# Nitrogen Fertilization Rate, Sawdust Mulch, and Pre-Plant Incorporation of Sawdust – Long-Term Impact on Yield, Fruit Quality, and Soil and Plant Nutrition in ‘Elliott’


B. Strik
Department of Horticulture
Oregon State University
4017 ALS
Corvallis, OR 97331
USA

G. Buller
NWREC
Oregon State University
15210 NE Miley Rd
Aurora, OR 97002
USA



**Keywords:** *Vaccinium corymbosum*, organic amendment, fruit firmness, berry weight



## Abstract

**A planting of ‘Elliott’ was established in October 2003. Treatments were: 1) raised beds constructed with or without the incorporation of sawdust; 2) with or without application of a sawdust mulch after planting; and 3) nitrogen (N) fertilizer rate (low: 22-56 kg/ha; medium: 67-168 kg/ha; and high: 112-269 kg/ha, depending on planting age). There was no significant effect of N rate on machine-harvested yield which increased from 10.8 t/ha in 2006 to 21.1 t/ha in 2011. While cumulative yield has not been affected by incorporation of sawdust or mulch, plots in which sawdust was incorporated before planting had a higher cumulative yield if no mulch was used (103.2 vs. 93.3 t/ha for mulched) whereas the opposite was true for plots in which no sawdust was incorporated (91.2 and 94.6 t/ha, for bare soil or with sawdust mulch, respectively). While leaf N concentration has been lower than recommended standards in some years, this has had no negative impact on yield. Nitrogen fertilization with the high rate decreased average berry weight. Plants fertilized with the highest rate of N had a greater average firmness (over the 6 years) than those fertilized with lower rates, likely related to an associated reduction in berry weight. Plants fertilized with the low rate of N had a lower fruit N concentration at harvest in 2010, but not in 2011. Use of sawdust before planting increased soil organic matter. Soil pH of plots fertilized with the high rate of N was lower than in plots fertilized with the medium or low rate of N in 2010.**


## INTRODUCTION

Blueberries are long-lived perennials, requiring 7 or more years to reach full production. Blueberries grow best on well-drained soils, high in organic matter, and with a pH of 4.2 to 5.5 (Eck, 1988; Strik et al., 1993). In the Pacific Northwest USA, plantings are commonly established by first incorporating Douglas-fir (*Pseudotsuga menziesii* M.) sawdust and nitrogen (N) fertilizer into the soil prior to forming raised beds and planting the 2-year-old blueberry plants (Strik, 2007). Incorporation of sawdust before planting can increase planting establishment costs by as much as $ 4350/ha (Julian et al., 2011).

In most production regions, blueberry plants are grown on raised beds of about 0.3 m high to improve soil drainage in the root zone (Strik, 2007). Raised beds help prevent saturated soils, reduce compaction, improve internal drainage (Magdoff and Van Es, 2000) and reduce pest problems like phytophthora root rot (Bryla and Linderman, 2007).

Organic mulches, placed on the soil surface after planting, are commonly used in blueberry to help control weeds (Burkhard et al., 2009; Krewer et al., 2009) and to improve plant growth and yield (Clark and Moore, 1991; Karp et al., 2006; Krewer et al., 2009; Savage, 1942; White, 2006), root distribution (Spiers, 2000), number of whips (White, 2006) and water-holding capacity, and minimize temperature fluctuations (Cox, 2009; White, 2006). The mulch layer is maintained for the life of the planting. However, there are many successful plantings in which no mulch or weed barrier has been used (B.C. Strik, pers. observation). Douglas-fir sawdust is commonly used as a surface mulch in blueberry production systems in the Pacific Northwest. However, this has become an expensive input, increasing establishment costs by $ 2570/ha and requiring replenishment as the mulch decomposes. In addition, mulches like sawdust, with a high carbon (C) to N ratio, make fertilizer management more difficult. Sawdust mulch, for example, immobilizes N applied from granular fertilizers (White, 2006).

In general, the best growth and yield of blueberry have been achieved with N fertilization rates of 25 to 100 $kg \cdot ha^{-1}$ (Bañados, 2006; Chandler and Mason, 1942; Eck, 1988; Griggs and Rollins, 1947; Hanson, 2006; Hart et al., 2006). In 'Bluecrop', fertilizing with 50 $kg \cdot ha^{-1}$ of N, as ammonium sulfate, produced more growth and fruit production during the first 2 years after planting than either 0, 100 or 150 $kg \cdot ha^{-1}$ of N; plants recovered 17% of the fertilizer N applied at 50 $kg \cdot ha^{-1}$ N and 10% applied at 100 $kg \cdot ha^{-1}$ N (Bañados et al., 2012). In mature blueberry plantings, increasing N fertilization rate over several years did not increase yield (Bañados, 2006; Cummings, 1978). Evaluating plant response to N fertilizer would help optimize N fertilizer programs and minimize potential for N losses through leaching. Use of organic matter in blueberry production systems may influence N availability.

The objectives of this study are to determine the long-term impact of incorporation of sawdust before planting, surface sawdust mulch, and N fertilization rate on yield, fruit quality, and soil and plant nutrient status in 'Elliott'.

## METHODS AND MATERIALS

The research trial was established in October 2003 at the North Willamette Research and Extension Center (NWREC; 45°16'47.55"N; 122°45'21.90"W), Aurora, Ore., USA. Soil at the site is a Willamette silt loam (fine-silty, mixed, mesic pachic ultic argixerolls) with an average pH of 5.4 and 4% organic matter content. Two-year-old plants, growing in 3.8-L containers, were established on raised beds approximately 0.30 m high with 0.75 m between plants in the row and 3.1 m between rows (4300 plants/ha). Each treatment plot consisted of 20 plants with a 3 m unplanted buffer zone between plots. Guard rows flanked the planting.

The experimental design was a split plot with pre-plant incorporation of sawdust as the main plot effect (2 levels) and combinations of surface mulching with sawdust (2 levels) and N fertilization rate (3 levels) as the subplot effects. There were four replications.

Douglas-fir sawdust was applied at a rate of 141 $m^3 \cdot ha^{-1}$ with fertilizer (16-16-16) added to each incorporated treatment row at a rate of 45 $kg \cdot ha^{-1}$ of N to help facilitate decomposition of sawdust, a standard commercial practice (Julian et al., 2011). Douglas-fir sawdust (7.6 cm deep; 155 $m^3 \cdot ha^{-1}$) was added to mulched plots after planting and replenished as required during the study. Nitrogen fertilization rate varied with planting age. In years 1 and 2 (2004-05), N fertilizer rates were 22, 67, and 112 $kg \cdot ha^{-1}$ of N at the low, medium, and high rate, respectively. In 2006-07, N fertilization was at 31, 95, and 153 $kg \cdot ha^{-1}$ of N. In 2008-09, fertilizer rates were 39, 112, and 185 $kg \cdot ha^{-1}$ of N. Plants were fertilized with 56, 168, and 269 $kg \cdot ha^{-1}$ of N at the low, medium, and high rates, respectively, in 2010-11. Nitrogen fertilizer was applied as a granular product (ammonium sulfate in 2004-05; and urea subsequently) with the total rate divided into thirds, applied in late March/early April, mid-May, and mid-June of each year. The planting was otherwise maintained according to standard commercial practice (Strik et al., 1993).

Plants were harvested by hand in 2006-07 and by machine (Littau Harvesters Inc., Stayton, Ore.) in subsequent years. Fruit samples to assess firmness (FirmTech 2, Bioworks, Wamego, Kan.) were collected just prior to machine harvest (25 berries/plot). Tissue (2009-11) and soil sampling (2010) were done per standard practice (Hart et al., 2006) with samples sent to Brookside Laboratories, Inc. (New Knoxville, Ohio) for analysis. Fruit samples at harvest were analysed for total nutrient content in 2010-11. Plants were pruned annually.

Treatment effects were analyzed using PROC MIXED in SAS (SAS Institute,

1999) with mean separation using a protected LSD.

## RESULTS AND DISCUSSION

In this study, machine-harvested yield ranged from 10.8 t/ha in 2006 to 21.1 t/ha in 2011 as the planting matured (data not shown). There was no significant effect of incorporation of sawdust prior to planting in autumn 2003 or use of sawdust mulch and nitrogen (N) fertilization rate from years 1 through 8 on cumulative yield (Table 1). Our results agree with those of Cummings (1978) who, in an 8-year study, found that yield was not increased with N fertilization above the lowest rate applied (34 $kg{\cdot}ha^{-1}$). In 'Bluecrop', plants fertilized with 50 $kg{\cdot}ha^{-1}$ of N in the first two years of establishment had a higher yield in year 2 than those fertilized with 100 or 150 $kg{\cdot}ha^{-1}$ of N or left unfertilized (Bañados et al., 2012).

Our results disagree with reports by some others in blueberry, such as Pliska et al. (1993) in Poland and Clark and Moore (1991) in Arkansas, USA, who reported that mulch increased yield compared to bare ground. Differences between our study and some other reported findings may be related to weed management and soil type. Incorporation of sawdust or a surface mulch may be of more benefit for blueberry production when the soil has a lower organic matter content (e.g., sand). An organic mulch layer may also reduce nitrate leaching, as has been shown in apple (Merwin et al., 1996). In some studies, unmulched plots have had more weeds than mulched plots (e.g., Krewer et al., 2009). Higher N fertilization rates have increased weed presence in lowbush blueberry (*V. angustifolium*) (Smagula et al., 2009). In our study, weeds were managed in all treatments and were not considered a factor.

In sandy soil, rabbiteye blueberries (*V. virgatum*) had more vigor when poultry litter was incorporated prior to planting (Marshall and Spiers, 2009). In New Zealand, blueberry plant growth and yield in the first 3 years of establishment were improved when bark and elemental sulfur were incorporated into the planting hole (Haynes and Swift, 1986). In our study, there was a significant interaction between mulch treatment and pre-plant incorporation of organic matter for cumulative yield (Table 1). When sawdust was incorporated before planting, yield/plant was greater when no surface mulch was applied.

There was no effect of pre-plant incorporation of sawdust or mulch on average berry weight. Clark and Moore (1991) found that mulched plants produced larger fruit in one out of three years in southern highbush blueberry. In our study, plants that were fertilized with the highest rate of N produced smaller fruit that were more firm, on average, than plants fertilized with the low or medium rate of N (Table 1).

Leaf P, K, Mg, S, Fe, and Zn were not affected by N fertilization rate and did not have concentrations below recommended standards (data not shown; Hart et al., 2006). There was an interaction between pre-plant incorporation treatment and N fertilizer rate on leaf tissue N concentration (%N) in 2009 and boron (B) concentration in 2011 (Table 2). In 2009 and 2010, plants fertilized with the high rate of N had a higher leaf %N than plants fertilized with the low rate of N, which had leaf %N below recommended standards (Hart et al., 2006). In 2011, there was no effect of N fertilization rate on leaf %N. Tissue Ca concentration was highest in plants fertilized with the low rate of N in 2009-11 (Table 2). Leaf %B and %Ca were below normal in plants receiving the higher rates of N in 2011 and in 2010 (B only). On 25 August 2010, there was a trend for soil Ca to be lower in plots fertilized with the highest rate of N (data not shown). Leaf Mn concentration was highest in plants fertilized with the high rate of N (Table 2), likely due to the lower soil pH in this treatment (pH 4.81) increasing the availability of Mn; the pH of plot fertilized with the low and medium rate of N was 5.42 and 5.15, respectively. In 2010, mulching significantly increased leaf B, Mn, and Al, but decreased leaf P compared to bare soil, whereas in 2011 mulching only increased leaf Ca concentration (data not shown).

Soil organic matter was 3.42% in 2011 in plots where sawdust was incorporated before planting in 2003 compared to 2.80% in non-incorporated plots. Adding a sawdust mulch had no significant impact on soil organic matter.

Fruit N concentration ranged from 0.32 to 0.46% and was only affected by N fertilization rate in 2010 when plants fertilized with the low rate of N had a lower fruit %N than those fertilized with the medium or high rate (data not shown).

## CONCLUSIONS

The effects of pre-plant incorporation of sawdust, sawdust mulch, and N fertilization rate on yield, berry weight, and firmness were relatively small over the 8-year study reported here. While leaf %N has been lower than recommended standards in some years, this has had no negative impact on yield. Use of sawdust before planting still had a significant impact on soil organic matter 8 years later. We will next study the long-term implications of fertilization with high rates of N and use of organic matter in the blueberry production system on soil nutrient status, mycorrhizae, and plant nutrient allocation.

### Literature Cited


Bañados, M.P. 2006. Dry weight and $^{15}$N-nitrogen and partitioning, growth, and development of young and mature blueberry plants. Ph.D. thesis, Oregon State University, 172p.

Bañados, M.P., Strik, B.C., Bryla, D.R. and Righetti, T.L. 2012. Response of highbush blueberry to nitrogen fertilizer during field establishment. I. Accumulation and allocation of fertilizer nitrogen and biomass. HortScience 47:648-655.

Bryla, D.R. and Linderman, R.G. 2007. Implications of irrigation method and amount of water application on *Phytophthora* and *Pythium* infection and severity of root rot in highbush blueberry. HortScience 42:1463-1467.

Burkhard, N., Lynch, D., Percival, D. and Sharifi, M. 2009. Organic mulch impact on vegetation dynamics and productivity of highbush blueberry under organic production. HortScience 44:688-696.

Chandler, R.B. and Mason, E.C. 1942. The effect of mulches on soil moisture, soil temperature, and growth of blueberry plants. Proc. Amer. Soc. Hort. Sci. 40:335-337.

Clark, J.R. and Moore, J.N. 1991. Southern highbush blueberry response to mulch. HortTech. 1:52-54.

Cox, J. 2009. Comparison of plastic weedmat and woodchip mulch on low chill blueberry soil in New South Wales, Australia. Acta Hort. 810:475-482.

Cummings, G.A. 1978. Plant and soil effects of fertilizer and lime applied to highbush blueberries. J. Amer. Soc. Hort. Sci. 103:302-305.

Eck, P. 1988. Blueberry Science. Rutgers Univ. Press, New Brunswick, N.J. p.135-169.

Griggs, W.H. and Rollins, H.A. 1947. The effect of planting treatment and soil management systems on the production of cultivated blueberries. Proc. Amer. Soc. Hort. Sci. 49:213-218.

Hanson, E.J. 2006. Nitrogen nutrition of highbush blueberry. Acta Hort. 715:347-351.

Hart, J., Strik, B., White, L. and Yang, W. 2006. Nutrient Management for Blueberries in Oregon. EM 8918, 14p.

Haynes, R.J. and Swift, R.S. 1986. Effect of soil amendments and sawdust mulching on growth, yield and leaf nutrient content of highbush blueberry plants. Sci. Hort. 29:229-238.

Julian, J., Strik, B. and Yang, W. 2011. Blueberry economics: the costs of establishing and producing blueberries in the Willamette Valley, Oregon. AEB 0022, 25p. http://arec.oregonstate.edu/oaeb/files/pdf/AEB0022.pdf.

Karp, K., Noormets, M., Starast, M. and Paal, T. 2006. The influence of mulching on nutrition and yield of 'Northblue' blueberry. Acta Hort. 715:301-305.

Krewer, G., Tertuliano, M., Andersen, P., Liburd, O., Fonsah, G., Serri, H. and Mullinix, B. 2009. Effect of mulches on the establishment of organically grown blueberries in Georgia. Acta Hort. 810:483-488.

Magdoff, F. and Van Es, H. 2000. Building Soils for Better Crops. Sustainable Agriculture Network for the Sustainable Agriculture Research and Education Program

of the Cooperative State Research, Education, and Extension Service. Second Edition. 75, 133, 230p.
Marshall, D.A. and Spiers, J.M. 2009. Establishment of rabbiteye blueberries using poultry litter. Acta Hort. 810:723-727.
Merwin, I.A., Ray, J.A., Steenhuis, T.S. and Boll, J. 1996. Groundcover management systems influence fungicide and nitrate-N concentrations in leachate and runoff from a New York apple orchard. J. Amer. Soc. Hort. Sci. 121:249-257.
Pliszka, K., Ścibisz, K. and Rojek, H. 1993. The effect of soil, management and mineral fertilization upon growth and cropping of the highbush blueberry cv. 'Bluecrop'. Acta Hort. 346:149-154.
Savage, E.F. 1942. Growth responses of blueberries under clean cultivation and various kinds of mulch materials. Proc. Amer. Soc. Hort. Sci. 40:335-337.
Smagula, J.M., Yaborough, D.E., Drummond, F. and Annis, S. 2009. Organic production of wild blueberries. II. Fertility and weed management. Acta Hort. 810:673-684.
Spiers, J.M. 2000. Influences of cultural practices on root distribution of 'Gulfcoast' blueberry. Acta Hort. 513: 247-252.
Strik, B.C. 2007. Horticultural practices of growing highbush blueberries in the ever-expanding U.S. and global scene. J. Amer. Pom. Soc. 61:148-150.
Strik, B., Brun, C., Ahmedullah, M., Antonelli, A., Askham, L., Barney, D., Bristow, P., Fisher, G., Hart, J., Havens, D., Ingham, R., Kaufman, D., Penhallegon, R., Pscheidt, J., Scheer, B., Shanks, C. and William, R. 1993. Highbush Blueberry Production. Ore. State Univ. Ext. Serv. Publ. PNW 215.
White, L.D. 2006. The effect of pre-plant incorporation with sawdust, sawdust mulch, and nitrogen fertilizer rate on soil properties and nitrogen uptake and growth of 'Elliott' highbush blueberry. M.S. Thesis, Oregon State Univ., Corvallis.

## Tables

Table 1. Effects of pre-plant incorporation of sawdust (Oct. 2003), sawdust mulch, and nitrogen fertilizer rate on the cumulative yield (2006-2011) and average berry weight and firmness of 'Elliott' blueberry grown at the North Willamette Research and Extension Center, Oregon State University, Aurora, Oregon, USA.

| Treatment | Yield (kg/plant) | | Berry weight (g) | Berry firmness (g/mm) |
|---|---|---|---|---|
| Pre-plant incorporation | No mulch | Sawdust mulch | | |
| None | 21.2 | 22.0 | 2.08 | 139.8 |
| With sawdust | 24.0 | 21.7 | 2.07 | 140.1 |
| Mulch | | | | |
| None | 22.4 | | 2.06 | 139.9 |
| Sawdust | 21.9 | | 2.08 | 139.8 |
| Nitrogen fertilizer rate[z] | | | | |
| Low | 22.0 | | 2.08 ab | 138.4 b |
| Medium | 22.2 | | 2.09 a | 139.9 ab |
| High | 22.2 | | 2.04 b | 141.3 a |
| Significance[y] | | | | |
| Incorporation (I) | 0.46 | | 0.80 | 0.65 |
| Mulching (M) | 0.31 | | 0.18 | 0.83 |
| Fertilizer rate (F) | 0.89 | | **0.03** | **0.04** |
| I×M | **0.001** | | 0.65 | 0.24 |
| I×F | 0.37 | | 0.25 | 0.56 |
| M×F | 0.06 | | 0.54 | 0.24 |
| I×M×F | 0.44 | | 0.25 | 0.12 |

[z] Nitrogen fertilizer rate was: "Low" 22 (2004-05), 31 (2006-07), 39 (2008-09), and 56 (2010-11) $kg \cdot ha^{-1}$ of N; "Medium" 67 (2004-05), 95 (2006-07), 112 (2008-09), and 168 (1010-11) ) $kg \cdot ha^{-1}$ of N; and "High" 112 (2004-05), 153 (2006-07), 185 (2008-09), and 269 (2010-11) $kg \cdot ha^{-1}$ of N.

[y] *P* values given.

Table 2. Effects of pre-plant incorporation of sawdust (Oct. 2003), sawdust mulch, and nitrogen fertilizer rate on leaf tissue nutrient concentration of ‘Elliott’ blueberry grown at the North Willamette Research and Extension Center, Oregon State University, Aurora, Oregon, USA, 2009-11 (only nutrients significantly affected by treatments shown). Means followed by the same letter, within year, are not significantly different (*P*>0.05).

<table>
<tr><th rowspan="2">Sample date</th><th rowspan="2">N rate (kg·ha$^{-1}$)</th><th colspan="2">N (%)</th><th rowspan="2">Ca (%)</th><th colspan="2">B (ppm)</th><th rowspan="2">Mn (ppm)</th><th rowspan="2">Cu (ppm)</th></tr>
<tr><th>No incorporation</th><th>Sawdust incorporated</th><th></th><th></th></tr>
<tr><td rowspan="3">24 Aug. 2009</td><td>39</td><td>1.55 b</td><td>1.58 a</td><td>0.67 a</td><td colspan="2">47.9 a</td><td>158.7 b</td><td>1.23 a</td></tr>
<tr><td>112</td><td>1.57 b</td><td>1.58 a</td><td>0.63 a</td><td colspan="2">38.6 bc</td><td>168.0 b</td><td>1.07 a</td></tr>
<tr><td>185</td><td>1.66 a</td><td>1.58 a</td><td>0.64 a</td><td colspan="2">35.5 c</td><td>190.8 a</td><td>1.34 a</td></tr>
<tr><td rowspan="3">11 Aug. 2010</td><td>56</td><td colspan="2">1.65 b</td><td>0.553 a</td><td colspan="2">20.8 a</td><td>70.5 c</td><td>4.88 a</td></tr>
<tr><td>168</td><td colspan="2">1.70 ab</td><td>0.496 b</td><td colspan="2">17.8 b</td><td>83.6 b</td><td>4.28 b</td></tr>
<tr><td>269</td><td colspan="2">1.73 a</td><td>0.495 b</td><td colspan="2">16.2 b</td><td>96.1 a</td><td>3.98 b</td></tr>
<tr><td></td><td></td><td colspan="2"></td><td></td><td>No incorporation</td><td>Sawdust incorporated</td><td></td><td></td></tr>
<tr><td rowspan="3">1 Aug. 2011</td><td>56</td><td colspan="2">1.89 a</td><td>0.436 a</td><td>21.3 a</td><td>23.3 a</td><td>82.3 b</td><td>4.39 a</td></tr>
<tr><td>168</td><td colspan="2">1.76 a</td><td>0.400 b</td><td>20.6 a</td><td>17.3 b</td><td>85.1 b</td><td>3.82 b</td></tr>
<tr><td>269</td><td colspan="2">1.92 a</td><td>0.384 b</td><td>17.5 b</td><td>17.7 b</td><td>96.0 a</td><td>3.82 b</td></tr>
</table>