Effects of CPPU Applications on Southern Highbush Blueberries

Jeffrey G. Williamson 1
Horticultural Sciences Department, University of Florida, P.O. Box 110690, Gainesville, FL 32611-0690

D. Scott NeSmith
Department of Horticulture, University of Georgia, Griffin Campus, Griffin, GA 30223

Abstract. Greenhouse and field experiments were conducted to determine the effects of the growth regulator N-(2-chloro-4-pyridyl)-N’-phenyleneurea (CPPU) on fruit set, berry size, and yield of southern highbush blueberry (Vaccinium corymbosum hybrids). The experiments were conducted over a period of several years in Georgia and Florida. CPPU sprays were capable of increasing fruit set and berry weight of southern highbush blueberry, although the responses to CPPU treatment were variable and appeared to be influenced by factors such as rate, spray timing, and cultivar. In Florida, high natural fruit set may have prevented increased fruit set from CPPU. A slight delay in berry maturity was noted in several experiments. Spray burn occurred on several occasions and may be related to factors such as cultivar, rate, spray volume, and use of surfactant.

Materials and Methods
This research was conducted under both field and greenhouse conditions over several years. The greenhouse experiments were conducted at the University of Georgia Research Station in Griffin, GA. Field experiments were conducted at the University of Georgia Blueberry Research Farm in Alapaha, GA, on a commercial blueberry farm in Appling County, GA, and on two commercial blueberry farms in Alachua County, FL.

Greenhouse experiments
Experiments were conducted in 2001 and 2003. One-year-old southern highbush blueberry plants were grown in pine bark in 12-L (2001) or 4-L (2003) containers. Plants were grown outdoors through the winter until after bloom and the application of CPPU treatments. Flower development was monitored, and dates of 50% open blooms were determined. CPPU treatments were applied based on the number of days after flowering. There were six replications (single plants) of each treatment on each cultivar. All plants were exposed to bees and other pollinators. Fruit set of all plants was determined by tagging two shoots per plant and counting the number of flowers per shoot and later counting the number of fruit. At the beginning of commercial harvest time, 50-berry samples were collected from plants to determine berry weight. Additionally, a determination of the percent ripe fruit on a specified date was made for the treatments for each cultivar.

2005 experiment. This research was conducted under field conditions during 2005 at a grower site in Ware County, GA. Mature southern highbush blueberry plants were used for this experiment. Three cultivars were used: ‘Millennia’, ‘O’Neal’, and ‘Bluecrop’. Flower development of plants was monitored and dates of 50% open blooms were determined. CPPU treatments were applied based on the number of days after flowering. There were four treatments for each of the cultivars. These were: 1) a nontreated control; 2) 10 mg L-1 of CPPU applied 10 to 14 DAF; 3) 10 mg L-1 of CPPU applied 10 to 14 DAF without surfactant; and 4) 15 mg L-1 of CPPU applied to 14 DAF without surfactant. All CPPU applications consisted of spraying whole plants to the point of drip using a nonionic surfactant (Silwet L-77, Helena Chemical Co., Collierville, TN) at 0.05% v/v. The nonionic surfactant X-77 was included in all CPPU treatments at 0.25% (v/v). There were six replicates (single plants) of each treatment on each cultivar. All plants were exposed to bees and other pollinators. Fruit set of all plants was determined by tagging two shoots per plant and counting the number of flowers per shoot and later counting the number of fruit. At the beginning of commercial harvest time, 50-berry samples were collected from plants to determine berry weight. Additionally, a determination of the percent ripe fruit on a specified date was made for the treatments for each cultivar.
backpack sprayer. There were four replications (four plants each replication) of each treatment and cultivar.

Fruit set of all plants was determined by tagging two shoots per plant and counting the number of flowers per shoot and later counting the number of fruit. At the beginning of commercial harvest time, 50-berry samples were collected from plants to determine berry weight. Additionally, a determination of the percent ripe fruit on a specified date was made for the treatments for each cultivar.

**Florida field experiments**

*2001 experiment.* Three field experiments (one experiment per cultivar) were conducted using mature, field-grown ‘Santa Fe’, ‘Star’, and ‘Sharpblue’ southern highbush blueberry plants located on a commercial blueberry farm in Alachua County, FL. Each experiment (cultivar) consisted of the following treatments: 1) 10 mg L\(^{-1}\) of CPPU applied 14 d after full bloom; 2) 5 mg L\(^{-1}\) of CPPU applied 10 d after full bloom and 5 mg L\(^{-1}\) applied 10 d later; 3) 5 mg L\(^{-1}\) of CPPU applied 14 d after full bloom; 4) 10 mg L\(^{-1}\) of CPPU applied 10 d after full bloom and 10 mg L\(^{-1}\) applied 10 d later; and 5) a control consisting of water and surfactant applied at 14 d after full bloom. Sprays were applied to runoff with a backpack sprayer (1200 L/ha). Triton B 1956 was used as a surfactant (0.05% v/v) in all treatments. Full bloom was determined by assessing flower bud development twice weekly.

Randomized complete block designs with seven replications were used for both experiments. Individual plots consisted of one data plant with buffer plants on either side. Eight representative shoots were randomly selected on each data plant. Flower number and development were measured on each shoot. All ripe berries were harvested at 3- to 4-d intervals from the selected shoots and from whole plants. Individual shoots were used to determine fruit set, which was expressed as fruit number per flower bud. Average berry weight was determined for each treatment by subsampling 10 fruit from each harvest date. Analysis of variance was used to determine the effects of rate and time of spray on response variables. Duncan’s multiple range test was used to separate treatment means.

**Results and Discussion**

**Greenhouse experiments**

*2001 experiment.* Fruit set of ‘Magnolia’ was increased substantially by all applications of CPPU as compared with the control treatment (Table 1). Fruit set of ‘Reveille’ was increased only for the 5-mg L\(^{-1}\) single CPPU application. Berry size of ‘Reveille’ and ‘Magnolia’ was increased by 15% to 25% with a single application of 5 mg L\(^{-1}\) of CPPU when compared with the control berries. An additional increase in berry size was achieved for the 10-mg L\(^{-1}\) CPPU application for ‘Magnolia’. When 5 mg L\(^{-1}\) CPPU was applied in two split applications, berry size was not improved for either cultivar. Some phytotoxicity occurred in the form of leaf burn or necrosis with CPPU applications on southern highbush. The burning occurred primarily on newly emerging leaf buds. The degree of damage depended on stage of plant development and CPPU rate. The 5-mg L\(^{-1}\) single application caused less damage than the 10-mg L\(^{-1}\) single application; however, the treatment that consisted of two applications of 5 mg/L of CPPU 10 d apart caused the greatest leaf burn. A plausible reason for this is that the first application caused some leaf burn, which stimulated additional leaf budbreaks. The second application 10 d later caused additional damage on these newly emerging leaves. Southern highbush blueberry plants receiving the split application were reduced in vigor for the remainder of the experiment because of the loss of leaves.

*2003 experiment.* The effect of CPPU on fruit set of southern highbush blueberries depended on CPPU concentration, application timing, and cultivar (Table 2). The most positive response in fruit set was observed for the cultivar ‘Legacy’, when 10 mg L\(^{-1}\) of CPPU was applied 14 DAF. However, this same treatment on ‘Palmetto’ considerably lessened fruit set as compared with the control. ‘Star’ showed a trend for a slight increase in fruit set for most of the CPPU treatments.

Berry fresh weight was increased for all cultivars when CPPU was applied at 14 DAF (Table 2). Conversely, only ‘Legacy’ responded to the 7 DAF treatments. The treatment showing the most consistent response across cultivars was 5 mg L\(^{-1}\) of CPPU applied 14 DAF. This treatment increased berry weight from 20% to 40% depending on cultivar. Generally, ‘Legacy’ was most responsive and ‘Star’ least responsive to increased berry weight from CPPU treatments. Some damage to young, emerging leaf buds similar to that observed in 2001 was observed for some of these CPPU treatments in 2003.

**Georgia field experiments**

*2001 experiment.* Effects of a single application of 10 mg L\(^{-1}\) of CPPU on four field-grown southern highbush cultivars are depicted in Table 3. Two of the four cultivars (‘Georgiagem’ and ‘Palmetto’) had increased fruit set in response to CPPU, one cultivar (‘Bladen’) had decreased fruit set, and one cultivar (‘Reveille’) showed no effect of CPPU on fruit set. CPPU increased berry size of ‘Reveille’ and ‘Bladen’ by 20% compared with control berries, but there was no influence of CPPU on berry size for

### Table 1. Fruit set and berry weight of two southern highbush blueberry cultivars in response to CPPU treatments under greenhouse conditions.

| Cultivar | Magnolia | Reveille |
|----------|----------|----------|
| Control | 44.7 ± 7.2* | 73.5 ± 10.0 |
| 5 mg L\(^{-1}\) at 14 DAF* | 69.7 ± 10.7 | 96.1 ± 3.2 |
| 10 mg L\(^{-1}\) at 14 DAF | 71.6 ± 10.3 | 77.4 ± 9.1 |
| 5 mg L\(^{-1}\) at 10 DAF + 5 mg L\(^{-1}\) at 20 DAF | 69.2 ± 8.4 | 72.7 ± 5.1 |

*Individual berry weight (g)*

| Cultivar | Magnolia | Reveille |
|----------|----------|----------|
| Control | 1.51 ± 0.09 | 1.75 ± 0.11 |
| 5 mg L\(^{-1}\) at 14 DAF | 1.89 ± 0.07 | 2.01 ± 0.07 |
| 10 mg L\(^{-1}\) at 14 DAF | 2.00 ± 0.16 | 1.80 ± 0.06 |
| 5 mg L\(^{-1}\) at 10 DAF + 5 mg L\(^{-1}\) at 20 DAF | 1.57 ± 0.07 | 1.60 ± 0.06 |

*Controls were not treated.

*Values are means ± se with n = 6.

*DAF = days after flowering.
absence of a surfactant did not seem to con-
this may explain the lack of increase in fruit
of the nontreated controls was much higher
increased fruit set of ‘Bluecrisp’ and ‘Mil-
In 2001, fruit set was decreased for ‘Sharp-
treatments in either year (data not shown).
Florida field experiments
have been seen in our tests in other years.
treatments. Similar observations of some delay
berries that began ripening sooner than CPPU
by 15 d after treatment. In addition to the leaf
with a surfactant. No leaf or fruit injury was
‘O’Neal’ that received CPPU applications
injury, berry injury was also observed on
leaf buds was observed for CPPU treatments
not great. Considerable injury to young, emerging
although the magnitude of the increase was
not great.
Conceivable injury to young, emerging
leaves was observed for CPPU treatments on
‘O’Neal’ and ‘Bluecrisp’, especially in the
presence of a surfactant. In fact, severe damage
was noted on ‘Bluecrisp’ as early as 5 d after
The injury was more pronounced
injection. In addition to the leaf
injuriy, berry injury was also observed on
‘O’Neal’ that received CPPU applications
with a surfactant. No leaf or fruit injury was
detected on ‘Millennia’ for any of the CPPU
 treatments.
There was a slight delay in fruit ripening
with CPPU for some of the cultivars (data not
shown). The control plants nearly always had
berries that began ripening sooner than CPPU
treatments. Similar observations of some delay
have been seen in our tests in other years.

Florida field experiments
Fruit set was not increased by CPPU
 treatments in either year (data not shown).
In 2001, fruit set was decreased for ‘Sharp-
blue’ and ‘Santa Fe’ by the split application
of 10 mg L\(^{-1}\) CPPU. Reduced fruit set
appeared to be related to spray burn injury
to developing leaves or flowers, which was
severe for this treatment. Fruit set was unaf-
fected for ‘Star’, which showed the least
amount of spray burn of the three cultivars
tested in 2001. In 2002, fruit set was unaf-
fected by any CPPU treatment. This may
have been because natural fruit set was high
and at, or close to, the carrying capacity of
the plants and no spray injury was observed
during 2002. Effects on fruit yield from
CPPU varied with cultivar and year. In
2001, most CPPU treatments increased yield
of ‘Star’ but not ‘Santa Fe’ or ‘Sharpblue’
(Table 5). In fact, yield of ‘Sharpblue’ was
decreased by the 10-mg L\(^{-1}\) split application
 treatment. Yield appeared to be heavily in-
fluenced by spray burn in 2001. ‘Sharpblue’,
which showed the most spray injury of the
cultivars tested, also had reduced yields
for the split application of 10 mg L\(^{-1}\)
CPPU and a trend toward reduced yields for

\[ \text{Table 2. Fruit set and berry weight of three southern highbush blueberry cultivars in response to CPPU treatments under greenhouse conditions.} \]

| CPPU treatment | Star | Legacy | Palmetto |
|----------------|------|--------|----------|
| Control \(\text{t} \) | 74.5 ± 5.4\(\text{t} \) | 58.5 ± 6.1 | 64.2 ± 6.5 |
| 5 mg L\(^{-1}\) at 7 DAF \(\text{t} \) | 77.4 ± 5.1 | 65.3 ± 5.3 | 52.1 ± 8.3 |
| 10 mg L\(^{-1}\) at 7 DAF | 88.0 ± 2.8 | 68.5 ± 5.8 | 54.2 ± 10.1 |
| 5 mg L\(^{-1}\) at 14 DAF | 80.5 ± 4.5 | 69.0 ± 5.0 | 40.4 ± 7.4 |
| 10 mg L\(^{-1}\) at 14 DAF | 80.8 ± 5.6 | 80.9 ± 3.5 | 23.2 ± 8.2 |

individual berry weight (g)
| Control | 1.40 ± 0.13 | 1.50 ± 0.04 | 1.18 ± 0.09 |
| 5 mg L\(^{-1}\) at 7 DAF | 1.60 ± 0.23 | 1.62 ± 0.02 | 1.31 ± 0.14 |
| 10 mg L\(^{-1}\) at 7 DAF | 1.52 ± 0.11 | 2.15 ± 0.12 | 1.22 ± 0.05 |
| 5 mg L\(^{-1}\) at 14 DAF | 1.71 ± 0.16 | 2.16 ± 0.06 | 1.59 ± 0.09 |
| 10 mg L\(^{-1}\) at 14 DAF | 1.55 ± 0.12 | 1.97 ± 0.21 | 1.52 ± 0.12 |

\(\text{t} \) Controls were not treated.
\(\text{t} \) Values are means ± se with n = 12.

\[ \text{Table 3. Effects of CPPU on fruit set, berry size, and degree of ripening of field-grown southern highbush blueberries in Georgia during 2001.} \]

| CPPU treatment | Reveille | Bladen | Georgiagem | Palmetto |
|----------------|---------|--------|------------|---------|
| Control | 56.9 ± 6.0\(y\) | 50.3 ± 5.3 | 37.8 ± 4.2 | 49.4 ± 7.3 |
| 10 mg L\(^{-1}\) | 54.5 ± 4.8 | 35.4 ± 5.0 | 49.9 ± 4.7 | 70.6 ± 7.1 |

berry size (g/50 berries)
| Control | 55.4 ± 3.6 | 45.0 ± 2.2 | 47.9 ± 1.9 | 40.1 ± 2.9 |
| 10 mg L\(^{-1}\) | 66.1 ± 2.6 | 54.4 ± 1.7 | 49.0 ± 1.6 | 39.4 ± 2.6 |

percent ripe berries on May 10
| Control | 1% to 3% | 10% to 15% | 35% | 72% |
| 10 mg L\(^{-1}\) | <1% | 1% to 5% | 27% | 53% |

\(\text{t} \) Controls were not treated.
\(\text{y} \) Values are means ± se.
\(\text{x} \) Data were taken at a grower site in Ware County, GA, during 2005.
\(\text{z} \) CPPU treatments applied 10 d after full bloom (DAFB) for ‘Sharpblue’ and 13 DAFB for ‘O’Neal’ and Bluecrisp.
\(\text{a} \) Values are means ± se.

\[ \text{Table 4. Fruit set and berry weight of three southern highbush blueberry cultivars in response to CPPU applications under field conditions.} \]

| CPPU treatment | Surfactant | Millennia | O’Neal | Bluecrisp |
|----------------|-----------|----------|--------|----------|
| Control | 19.0 ± 3.9\(y\) | 59.2 ± 6.4 | 22.3 ± 2.4 | 22.3 ± 2.4 |
| 10 | 22.8 ± 4.9 | 71.3 ± 7.1 | 51.1 ± 6.0 | 51.1 ± 6.0 |
| 10 | 25.1 ± 4.4 | 59.4 ± 9.0 | 44.5 ± 7.5 | 44.5 ± 7.5 |
| 15 | 38.0 ± 10.2 | 67.1 ± 7.9 | 44.1 ± 7.8 | 44.1 ± 7.8 |

average berry yield (g)
| Control | 1.87 ± 0.06 | 1.67 ± 0.07 | 1.75 ± 0.03 | 1.75 ± 0.03 |
| 10 | 1.87 ± 0.08 | 1.73 ± 0.05 | 1.83 ± 0.05 | 1.83 ± 0.05 |
| 10 | 2.17 ± 0.08 | 1.80 ± 0.05 | 1.78 ± 0.07 | 1.78 ± 0.07 |
| 15 | 1.97 ± 0.15 | 1.78 ± 0.09 | 1.85 ± 0.03 | 1.85 ± 0.03 |

\(\text{a} \) Data were taken at a grower site in Ware County, GA, during 2005.
\(\text{b} \) CPPU treatments applied 10 d after full bloom (DAFB) for ‘Sharpblue’ and 13 DAFB for ‘O’Neal’ and Bluecrisp.
\(\text{c} \) Values are means ± se.

\[ \text{Table 5. Effect of CPPU on berry yield and mean fresh weight of three southern highbush cultivars in 2001.} \]

| Yield (g/plant) | Berry size (g/berry) |
|----------------|---------------------|
| CPPU treatment | Sharpblue | Star | Santa Fe | Sharpblue | Star | Santa Fe |
| Control | 2750a | 3656d | 2066a | 1.21b | 1.04b | 1.18c |
| 5 mg L\(^{-1}\) at 14 DAF | 2479ab | 5259a | 2013a | 80.9 ± 1.46a | 1.57a | 1.48ab |
| 5 mg L\(^{-1}\) at 10 DAFB | 1873ab | 4911ab | 1282a | 1.34ab | 1.53a | 1.36b |
| 10 mg L\(^{-1}\) | 1895ab | 4089cd | 1848a | 1.46a | 1.49a | 1.47ab |
| 10 mg L\(^{-1}\) at 14 DAF | 1520b | 4443bc | 1507a | 1.51a | 1.59a | 1.50a |

\(\text{a} \) Controls were sprayed with water and surfactant at 14 DAFB.
\(\text{b} \) Means followed by the same letter, within columns, are not significantly different, Duncan’s multiple
range test, \(P \leq 0.05\).
\(\text{c} \) DAFB = days after full bloom.
some of the other CPPU treatments. Conversely, ‘Star’, which showed the least amount of spray injury, had increased yields from most of the CPPU treatments. In 2002, fruit yields were unaffected by any of the CPPU treatments when compared with the controls (data not shown).

In 2001, seasonal mean berry fresh weights of ‘Star’ and ‘Santa Fe’ were increased by all CPPU treatments (Table 5). Mean berry weight of ‘Sharpblue’ was increased by all CPPU treatments except for the split application of 5 mg L\(^{-1}\) of CPPU applied to 10 DAFB and again 20 DAFB. In 2002, all CPPU treatments except for 10 mg L\(^{-1}\) applied at 7 DAFB increased mean berry weight of ‘Star’ when compared with control fruit (Table 6). ‘Millennia’ was less responsive than ‘Star’. However, 10 mg L\(^{-1}\) CPPU applied at 20 DAFB increased ‘Millennia’ seasonal mean berry weight compared with control fruit (Table 6).

In 2001, there was a trend toward delayed fruit ripening for most of the CPPU treatments (data not shown). The delay was most noticeable when young emerging leaves were burned by spray applications. In 2002, several CPPU treatments resulted in delayed fruit ripening of ‘Star’ but not ‘Millennia’, although no spray burn was noted that year (Table 6). The greatest delay in fruit ripening appeared to be associated with the treatments that increased mean berry weight the most.

In 2001, considerable spray burn was associated with most of the CPPU treatments. ‘Sharpblue’ was affected more than the other cultivars, which probably accounted for the reduced yield of ‘Sharpblue’ at the 10 ppm split application in 2001. In 2002, no spray burn was observed for any of the CPPU treatments. Two notable differences between the 2001 and 2002 studies were: 1) sprays were applied to drip in 2001 and to complete coverage in 2002. Therefore, spray volumes were greater in 2001 than in 2002; and 2) a surfactant was included in the 2001 sprays but not in the 2002 sprays. It appears likely that the higher spray volumes used in 2001, or the addition of a surfactant in 2001, contributed to the spray burn observed in 2001 but not in 2002.

Overall, the data from these greenhouse and field experiments indicate that CPPU can increase fruit set and berry size of southern highbush blueberries. Consequently, total fruit yield may also be increased by CPPU. However, these responses appear to be cultivar-dependent and varied with year, rate, and timing of sprays relative to bloom. Fruit set was increased in both greenhouse and field experiments in Georgia, but not in field experiments in Florida where natural fruit set was high and probably approaching the maximum carrying capacity of the plants. The effect of CPPU on fruit set may be heavily influenced by the presence or absence of other factors leading to high natural fruit set. CPPU sprays delayed fruit maturity in several of the experiments. This result is not surprising because maturity date of southern highbush blueberry is often related to crop load. Several CPPU treatments resulted in burn or necrosis of newly emerging leaves, which could be detrimental to yields and probably contributed to delayed fruit maturity in some cases. This was observed under both greenhouse and field conditions and in multiple years. The addition of a surfactant appeared to increase the occurrence of spray injury, but other factors such as cultivar sensitivity, growth stage, and spray volume may also be involved. CPPU should be further explored for use in southern highbush blueberry production. Additional research examining yields, berry quality, and time of harvest is needed to determine possible benefits of the growth regulator. Also, the issue of CPPU causing leaf burn needs careful examination.

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### Table 6. Effect of CPPU on mean berry fresh weight and harvest period of two southern highbush cultivars in 2002.

| CPPU treatment | Berry size (g/berry) | Cumulative yield (% of total) | Star | Millen

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|  | 4/24–5/6 | 4/24–5/15 | 4/15–4/29 | 4/15–5/13 |
|---|---|---|---|---|
| Control\(^c\) | 1.22\(^c\) | 52.4 a | 94.4 a | 1.43 b | 28.3 a | 78.9 a |
| 10 mg L\(^{-1}\) at full bloom | 1.41 b | 40.2 b | 90.4 ab | 1.56 ab | 26.8 a | 75.4 a |
| 10 mg L\(^{-1}\) at 7 DAFB\(^b\) | 1.34 bc | 43.3 b | 89.4 b | 1.40 b | 20.0 a | 72.1 a |
| 10 mg L\(^{-1}\) at 14DAFB (Star) or 20 DAFB (Mill.) | 1.44 ab | 28.4 c | 78.9 c | 1.60 a | 24.6 a | 75.4 a |
| 5 mg L\(^{-1}\) at full bloom + 5 mg L\(^{-1}\) at 7 DAFB | 1.36 b | 45.7 ab | 90.1 ab | 1.41 b | 27.2 a | 78.6 a |
| 5 mg L\(^{-1}\) at 14 DAFB (Star) or 20 DAFB (Mill.) | 1.53 a | 27.4 c | 83.1 c | 1.51 ab | 25.8 a | 76.9 a |

\(^c\) Controls were not treated.  \(^b\) Means followed by the same letter, within columns, are not different, Duncan’s multiple range test, \(P \leq 0.05\).  \(^b\) DAFB = days after full bloom.