivar. Values in the same column with the same letter are not significantly different according to Tukey's test at α = 0.05.

**Table 2.** Effect of cultivar on disease intensity (combined upper and mid canopy) and yield (floral biomass and CBD kg/ha).

| Year | Location | Cultivar | Bipolaris Disease Intensity[1] | Cercospora Disease Intensity[1] | Septoria Disease Intensity[1] | Biomass Yield[2] (dry weight) (kg/ha) | CBD Yield[2] (kg/ha) |
|---|---|---|---|---|---|---|---|
| 2020 | APP | Wife | 132.7 a | 12.8 ab | 7.3 a | 3793.92 ab | 342.69 ab |
| | | BaOx | 74.8 b | 21.0 a | 9.4 a | 3470.40 b | 363.50 a |
| | | Cherry Citrus | 58.0 c | 16.3 ab | 6.0 a | 4122.70 a | 344.37 ab |
| | | Otto II | 22.4 d | 4.5 b | 0.8 a | 4027.44 ab | 278.06 b |
| | | *P-value* | *<0.0001* | *<0.0001* | *0.3801* | *0.0479* | *0.0127* |
| | LEX | T1 | 30.3 a | 1.5 a | 56.6 a | 3818.98 b | 264.45 b |
| | | BaOx | 20.1 c | 0.1 a | 36.4 b | 4678.46 a | 360.79 a |
| | | Cherry Citrus | 17.3 c | 0.2 a | 25.2 c | 4666.50 a | 357.24 a |
| | | Endurance | 25.4 b | 0.0 a | 6.3 d | 3907.83 b | 166.73 c |
| | | *P-value* | *<0.001* | *0.8146* | *<0.0001* | *0.0001* | *<0.0001* |
| 2021 | APP | Wife | 31.6 a | 42.7 a | 51.8 a | 3827.98 a | 271.34 a |
| | | BaOx | 19.9 b | 36.4 ab | 46.5 a | 2454.85 b | 252.55 ab |
| | | Cherry Citrus | 15.9 bc | 28.2 b | 45.6 a | 2582.89 b | 267.09 a |
| | | Otto II | 6.3 c | 0.71 c | 30.9 b | 3775.35 a | 182.71 b |
| | | *P-value* | *0.0003* | *<0.0001* | *0.0021* | *0.0002* | *0.0143* |
| | LEX | T1 | 11.9 a | 48.3 a | 89.7 a | 2607.50 b | 181.24 a |
| | | BaOx | 2.6 a | 29.5 b | 51.3 b | 2725.40 b | 157.53 ab |
| | | Cherry Citrus | 1.5 a | 33.8 b | 46.1 b | 3120.11 ab | 188.79 a |
| | | Endurance | 2.0 a | 5.8 c | 34.5 c | 3834.36 a | 142.09 b |
| | | *P-value* | *0.2457* | *<0.0001* | *<0.0001* | *0.0001* | *0.0427* |

[1]Average combination of mid and upper canopy disease intensities for each cultivar. Values in the same column and in the same year-location with the same letter are not significantly different according to Tukey's test at α = 0.05.
[2]Average yield for each cultivar. Values in the same column and in the same year-location with the same letter are not significantly different according to Tukey's test at α = 0.05.

**Table 3.** Yield loss potential (percentage) for floral biomass and CBD yield (kg/ha) for combined leaf spot diseases (Bipolaris, Cercospora, and Septoria leaf spots) at the APP and LEX locations in 2020 and 2021 by comparison of inoculated treatments and fungicide treatments. Dashes represent no significant yield loss.

| Year | Location | Treatment | Disease Intensity[1] | Biomass Yield[2] (kg/ha) | Biomass Yield Loss[3] (%) | CBD Yield[2] (kg/ha) | CBD Yield Loss[3] (%) |
|---|---|---|---|---|---|---|---|
| 2020 | APP | Fungicide | 18.8 b | 3992.92 a | - | 345.78 a | - |
| | | Inoculated | 40.1 a | 3797.19 a | | 315.94 a | |
| | | *P-value* | ***0.0008*** | ***0.4239*** | | ***0.2615*** | |
| | LEX | Fungicide | 7.5 b | 4423.86 a | - | 270.78 a | - |
| | | Inoculated | 38.4 a | 4154.74 a | | 296.14 a | |
| | | *P-value* | ***<0.0001*** | ***0.2816*** | | ***0.4936*** | |
| 2021 | APP | Fungicide | 15.8 b | 3693.39 a | 23 | 280.01 a | - |
| | | Inoculated | 36.8 a | 2839.88 b | | 225.51 a | |
| | | *P-value* | ***<0.0001*** | ***0.0476*** | | ***0.0805*** | |
| | LEX | Fungicide | 14.1 b | 3661.35 a | 24 | 170.33 a | - |
| | | Inoculated | 40.7 a | 2796.31 b | | 169.58 a | |
| | | *P-value* | ***<0.0001*** | ***0.0324*** | | ***0.9735*** | |

[1]Average disease intensity of combination foliar diseases at all canopy positions for each treatment. Values in the same column and in the same year-location with the same letter are not significantly different according to Tukey's test at α = 0.05. Analysis was performed with removal of naturally infected treatment.
[2]Average yield for each treatment. Values in the same column and in the same year-location with the same letter are not significantly different according to Tukey's test at α = 0.05. Analysis was performed with removal of naturally infected treatment.
[3]Yield loss was calculated by Yield loss = (Yield of fungicide treatment – Yield of inoculated treatment)/Yield of fungicide treatment) x 100%.

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**Complete research study can be found at**

Munir, M., Smith, H., Valentine, T., Leonberger, K., Szarka, D., Dixon, E., Anthony, N., Ricciardi, M., Adedokun, T., Keeme, T., Pearce, R., Gauthier, N. A. 2023. Leaf spot disease development and its effect on yield of essential oil-producing hemp cultivars in Kentucky. Plant Disease. https://doi.org/10.1094/PDIS-11-23-2483-RE