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THE USE OF METABOLIC INHIBITORS, FILM-FORMING ANTITRANSPIRANTS, AND MAXIJET IRRIGATION TO INCREASE YIELD, IMPROVE QUALITY AND WATER USE EFFICIENCY OF BLUEBERRIES

MAKRAM M. HUSSIN AND FOUAD M. BASIOUNY[1]
Plant and Soil Sciences,
Tuskegee Institute,
Tuskegee, AL 36088

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Abstract. **Application of the metabolic inhibitors, abscisic acid (ABA) and phenyl mercuric acetate (PMA), and the antitranspirants Vapor Gard and Clear Spray, separately or in combination with the Maxijet irrigation significantly increased the water use efficiency of rabbiteye blueberries (*Vaccinium ashei* Reade 'Tifblue'). Spraying these materials increased stomatal diffusive resistance, reduced transpiration and increased leaf temperature. At ripening stages, and with all treatments, total soluble solids, berry weight, volume and yield were increased; firmness and pH were significantly decreased.**

Rabbiteye blueberries (*Vaccinium ashei* Reade) grow wild in the southeast region of the United States. They are less sensitive to soil acidity and more resistant to heat and drought than highbush blueberries.

Interest in rabbiteye blueberry has increased significantly in recent years due to its popularity as a "pick your own fruit", high yield, and comparatively low maintenance requirements. Despite the fact that Alabama's climate is considered quite suitable for blueberry production, rabbiteye blueberry acreage is relatively small. Three major factors have limited the rabbiteye blueberry production in Alabama: 1) Alabama receives 130-140 cm rainfall annually which is not distributed uniformly over the state or throughout the year, a problem which frequently necessitates supplemental irrigation; 2) a large portion of the rainfall received annually is lost as run-off or through evapotranspiration; 3) blueberry bushes generally have shallow root systems and develop fruits during the early spring and summer. This period is considered Alabama's dry or low rain season.

In recent years, the use of chemicals to reduce transpiration has led to the moisture conservation and subsequent reduction in irrigation frequency (8, 9, 10, 17).

Maxijet, low volume, is a new system of irrigation which has many advantages including increased plant growth and crop yield; uniform distribution of moisture in the root zone, and conservation of water and energy.

The objectives of this research were to compare metabolic inhibitors, film-forming antitranspirant materials and maxijet irrigation for improving quality, yield and water use efficiency of rabbiteye blueberries.

Materials and Methods

This study was conducted utilizing 2-yr-old rabbiteye blueberry (*Vaccinium ashei* Read) bushes planted in sandy loam soil (pH 4.5 to 5.0). A maxijet irrigation system (Maxijet International, Inc., Dundee, FL) was installed and monitored to deliver 7.5 liters or 15 liters/day/bush.

Two metabolic inhibitors, abscisic acid (ABA) and phenyl mercuric acetate (PMA) both at a concentration of 10^{-4}M, were used as foliar sprays. Two film-forming antitranspirant materials, Vapor Gard (VG) and Clear Spray (CS), were foliarly sprayed at a concentration of 2.5% in water. Both the metabolic inhibitors and the film-forming materials were prepared fresh the day of spray and were used separately or in combination with maxijet irrigation. The experiment was a randomized complete block design with 8 replications.

The experimental bushes were sprayed 2 times each growing season, during maturation (May) and ripening (July). Stomatal diffusive resistance, transpiration and leaf temperature were determined using a steady state porometer LI1600 (LiCor, Inc., Lincoln, NE). Fruit weight and volume, total soluble solids (TSS), pH, and firmness of the fruit were measured at ripening (end of July and early August).

Results and Discussion

Stomatal diffusive resistance. Spraying both the metabolic inhibitors and the film-forming antitranspirants materials, separately or in combination, substantially affected the stomatal diffusive resistance (Tables 1 and 2). In general, leaf transpiration was increased in bushes receiving irrigation at 7.5 liters/day compared to those receiving 15 liters/day. This could be due to the availability of the water and less closure of the stomata in the latter than in the former. Both ABA and PMA, when applied separately, increased the stomatal diffusive resistance of the blueberry leaves, with ABA being more effective in retaining plant moisture than PMA. The addition of antitranspirants VG and CS to either ABA or PMA significantly increased stomatal diffusive resistance more than applying these materials separately. VG showed obvious advantages over CS.

Blueberry bushes which received no irrigation water (control) gave the lowest stomatal diffusive resistance read-

Table 1. Effects of metabolic inhibitors, film-forming antitranspirants, and maxijet irrigation on leaf function of 'Tifblue' blueberry at maturation.[z]

Treatment[y]	Diff. resist. (s cm^{-1})		Transpiration ($\mu g\ cm^{-2}s^{-1}$)		Leaf temp. (°C)	
	7.5 l[x]	15 l[x]	7.5 l	15 l	7.5 l	15 l
ABA	9.1c	7.4b	11.7a	12.4a	21.6a	20.4a
ABA + CS	11.4b	9.4a	12.4a	10.1b	22.4a	20.8a
ABA + VG	12.6a	10.3a	10.3b	11.7a	22.3a	23.0a
PMA	6.9d	7.5b	11.4a	10.6b	22.8a	20.6a
PMA + CS	10.5b	7.4b	11.6a	10.2b	23.1a	23.4a
PMA + VG	13.3a	10.2a	10.4b	10.5b	22.7a	22.2a
VG	9.4c	8.3b	12.7a	12.0a	23.6a	21.5a
CS	7.1d	8.2b	12.8a	11.4a	22.4a	20.6a
NI	6.1e	7.0c	14.1c	14.4c	17.3b	16.2b

[z]Average of 8 replications. Mean separation in columns by Duncan's multiple range test, 5% level.
[y]ABA, Abscisic acid; PMA, phenyl mercuric acetate; CS, Clear Spray; VG, Vapor Gard; NI, control.
[x]Irrigation of 7.5 liters/bush/day or 15 liters/bush/day.

[1]Graduate student and professor, Department of Agricultural Sciences. This investigation is part of a thesis submitted by the senior author in partial fulfillment of the requirements for the M.S. degree. The research was supported by a grant No. 14-34-0001-0510 from the Bureau of Reclamation, U.S. Department of Interior. The authors would like to express their appreciation to the Maxijet International, Inc., Dundee, FL for the generous contribution made for this study.

Table 2. Effects of metabolic inhibitors, film-forming antitranspirants, and maxijet irrigation on leaf function of 'Tifblue' blueberry at ripening.[z]

Treatment[y]	Diff. resist. (s cm^{-1}) 7.5 l[x]	15 l[x]	Transpiration (μg cm^{-2}s^{-1}) 7.5 l	15 l	Leaf temp. (°C) 7.5 l	15 l
ABA	11.3a	10.0b	11.1b	12.1b	24.6a	23.7a
ABA + CS	10.8b	10.0b	12.2a	13.6a	25.7a	24.7a
ABA + VG	11.4a	11.1a	10.9b	11.7b	26.9a	24.3a
PMA	10.3b	9.1c	12.8a	13.2a	23.7a	23.1a
PMA + CS	11.4a	10.1b	11.9a	13.0a	24.6a	23.2a
PMA + VG	12.1a	11.3a	10.9b	12.1b	24.4a	22.1a
VG	10.7b	10.0b	12.1a	13.1a	25.5a	23.2a
CS	9.1c	7.0d	12.8a	12.7a	24.2a	23.9a
NI	8.0d	8.3c	15.4c	15.6d	17.6b	16.9b

[z]Average of 8 replications. Mean separation in columns by Duncan's multiple range test, 5% level.
[y]ABA, Abscisic acid; PMA, phenyl mercuric acetate; CS, Clear Spray; VG, Vapor Gard; NI, control.
[x]Irrigation of 7.5 liters/bush/day or 15 liters/bush/day.

ings. These observations were different from those obtained by Anderson et al. (4) and Albrigo (2, 3). Control bushes received no spray treatments which could have maintained the plant moisture contents and influenced stomatal closure.

Blueberry leaves from bushes receiving 7.5 liters/day and 15 liters/day showed much higher stomatal diffusive resistance during the ripening period than during maturation. This could be due to 2 factors: 1) many of the leaves (also stomatal function) were not fully developed during maturation, and while the cuticular layer was significantly higher during ripening; 2) the temperature and light intensity were different during maturation in May (16.7°C and 1259 μE/m^2/sec) than during ripening in July (25°C and 1600 μE/m^2/sec).

Transpiration. Transpiration of blueberry leaves varied with the different metabolic inhibitors and film-forming antitranspirant treatments (Tables 1 and 2). Transpiration was substantially reduced by the spray materials during maturity and ripening. ABA and PMA reduced transpiration more than VG and CS. However, when the latter materials were added to the metabolic inhibitors, transpiration was decreased. There was a tendency of the leaves to transpire more during maturation than during ripening. This increase in transpiration was attributable to differences in temperature and light intensity during maturity sampling in May and during ripening sampling in July.

Blueberry bushes which received no irrigation water had the lowest transpiration. These transpiration values were much lower than those obtained from the use of metabolic inhibitors or film-forming antitranspirant materials. Transpiration from blueberry leaves receiving 15 liters of water per day were higher than those from plants that received 7.5 liters.

Leaf temperature. Spraying blueberry plants with metabolic inhibitors and film-forming antitranspirant materials significantly raised leaf temperature above those of controls (Table 1 and 2). There were no significant differences among the tested materials on their effects on leaf temperature. These data agreed with those of others (4, 7).

Metabolic inhibitors induced stomatal closure without interfering with the leaf's ability to assimilate CO_2 (8). Antitranspirants, on the other hand, when applied to transpiring plant surfaces reduce water losses. Spraying blueberry leaves with these materials significantly reduced transpiration, which functions in cooling of the leaves and reducing plant temperature (13). The rise in leaf temperature suggested that the antitranspirant materials resulted in coating the leaf adaxial and abaxial surfaces, impaired gas exchange and significantly restricted transpiration which in turn raised leaf temperature. Many of the available film-forming antitranspirant materials are more permeable to water vapor than to CO_2 (8). However, in this study, it is conceivable that the concentration used (2.5%) was quite high and contributed to substantial closure of the leaf pores and restriction in transpiration.

There were obvious differences in leaf temperature from plants that received 7.5 liters/day and those receiving 15 liters/day of irrigation water. Temperature in the latter tended to be less than the former. Leaves from the control plants were lower in temperature than treated plants despite the fact that the former plants received no irrigation water. This was attributed to higher transpiration occurring in the control plants which contributed to the reduction in leaf temperature.

Total soluble solids. Total soluble solids of fruits picked from treated plants were significantly higher than those of the controls (Table 3). However, higher TSS were recorded from plants that received 15 liters/day than from those that received 7.5 liters/day of irrigation water. Both the irrigation practice and the spray materials, separately or in combination, increased total soluble solids of the blueberry fruits. These findings were in accord with a previous report (5). Samples from plants sprayed with VG, in combination with ABA or PMA produced the highest TSS under 7.5 liters/day or 15 liters/day water regimes.

Table 3. Effects of metabolic inhibitors, film-forming antitranspirants and maxijet irrigation on fruit quality of 'Tifblue' blueberry.[z]

Treatment[y]	Total soluble solids (%) 7.5 l[x]	15 l[x]	pH 7.5 l	15 l	Firmness (g/2.4 mm) 7.5 l	15 l
ABA	12.34b	12.86b	4.10a	3.98a	7.6b	6.9b
ABA + CS	12.17b	12.50b	4.21a	4.22a	7.8b	7.2b
ABA + VG	13.27a	13.87a	4.00a	4.07a	7.8b	7.5b
PMA	12.22b	12.84b	3.98a	4.13a	7.8b	7.2b
PMA + CS	11.91b	12.23b	3.46b	3.40b	7.7b	7.0b
PMA + VG	12.34b	14.08a	3.51b	3.53b	7.8b	6.9b
VG	12.40b	12.28b	3.88a	3.87a	6.9a	6.9a
CS	11.89b	12.17b	3.41b	3.43b	7.5b	7.6b
NI	11.00c	11.93c	2.23c	2.03c	8.6c	8.6c

[z]Average of 8 replications. Mean separation in columns by Duncan's multiple range test, 5% level.
[y]ABA, Abscisic acid; PMA, phenyl mercuric acetate; CS, Clear Spray; VG, Vapor Gard; NI, control.
[x]Irrigation of 7.5 liters/bush/day or 15 liters/bush/day.

pH. Application of different metabolic inhibitors and film-forming antitranspirants in combination with the maxijet irrigation significantly raised the pH values of treated bushes over the control (Table 3). However, differences in pH values among treatments were not obvious under 7.5 and 15 liters/day water regimes.

pH value is considered an important parameter in determining blueberry quality. It was obvious from these studies that both irrigation and the spray materials raised fruit pH, enhanced maturity and ripening of blueberry fruits.

Firmness. Fruits from control bushes were significantly firmer than fruits from treated plants (Table 3). Among the spray chemicals used, VG significantly softened the fruits from plants subjected to 7.5 and 15 liters/day regimes. Fruits from plants that received 15 liters were generally softer than fruits from plants subjected to 7.5 liters/day. This finding agrees with earlier reports (6). Firmness is an important component of blueberry fruit quality (16, 18). The degree or lack of resistance to cracking has been associated with maturity in many fruits (15).

In general, pectic substances have been correlated with firmness (12, 14). It has been reported that firm cultivars contain considerably more pectin materials than soft ones (11). It is conceivable that the spray materials, combined with consistent water regimes, have contributed to the enhancement of several metabolic processes which lead to the conversion of insoluble materials to soluble ones or the activity of pectinase and cellulase enzyme systems associated with the softening of blueberry fruits.

Fruit weight and volume. Weight of ripened fruits from treated plants were significantly higher than from the controls which depended solely on rain water during the growing season (Table 4). This confirms previous reports of several investigators (1, 7). The spray materials induced noticeable differences in berry weights. ABA, separately or in combination with VG, produced fruits with higher weights than the other spray materials. On the other hand, fruits harvested from bushes subjected to the 15 liters of water regime tended to be heavier than fruits harvested from bushes subjected to 7.5 liters.

Table 4. Effects of metabolic inhibitors, film-forming antitranspirants and maxijet irrigation on berry number of 'Tifblue' blueberry.[z]

Treatment[y]	Berry no./bush		Berry wt./bush (g)		Berry vol./bush (cm³)	
	7.5 l[x]	15 l[x]	7.5 l	15 l	7.5 l	15 l
ABA	446a	469a	427a	480a	423a	474a
ABA + CS	427a	436a	402a	459a	392a	438a
ABA + VG	468a	455a	463a	464a	441a	461a
PMA	338b	372b	311b	344b	309b	368b
PMA + CS	330b	351b	326b	319b	325b	348b
PMA + VG	363b	363b	332b	357b	328b	359b
VG	343b	378b	335b	340b	331b	343b
CS	296b	270c	280b	298b	289b	329b
NI	218c	222d	220c	221c	218c	220c

[z]Average of 8 replications. Mean separation in columns by Duncan's multiple range test, 5% level.
[y]ABA, abscisic acid; PMA, Phenyl mercuric acetate; CS, Clear Spray; VG, Vapor Gard; NI, control.
[x]Irrigation of 7.5 liters/bush/day or 15 liters/bush/day.

There was a correlation between the weight and volume of the fruits as determined by replacement of water (Table 4). In general, fruits with less weight were smaller in size than fruits with heavier weight. This was not necessarily true in several cases where lighter fruits were bigger. However, there were marked differences among fruits that received water at 7.5 versus 15 liters/day.

Yield. Both the spray materials and the maxijet irrigation regimes significantly increased yield of 'Tifblue' blueberries as measured by the number of berries/plant (Table 4). Yield from treated bushes was significantly higher than control yields. This increase was estimated to be between 25 to 30%. Blueberry plants sprayed with ABA separately or in combination with VG produced the highest yield.

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