Irrigation Management Effects on Yield and Fruit Quality of Highbush Blueberry

D.R. Bryla[1], B. Yorgey[2] and A.D. Shireman[1]
[1] USDA Agricultural Research Service, Horticultural Crops Research Unit, 3420 NW Orchard Avenue, Corvallis, Oregon 97330, USA
[2] Department of Food Science and Technology, Oregon State University, 100 Weigand Hall, Corvallis, Oregon 97331, USA

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Abstract

A study was done to determine the effects of irrigation method and level of water application on yield and fruit quality of 'Elliott' highbush blueberry (*Vaccinium corymbosum* L.). Plants were grown on mulched, raised beds and irrigated by overhead sprinklers, microsprays, or drip at 50, 100, and 150% of the crop evapotranspiration requirement (ET_c). Overall, marketable yield and individual berry weight were higher in plants irrigated by drip than in those irrigated by sprinklers and microsprays. Yield and berry weight were also higher on average when plants were irrigated at 100% ET_c than at 50% ET_c but were similar between plants irrigated at 100% and 150% ET_c. Thus, as expected, plants were generally under-irrigated at 50% ET_c and over-irrigated at 150% ET_c; however, this was not always the case. Yield did not increase between 50% and 100% ET_c when plants were irrigated by drip, and berry weight increased from 100% to 150% ET_c when plants were irrigated by microsprays. Interestingly, drip reduced berry firmness and soluble solids relative to sprinkler and microspray irrigation, potentially increasing problems with soft fruit during shipping and storage. Titratable acidity was also lower with drip but only when plants were irrigated at 50% ET_c. While irrigation method and the amount of water application affected yield and fruit quality in blueberry, more work is needed to identify the best combinations of each to produce the most marketable fruit.

INTRODUCTION

Overhead sprinklers and drip are the most common irrigation systems used in highbush blueberry production (Strik and Yarborough, 2005; Bañados, 2006). Sprinkler systems are relatively simple to install and maintain and, when designed properly, obtain reasonable uniformity of water application. Some major advantages of sprinklers are that they can be used to maintain a cover crop, protect the crop from frost damage during subfreezing temperatures, cool the crop during hot conditions, and wash dust off the crop before harvest. Drip systems, by comparison, are somewhat more expensive to install and more difficult to maintain than sprinklers but offer superior water control and distribution uniformity, improved application of fertilizer and other chemicals, and enhanced cultural conditions, including fewer weed and disease problems and the ability to irrigate during harvest (Kruse et al., 1990). Water is typically applied one to two times per week as needed with sprinklers and every 1 to 3 days with drip.

A few growers also use microsprays on blueberry. Microspray irrigation offers advantages similar to drip but applies the water to the soil surface by a small spray. Although microsprays are not commonly used in blueberry, Holzapfel et al. (2004) found that production in Chile was higher with microsprays than with drip. Because microsprays wet more soil volume than drip, plants tend to produce a larger root system, which may be a considerable advantage in a shallow, densely-rooted crop like blueberry (Patten et al., 1988; Bryla and Strik, 2007).

We began a trial in 2004 to compare the effects of sprinkler, microspray, and drip irrigation on water use in blueberry. The primary goal was to identify the best irrigation practices for optimizing growth and fruit production. Irrigation was examined in an early-season cultivar, 'Duke', and a late-season cultivar, 'Elliott'. By the end of the first season, drip irrigation produced the largest plants in both cultivars, while microspray-irrigated plants were intermediate, and sprinkler-irrigated plants were smallest. However, by year 2, drip irrigation increased the incidence of root rot in 'Duke', leading to weakened and smaller plants than those irrigated by either sprinklers or microsprays (Bryla and Linderman, 2007). 'Duke', which tends to be susceptible to root rot (Bryla et al., 2008), may be better suited to sprinklers or microsprays, especially when grown at sites prone to the disease, e.g., heavy soil, poor drainage, or a disease history. 'Elliott', conversely, had no root rot. In this case, plants with drip required only half the water for maximum shoot production as those irrigated by sprinklers or microsprays (Bryla, 2008). The benefit in 'Elliott' was because drip consistently maintained higher soil water content in the root zone than did the other two systems and, therefore, reduced soil water deficits between irrigations (Bryla and Strik, 2007).

The objective of the present study was to continue the trial and compare the effects of sprinklers, microsprays, and drip on yield and fruit quality in 'Elliott' blueberry. The study was conducted during the third and fourth seasons when plants were in the first 2 years of production. 'Duke' was not included in this report due to continued problems with root rot.

MATERIALS AND METHODS

The planting was established at the Oregon State University Lewis-Brown Horticultural Research Farm, Corvallis, Oregon, USA (44°38'N, 123°11'W) in April 2004. Soil at the site is a Malabon silty clay loam adjusted to a pH of 5.5. The plants were grown on mulched raised beds and spaced 0.76 m apart within rows and 3.05 m apart between rows. Normal cultural practices for mulching, fertilizing, and pruning were followed (Strik et al., 1993). Plants were cropped beginning the third year after planting.

Nine irrigation treatments were arranged at the site in a split-plot design with three irrigation methods (overhead sprinkler, microspray, and drip) as main plots and three irrigation levels (50, 100, and 150% of the estimated crop evapotranspiration requirements, ET_c) as subplots. Each subplot consisted of three rows of eight plants and was replicated five times. Overhead sprinkler treatments were irrigated by four sprinklers per subplot; a sprinkler was located on each corner of the plots and set to rotate in a 90° wetting pattern. Microspray treatments were irrigated with fan-jet emitters located between every other plant and suspended on a trellis wire 1.2 m above the plants. Drip treatments were irrigated by drip tubing, with in-line emitters spaced 0.30 m apart, placed along the row at the base of the plants. Irrigations were controlled by an automatic timer set weekly.

Sprinkler treatments were irrigated twice per week, as needed, while drip and microspray treatments were irrigated three times per week. Crop ET estimates were obtained from the Pacific Northwest Cooperative Agricultural Weather Network (AgriMet) website (http://www.usbr.gov/pn/agrimet/) and were adjusted for plant size and irrigation system efficiency following procedures outlined in Holzapfel et al. (2004). Water applications were scheduled with a timer and measured using flow meters installed in the irrigation manifold.

Fruit was harvested in August each year and required three to four pickings per year. Ripe fruit was collected from the center six plants of each subplot, sorted to remove unmarketable (green, red, shriveled, or bird-pecked) fruit, and weighed. A subsample of fruit from each replicate was then analyzed for quality characteristics, including average individual berry weight, berry firmness using a firmness tester, soluble solids concentration (°Brix) using a refractometer, juice pH using a pH meter, and percent acidity using acid titration (Kalt et al., 2001).

Data were analyzed by split-plot analysis of variance using SAS v. 9.1 (SAS Institute, Cary, N.C., USA) with irrigation system treated as the main plot effect and irrigation level treated as the subplot effect. Irrigation system means were compared within irrigation levels using the least significant difference ($LSD_{0.05}$) test.

RESULTS AND DISCUSSION

The total amount of water applied to each treatment during the first 2 years of production (2006 and 2007) is shown in Table 1. After adjustments for plant size and system efficiency, we applied, depending on the year and the level of irrigation, 22-66% more water by microspray and 145-250% more water by sprinkler than by drip. Plant size based on measures of canopy volume was somewhat larger in 2007 than in 2006, but weather conditions were cooler and wetter the second year, resulting in similar amounts of water applied to the treatments each year (Table 1).

During both years of the study, yield was significantly affected by irrigation system ($F_{2,8}$ = 17.0 and 14.0; both $P < 0.01$) and irrigation level ($F_{2,24}$ = 25.1 and 39.9; both $P < 0.01$). Interaction between system and level were also significant ($F_{4,24}$ = 5.22 and 10.3; both $P < 0.01$). Drip irrigation generally produced the highest yields among the different irrigation systems, averaging 5.6-6.4 $t{\cdot}ha^{-1}$ in 2006 and 6.5-7.3 $t{\cdot}ha^{-1}$in 2007, but plants irrigated by drip were less responsive to increasing levels of water application than those irrigated by sprinklers or microsprays (Fig. 1). Thus, while yield was highest with drip at 50% ET_c, it was similar among the systems at 100-150% ET_c. However, unlike drip or microsprays, yield decreased when sprinkler irrigation was increased from 100% to 150% ET_c. Shoot dry weight had a similar response to sprinkler treatments during the first 2 years of the study (Bryla, 2008), suggesting that yield reductions at 150% ET_c may have been simply due to smaller plant size. It was later concluded that the reductions in plant size and yield were related to drier soil conditions and lower plant water potentials at the highest irrigation level (Bryla, unpublished results). Visually, plants in this treatment produced the densest canopy, shedding water away from the roots during rain or irrigation.

Berry weight was also affected by irrigation system ($F_{2,8}$ = 11.8; $P < 0.01$) and level ($F_{2,24}$ = 12.3; $P < 0.01$), but only in 2006, when fruit were largest with drip and increased from an average size of 1.18 g per berry at 50% ET_c to 1.34-1.35 g per berry at 100-150% ET_c (Fig. 2). In 2007, the effects of irrigation system and level on berry weight were more complicated as evidenced by a significant interaction between the main effects ($F_{4,24}$ = 5.86; $P < 0.01$). Berry weight during this second year was very similar between sprinklers and drip and smaller with microsprays at 50-100% ET_c, but was similar between microsprays and drip and smaller with sprinklers at 150% ET_c (Fig. 2). Like yield, smaller fruit at 150% ET_c was likely related to lower water status in the sprinkler-irrigated plants. Conversely, larger fruit at 50% ET_c with sprinklers was probably due to a lower crop load. Fruit size often increases in blueberry as the number of fruit per plant decreases (Strik et al., 2003). This size increase is due not only to less competition among the fruit for carbohydrates but also to increased water status of the plants during fruit ripening (Bryla, unpublished results).

Aside from berry size, irrigation method and level also significantly affected other aspects of fruit quality, including firmness and soluble solids concentration. Both characteristics were significantly affected by system x level interactions [$F_{4,24}$ = 9.35 and 19.0 (firmness) and 5.17 and 17.0 (soluble solids); all $P < 0.01$] and, in both cases, were generally lower in fruit harvested from drip-irrigated plants than in those harvested from plants irrigated by sprinklers or microsprays (Figs. 3 and 4). These differences were most apparent at 50% ET_c but decreased among the systems as irrigation levels increased to 100-150% ET_c. Such reductions were likely due to less water stress in these treatments. Water stress often increases fruit firmness and soluble solids due to reductions in fruit volume (e.g., Crisosto et al., 1994). Smaller berries were indeed firmer and higher in soluble solids than larger-sized berries in the present study.

Juice pH and titratable acidity were also significantly affected by system x level interactions each year [$F_{4,24}$ = 4.47 and 7.22 (pH) and 14.2 and 10.8 (titratable acidity); all $P < 0.01$], indicating irrigation treatment effects on fruit taste and ripening were complicated (Figs. 5 and 6). While less straightforward than with other characteristics of fruit quality, irrigation treatments that received less than enough water to maximize production (and therefore probably experiencing water stress) often had higher pH and titratable acidity. However, some exceptions occurred, including lower pH when plants were irrigated at 50% ET_c by either sprinklers or microsprays in 2007 (Fig. 5) and lower titratable acidity when plants were irrigated at 50% ET_c by drip in 2006 (Fig. 6). Further study is underway to help clarify these relationships.

CONCLUSION

The results indicated that drip generally produced higher yields and larger berries with much less water than sprinklers or microsprays. Plants irrigated by microsprays required at least 130% more water than those irrigated by drip to achieve the same level of production, while plants irrigated by sprinklers always had less production than drip even with 250% more water. Sprinklers and microsprays, conversely, produced firmer fruit with higher soluble solids than drip, especially when less water was applied. Soft fruit is often a problem in 'Elliott', particularly when weather is sunny and hot. Thus, under certain circumstances, irrigation with sprinklers or microsprays may improve storage and quality of the fruit for market; however, based on irrigation at 50% ET_c, deficit irrigation with drip would likely produce a similar result.

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Tables

Table 1. Irrigation applied to 'Elliott' blueberry in 2006 and 2007.

Irrigation level	Irrigation (mm)[z]					
	2006			2007		
	Sprinkler	Microspray	Drip	Sprinkler	Microspray	Drip
50% ET_c	497	232	153	493	219	180
100% ET_c	994	506	305	951	512	388
150% ET_c	1531	724	437	1416	773	548

[z]Reference ET, precipitation, average mean temperature, and average daily solar radiation from April to September (growing season) were: 1066 mm, 170 mm, 16.2°C, and 256 $W \cdot m^{-2}$, respectively, in 2006; and 956 mm, 216 mm, 15.3°C, and 250 $W \cdot m^{-2}$, respectively, in 2007. Total growing degree days (base 10°C) were 1290 in 2006 and 1194 in 2007.

Figures

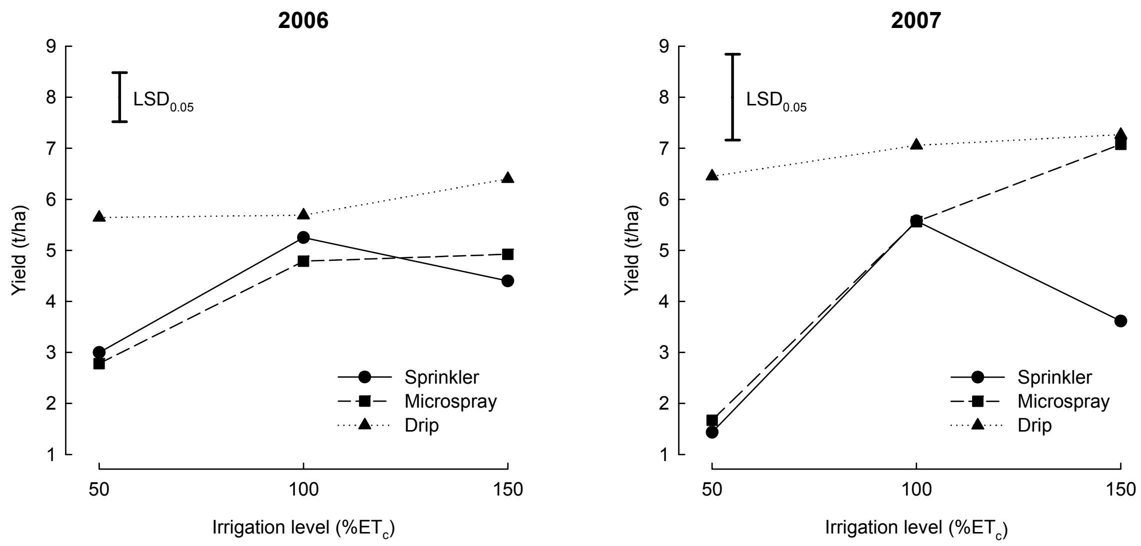

Fig. 1. The effect of irrigation method and level of irrigation on marketable yield of 'Elliott' blueberries harvested in 2006 and 2007. Each symbol represents the mean of five replicates and error bars represent the least significant difference for comparing irrigation methods at the 5% level of significance ($LSD_{0.05}$).

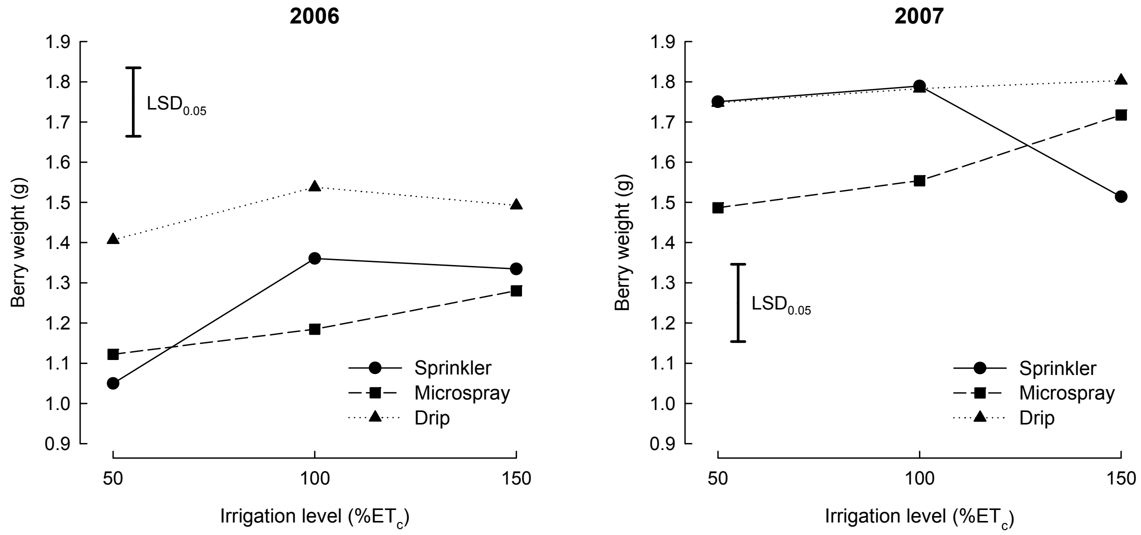

Fig. 2. The effect of irrigation method and level of irrigation on average individual weight of 'Elliott' blueberries harvested in 2006 and 2007. Each symbol represents the mean of five replicates and error bars represent the least significant difference for comparing irrigation methods at the 5% level of significance ($LSD_{0.05}$).

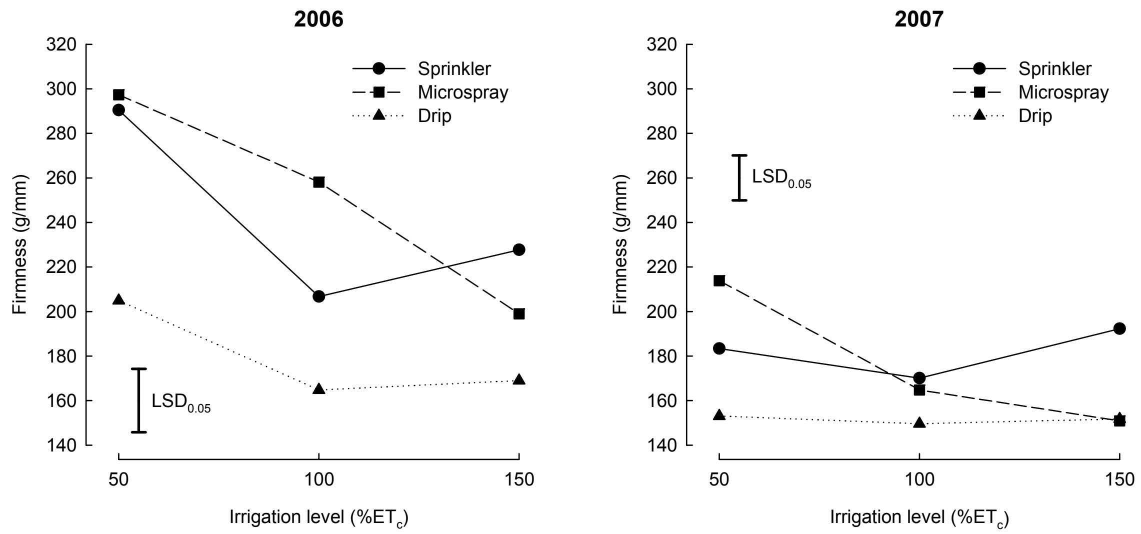

Fig. 3. The effect of irrigation method and level of irrigation on firmness of 'Elliott' blueberries harvested in 2006 and 2007. Each symbol represents the mean of five replicates and error bars represent the least significant difference for comparing irrigation methods at the 5% level of significance ($LSD_{0.05}$).

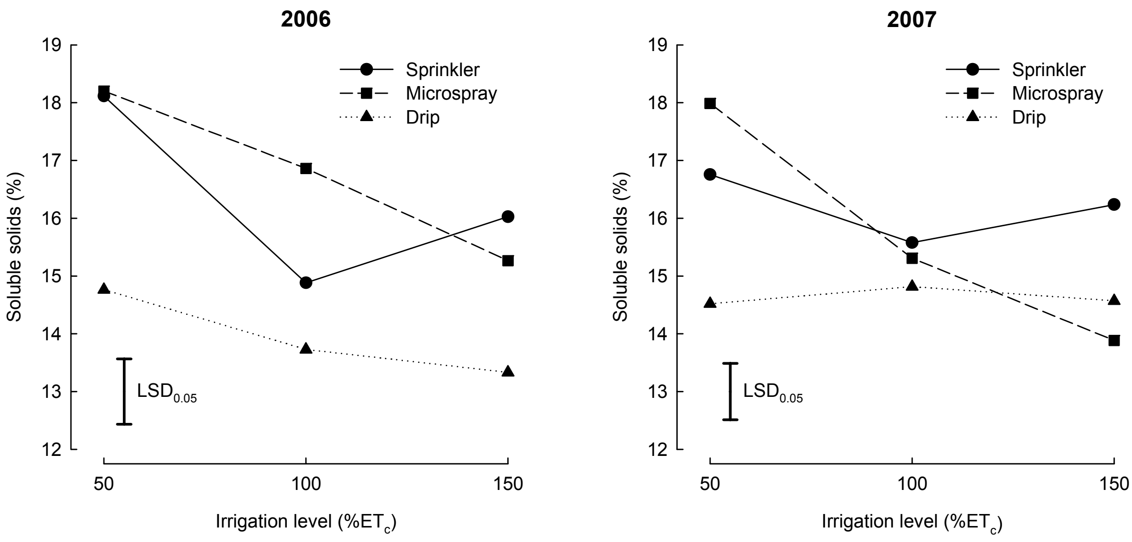

Fig. 4. The effect of irrigation method and level of irrigation on soluble solids concentration of 'Elliott' blueberries harvested in 2006 and 2007. Each symbol represents the mean of five replicates and error bars represent the least significant difference for comparing irrigation methods at the 5% level of significance ($LSD_{0.05}$).

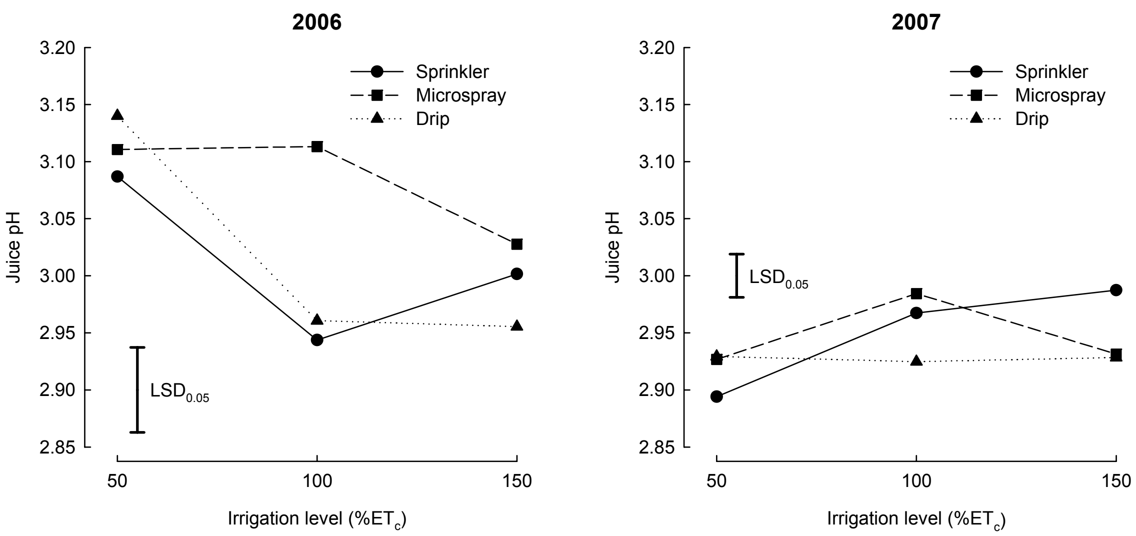

Fig. 5. The effect of irrigation method and level of irrigation on juice pH of 'Elliott' blueberries harvested in 2006 and 2007. Each symbol represents the mean of five replicates and error bars represent the least significant difference for comparing irrigation methods at the 5% level of significance ($LSD_{0.05}$).

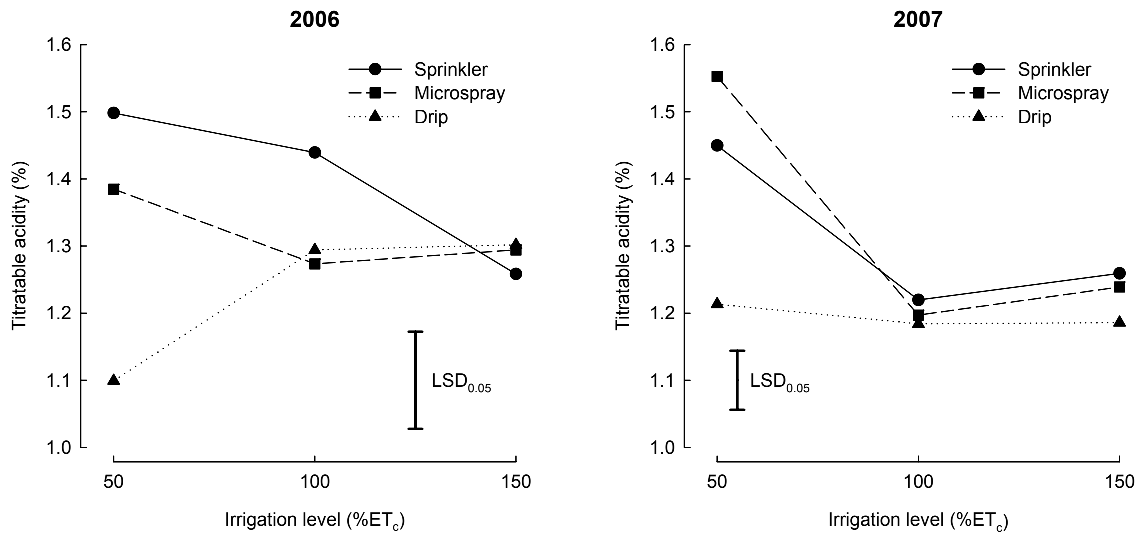

Fig. 6. The effect of irrigation method and level of irrigation on titratable acidity of 'Elliott' blueberries harvested in 2006 and 2007. Each symbol represents the mean of five replicates and error bars represent the least significant difference for comparing irrigation methods at the 5% level of significance ($LSD_{0.05}$).