Open Journal of Soil Science, 2024, 14, 180-189
https://www.scirp.org/journal/ojss
ISSN Online: 2162-5379
ISSN Print: 2162-5360

# Humic Acid Effects on Reducing Corn Leaf Burn Caused by Foliar Spray of Urea-Ammonium Nitrate at Different Humic Acid/Urea-Ammonium Nitrate Ratios

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**How to cite this paper:** Yin, X.H. (2024) Humic Acid Effects on Reducing Corn Leaf Burn Caused by Foliar Spray of Urea-Ammonium Nitrate at Different Humic Acid/Urea-Ammonium Nitrate Ratios. *Open Journal of Soil Science*, **14**, 180-189.
https://doi.org/10.4236/ojss.2024.143010

**Received:** February 1, 2024
**Accepted:** March 24, 2024
**Published:** March 27, 2024



## Abstract

Technologies for reducing corn leaf burn caused by foliar spray of urea-ammonium nitrate (UAN) during the early growing season are limited. A field experiment was carried out to evaluate the effects of humic acid on corn leaf burn caused by foliar spray of undiluted UAN solution on corn canopy at Jackson, TN in 2018. Thirteen treatments of the mixtures of UAN and humic acid were evaluated at V6 of corn with different UAN application rates and different UAN/humic acid ratios. Leaf burn during 1 2, 3, 4, 5, 6, 7, and 14 days after UAN foliar spray significantly differed between with or without humic acid addition. The addition of humic acid to UAN significantly reduced leaf burn at each UAN application rate (15, 25, and 35 gal/acre). The reduction of leaf burn was enhanced as the humic acid/UAN ratio went up from 10% to 30%. Leaf burn due to foliar application of UAN became severer with higher UAN rates. The linear regression of leaf burn 14 days after application with humic acid/UAN ratio was highly significant and negative. However, the linear regression of leaf burn 14 days after application with the UAN application rate was highly significant and positive. In conclusion, adding humic acid to foliar-applied UAN is beneficial for reducing corn leaf burn during the early growing season.

## Keywords

Humic Acid, Urea-Ammonium Nitrate, Corn, Leaf Burn, N rate, Ratio

## 1. Introduction

Undiluted urea-ammonium nitrate (UAN, 28 and 32% N) is sometimes applied directly on corn canopy as an N source via foliar spray during the early growing season. However, this practice has the potential risk to result in phytotoxic symptoms of leaf burn, necrosis, loss of leaves, and plant stunting. Hot and dry weather conditions will increase leaf burn and reduce plant growth. Leaf burn symptoms can be visible within 24 to 48 hours after application [1]. Darkened leaf tissues can even be observed within a few hours after application under dry and hot conditions [1]. Depending upon the severity of damage, reduced plant growth may be visible and last for several weeks. Because the plant growing point remains below ground for several weeks after emergence until approximately the fifth leaf growth stage (V5), it is not directly influenced by foliar application of UAN before this leaf growth stage. Thus, little prolonged damage will occur as long as plants are small.

Leaf burn caused by foliar application of UAN during the early growing season may or may not lead to corn yield reduction. Randall in Minnesota in 1984 reported that when corn plants were at the third leaf (V3) growth stage, phytotoxic effects were worse at N rates greater than 60 lb N/acre (rates applied were 0, 60, 90, and 120 lb N/acre as UAN), but damage was not permanent and did not negatively influence plant population or grain yield [2]. When plants were larger than the V3 stage, plant damage was worse and some yield decrease occurred with the 120 lb N/acre rate of UAN. When atrazine at 2 lb active ingredient/acre was applied together with UAN, leaf damage and plant stunting increased, and grain yield reduction was observed when atrazine was combined with UAN at rates greater than 60 lb N/acre [2].

There are measures that can be taken to reduce leaf burn due to post emergence UAN foliar application. For instance, Sawyer in Iowa in 2003 recommended UAN at no more than 90 lb N/ac applied at the V3 stage of corn or younger, no more than 60 lb N/ac between the V3 to V7 stage, and no application to foliage if plants are larger than the V7 stage to avoid grain yield loss [3]. When corn is too tall to risk damage during foliar application, UAN should be applied with drop nozzles in the between-row areas. Furthermore, if foliar spray of UAN is the only option available, the tradeoff between the potential for yield increase from added N nutrition and potential yield reduction from leaf burn needs to be weighed.

Technologies available for reducing leaf burn caused by foliar spray of UAN during the corn early growing season are limited. Humic acid is a mixture of organic acids with long chain molecules, high molecular weight, and dark brown color. It is extracted from ancient humic shale and soluble in alkali. Although humic acid has been used to improve the quality of some soils and stimulate plant growth, its influence on crop leaf damage caused by foliar UAN application is unknown. Therefore, the objective of this study was to examine the effects of adding humic acid to foliar applied UAN on corn leaf burn at different UAN application rates and different humic acid/UAN ratios early in the growing season.

## 2. Materials and Methods

A field experiment was carried out on corn to evaluate the effects of adding humic acid undiluted UAN solution for foliar spray on reducing leaf burn caused on a Granada silt loam soil at Jackson, TN in 2018. Thirteen treatments of foliar spray of the mixtures of UAN and humic acid with different UAN application rates and humic/UAN acid ratios were evaluated in this study (Table 1).

An initial composite soil sample with thirty probes of 2.5-cm diameter was collected at the 0-6 inch depth from the entire experiment area before the treatment imposition on February 5, 2018. After the soil sample was air dried, ground to pass through a 2-mm sieve, and thoroughly mixed, it was analyzed by the Brookside Laboratories Inc. (New Bremen, OH). The results showed this experimental field had pH: 7.1, organic matter: 1.52%, total exchange capacity: 8.89 meq/100 g, nitrate-N: 0.8 ppm, ammonium-N: 2.9 ppm, estimated N release: 50 lbs/a, P: 28 ppm, K: 204 ppm, Ca: 1442 ppm, Mg: 232 ppm, S: 5 ppm, B: 0.40 ppm, Fe: 186 ppm, Mn: 243 ppm, Cu: 4.03 ppm, Zn: 1.66 ppm, and Al: 703 ppm with Mehlich III as the extractant.

Phosphorus and K fertilizers were applied at 80 lbs $P_2O_5$/acre as triple superphosphate (N0-P45-K0) and 60 lbs $K_2O$/a as muriate of potash (N0-P0-K60), respectively, to soil surface uniformly across the test area with a Gandy spreader on April 17 according to the initial soil testing results. Corn cultivar DK 62-08 was no-till planted in 30-inch rows at a seeding rate of 1500 seeds/acre on May 8. The plot size was 10 ft. wide × 30 ft. long with four rows of corn. Corn was grown using the standard no-till non-irrigated corn management practices (including the management of weeds, insects, and diseases) of the region.

Table 1. Treatment combinations of UAN and humic acid.

| Treatment # | UAN | Humic acid | Humic acid/UAN ratio |
|---|---|---|---|
| | Gallons/acre | Gallons/acre | |
| 1 | 15 | 0 | 0% |
| 2 | 15 | 1.5 | 10% |
| 3 | 15 | 3 | 20% |
| 4 | 15 | 4.5 | 30% |
| 5 | 25 | 0 | 0% |
| 6 | 25 | 2.5 | 10% |
| 7 | 25 | 5.0 | 20% |
| 8 | 25 | 7.5 | 30% |
| 9 | 35 | 0 | 0% |
| 10 | 35 | 3.5 | 10% |
| 11 | 35 | 7 | 20% |
| 12 | 35 | 10.5 | 30% |
| 13 | 0 | 0 | 0% |

All the UAN and humic acid treatments were foliar sprayed on corn canopy in the designated plots at V6 of corn on June 4. The seasonal N application rate was 180 lbs/acre for Treatments 1 to 12, but Treatment 13 received zero N as the control. In addition to the N from the UAN treatments, the rest of N was broadcast on soil surface as coated urea (ESN) along with granular humic acid on June 4 in making up the total N application rate to be 180 lbs/acre for Treatments 1 to 12.

Leaf burn was visually rated beginning from June 5 on a daily basis for seven days. Leaf burn was also visually rated on June 18, two weeks after foliar spray of UAN and humic acid. Leaf burn was expressed as percentage of total burned leaf area ÷ total leaf area × 100.

Analysis of variance was conducted on the leaf burn measurement with the ANOVA procedure in SAS for Windows V9 (4) (SAS Institute, Cary, NC). A randomized complete block design with four replications was used for the analysis. Treatment means were separated with the Fisher's protected least significant difference (LSD) test. Probability levels lower than 0.05 were designated as significant.

## 3. Results and Discussion

### 3.1. Weather Conditions

All the treatments were foliar sprayed on corn canopy in the designated plots at V6 of corn on June 4. There was no rainfall during June 4 to June 18 except June 14 and 18 which received 0.48 and 0.41 inch of rain, respectively (Table 2). Overall, the weather conditions of 2018 were normal and favorable for non-irrigated corn production.

**Table 2.** Weather conditions for the 14-day period after foliar spray of UAN.

| Date (dd/mm) | Rainfall | High temperature | Low temperature |
|---|---|---|---|
| | Inch | ˚F | ˚F |
| 04/06 | 0.00 | 84 | 60 |
| 05/06 | 0.00 | 85 | 61 |
| 06/06 | 0.00 | 86 | 59 |
| 07/06 | 0.00 | 90 | 63 |
| 08/06 | 0.00 | 92 | 63 |
| 09/06 | 0.00 | 94 | 68 |
| 10/06 | 0.00 | 92 | 70 |
| 11/06 | 0.00 | 93 | 71 |
| 12/06 | 0.00 | 93 | 72 |
| 13/06 | 0.00 | 91 | 70 |
| 14/06 | 0.48 | 88 | 73 |
| 15/06 | 0.00 | 92 | 72 |
| 16/06 | 0.00 | 93 | 72 |
| 17/06 | 0.00 | 94 | 74 |
| 18/06 | 0.41 | 94 | 72 |

### 3.2. Regression of Leaf Burn with UAN Foliar Application Rate

There was a highly significant and positive regression of leaf burn at 14 days after UAN application with UAN (without any humic addition) foliar application rate under a linear model without any humic addition to UAN ($P < 0.001$; $R^2 = 0.49$) (Figure 1). Specifically, leaf burn increased by 0.725 percentage unit with the increase of one gallon of UAN per acre. Similarly, the linear regression of leaf burn 14 days after UAN foliar application with UAN rate was highly significant and positive at each of the other three humic acid/UAN ratios or with all the three ratios combined (data not shown).

### 3.3. Effects of Humic Acid Addition to UAN for Foliar Application on Leaf Burn

The results showed that leaf burn at 1 day, 2 days, and 7 days after UAN foliar application with or without humic acid addition significantly differed (Table 3). In general, the percentage of leaf burn caused by UAN was increased with each increment of UAN application rate from 15 to 25 gallons/acre and from 25 to 35 gallons/acre. Furthermore, the addition of humic acid to UAN significantly reduced leaf burn at each UAN application rate, and the effects of humic acid on reducing leaf burn were increased as the humic acid/UAN ratio was enhanced from 10% to 30%. Leaf burn values at 3, 4, 5, and 6 days after UAN foliar application were similar to those 2 days after UAN foliar application. Leaf burn values 14 days after UAN foliar application were exactly the same as those 7 days after UAN foliar application, indicating that leaf burn did not turn worse one week after UAN foliar application.

Figure 2 shows the effects of UAN application rate on leaf burn four days after foliar spray without humic acid addition. Obviously, the severity of foliar damage went up with increasing N application rate from 0 to 35 gal UAN/acre. Figure 3 shows the effects of humic acid addition to UAN for foliar application on leaf burn at 35 gal UAN/acre 4 days after foliar spray. It demonstrated that adding humic acid to UAN for foliar spray reduced leaf burn of corn plants.

The positive effects of humic acid on reducing corn leaf burn might be explained as follows. Similar to the use of humic acid in drought stress reduction, plants responded to humic acid by regulating osmotic potential through maintaining water absorption and cellular swelling [4], which reduced the severity of leaf burn caused by UAN foliar application.

Urea-ammonium nitrate can also be foliar sprayed on corn canopy during the late growing season, which will result in moderate to severe leaf burn. Research in Missouri showed that for two-foot tall corn, 32% UAN resulted in much greater leaf burn than ammonium nitrate or urea under foliar spray [1]. Between-row applications resulted in little damage. Therefore, they did not recommend foliar spray of UAN when the corn is over one foot tall, while between-row applications of UAN and other N sources are recommended when the corn is between one and four feet tall.

**Table 3.** Effects of humic acid addition to UAN foliar application on corn leaf burn.

| Treatment # | UAN | Humic acid | Humic acid/UAN ratio | Leaf burn 1 day after application | Leaf burn 2 days after application | Leaf burn 3 days after application | Leaf burn 4 days after application | Leaf burn 5 days after application | Leaf burn 6 days after application | Leaf burn 7 days after application | Leaf burn 14 days after application |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | gallons/acre | gallons/acre | | % | % | % | % | % | % | % | % |
| 1 | 15 | 0 | 0% | 25.8h[†] | 46.0de | 47.0e | 46.0ef | 46.0de | 46.0de | 47.0ef | 47.0ef |
| 2 | 15 | 1.5 | 10% | 21.0i | 40.8f | 43.3f | 43.0f | 40.8f | 40.8f | 44.3f | 44.3f |
| 3 | 15 | 3 | 20% | 16.5j | 32.5h | 32.5h | 33.3h | 33.8h | 32.5g | 33.8h | 33.8h |
| 4 | 15 | 4.5 | 30% | 13.3k | 24.3i | 24.3i | 24.3i | 24.8i | 27.0h | 27.0i | 27.0i |
| 5 | 25 | 0 | 0% | 45.0c | 52.8b | 53.3bc | 52.8bc | 52.8b | 52.8b | 53.3bc | 53.3bc |
| 6 | 25 | 2.5 | 10% | 37.8e | 45.0de | 45.0ef | 46.0ef | 45.0de | 45.0de | 46.0ef | 46.0ef |
| 7 | 25 | 5.0 | 20% | 35.0f | 44.5e | 45.0ef | 45.0ef | 44.5e | 44.5e | 45.5ef | 45.5ef |
| 8 | 25 | 7.5 | 30% | 30.0g | 37.5g | 37.5g | 37.5g | 37.5g | 39.5f | 39.5g | 39.5g |
| 9 | 35 | 0 | 0% | 55.5a | 60.0a | 61.5a | 60.0a | 60.0a | 60.0a | 61.5a | 61.5a |
| 10 | 35 | 3.5 | 10% | 50.0b | 54.0b | 54.0b | 54.0b | 54.0b | 54.0b | 54.0b | 54.0b |
| 11 | 35 | 7 | 20% | 45.5c | 49.8c | 50.5cd | 49.8cd | 49.8c | 49.8c | 50.5cd | 50.5cd |
| 12 | 35 | 10.5 | 30% | 40.5d | 47.5cd | 47.5de | 48.0de | 47.5cd | 47.5cd | 48.0de | 48.0de |
| 13 | 0 | 0 | 0% | 0.0l | 0.0j | 0.0j | 0.0j | 0.0j | 0.0j | 0.0j | 0.0j |
| LSD (P = 0.10 ) | | | | 2.1 | 2.8 | 3.1 | 3.1 | 2.7 | 2.9 | 3.0 | 3.0 |
| Probability for F test | | | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |

[†]Means in a column without any same lower case letter are significantly different at the 5% probability level.

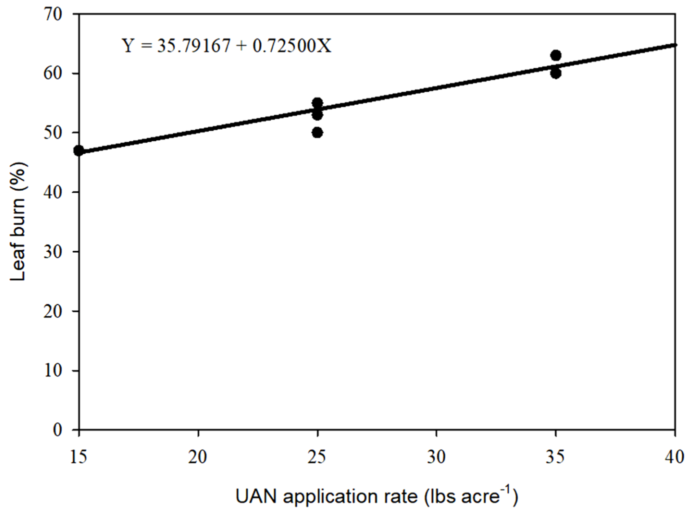


**Figure 1.** Linear regression of leaf burn at 14 days after UAN foliar application with UAN application rate without any humic acid addition.

**Figure 2.** Effects of UAN application rate on leaf burn without humic acid addition at 4 days after foliar spay. Pictures from left to right with 0, 15, 25, and 35 gal UAN/acre, respectively.

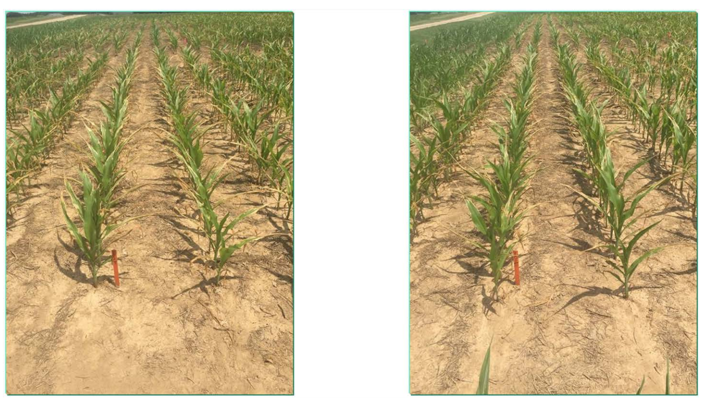

**Figure 3.** Effects of humic acid addition to UAN for foliar application on leaf burn at 35 gal UAN/acre at 4 days after foliar spray. Pictures from left to right with 0% and 20% of humic acid/UAN ratio in volume, respectively.

Leaf burn is associated with the application rate, timing, and source of N fertilizer. Although any N fertilizer solution sprayed on cereal plants may result in visual foliar damage including leaf burning, scorching, and tipping [5], yield reductions may or may not occur, depending on severity of the foliar damage. Kettlewell and Juggins observed in 1992 that wheat plants receiving the highest rate of N in one application suffered the most foliar damage; however, no significant yield reduction was observed [6]. Similarly, Phillips and Mullins found in 2004 that when UAN was foliar applied on winter wheat at the recommended growth stage (GS 30), leaf burn increased with increasing N rate (0, 34, and 67 $kg \cdot ha^{-1}$) [7]. Poulton *et al.* reported in 1990 that wheat yield reductions due to severe leaf scorching occurred after foliar application compared with soil application at the same N rate [8]. Powlson *et al.* found in 1989 that no leaf damage or wheat yield decrease when 40 $kg \cdot N \cdot ha^{-1}$ was foliar applied [9]. Leaf damage was only observed when a foliar spray was done with 60 $kg \cdot N \cdot ha^{-1}$, which reduced wheat yield by 460 $kg \cdot ha^{-1}$. Woolfolk *et al.* reported in 2002 a trend for increased leaf burn when an ammonium sulfate solution was foliar applied relative to UAN; however, no wheat yield difference was observed between the two fertilizers applied at the same N rates [10].

Leaf burn is also related to various factors including characteristics of the crop and spray equipment and weather conditions. For example, a wheat variety with a prostrate leaf that leans out and tries to canopy over will burn worse. The fertilizer needs to be sprayed on the canopy when the plant is small and dry or when it is raining. Less fertilizer will adhere to plants when they are dry or falls into the whorl when plants are small. Streamer nozzles also make a difference. Nozzles that shoot straight down will result in uniform and worse burn. Dilution of fertilizer solution is another key; adding one part water to one part UAN is beneficial for reducing leaf burn.

### 3.4. Regression of Leaf Burn with the Humic Acid/UAN Foliar Application Rate Ratio

The linear regression of leaf burn at 14 days after UAN application with the humic acid/UAN foliar application rate ratio was highly significant and negative across all the three UAN application rates ($P < 0.001$; $R^2 = 0.42$) (**Figure 4**). Specifically, leaf burn decreased by 0.521 percentage unit with the increase of one percentage unit of the humic acid/UAN ratio. Similarly, the linear relationship of leaf burn 14 days after UAN foliar application with humic acid/UAN ratio was highly significant and negative at each of the three UAN application rates (data not shown).

## 4. Conclusions

The results generally showed that corn leaf burn at 1 2, 3, 4, 5, 6, 7, and 14 days after UAN foliar spray significantly differ between with or without humic acid addition. Addition of humic acid to UAN significantly reduces leaf burn at each of the three UAN application rates (15, 25, and 35 gal/acre). Reduction of leaf burn is enhanced as the humic acid/UAN ratio goes up from 10% to 30%. Leaf burn due to foliar application of UAN becomes severer with higher UAN rates.

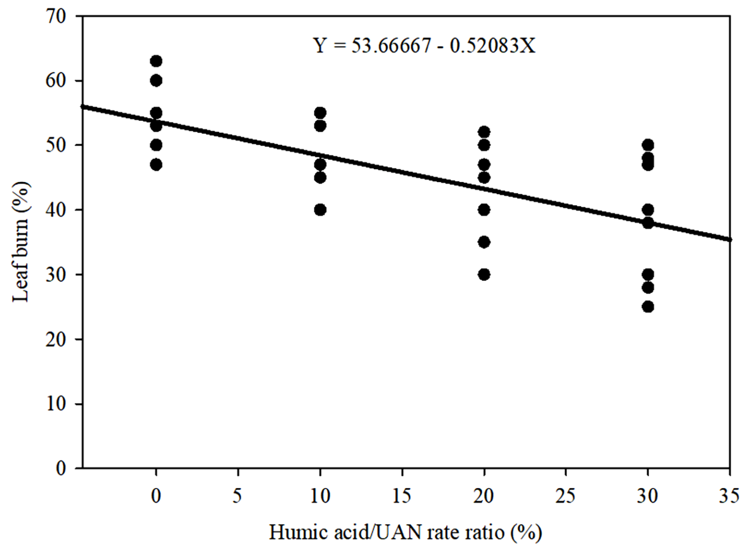


**Figure 4.** Linear regression of leaf burn at 14 days after UAN foliar application with the humic acid/UAN ratio across all UAN rates.

There was a highly significant and positive linear regression of leaf burn at 14 days after application with UAN application rate at each humic acid/UAN ratio or with all the ratios combined. Similarly, the linear relationship of leaf burns at 14 days after application with humic acid/UAN ratio was highly significant and positive at each UAN rate or with all rates combined. In conclusion, adding humic acid to UAN for foliar application is beneficial for reducing corn leaf burn during the early growing season. Since the foliar application of UAN on corn is increasingly used, further research may be needed to compare different corn varieties in their responses to UAN foliar application in terms of leaf burn. Different foliar application times of UAN on corn leaf burn also deserve research in the future.

## Acknowledgments

We acknowledge the support of this study by the Live Earth Products, Inc. We are grateful to Mr. Robert Sharp and the staff of the West Tennessee Research and Education Center of the University of Tennessee at Jackson for their technical assistance.

## Conflicts of Interest

The author declares no conflict of interest.

## References

[1] Nelson, K.A., Scharf, P., Burdick, B. and Stevens. G. (2003) Rescue N Applications for Corn: Yield Response, Leaf Burn, and Yield Loss. http://aes.missouri.edu/pfcs/research/prop403a.pdf

[2] Randall, G.W. (1984) Postemergence Application of Urea-Ammonium Nitrate (UAN) and Atrazine Combinations to Corn. *Journal of Fertilizer Issues*, **1**, 50-53.

[3] Sawyer, J.E. (1988) Watch for Damage from Broadcast Postemerge UAN Applications. Integrated Crop Management News. https://lib.dr.iastate.edu/cropnews/1988

[4] Azevedo, R.A. and Lea, P.J. (2011) Research on Abiotic and Biotic Stress-What Next? *Annals of Applied Biology*, **159**, 317-319. https://doi.org/10.1111/j.1744-7348.2011.00500.x

[5] Gooding, M.J. and Davies, W.P. (1992) Foliar Urea Fertilization of Cereals: A Review. *Fertilizer Research*, **32**, 209-222. https://doi.org/10.1007/BF01048783

[6] Kettlewell, P.S. and Juggins, S.A. (1992) Can Foliar Application of Nitrogen Fertiliser to Winter Wheat Reduce Nitrate Leaching. *Aspects of Applied Biology*, **30**, 103-108.

[7] Phillips, S.B. and Mullins, G.L. (2004) Foliar Burn and Wheat Grain Yield Responses Following Topdress-Applied Nitrogen and Sulfur Fertilizers. *Journal of Plant Nutrition*. **27**, 921-930. https://doi.org/10.1081/PLN-120030679

[8] Poulton, P.R., Vaidyanathan, L.V., Powlson, D.S. and Jenkinson, D.S. (1990) Evaluation of the Benefit of Substituting Foliar Urea for Soil-Applied Nitrogen for Winter Wheat. *Aspects of Applied Biology*, **25**, 301-308.

[9] Powlson, D.S., Poulton, P.R., Moller, N.E., Hewitt, M.V., Penny, A. and Jenkinson, D.S. (1989) Uptake of Foliar-Applied Urea by Winter Wheat (*Triticum aestivum*): the Influence of Application Time and the Use of a New 15N Technique. *Journal of the Science of Food and Agriculture*, **48**, 429-440. https://doi.org/10.1002/jsfa.2740480405

[10] Woolfolk, C.W., Raun, W.R., Johnson, G.V., Thomason, W.E., Mullen, R.W., Wynn, K.J. and Freeman, K.W. (2002) Influence of Late-Season Foliar Nitrogen Applications on Yield and Grain Nitrogen in Winter Wheat. *Agronomy Journal*, **94**, 429-434. https://doi.org/10.2134/agronj2002.4290