Effects of Air Pollution, Nitrogen Levels, Supplemental Irrigation, and Plant Spacing on Weather Fleck and Leaf Losses of Maryland Tobacco[1]

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Introduction

Relatively high levels of atmospheric ozone under conditions of urban photochemical air pollution were cited by Heggestad and Middleton (3) as a cause of weather fleck, a quality-deteriorating leaf spot of certain types of cigar and cigarette tobaccos. Fleck symptoms appeared in tobacco fields near Washington, D. C., on days immediately following elevated ozone levels. Burk and Heggestad (2) described histologically the collapse of cells in affected leaf areas. Taylor, De Roo, and Waggoner (8) stressed the effect of excess soil moisture in causing increased fleck injury and regarded ozone as a probable cause of weather fleck in the Connecticut River Valley, where losses to cigar-wrapper producers were extremely severe. Walker and Vickery (11) reported more severe fleck losses in irrigated flue-cured tobacco grown in southern Ontario, Canada, near the northern shores of Lake Erie. Air pollution was a suspected fleck cause.

Fleck was observed in Maryland tobacco at least since 1957. Symptoms in plantings at the University of Maryland Tobacco Experimental Farm, 14 miles east-southeast of downtown Washington, were more severe in some varieties than in others. Varietal responses of tobacco to weather fleck were described by Burk and Heggestad (2), Sand (7), and Povilaitis (5). Wanta, Moreland, and Heggestad (12) reported a degree of rubber cracking at the Tobacco Experimental Farm comparable with that found in the tobacco field at Beltsville, Maryland.

The economic significance of weather fleck in Maryland was not previously ascertained since damaged areas of the leaf do not become "shot-holed" as in shade-grown wrapper, or darkly stippled, as in the Canadian flue-cured varieties. Since flecking is most frequent and severe in recently mature leaves, the greatest potential loss in Maryland tobacco is, therefore, in the thin-crop, more valuable grades. In this respect the abscission of overmature leaves during harvesting accounts for large numbers of high-quality leaves on the ground.

The influence of air pollution on premature leaf senescence and abscission of several crop species has been investigated by Taylor (9), Taylor *et al.* (10), and Ledbetter, Zimmerman, and Hitchcock (4). Taylor (9) exposed lemon plants to synthetic smog containing the reaction products of ozone and 1-hexene, and after several exposures observed that older leaves were chlorotic and dropped prematurely. Ledbetter, Zimmerman, and Hitchcock (4) also noted chlorosis and early abscission of the older leaves of tomato and sweet potato plants exposed repeatedly to low concentrations of ozone.

In 1959 and 1960 at the University of Maryland Tobacco Experimental Farm, a relation between the incidence and severity of fleck and the early senescence and leaf loss of Catterton tobacco became apparent in a factorial experiment combining irrigation, nitrogen application rates, and three plant spacings.

There was more fleck where soil was supplementally irrigated and fertilized at the lowest nitrogen level. This fleck was accompanied by considerable premature senescence and leaf abscission.

In 1961 a study was undertaken to determine relations between fleck and leaf losses at three nitrogen application rates and three plant spacings in the presence of urban air pollution in the vicinity of the Experimental Farm. The purpose of the evaluation was to study the interaction of air pollution and these experimental practices in producing

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the fleck syndrome.

Materials and Methods

The plots used in this experiment were established in 1959 to study the effects of supplemental irrigation, nitrogen fertilization, and plant spacing on the yield and quality of Maryland tobacco. In the present experiment they were utilized to study the effects of these variables on amount of fleck, premature senescence, and leaf loss.

The experimental design was a 3 x 3 x 2 factorial planted in randomized blocks replicated four times. Nitrogen levels of 60, 90, and 120 pounds per acre and spacings of 4840, 7260, and 9680 plants per acre were arranged in treatment combinations with supplemental irrigation and natural rainfall. Fertilizer was supplied at planting time by broadcast applications of a mixture prepared from commercial 4-8-12, superphosphate, and sulfate of potash. The mixture contained plant nutrients equivalent to a 3-9-12 formula and was applied at a rate equal to 2,000 pounds per acre. Ammonium nitrate was used to supply the additional nitrogen. The soil in the experimental area is classified as a Monmouth loamy fine sand, a type considered well drained and suitable for production of good quality Maryland tobacco.

Dimensions of individual polts were 24′ x 18′ with 6 rows of tobacco planted 3 feet apart. Plant populations were determined by spacing plants within the row at 36″, 24″, or 12″, so that 4840, 7260, or 9680 plants per acre resulted.

Catterton, a medium broadleaf variety noted for its wide environmental adaptation and high cigarette quality, was planted in the experiment. The variety is extensively distributed in the southern Maryland area.

Moisture levels in the various plots were periodically measured by using a slow neutron counter, augmented by gypsum blocks buried in each plot. The frequency of irrigation depended upon the soil moisture tension indicated by Richards irrometers inserted in plots within the plow-sole. Irrigation by overhead oscillating-type sprinklers was begun when plot moisture tensions exceeded three-fourths of an atmosphere.

Fleck incidence was determined by recording the number of leaves flecked on five representative plants on each plot.

The severity of fleck damage was based on an arbitrary rating scale corresponding to visible leaf damage of 0, 25, 50, 75, and 100 per cent.

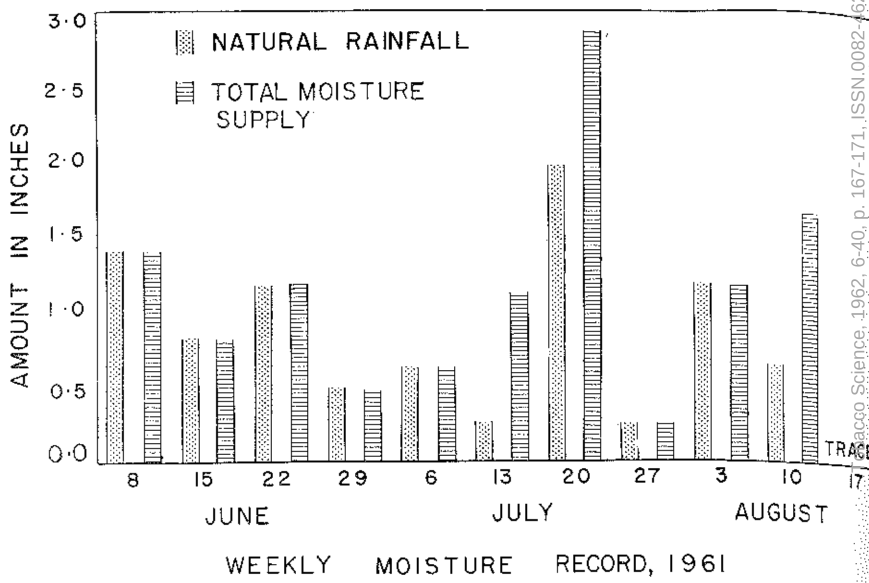


Figure 1.—Record of moisture supply to natural rainfall and supplementally irrigated plots, University of Maryland Tobacco Experimental Farm, Upper Marlboro, Maryland, 1961.

The amount of leaf loss was ascertained by recording the number of potentially marketable leaves in each plot immediately after harvest. All whole leaves on the ground were counted.

Incidence and severity evaluations were made on August 3 and 4, and the tobacco was harvested on August 17.

The tobacco was stripped and graded, the yields were recorded, and Federal grades were assigned to samples taken from each plot. The value was estimated from the yields and the 1954-58 average prices of the appropriate grades.

All data were statistically analyzed by using standard analysis of variance.

Results

The amount and distribution of precipitation received by supplementally irrigated and natural rainfall plots during the summer of 1961 are shown in **Figure 1.** A total of 8.86 inches of rain fell during the 10-week period of tobacco growth and maturation. It was well-distributed and considered adequate for Maryland standards of production. In contrast, irrigated plots received an additional 2.75 inches of water in three irrigations on July 11 and 17, and August 5.

The fleck syndrome followed a distinct order in all plots; typical symptoms are pictured in **Figure 2.** As in cigar-wrapper and flue-cured tobacco varieties, the oldest leaves were affected first, and susceptibility progressed toward the upper part of the plant. Injury appeared first at the base of the leaf as tiny gray water-soaked areas, which passed through intermediate stages of development without increase in size and eventually became tan or white flecks about 1 mm. in diameter. These changes occurred over a period of 3 or 4 days. Affected areas did not coalesce and become "shot-holed" as often occurs in the severe flecking of wrapper varieties. On August 3 and 4, the dates of the fleck evaluation, severely flecked leaves at the base of many plants had yellowed excessively and in some cases had become detached. The yellowing and abscission re-

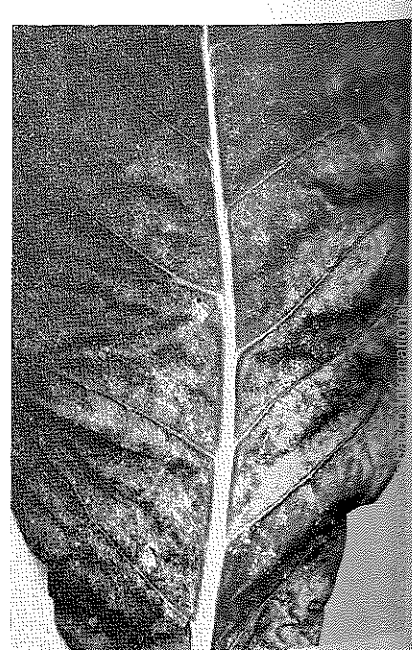
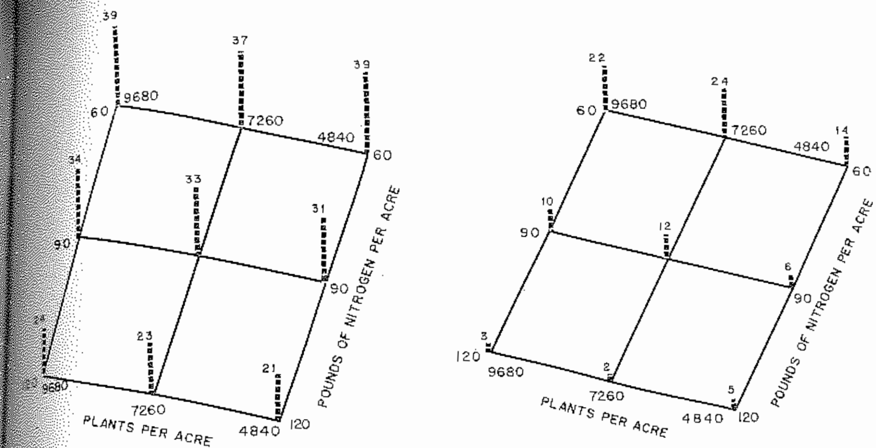


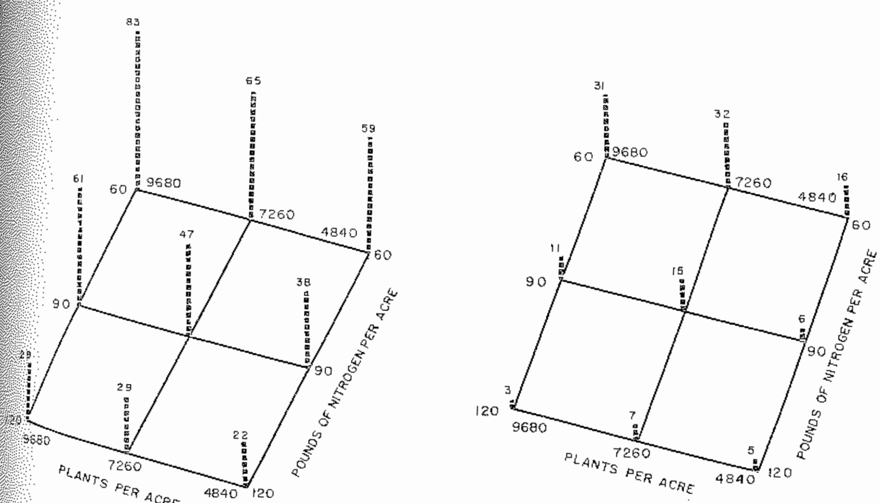
Figure 2.—Typical weather fleck symptoms on a leaf of the Maryland tobacco variety Catterton.



PERCENTAGE OF FLECKED LEAVES ON IRRIGATED PLOTS

PERCENTAGE OF FLECKED LEAVES ON NON-IRRIGATED PLOTS

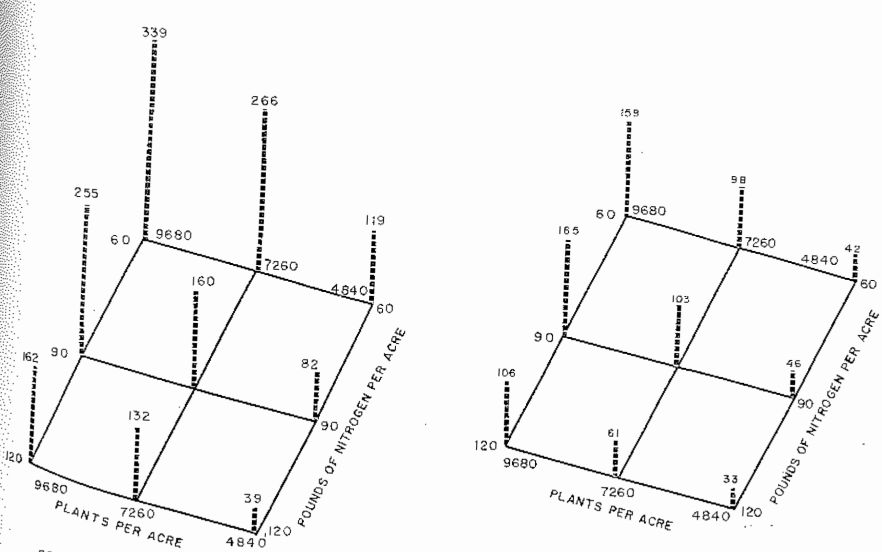
Figure 3.—Fleck incidence (percentage of leaves flecked) as affected by nitrogen rate, plant population, and moisture supply.



SEVERITY OF FLECK ON IRRIGATED PLOTS

SEVERITY OF FLECK ON NON-IRRIGATED PLOTS

Figure 4.—Fleck severity (proportion of leaf area injured) as affected by nitrogen rate, plant population, and moisture supply.



POST HARVEST COUNT OF MARKET QUALITY LEAVES LEFT ON IRRIGATED PLOTS

POST HARVEST COUNT OF MARKET QUALITY LEAVES LEFT ON NON-IRRIGATED PLOTS

Figure 5.—Count of potentially marketable leaves lost during harvest of plots affected by nitrogen rate, plant population, and moisture supply.

sponse was very pronounced when supplemental irrigation, intermediate to high plant populations, and the lowest nitrogen rate were combined.

The incidence as a percentage and relative severity of fleck observed in plots appears in **Figures 3 and 4.** More leaves of each plant showed fleck in plots that received supplemental irrigation than the corresponding plots that received natural rainfall. At the 90-pound nitrogen rate, fleck incidence was two times greater than at the same level of nitrogen used with natural rainfall. At the lowest nitrogen rate more leaves were flecked regardless of the soil moisture; the percentage of flecked leaves declined as the nitrogen rate increased to the 90- and 120-pound levels, irrespective of moisture. The planting density at all three nitrogen levels and in both moisture practices seemed relatively unimportant as an influence upon the incidence of fleck. Fleck incidence at the 120-pound nitrogen level was less than at the 60- and 90-pound nitrogen levels.

The relative severity of leaf damage was based on a scale ranging from 0 to an upper limit of total injury with a value of 240. The most fleck damage was found with supplemental irrigation and the highest planting density with a 60-pound nitrogen rate. Nearly 35 percent visible leaf injury occurred with this combination, while in other irrigated combinations the severity of injury was less.

The severity of injury in natural rainfall plots at all nitrogen rates and plant spacings was much less than in the corresponding irrigated plots. There was 12 percent leaf surface injnry at the 60-pound nitrogen rate and closest plant spacing, or about one-third as much injury as in the corresponding irrigated treatment.

Statistical analysis of the data for the incidence and severity of fleck showed that differences between treatments and between the two moisture practices were significant at the 0.01 level of probability.

Leaf losses before and during harvest are presented in **Figure 5.** Substantially more leaf loss occurred on most of the irrigated plots, particularly at the lowest nitrogen rate. The leaf loss at the closest spacing was 3 to 4 times as great as the widest spacing, although the number of plants at the closest spacing was two times as great. Treatment differences were statistically significant at the 0.01 level.

Tobacco yields and the estimated

dollar value for each treatment in relation to the general mean for yield per acre and value per acre are shown in **Figures 6** and **7.** The lowest yields appeared in supplemental irrigation at a 60-pound nitrogen rate, while with natural rainfall at the same nitrogen rate, yields increased as the plant population increased. Differences between moisture practices for the yield and value criteria exhibited parallel relation to the fleck data and were significant at the 1 percent level. The effects of an inadequate nitrogen supply were clearly evident at a high planting density and with abundant moisture. The dollar value of the low nitrogen plots corresponded to the trend of the yield except for the closest spacing of irrigated plots. In this instance the quality was reduced by chaffy leaf texture poorly suited to cigarette manufacture. Large differences in tobacco yield and value at the 90-pound nitrogen level were found between moisture practices, especially at intermediate and high plant populations. The average yield and value of tobacco grown at the three plant spacings with natural rainfall was higher than the same spacings with irrigation. Only after the nitrogen rate had been increased to the highest level did the yield and value of supplementally irrigated plots exceed that of natural rainfall.

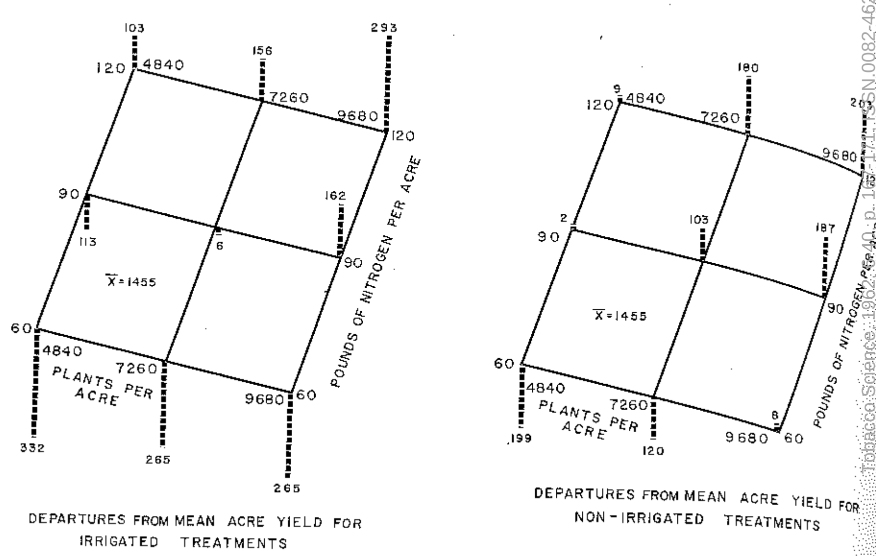


Figure 6.—Yield departures (pounds per acre) from the general mean of all plots affected by nitrogen rate, plant population, and moisture supply.

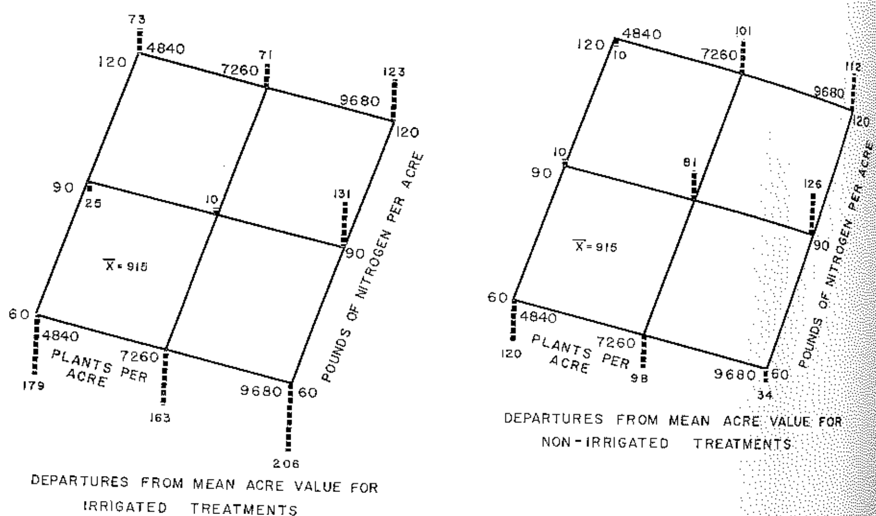


Figure 7.—Value departures (dollars per acre) from the general mean of all plots affected by nitrogen rate, plant population, and moisture supply.

Discussion

The importance of nitrogen fertilization in the production of Catterton tobacco is clearly evident in the results of yield and estimated value of the tobacco when grown with certain other cultural practices. Yields were greatly reduced when 2.75 inches of irrigation water was applied to plots fertilized at a 60-pound per acre nitrogen rate. The application of the additional moisture apparently occurred at a critical period of growth and maturation in causing this effect.

In addition, this study provides evidence of the effect of cultural practices on the nitrogen supply and the close relation of these cultural practices to the pattern of leaf losses and fleck. The results seem to indicate that a higher nitrogen level may produce a protective effect in the reaction of the plant to the atmospheric causes of fleck and early senescence. Plants were the least sensitive to fleck at the highest nitrogen rate with both moisture practices however, the effect of additional moisture seemed to enhance greatly the influence of a decreasing nitrogen supply. The work of Walker and Vickery (11) and Taylor, De Roo, and Waggoner (8) clearly demonstrated the importance of irrigation in the fleck response where fleck occurred earlier and at higher intensity after irrigation.

Experimental fumigations have shown the relation between physiological condition of leaf tissues and the maximum sensitivity to ozone and other pollutant-type gases[3] (10). In general, the most recent physiologically-matured leaves or portions of the leaf are affected and plant injury follows the advance of leaf maturity. Tobacco leaves are highly fleck-susceptible immediately after physiological maturity is attained.

In the field, a low rate of nitrogen supply, excess soil moisture, and plant competition would seem to create conditions most favorable for severe fleck. Excess moisture at certain nitrogen levels may contribute to a physiological state of prolonged sensitivity. Therefore, if nitrogen levels induce fleck protection it may be the result of delaying and shortening the fleck-sensitive stage.

Brewer, Guillemet, and Creveling (1) recently reported experimental results in which ozone and synthetic smog caused variable amounts of injury to spinach and mangels grown in the greenhouse in potted soil containing factorially combined levels of nitrogen, phosphate, and potash. Injury to both species was more severe at the high nitrogen levels.

[3] *Menser, H. A., Ph.D. Thesis, University of Maryland, 1962.*

which also produced the greatest growth. A highly susceptible physiological state following rapid growth may have contributed to the greater sensitivity of these plants—a situation contrasting with that found in the tobacco field experiment. This may be true especially if growth of spinach and mangels at low nitrogen level was extremely slow and the plants were less sensitive because of the physiological resistance that occurs with certain environmental stresses. The injury reduction reported by Brewer, Guillemet, and Creveling at highest balanced element levels is interesting since it could reflect changes in metabolism that could relate to smog protection by controlling element levels.

The possible effect of air pollution on premature senescence and loss of tobacco leaves may be considered in relation to the report of Taylor *et al.* (10). Petunia plants receiving repeated fumigation with low concentrations of ozone developed a chlorosis of the older leaves followed by early senescence and abscission. The reaction products of ozone and 1-hexene, often described as synthetic smog, produced a similar effect. Richards *et al.* (6), in a discussion of oxidant stipple of grape, believed ozone to be the principal causal agent of leaf injury. Premature senescence and leaf abscission were frequently observed in vineyards and were thought to be a secondary consequence of oxidant injury.

In conclusion, fleck and leaf loss often found in Catterton tobacco production probably result from the interaction of many factors. The influences of nitrogen fertilization, plant competition, and moisture supply in the presence of products of urban photochemical air pollution occupy a highly important position in the total interaction. Other effects such as leaf diseases, poor soil aeration, and root damage from excess moisture undoubtedly contribute; however, their importance is difficult to assess.

Acknowledgment

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