2019

Application of a Formulated Humic Product Can Increase Soybean Yield

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Abstract

Application of humic products to crops remains controversial. We conducted a field study in Iowa over four environments from 2012 to 2014 examining productivity of soybean [*Glycine max* (L.) Merr.] receiving foliar application of a humic product at one of four application times based on plant development. Humic product application never influenced soybean height at harvest. Soybean yield increased following application of the humic product in two of four environments, but application timing was not completely consistent between these two environments. In one 2012 environment, humic product application at V2, V6, and R2 resulted in greater yield than the untreated control. In the other 2012 environment, application of the humic product at V2 resulted in improved yield over the untreated control. Application of the humic product never influenced seed oil concentration; however, seed protein concentration was decreased following application of humic product at V2 and R2 in a single 2012 environment. Use of the formulated product influenced returns from –\$81 acre^{-1} to +\$171 acre^{-1}, depending on the environment. The environments where humic product application positively influenced yield and seed quality had greater rainfall deficits and air temperatures above the long-term average.

Published August 29, 2019

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Abstract

Application of humic products to crops remains controversial. We conducted a field study in Iowa over four environments from 2012 to 2014 examining productivity of soybean [*Glycine max* (L.) Merr.] receiving foliar application of a humic product at one of four application times based on plant development. Humic product application never influenced soybean height at harvest. Soybean yield increased following application of the humic product in two of four environments, but application timing was not completely consistent between these two environments. In one 2012 environment, humic product application at V2, V6, and R2 resulted in greater yield than the untreated control. In the other 2012 environment, application of the humic product at V2 resulted in improved yield over the untreated control. Application of the humic product never influenced seed oil concentration; however, seed protein concentration was decreased following application of humic product at V2 and R2 in a single 2012 environment. Use of the formulated product influenced returns from –$81 acre^{-1} to +$171 acre^{-1}, depending on the environment. The environments where humic product application positively influenced yield and seed quality had greater rainfall deficits and air temperatures above the long-term average.

Humic acid products are widely available commercially for application to soils and crops. Burdick (1965) stated that humate content of soil should be maintained for optimum crop and garden productivity. As soil organic matter decreases, application of humic acids may improve depleted soil quality and perhaps improve crop productivity. The use of humic products in agricultural systems has been controversial, in part, because their application has produced a wide range of results for crop yield and quality. An older review suggested that cereals were, in general, more responsive to humic acid application than were grain legumes or oilseed crops (Khristeva and Manoilova, 1950; Khristeva, 1953). Following a review and meta-analysis, Rose et al. (2014) concluded that application of humic substances increased shoot dry weights by 22%, but responses were highly variable. Halpern et al. (2015) and Canellas et al. (2015b) reviewed humic substances, citing numerous examples where yield and quality of horticultural crops were improved. In another recent review, Lyons and Genc (2016) concluded that commercial humates were closer to "smoke and mirrors… than real substance." Olk et al. (2018) noted the abundance of studies under controlled conditions showing favorable plant responses to commercial humic products but also the dearth of corresponding

Crop Management

Core Ideas

- Formulated humic acid product containing humic and fulvic acid plus N, P, and K application to soybean at V2 and R2 improved yield in two of four environments.
- Formulated humic acid product application did not influence seed oil concentration.
- Seed protein concentration decreased following formulated humic acid product application in one of four environments.
- Soybean yield can increase following formulated humic acid product application in some stress environments.

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Received 9 July 2018.
Accepted 27 June 2019.

Conversions: For unit conversions relevant to this article, see Table A.

Crop Forage Turfgrass Manage.
5:180053. doi:10.2134/cftm2018.07.0053

Table A. Useful conversions.

To convert Column 1 to Column 2, multiply by	Column 1 Suggested Unit	Column 2 SI Unit
28.4	ounce (avdp), oz	gram, g
0.405	acre	hectare, ha
67.25	60-lb bushel per acre, bu/acre	kilogram per hectare, kg/ha
1.12	pound per acre, lb/acre	kilogram per hectare, kg/ha
1	ppm, ppm	milligram per kilogram, mg/kg
2.54	inch	centimeter, cm

field studies. The authors emphasized this discrepancy, noting that humic products often improve crop economic yield through alleviation of environmental stresses, which can be limited or absent under controlled conditions.

Numerous crops had greater yield following applications of humic products, including alfalfa (*Medicago sativa* L.) and corn (*Zea mays* L.) (Olk et al., 2013; Canellas et al., 2015a), cucumber (*Cucumis sativus* L.) (Sure et al., 2012), custard apple (*Annona squamosa* L.) (Cunha et al., 2015), wheat (*Triticum aestivum* L.) (Turgay et al., 2011), mung bean [*Vigna radiata* (L.) Wilczek] (Waqas et al., 2014), soybean [*Glycine max* (L.) Merr.], peanut (*Arachis hypogaea* L.), and arrowleaf clover (*Trifolium vesiculosum* Savi) (Tan and Tantiwiramanond, 1983). Conversely, a wide range of crops had little or no response in productivity following application of humic acids, including corn (Albuquerque et al., 2015), dry bean (*Phaseolus vulgaris* L.) (Soltani et al., 2015; Mahoney et al., 2017), tomato (*Lycopersicon esculentum* Mill.) and lettuce (*Lactuca sativa* L.) (Hartz and Bottoms, 2010), perennial ryegrass (*Lolium perenne* L.) (Little et al., 2014; Nikbakht et al., 2014), onion (*Allium cepa* L.) (Feibert et al., 2003), and alfalfa (Little et al., 2014).

Specific molecular mechanisms and biochemical pathways upregulated by humic substances are unknown, but certain effects are reported from multiple plant species. Humic product application increased root growth in tobacco (*Nicotiana tabacum* L.) (Mylonas and McCants, 1980) and wheat (*Triticum aestivum* L.) (Malik and Azam, 1985). Several reports propose that humic substances influence hormonal transduction and have auxin-like activity (Trevisan et al., 2010; Mora et al., 2014). Few reports are available on the influence of humic product application on soybean productivity and quality. Consequently, we conducted a field study with the objectives of determining the influence of foliar application of a commercial humic product on soybean at four developmental stages on yield and seed quality of soybean.

Experiment Locations and Site Descriptions

The experimental sites were located on Iowa State University research farms near Boone (42° 01′ N 93° 45′ W) in 2012 and 2014, Chariton (40° 59′ N 93° 25′ W) in 2012, and Ames (42° 00′ N 93° 67′ W) in 2013. Each farm is equipped with an automated recording weather station, and long-term weather data are available for each site (Iowa Environmental Mesonet, 2018). The research site near Boone in 2012 was located on Nicollet clay loam soil (fine-loamy, mixed, superactive, mesic Aquic Hapludolls); sites near Ames in 2013 and Boone in 2014 were located on Clarion loam soil (fine-loamy, mixed, superactive, mesic Typic Hapludolls); the Chariton site was located on Haig silt loam (fine, smectitic, mesic Vertic Argiaquolls). The previous crop was maize at all sites. Following harvest of maize, each site was tilled with a tandem disk. The subsequent spring, preplant tillage was done with two passes with a field cultivator for seedbed preparation, except Chariton was planted without spring tillage. Prior to spring tillage, soils were sampled at 0- to 6- and 6 to 12-inch depths. The available (Mehlich-3) P and K concentrations were suitable for soybean production (Table 1), so P and K fertilizer applications were not required (Sawyer et al., 2002; Mallarino et al., 2013). Additionally, soil pH was appropriate for soybean

Table 1. Preplant soil nutrient status at two depths for four environments, 2012–2014.

Environment	Depth (inches)	Mehlich3-P	Mehlich3-K	NO_3–N	pH	OM
		ppm				%
Boone 2012	0–6	76	297	7	6.7	5.2
	6–12	47	189	8	6.6	4.4
Chariton 2012	0–6	16	160	4	6.2	3.3
	6–12	8	183	1	6.3	2.1
Ames 2013	0–6	20	158	6	6.8	3.3
	6–12	6	125	4	7.1	3.5
Boone 2014	0–6	58	206	6	5.6	3.0
	6–12	27	119	3	5.9	2.6

production in all environments except for Boone 2014,where it was lower than preferred (Table 1).

Experimental Design and Treatments

The experimental design was a randomized complete block of five treatments with four replicates conducted in four environments. Environments were the four site-years previously described. Treatments were foliar application of a formulated humic product applied at 3.0 pt acre^{-1} at four growth stages of soybean and an untreated control. The humic product was Yield Igniter (Innovative Crop Solutions, Radcliffe, IA), which is derived as a liquid extract from leonardite and includes N, P, and K. Nutrient concentrations for this product are presented (Table 2) as per recommendations by Lamar et al. (2014). As formulated, Yield Igniter applications included urea-N, P_2O_5, and K_2O at 0.164, 0.164, and 0.055 lb acre^{-1}, respectively; however, soil fertility at the research sites was adequate for soybean production, and these application levels should not have impacted yield. In 2012, the humic product was applied at each of four growth stages: V2 (second unrolled trifoliolate leaf), V4 (fourth unrolled trifoliolate leaf), V6 (sixth unrolled trifoliolate leaf), and R2, full bloom (plants have an open flower immediately below the uppermost node) (Wright and Lenssen, 2013). In 2013 and 2014, applications were made at V2, V4, R1 (beginning bloom when plants have at least one open flower at any node), or R2 because plants with six leaves had one open bloom per plant. Soybean cultivar P92M54, relative maturity 2.5 (DuPont Pioneer, Johnston IA), was used at both sites in 2012 while soybean cultivar P92M40, relative maturity 2.4 (DuPont Pioneer, Johnston, IA), was used in 2013 and 2014. Seed of both entries was treated with a combination of mefenoxam and fludioxonil (ApronMaxx, Syngenta, Greensboro, NC) prior to purchase. Individual plot size was 10 ft wide and 25 ft long. Plots were planted with a four-row Kinze 3000 no-till planter (Kinze, Williamsburg, IA) at 1.5-inch depth on 2.5-ft row spacing at 140,000 seed acre^{-1}. Planting dates were 14 May 2012 for Boone, 17 May 2012 for Chariton, 13 June 2013 at Ames, and 6 June 2014 at Boone.

Table 2. Nutrient concentrations in Yield Igniter.

Component	Concentration (%)
Urea ammonium nitrate	9.0
P_20_5	9.0
K_20	3.0
Humic acid	1.21
Fulvic acid	0.78

Site Management and Data Collection

Weed management was performed with one or two postemergence applications of glyphosate [N-(phosphonomethyl) glycine] at 0.65 lb a.e. acre^{-1} with the addition of ammonium sulfate at 3 lb acre^{-1} in 20 gal acre^{-1} water. The 2013 site also received an application of imazamox (2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-(methoxymethyl)-3-puridinecarboxylic acid) at 0.605 oz a.i. acre^{-1} with crop oil concentrate. Weed escapes were controlled by hand hoeing.

Stand density was determined by counting all soybean plants in 17.5 ft of row at V1 to V2 stage. Soybean height was measured on five plants per plot at R7 to R8. Harvest dates were 26 Sept. 2012 for Boone, 1 Oct. 2012 for Chariton, 2 Nov. 2013 for Ames, and 8 Oct. 2014 for Boone. Yield was determined by self-propelled combine harvest of the central two rows in each plot. The combine was equipped with an onboard computerized scale. Subsamples were saved from each plot and used for determination of seed protein and oil concentrations by calibrated NIRS (2012: Model 7200, Perten Industries, Springfield, IL; 2013 and 2014: Foss Infratec-1299 Whole Grain Analyzer, Foss North America, Eden Prairie, MN).

The experiment was a randomized complete block design conducted in four environments. The PROC MIXED procedure of SAS v9.2 was used for analysis of all parameters (SAS Institute, Cary, NC). Humic acid product application and environment were considered fixed effects; replicate and

Table 3. Mean monthly and long-term† precipitation and temperature for four environments in Iowa.

	Boone 2012	Boone 2014	Boone long-term	Chariton 2012	Chariton long-term	Ames 2013	Ames long-term
Precipitation, inches							
April	3.27	4.76	3.62	4.29	3.62	5.83	3.59
May	1.93	4.25	4.61	3.19	4.57	7.09	4.51
June	2.17	8.86	5.24	2.87	4.96	1.02	5.02
July	1.42	2.87	4.33	0.51	4.45	1.02	4.08
August	1.65	5.83	4.33	2.95	4.13	1.18	4.32
September	1.54	5.43	3.19	0.47	4.06	1.18	3.18
April-September	11.98	32.00	25.32	14.28	25.79	17.32	24.71
Temperature, °F							
April	53.6	48.0	48.2	55.4	51.8	46.4	50.1
May	66.2	62.6	60.8	66.2	60.8	60.8	61.3
June	71.6	71.8	69.8	73.4	69.8	69.8	70.4
July	78.8	69.0	73.4	80.6	75.2	73.4	74.1
August	71.6	71.6	71.6	73.4	73.4	73.0	71.8
September	64.4	62.6	62.6	66.2	64.4	67.0	64.0

† Long-term = 1951–2012.

Table 4. Effect of a humic acid product applied at four developmental stages on height, seed yield, and seed protein and oil concentrations and yields of soybean in four environments.

Application time	Application	Stand	Height	Yield	Protein	Oil
	day of the year	no. acre^{-1}	inch	lb acre^{-1}	——%	——
Boone 2012						
V2	163	112590	35	4257 ab	36.5	17.9
V4	176	116640	36	4045 bc	36.6	17.7
V6	183	111375	37	4532 a	36.6	17.7
R2	191	116640	35	4307 ab	36.3	17.7
Untreated control	–	109775	34	3775 c	36.3	17.9
P > F						
Application timing		0.971	0.193	0.043	0.262	0.616
Chariton 2012						
V2	163	93555	31	2773 a	33.4 b	19.6
V4	176	104085	32	2412 b	34.0 ab	19.5
V6	183	90720	30	2436 b	33.9 ab	19.3
R2	191	100035	30	2651 ab	33.3 b	19.6
Untreated control	–	105300	28	2513 b	34.4 a	19.3
P > F						
Application timing		0.311	0.324	0.063†	0.043	0.203
Ames 2013						
V2	–	107730 b	–	2965	35.5	20.1
V4	188	111375 b	–	3016	35.9	20.0
R1	–	127575 a	–	2990	35.7	20.2
R2	–	108540 b	–	2913	35.9	20.1
Untreated control	–	118855 ab	–	3219	35.5	20.1
P > F						
Application timing		0.026	–	0.947	0.456	0.873
Boone 2014						
V2	184	116235	31	2994	36.2	18.3
V4	190	111375	31	2953	35.7	18.5
R1	198	116640	33	3194	35.8	18.3
R2	204	114615	32	2890	35.8	18.3
Untreated control	–	111375	32	3115	35.8	18.4
P > F						
Application timing		0.701	0.181	0.522	0.604	0.625

† $P = 0.063$ considered significant.

interactions with replicate were considered random effects. Mean separations were done with the PDIFF procedure when *F* tests were significant for humic product application. The 0.05 significance level was used for *F* tests and mean separations, unless otherwise noted.

Weather Conditions

Growing season (April-September) precipitation was 47 and 55% of the long-term mean at Boone and Chariton in 2012, respectively (Table 3). Additionally, mean daily temperature was warmer than long-term normal at Boone and Chariton in 2012 for April through July. Visual observations were that soybean was stressed by these conditions in both environments. Precipitation at Ames in 2013 was 70% of long-term normal despite April through May precipitation being 60% greater than long-term average for this period (Table 3). However, monthly mean temperatures were similar to long-term values for this environment, and visual observations did not indicate soybean was stressed. Monthly precipitation at Boone in 2014 was similar to, or above, long-term monthly precipitation, except for July when soybean received 1.46 inches less rainfall than long-term normal. The 3.5 inches greater-than-normal precipitation received in June likely provided adequate soil water content to preclude moisture stress in that singular drier month. The air temperature in July 2014 at Boone was 4.4°F below the long-term average, and soybean plants did not appear to be under any stress in this environment.

Plant Stand Density and Height

The application of the humic product did not influence soybean stand density in either of the 2012 environments or in 2014 (Table 4). In the 2013 environment, stand density for soybean receiving humic acid at the R1 stage was greater than for soybeans treated at the V2, V4, and R2 stages. Since stand densities were determined prior to the application of the humic product, we are not certain how or why this occurred. As documented in numerous studies, soybean exhibits little yield response over a comparatively broad range of stand densities (De Bruin and Pedersen, 2008; Elmore, 1991; Weber et al., 1966). Plant height at maturity was not influenced by humic product application in the three environments where measured (Table 4).

Soybean Seed Yield and Quality

Formulated humic product application influenced soybean seed yield in two of four environments (Table 4). Soybean receiving humic product at V2, V6, and R2 had greater yield than the untreated control in the Boone 2012 environment. Soybean treated at V6 had a 20% greater yield than the untreated control. Soybean yield between treatments in the Chariton 2012 environment did not differ at the $P = 0.05$ level, but soybean receiving humic product application at V2 had greater yield ($P = 0.063$) compared with humic product application at V4, V6, and the untreated control, and we consider this significant. Conversely, formulated humic product application did not influence yield of soybean in the Ames 2013 and Boone 2014 environments (Table 4).

Protein concentration of seed was influenced by humic product application in one of four environments (Table 4). In Chariton 2012, seed from the untreated control had greater protein concentration than seed from plants treated with humic product at the V2 and V6 growth stages. Humic product application to soybean did not influence seed oil concentration in any environment (Table 4).

Yield increase alone should not be the only determinant when considering application of a formulated humic acid product to soybean or other crops. The influence of such application(s) should provide return on the investment. The average cost per acre for a spray application in Iowa was \$6.35 acre^{-1} in 2012 (Edwards, 2012) and \$6.65 and \$6.90 acre^{-1} in 2013 and 2014, respectively (Edwards and Johanns, 2014). The average price received for soybeans in October was \$14.94, \$12.42, and \$9.03 per bushel, respectively, for 2012, 2013, and 2014 (Iowa Department of Agriculture, 2018). The retail cost of the formulated product, without any dealer discounts, was \$11.15 acre^{-1} for the 3 pt application rate recommended and used in this study. For 2012 at Boone, the average yield with the formulated humic product from the treatments that were significantly greater than the untreated control was 8.8 bu acre^{-1}, providing an additional \$136 acre^{-1}. The economically best application time, V6, provided an additional 12.6 bu acre^{-1}, or \$171 acre^{-1}; conversely, application at V4, the only timing not different from the untreated control, only provided an additional \$ 56 acre^{-1}. For 2012 at Chariton, yield following the V2 application of the formulated humic product treatment provided \$47 acre^{-1} greater income than the untreated control. Conversely, in 2013, the lowest-yielding formulated humic product treatment yielded 5.1 bu acre^{-1} less than the untreated control, resulting in \$81 acre^{-1} decreased income. Likewise, in 2014, the lowest-yielding formulated humic product application resulted in 3.8 fewer bu acre^{-1}, with the loss of \$43 acre^{-1}. Application of a formulated humic acid product to soybean may provide a substantial increase in yield and income in some seasons but can lead to decreased income in others.

Conclusions

Humic product application to soybean increased seed yield and income in one of four environments regardless of application time and with application at V2 in another environment. Both environments experienced some drought stress or elevated temperatures. This is consistent with the hypothesis by Olk et al. (2018) and others that favorable crop yield responses to humic products largely result from alleviation of environmental stresses. However, additional research under more environments is necessary to confirm this hypothesis.

Acknowledgments

The authors gratefully acknowledge James Lee and Roger Hintz for excellent technical support for this study.

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