8 Yields of potato and alternative crops impacted by humic product application

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Abstract Humic substances (HS—humic acid, fulvic acid, and humin) are a family of organic molecules made up of long carbon chains and numerous active functional groups, such as phenols and other aromatics. Humic substances play dynamic roles in soil physical, chemical, and biological functions essential to soil health and plant growth. This chapter reviews field trials conducted in the Western and Midwestern USA on the effects of application of commercial humic products on yields of potato and several other crops. Examination of these studies reveals that potato growth is more responsive to P fertilization and minimal soil fertility, but less responsive to N fertilization. Whereas some observations were not always consistent, the different soil properties and qualities of humic products from different supplies might have attributed to the inconsistencies. Thus, it is recommended that commercially available humic products be tested locally to determine benefits on potato and other crop production. . Research on the impact of long-term humic application on potato production is especially needed, as little such information is currently available in the scientific literature for U.S. potato producing regions.

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8.1 Introduction

Organic matter undergoes a biological degradation process termed “humification” by a community of soil macro- and microorganisms, where it is broken down and recycled for use as energy and substrate for cellular metabolism (Chen and Aviad 1990). Humic substances (HS) are the products of the humification process of plant and animal residues in various stages of decomposition and are found in soil and geologic deposits, including, peat, lignite, and leonardite.

As the major constituents of soil organic matter (SOM), HS can be divided into three major fractions, humic acid (HA), fulvic acid (FA) and humin, based on their solubility in acid and alkali (Tan 2003). HS are recognized as the most chemically active compounds in soils, with cation and anion exchange capacities that far exceed those of clays (Stevenson 1982). Their properties of chelation, mineralization, buffer effect, clay-mineral organic interaction, and cation and ion exchange capacities profoundly influence soil physical, chemical and biological functions essential to soil health and plant growth (Stevenson 1982). Humic acid from lignite is a ready source for carbon and N for both plants and the microbial community. Ubiquitous in the environment, HS are an integral part of all ecosystems, and play an important role in the global cycling of nutrients and carbon (MacCarthy et al. 1990).

Because of their ability to aid in the formation of soil aggregates, HA can increase soil water holding capacity, reduce crusting, and improve tilth. HS support the biological activities of soil macro- and microorganisms, and serve as an adsorption and retention complex for inorganic plant nutrients. The positive effect of HS on plant growth is documented under laboratory and greenhouse conditions (Visser 1986; Chen and Aviad 1990). Whereas Chen and Aviad (1990) reported positive results from lab and greenhouse studies, they concluded that humic products cannot have any effect on crop growth in field conditions at the low application rates recommended by industry. Several authors (Nardi et al. 2002; Tan 2003) have demonstrated that the addition of HS in appropriate concentrations can stimulate root growth and enhance efficiency of the root system. Other claimed benefits of HS include increased N uptake by plants, which serves to increase soil N utilization efficiency and can enhance the uptake of K, Ca, Mg, and P, and improve availability of nutrient and trace mineral uptake to plants.

Over the last half century, several research groups have conducted applied field trials in the western U.S. to evaluate the impact of applications of different commercial humic products on yield and quality of potato and alternative crops. This chapter reviews some of these research findings. Summarization of these

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findings suggests that nutrient and health statuses of soil are critical factors for achieving positive results of humic product application on yield of potato and other crops.

8.2 Effects of humic product application on potato yield

8.2.1 Effects of humic product addition with variable N fertilization

Early studies of humic product effects were focused on whether the addition of humic products to a fertilizer might be beneficial for potato production (Kunkel and Holstad 1968; Lorenz et al. 1974). The humic product was from "Aqua Humus", a leonardite ore from which the insoluble fractions were removed. It contained ~60% humic and fulvic acid derivatives. It was a dark brown to black hydrophilic colloid with a very high base exchange capacity. In addition to the inherent organic constituents, the "Aqua Humus" was sometimes enriched with inorganic N, P, and K.

Kunkel and Holstad (1968) tested the effects of humic product application on the yield and quality of Russet Burbank potatoes grown in neutral (pH 7) Columbia soils. The experiments were conducted in 1963 and 1964 on a coarse silt loam with a moderate to slow water infiltration rate and an organic matter content of ~1%. Kunkel and Holstad (1968) mixed the humic product at 200 lb acre^{-1} (i. e. 224 kg ha^{-1}) with acid (pH 5.4, 16-16-16) and base (pH 8, solid 15-15-15, liquid 12-12-12) NPK fertilizers. These mixtures were applied in bands at planting time at different rates to provide 80-500 lb N acre^{-1} (i. e. 90-560 kg N ha^{-1}). In addition, humic product was also applied at 100 and 300 lb acre^{-1} with each solid base fertilizer rate to further test the impact of product application. These experiments show that potato yields continued to increase, but at a decreasing rate from the lowest to the highest rate of fertilizer applied. Addition of humic product to the acid fertilizer and solid base fertilizer did not change either total yield or yield of No. 1 grade potatoes. For example, the average yield for 16 plots with humic product addition was 59.8 Mg ha^{-1} whereas the average yield of those receiving the same fertilizer without humic product was 59.2 Mg ha^{-1}. When the dry base fertilizers were used at the equivalent rate, the yields were roughly 7% lower than that for acid fertilizer. On the other hand, the addition of humic product to the base liquid fertilizer significantly increased the potato yield at all five fertilizer rates tested. When humic product was applied, potato yield was roughly 21% higher, than plots that received only liquid base fertilizer. The authors (Kunkel and Holstad 1968) hypothesized that the high base exchange capacity of the organic colloidal humate might have reduced a salt effect early in the growing season, and concluded that the interaction between humate and forms of fertilizer was highly significant.

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Kunkel and Holstad (1968) also found that, in some cases, humic product mixed with fertilizer increased the levels of several elements (e g. N, P. K, Mg, and Mo) in the petiole. Under conditions where these nutrients are marginal, humic product addition could increase potato production; however, they proposed that similar results could be achieved with adequate fertilization without humate addition.

Lorenz et al. (1974) conducted similar field experiments for furrow-irrigated White Rose or Kennebecs potatoes grown in fine sandy loam soils in three counties of California. These soils were light to medium textured, alkaline calcareous, with pH values about 7.6. They used the same "Aqua Humus" product as Kunkel and Holstad (1968), and evaluated the addition of the humic product to N-containing fertilizer in five experiments. Fertilizer with or without humic product was applied in bands (3 inches to each side and 2 inches below the seed) at time of planting. Comparisons were made with $(NH_4)_2SO_4$, fertilizer 16-20-0, and urea at two rates (Fig. 8.1). The results show that the addition of humate had no significant effect on yield-either positive or negative. Therefore, they suggested that this humic product did not improve fertilizer N uptake efficiency.

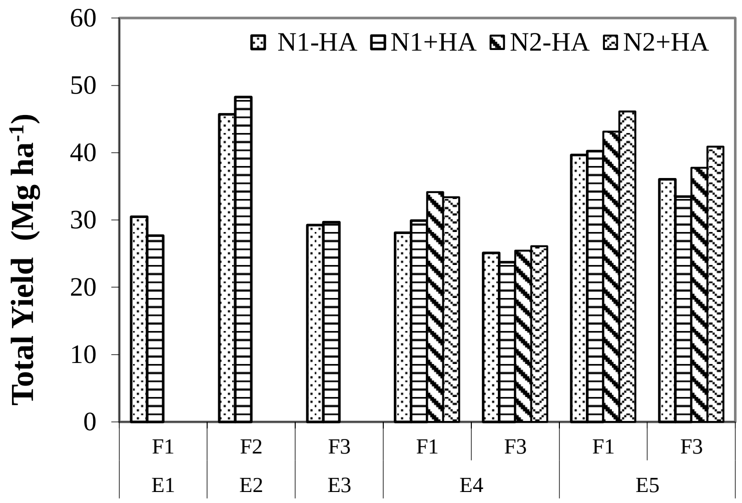

Fig. 8.1 Effects of "Aqua Humus" humate product on potato yield tested in California in 1960's. Refer to Lorenz et al. (1974) for details of the five experiments E1 to E5. F1, $(NH_4)_2SO_4$; F2, fertilizer 16-20-0; F3, urea. Fertilizer was applied at 134 (N1) and 269 (N2) kg N ha^{-1} with (+HA) or without (-HA) humic product.

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8.2.2 *Effects of humate addition on P availability*

Precipitation of Ca phosphates negatively affects plant availability of P fertilizer applied to calcareous soils. Delgado et al. (2002) investigated availability improvement of applied P fertilizer from soils by a commercial liquid mixture of humic and fulvic acids (Solfer húmicos, Valencia, Spain). In this study, the mixture of HA and FA was applied to calcareous soils, with different levels of salinity and Na^+ saturation, which were fertilized with 200 and 2000 mg P kg^{-1} as $NH_4H_2PO_4$. Recovery was measured as the ratio of Olsen P-to-applied P after 30, 60 and 150 days. Their laboratory work (Delgado et al. 2002) indicated that application of the HA-FA mixture increased the amount of applied P that was recovered as Olsen P in all the soils, with the exception in one soil with the highest Na saturation. This observation implies the potential of humic product application in increasing crop production in soils where the low levels of available P are a limiting factor for crop production.

In a three-year (2000-2002) study at the University of Idaho, Hopkins and Stark (2003) evaluated the effect of three rates of P (0, 60, and 120 lbs P_2O_5 $acre^{-1}$, i. e. 0, 29.4 and 58.7 kg ha^{-1}) applied in the mark-out band with and without humic product at a 10:1 v/v ratio. The field site was located at the University of Idaho Aberdeen R&E Center. The soil was a Declo sandy loam, calcareous (4 to 9% free lime), with pH ranging from 8.0 to 8.2. With medium soil test P levels (15 to19 ppm) and low organic matter levels (1.1 to 1.3%), the properties of the soils used in this study were typical of potato producing regions in Idaho. The humic product was Quantum H (Horizon Ag). Seed pieces of Russet Burbank potatoes were planted with 12-inch spacing, and the 10-34-0 fertilizer, with and without added humic product, was applied in the mark-out band three inches to the side of the seed piece.

With the results from this experiment, Hopkins and Stark (2003) demonstrated that addition of humic product to the fertilizer band tended to increase total yield at both the high and the low P levels (Table 8.1). Similarly, U.S. No.1 yields generally increased as P was added at both rates, with a tendency for further yield increases occurring when the humic product was included in the fertilizer band. The primary effect of P and humic product treatment on U.S. No. 1 tuber yields was an increase in tuber size. In particular, yields of U.S. No. 1 tubers greater than 10 ounces increased in 2001 and 2002 with the application of P in combination with the humic product. Addition of P with the product also increased specific gravity in one of the three years of the study, compared with the untreated control, but the combined data suggested the general effects on specific gravity were negligible (Table 8.1). Addition of the humic product resulted in further increases (an average of 0.03%) in petiole P concentrations to levels greater than the marginal range in all three years at both rates. The authors proposed that the increases in petiole P were at least partially responsible for the increased tuber yield and size observed in their study.

Hopkins and Stark (2003) calculated that addition of humic product would increase gross revenue an average of \$248 ha^{-1} due to the tuber yield and quality increases. As average costs of humic product application were approximately \$25-50 ha^{-1}, application of the product to calcareous, low organic matter soil shows potential as a profitable management tool. However, Hopkins and Stark (2003) cautioned that growers wishing to apply humic acid amendments should work with reputable companies that can provide a consistent material with documented, non-biased data showing their product to work under local growing conditions. Furthermore, it is reasonable to assume that the effect of a humic product applied at relatively low rates is more effective if applied in a concentrated band. Although positive results were found for banded application of humic product with P fertilizer on potatoes grown on low organic matter, calcareous soil; the potential benefits of humic products with other soil types, crops, and fertilizer/amendment placements should be evaluated before expecting satisfactory results (Hopkins and Ellsworth 2005).

8.2.3 Effects of humate application under minimal soil fertility conditions on potato yield and quality

In fields with minimal soil fertility, according to the University of Idaho Fertility Guide, Seyedbagheri (2010) conducted experiments at Saylor Creek and Mountain Home, ID, to evaluate the effects of different rates of humic product application on potato yield and quality. Climatic conditions were similar in the two areas, as both sites are semi-arid, with an annual rainfall of 152.4-203.2 mm. The soil in these fields was calcareous (5-7% free lime) pH was 8.0-8.2, and organic matter content was 0.9-1.0%. In these experiments, Russet Burbank seed pieces were planted by hand, spaced 25.4 cm apart. Each individual plot was 3.65-m wide and 7.6-m long and included four rows. The humic product used at the Saylor Creek fields had 6% HA by weight and was from Bio-Tech Company. At Mountain Home, granular humate (Agri-Plus) and liquid HA (Quantum-H) were applied. Liquid humic products were side-dressed, and granular humic product was top-dressed.

Fig. 8.2 summarizes the effects of product application rates on potato yield at three farmers' fields at Saylor Creek, ID. These data are the average yields of three experimental fields. Evaluation of stand and vigor showed that plots treated with humic product rated very high (8 out of 10) in comparison with control plots (5 out of 10) (Seyedbagheri 2010). The Russet Burbank tuber yield increased from 37.6 to 43.1 T ha^{-1} (i.e. Mg ha^{-1}) from the control to product application at

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the rate of 37 L ha^{-1}. Yield declined when the application rate applied exceeded 75 L ha^{-1}. The non linear relationship implies the mechanism of humic product impact is quite complicated.

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Table 8.1 Effect of P fertilizer with and without humic product on potato yield, specific gravity, petiole phosphorus

P_2O_5 (kg· ha^{-1})	Humic product (L· ha^{-1})	Total tuber yield (Mg ha^{-1})	Yield US No 1tubers (Mg ha^{-1})	Yield tubers >283 g (Mg ha^{-1})	Specific gravity (g cm^{-3})	Petiole P (% dwt)	Gross return (US$ ha^{-1})
0	0	44.23	25.26	16.39	1.077	0.24	4523
67.36	0	48.39	29.19	19.87	1.079	0.29	5110
67.36	14	49.85	31.32	20.88	1.080	0.31	5390
134.7	0	49.17	29.3	20.10	1.079	0.30	5187
134.7	28	50.07	31.21	21.67	1.079	0.32	5402
LSD (1%)		5.39	3.71	2.58	0.003	0.03	

and gross return. Combined (average) three years' data adapted from Hopkins and Stark (2003).

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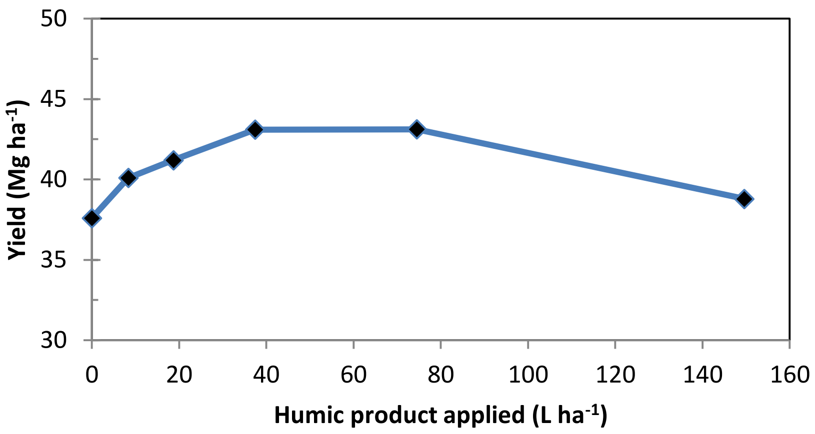

Fig. 8.2 Average potato yield affected by humate application at 3 sites in the Saylor Creek, ID experiment. Adapted from Seyedbagheri (2010).

Moreover, this observation is in contrast with the early observation reviewed in section 8.2.1. The difference is, in this experiment, humate product was applied under minimal soil fertility. Moreover, the positive impacts of HA application observed in this study are consistent with studies under controlled conditions on HA application and plant growth (Chen 1986; Chen and Aviad 1990; MacCarthy and IHSS 1990). In this study the product performed better in poor soil with high Ca (3500 to 5000 ppm, i. e. 5-7% free lime) than in more fertile soil (data not shown). The humic product used in this study seemed to enhance fertilizer use efficiency by increasing P, K, Zn and Fe uptake by the plants (Delgado et al. 2002). On the other hand, the HA could have had effects directly on the plant, not on soil nutrients. More research is needed to elucidate the mechanism of the humic product's role.

In the Mountain Home experiment, the potatoes were harvested and graded by weight (Table 8.2). Data in the table show that there was no statistical significant difference in potato tuber yield between control and humic product treatments. However, it is important to note that in the year following this study, the grower planted small grains in the same field. The area in the experimental plot that had been treated with the humic product showed a major yield difference (data not shown), which indicates that long-term field trials are also needed for evaluating the effects of humic products on plant growth.

Table 8.2 Effect of humic products on tuber yield (Mg ha^{-1}) in field trials conducted at Mountain Home, ID (Seyedbagheri 2010).

Treatments	Tuber size (g)					
	0-113.4	113.4-220.8	226.8-340.2	>340.2	Culls	Total
#1: Control	10.2 a [1]	17.9 a	8.2 a	5.0 a	3.4 a	44.6 a
#2: Granular Humate Only (Agri-Plus)	10.7 a	16.7 a	8.4 a	5.5 a	2.8 a	45.1 a
#3: Granular Humate (Agri-Plus) + 46.5 L ha^{-1} Liquid Humic Acid (Quantum-H)	11.5 a	16.7 a	7.0 a	5.0 a	4.5 a	44.7 a
#4: Granular Humate (Agri-Plus) + 93.0 L ha^{-1} Liquid Humic Acid (Quantum-H)	11.0 a	15.3 a	6.4 a	4.2 a	4.6 a	41.5 a

[1] Means followed the same letter in the same column are not significantly different at the 0.05 level (Neuman-Keul test)

8.3 Effects of humic product application on yields of alternative crops

Crop rotation is a sustainable cropping management practice for potato production (refer to Chapter 2-7). Therefore, in this section, we present some data on several other crops for general information. Similar to the potato studies, the effects of humic product application on the yields of other crops are not always consistent. In Montana, Jones et al. (2007) conducted a greenhouse study to determine the effects of a low, commercially recommended rate of HA on P, Fe, and Zn availability and spring wheat yields, in both a calcareous soil and a noncalcareous soil. Their greenhouse results suggest that low commercial HA rates (∼1.7 kg humate ha^{-1}) may be insufficient to enhance spring wheat growth, as no significant differences were found in nutrient uptake, shoot biomass, or grain yield between humate and control treatments. On the other hand, Belgium scientists Verlinden et al. (2009) show that application of a liquid mixture of HA and FA (Commercial name Humifirst) resulted in consistent increases in crop yield and nutrient uptake. These crops included grass, maize, and spinach, in addition to potato. The observed effects were largest for the potato field, followed by the grasslands and were smallest for the maize fields.

A liquid humic product (Innovative Crop Solutions) is currently being evaluated in dryland maize production in Iowa. Test strips of the product were established on maize farms in two years. For 30 farms in the first year (2009), eight representative maize plants were hand-sampled from each test strip and another eight plants were sampled from adjacent, unamended maize. A numeric increase in grain weight was observed in 25 of the 30 farms (Fig. 8.3). If each farm is considered a replicate, this yield increase was highly significant ($P<0.01$). Presuming a planting density of 74,000 plants ha^{-1} on all farms, the mean grain yield increase with product application was 630 kg ha^{-1} (dashed line). On nearly 100 other farms, combine grain yield increased with product application in about 70% of the cases, and the mean increase was about 440 kg ha^{-1}, which was also highly significant (data not shown). Comparable results were obtained in 2010. These grain yield increases provide a several-fold return on the application cost of the product: only 3.5 L ha^{-1} was applied at a cost of about $ 22 ha^{-1}, and the product can be applied as part of routine pesticide applications.

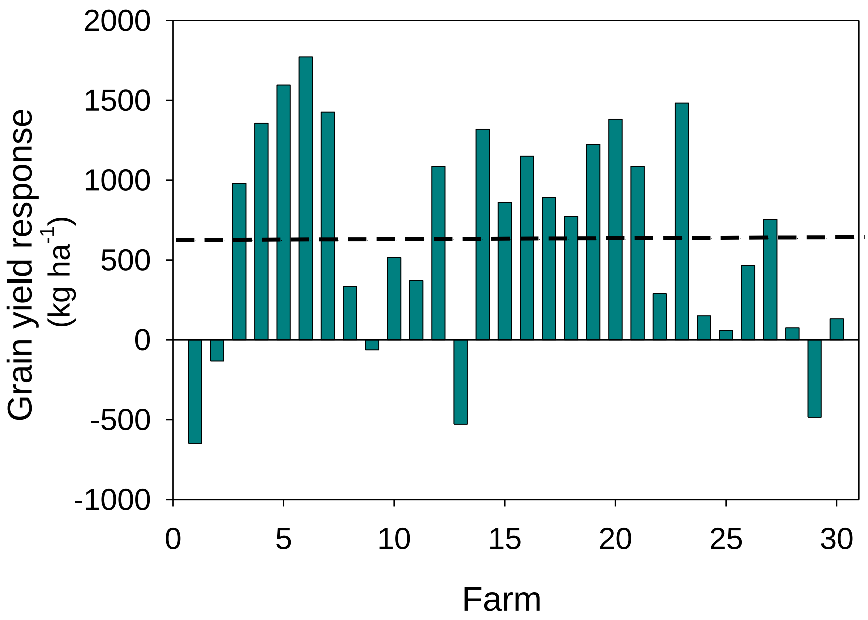

Fig. 8.3 Mean response of maize grain yield to application of a liquid humic product in 30 Iowan farms. Values were based on eight pairs of harvested plants and presume a planting density of 74,000 plants ha^{-1}.

8.4 Conclusion

Relevant applied field trial experiments in the past half century reviewed in this chapter showed inconsistent effects of humic products on the yields of potato and other crops. Whereas some studies showed no significant yield response, findings in others showed some yield increase. Crop response might have been affected by the application rate of humic products and the soil nutrient status. In this limited set of experiments, humic product efficacy seems more responsive to P fertilization than N fertilization, as the humic product could release phosphate bound to Ca. Yet it is difficult to generalize across studies, for the efficacy of humic products would seem to depend on a large number of factors, including solar radiation, weather damage, soil type, crop, yield level, and absence or presence of other yield constraints (disease, pests, weeds, water stress). The absence of any industry-wide standards for producing humic products could also contribute to differences in findings from multiple research groups who used different commercial humic products. None of these potential factors has been systemically evaluated. Currently, the humic product effects were evaluated in the application year with a maximum of 3 continuous years. Research is needed to evaluate the potential of long-term product application for improving soil fertility and quality.

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