Foliar Application of Humic Acids on Strawberry (cv Onda)

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Abstract

In June-bearing strawberries (*Fragaria x ananassa* L.), soil nutrient uptake has two major peaks during fall and spring growth. After the beginning of fruit maturation in late spring, nitrogen moves directly from leaves to fruit and its soil uptake is negligible. As a result, in organic farming, soil nutrients may be sub-optimal and unable to support these short periods of high absorption. The present field trial was undertaken with the cultivar Onda in an organic production system and was designed to improve fruit quality using foliar application of humic acids applied between bloom and fruit harvest. An experimental, dilute mixture of humic and fulvic acids (Zymo) extracted from earthworm humus was compared with a mineral solution containing a similar amount of nitrogen. Foliar applications, performed weekly starting from bloom and until fruit maturity included: 1) control, sprayed eight times with tap water; 2) mineral solution, sprayed eight times; 3) Zymo, sprayed eight times; 4) Zymϙ, sprayed four times (only to the beginning of fruit maturity). Humic acid sprays significantly reduced fruit set and commercial production. Prolonged applications (8 weeks) stimulated higher photosynthetic pigment accumulation and greater photosynthetic efficiency starting from the 5th application at the beginning of fruit harvest. These same physiological parameters decreased two weeks after bloom in the control treatment, four weeks after bloom with the mineral solution treatment, and after five weeks in the humic acid treated plants. Prolonged humic acid application had a positive effect on fruit quality, reducing the number of misshapen and rotten fruits, and increasing the sugar content. These positive effects on fruit quality are likely due to an indirect positive physiological effect of the humic acid foliar applications on the whole plant and may not relate to any curative action.

INTRODUCTION

In the last ten years in Italy, there has been receive increased attention paid to decreasing the rate of mineral fertilisation in order to guarantee higher fruit quality while reducing environmental impact. Integrated fruit production has largely replaced conventional production. In addition, organic farming has been widely introduced is now carried out on approximately 6.5% of the national agricultural land (Nasolini and Quadretti, 2001).

However, in organic farming a number of species may develop nutritional problems, as a result of high nutrient demand during restricted periods of the growth cycle. June bearing strawberries, in particular, have fairly high nutrient requirements (i.e. N = 60 - 70 kg/ha) to sustain an average production of 700-800 g per plant (25-30 t/ha). These requirements may not actually be matched by the average soil fertility and organic fertilization practiced in organic farms, thus negatively affecting production.

June-bearing strawberries show a dynamic nutrient uptake and N partitioning during the annual growth cycle. In the fall, for example, root N content is very high, as root tissues play a significant role in storage and internal cycling of N, which may be remobilised in the spring (Archbold and MacKown 1995). Although N availability in the soil may influence foliar N level, foliar N content of June-bearing cultivars declines markedly throughout the spring, reaching a minimum at harvest (Hunana and Kotze 1990). Fruits and leaves make up a significant and increasing N sink during the growing season and the root N level declines after production begins (Archbold and MacKown

1995). During fruit maturation, N and K move directly from leaves to fruits and soil uptake is negligible (Tagliavini et al, 2000).

The present field experiment aims to study if foliar applications of humic substances in the period between bloom and the end of fruit maturation can improve leaf nutrient availability, therefore sustaining vegetative and reproductive growth and fruit quality.

MATERIALS AND METHODS

The field trial was carried out in a hilly organic farm, with southern exposure, in the Marche Region. The soil was a sandy loam with pH 7.59, organic matter 1.58%, total N 0.53%, available P (as P_2O_5) 32.4 mg/Kg (Olsen's method), exchangeable K (as K_2O) 286.02 mg/Kg (in CH_3COONH_4). Prior to transplanting, the soil was amended with about 60 t/ha of stabilized bovine manure (60% moisture content), ploughed in to 30 cm depth. Two row beds were raised and covered by black polyethylene mulch with a drip irrigation system (Ecodrip type, 8 liter $m^{-1}h^{-1}$). Plant density was 55,000 per ha (0.3 m distance along and between the rows and 1.1 m between beds) and field area was 0.2 ha.

On 23rd July 1999, cold stored "Onda" (sel. "83.52.1" x Marmolada) strawberry plants (*Fragaria x ananassa* L.) were transplanted. "Onda" is a promising June bearing, medium vigour variety, with a moderate sucker growth, medium bloom and a medium-late harvest. Fruits are large with high soluble solids content and low acidity. "Onda"'s best characteristics are the bright colour of the fruit and very low sensitivity to rot (Faedi et al., 1998) and thus the cultivar is suitable for organic farming.

The foliar applications were performed weekly starting from bloom (19th April 2000) and the treatments were: 1) control, tap water sprayed eight times; 2) mineral solution containing 0.0126 g per liter of mineral N (ammonium nitrate) and 2 g per liter of Fruttaflor (a commercial product containing B 3%, Mn 2.5%, Zn 2.5%, Fe 2%) sprayed eight times up to fruit maturity; 3) Zymo at 0.18 g dry weight per liter (0.0126 g per liter of N), an aqueous mixture of humic and fulvic acids extracted from earthworm humus (Table 1), sprayed eight times up to fruit maturity; 4) Zymo, sprayed four times before the beginning of fruit harvest. Foliar applications were performed using a manual pump with care taken to wet all plant leaves. Excess water was prevented from reaching the roots by plastic mulch.

Weekly analysis of chlorophyll a, chlorophyll b, and total carotenoids content was made using a spectrophotometer on acetone extracts. Net photosynthesis rate and transpiration were measured on mature and completely expanded leaves the day after each treatment, using a portable open system photosynthetic meter (ADC-LCA4, UK).

At harvest, qualitative and quantitative analysis of mature fruits was made to evaluate commercial, misshapen, snail-damaged, rotten (*Botrytis*), and fruit size, number and weight. Fruit firmness, juice acidity and soluble solids content (°Brix) were also measured on ten fruits every single harvest date.

Experimental design was a completely randomized block with 3 replications of ten plants each, for a total of 30 plants for each treatment. ANOVA was performed using Statgraphic plus (Manugistics, USA).

RESULTS

Foliar applications had a positive effect on leaf pigment concentration. Chlorophyll a and b concentration was slightly increased starting from the third spray, both with organic and mineral foliar applications (Fig. 1). From then to the end of harvest, pigment concentration dramatically decreased in control plants, and two weeks later also for plants sprayed for four weeks with humic acids or with minerals. Only plants treated with humic acids for eight weeks maintained a high pigment concentration, which increased, toward the end of harvest.

This positive effect of eight humic acid sprays was also confirmed by net photosynthetic rate measurements (Fig. 2). This parameter remained relatively stable during the harvest period but dramatically decreased only at the end of harvest for this treatment. In contrast, for the other treatments, net photosynthesis was reduced to almost half of the initial level starting from one week after the beginning of the harvest period declining to near zero levels at the end of harvest.

Transpiration was uniform for all treatments, never showing significant differences. Therefore considering the ratio between net photosynthesis and transpiration, the eight-week-humic acid treated plants showed higher water use efficiency throughout the harvest period and, in particular, during the last few weeks.

Nevertheless, humic acid applications (both 4 and 8 times) did not stimulate an increase in fruit production. Fruit set was reduced (Fig. 3) and increased average fruit weight for these treatments was not able to compensate for the reduction in fruit set so plant yield was slightly reduced (Fig. 4). However, fruit quality was improved, since the soluble solids content was always higher and acidity lower than in control and mineral sprayed fruits. Therefore the acidity to soluble solids ratio was lower in the treatments with humic acids particularly for plants treated for eight weeks (Fig. 5). Finally, foliar humic acids application reduced misshapen fruit per plant and also incidence of rotten fruits (mainly *Botrytis*, Figure 6). No significant differences were observed for small and snail damaged fruits.

DISCUSSION

Humic acid applications at bloom had a negative effect on plant production. This suggests that early foliar applications may interfere with bloom and fruit set slightly reducing the total number of fruit per plant. It can be argued that mostly tertiary and quaternary flowers failed, decreasing fruit set.

During fruit maturation and at harvest, humic acids stimulated pigment accumulation, resulting in greener leaves with greater photosynthetic efficiency. In this period, because fruits are the strongest sink for carbohydrates and nutrients (Hancock 1999) roots may consequently become less efficient in absorbing mineral nutrients. It can be hypothesised that foliar application of humic acids had mostly positive effects on nutrient availability. This new favourable nutritional status, induced by repeated foliar applications, could be the indirect cause of the improvement of fruit characteristics. As a result, fruit quality was significantly increased and it is worth noting that fruit resistance to rot was also higher.

Moreover, foliar application of humic acids seems to be very promising for late applications to sustain plant vigour during final fruit growth. This strategy may counteract the possibility of plant breakdown, which was found in cultivars with low leaf to fruit ratios (Neri *et al,* 1998). Finally, reduced soil fertilization together with precise foliar applications may prevent excessive leaching of nutrients and pollution.

ACKNOWLEDGMENTS

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Tables

Table 1. Characteristics of Zimo, an experimental aqueous mixture of humic and fulvic acids extracted from earthworm humus

	Total organic matter (%)		Humic and fulvic substances (% of total organic matter on dry basis)	Organic N (%)	Total N (%)	C/N
	on fresh basis	on dry basis				
Zymo	11.5	65.0	55.0	1.20	2.6	25

Figures

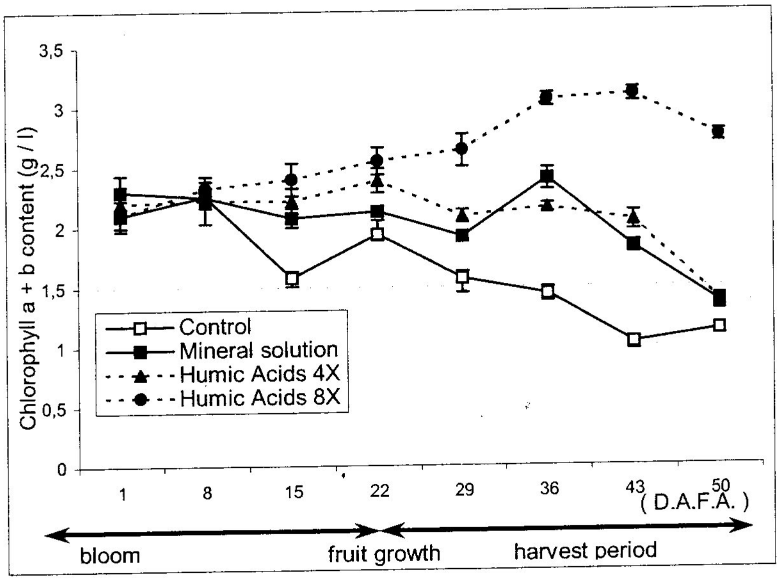

Fig. 1. Total leaf chlorophyll a and b concentration as affected by foliar spray treatment. Vertical bars indicate standard error of the means. Days After First Application (D.A.F.A.).

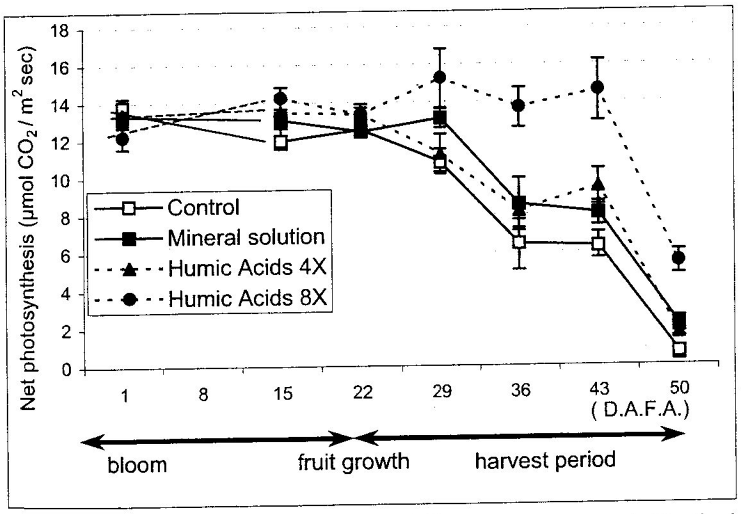

Fig. 2. Net photosynthetic rate as affected by foliar spray treatment. Vertical bars indicate standard error of the means. Days After First Application (D.A.F.A.).

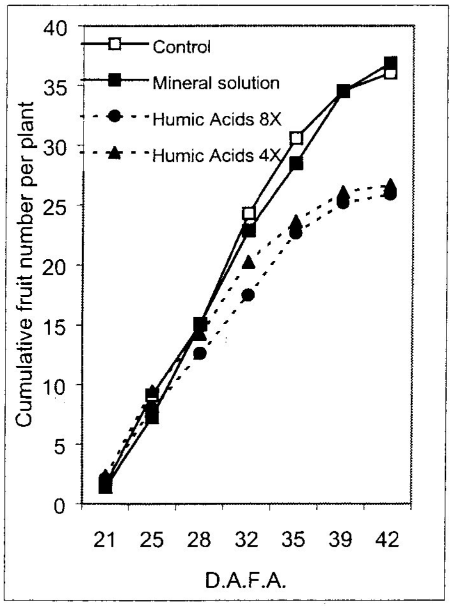

Fig. 3. Number of harvested fruits per plant at different picking dates,as affected by foliar spray treatment. Days After First Application (D.A.F.A.).

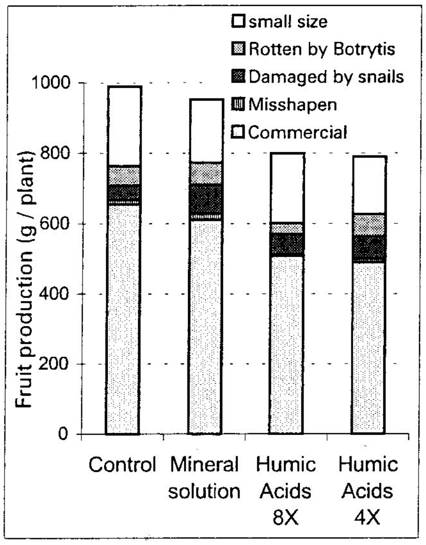

Fig. 4. Total fruit production divided into 5 different qualitative categories.

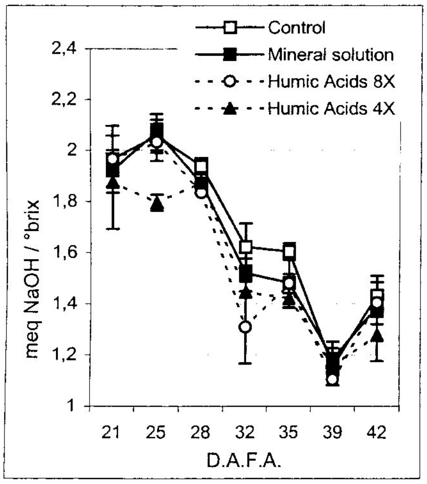

Fig. 5. Change of acidity to soluble solids ratio during harvest season as influenced by foliar spray treatment. Vertical bars indicate standard deviation. Days After First Application (D.A.F.A.).

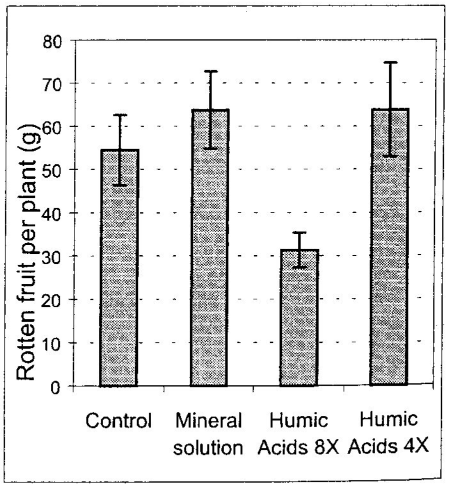

Fig. 6. Total rotten fruits harvested per plant as influenced by foliar spray treatments. Vertical bars indicate standard deviation.