EFFECTS OF SOLID AND LIQUID MULTI-FERTILIZERS WITH OR WITHOUT HUMIC ACID ON CRANBERRY GROWTH AND YIELD

YU, Z. M.[1] – LV, P.[1*] – WANG, L. M.[1] – WANG, H.[1] – ZHOU, L. P.[1] –ZHANG, J. Z.[1] – SHI, J.[2*]

[1]*Institute of Natural Resources and Ecology, Heilongjiang Academy of Sciences, Harbin 150040, China*

[2]*Heilongjiang Natural Resources Ecological Protection Restoration Monitoring Center, Harbin 150090, China*

(Received 5th Jun 2023; accepted 11th Aug 2023)

Abstract. This study aimed to determine the optimal fertilization conditions for perennial cranberry. The effects of fertilizer with low, medium, or high nutrient levels, supplied in solid or liquid form and with or without humic acid (HA) on cranberry were determined in a field experiment. The number of erect stems, fruit diameter, number of fruit set, 100-grain weight, and yield increased as the nutrient supply level increased from nitrogen-phosphorous-potassium (NPK) 3.30 kg/667 m^2 (low) to NPK 6.00 kg/667 m^2 (medium) to NPK 9.90 kg/667 m^2 (high). At the medium nutrient level, fruit diameter, fruit set, 100-grain weight, and yield were significantly higher in the liquid fertilizer treatments than in the solid fertilizer treatments. A compound fertilizer consisting of HA and NPK was better than inorganic NPK fertilizer. The addition of HA to solid fertilizer significantly increased fruit diameter, fruit set, and fruit yield; and the addition of HA to liquid fertilizer significantly increased fruit set. Considering fertilizer costs and the health of the soil ecological environment, NPK 6.00 kg + 4 kg HA/667 m^2 solid or liquid fertilizer is recommended for cranberry plants cultivated on a large scale.
Keywords: *Vaccinium macrocarpon, multiple ratio, different forms, yield index; agronomy traits*

Introduction

Cranberry (*Vaccinium macrocarpon* Ait), also known as large cranberry, American cranberry, or bearberry, is a small berry in the *Vaccinium* genus in the Rhododendron family. This crop is mainly grown in cool zones of the northern hemisphere in acidic peat soil, and is widely distributed in the United States (Zhao et al., 2020). Cranberries are known as “superfruits” because they contain natural nutrients and phytochemicals with nutritional properties, are rich in moisture, fiber, vitamins, and minerals, and have a low calorific value (Pappas et al., 2009). Cranberries are also rich in polyphenols, organic acids, terpenes, and complex carbohydrates. Extracts prepared from cranberries have been shown to have antioxidant properties and anti-tumor activity, to prevent cardiovascular disease, and to delay aging (Zou et al., 2013; Wei et al., 2017). Wild cranberry resources are becoming scarce as a result of climate change and large-scale habitat destruction by humans, so it is important to be able to cultivate this plant successfully.

Many studies have explored various aspects of cranberry, including its introduction and domestication, nutritional characteristics, and breeding, as well as suitable planting technologies including weed control and pest control (Eaton et al., 1971; Doehlert, 1972; Eaton, 1976; Doughty, 1984; Vorsa et al., 2002, 2005; Guédot et al., 2019). In terms of nutrient regulation, DeMoranville (1992) and Carolyn (1993) conducted field experiments to determine the optimum annual amount of nitrogen-phosphorous-potassium (NPK) fertilizer required for growth and determined the effects of different

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_49114929

fertilizer types and application methods on cranberry crops. Their results showed that the amount of N should not exceed 40 pounds/acre, and the amount of P_2O_5 should not exceed 20 pounds/acre. They concluded that fertilization exceeding these amounts did not increase production and polluted the environment (DeMoranville, 1992 and Carolyn, 1993). Davenport (1997) also determined the effect of different N fertilization levels and application times on cranberry yield, and found that the optimum amount of N was 20–40 pounds/acre, and the maximum fertilizer demand was during the early flowering period (Davenport et al., 1996, 1997). DeMoranville et al. (1997) tested the effects of different forms, application rates, and application times of fertilizer on cranberry production in Massachusetts, USA, and found that the optimal P_2O_5 application rate was 10–20 pounds/acre (DeMoranville et al., 1997).

Research on cranberry production in China was carried out later, and this crop is still not grown on a large scale domestically. Chinese studies on cranberry have focused on the collection and identification of germplasm resources, introduction and cultivation, establishment of gardens and nurseries, extraction and utilization of functional components, and molecular markers (Wu et al., 2010; Qu and Li, 2014; Jiang et al., 2016; Gai et al., 2017; Geng, 2017). To date, however, there have been no studies on the nutrient requirements of cranberry plants grown in China. Researchers in other countries have explored the nutrient requirements of cranberry, including its requirements for macronutrients (NPK) and some micronutrients (calcium, magnesium, sulfur, and trace elements). However, there has been less attention paid to the influence of different nutrient levels, different fertilizer forms (solid or liquid), and different fertilizer types (organic or inorganic or a combination) on the growth of cranberries under large-scale cultivation. In particular, little is known about how combinations of fertilizers affect the growth of cranberry plants. The effects of different fertilizers on cranberry have not been reported so far.

The main component of the organic fertilizer applied with the inorganic fertilizer in this study was humic acid (HA), a natural organic substance with excellent nutritional functions and properties because of its abundant functional groups. Previous studies have shown that HA positively affects the root growth, flower bud differentiation, fruit yield, and quality of berry crops such as grapes and blueberries (Cao et al., 2019; Han et al., 2019; Tian et al., 2019). Therefore, we speculated that it may also be beneficial for the growth of cranberry crops.

The aim of this study was to compare the effects of different forms of fertilizer on cranberry in a field trial. We compared formulated fertilizers and commercial fertilizers applied at high, medium and low nutrient levels, in solid and liquid forms, with and without HA. We measured growth and productivity indices of cranberry including the number of erect stems, fruit diameter, number of fruit set, 100-grain weight, and yield. On the basis of the results, we determined the optimal fertilization conditions for cranberry plants grown on a large scale.

Materials and methods

Test site and test materials

Fuyuan is located at the confluence of the Heilongjiang River and the Ussuri River (133° 40′ 08″ to 135° 5′ 20″ East longitude and 47° 25′ 30″ to 48° 27′ 40″ North latitude). This area has a temperate monsoon climate, and is in the fourth and fifth cumulative temperature zone, with an annual cumulative temperature of 1900°C–

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_49114929

2100°C, comparable to the climatic conditions in Wisconsin, USA. The soil at the field site was a peat soil with the following properties: organic matter 60.9 g/kg; HA ≥ 43.1 g/kg; N, P, K ≥ 400 mg/kg, pH 4.81. The cranberry plants were 3 years old and were the 'Stevenson' variety.

Experimental design

The experiment was divided into three nutrient levels according to inorganic fertilizer concentrations (i.e. N, P and K content), which low nutrient was total amount of 3.30 kg ≤ NPK ≤ 6.00 kg; medium nutrient was total amount of 6.00 kg ≤ NPK ≤ 9.90 kg; high nutrient was total amount of NPK ≥ 9.0 kg. The experiment consisted of a control (CK, no fertilizer) and 10 treatments: Multi-component solid fertilizer supplying low, medium, and high nutrient levels with HA (T1–3); multi-component solid fertilizer supplying a medium nutrient level without HA (T4); multi-component liquid fertilizer supplying low, medium, and high nutrient levels (T5–7), multi-component liquid fertilizer supplying a medium nutrient level with HA (T8); and two commercially available acidic commercial fertilizers: Multi-component solid fertilizer (T9) and an HA-based multi-component liquid fertilizer (T10) (*Table 1*).

Table 1. *Nutrient ratios and dosage of fertilizers in different treatments and the control*

Treatment	Name	Nutrient distribution ratio and amount applied/667 m^2
CK	Control	No fertilizer
T1	Solid multi-component fertilizer 1	Nutrient distribution ratio: N-P_2O_5-K_2O = 0.74-1.25-1.35 Fertilizer amount: total amount of NPK ≥ 3.30 kg + HA ≥ 4.0 kg
T2	Solid multi-component fertilizer 2	Nutrient distribution ratio: N-P_2O_5-K_2O = 1.50-1.86-2.70 Fertilizer amount: total amount of NPK ≥ 6.00 kg + HA ≥ 4.0 kg
T3	Solid multi-component fertilizer 3	Nutrient distribution ratio: N-P_2O_5-K_2O = 3.7-2.50-3.78 Fertilizer amount: total amount of NPK ≥ 9.90 kg + HA ≥ 4.0 kg
T4	Solid multi-component fertilizer 4	Nutrient distribution ratio: N-P_2O_5-K_2O = 1.50-1.86-2.70 fertilizer amount: total amount of NPK ≥ 6.00 kg
T5	Liquid multi-component fertilizer 1	Nutrient distribution ratio: N-P_2O_5-K_2O = 0.74-1.25-1.35 fertilization amount: total amount of NPK ≥ 3.30 kg, pH ≤ 6.5, water insoluble matter ≤ 2.5 g/100 mL
T6	Liquid multi-component fertilizer 2	Nutrient distribution ratio: N-P_2O_5-K_2O = 1.50-1.86-2.70 fertilization amount: total amount of NPK ≥ 6.00 kg, pH ≤ 6.5, water insoluble matter ≤ 2.5 g/100 mL
T7	Liquid multi-component fertilizer 3	Nutrient distribution ratio: N-P_2O_5-K_2O = 3.70-2.50-3.78 fertilization amount: total amount of NPK ≥ 9.90 kg, pH ≤ 6.5, water insoluble matter ≤ 2.5 g/100 mL
T8	Liquid multi-component fertilizer 4	Nutrient distribution ratio: N-P_2O_5-K_2O = 1.50-1.86-2.70 fertilization amount: total amount of NPK ≥ 6.00 kg + HA ≥ 4.0 kg, pH ≤ 6.5, water insoluble matter ≤ 2.5 g/100 mL
T9	Multi-formula Fertilizer	Nutrient distribution ratio: N-P_2O_5-K_2O = 0.65-0.65-2.05 fertilizer amount: total amount of NPK ≥ 3.30 kg
T10	Humic acid liquid fertilizer	Nutrient distribution ratio: N-P_2O_5-K_2O = 2.26-1.10-2.70 fertilization amount: total amount of NPK ≥ 6.00 kg + HA ≥ 4.0 kg, pH ≤ 6.5, water insoluble matter ≤ 2.5 g/100 mL

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_49114929

Each plot had an area of 12 m^2 (3 m × 4 m). Degradable plastic sheets were laid at a depth of 50 cm between the plots to block the lateral flow of nutrients between the cells. Each cell was 1 m wide, and each treatment was randomly arranged and repeated three times.

We selected *in vitro* cuttings with consistent growth, washed the roots with water, and then planted them with a spacing of 20 cm. Because some plots contained sprinkler irrigation equipment, the number of cuttings planted in the plots ranged from 250 to 280. The growth of cranberry plants can be divided into the germination stage, budding stage, thick-neck stage, hook stage, early flowering stage, mid-flowering stage, fruit-setting stage, bud-differentiation stage, and harvest stage. The cuttings were planted between 30 May 2018 and June 10 2018. After planting the cuttings, fertilizer was applied once. In 2019 and 2020, the total amount of fertilizer applied was unchanged, but it was applied twice; one-third was applied at the bud-differentiation stage and two-thirds was applied at the early flowering stage. Solid fertilizer was mechanically evenly spread on the soil, and liquid fertilizers were diluted 1:800 with water. Growth and fruit parameters were measured on September 26, 2020. All other field management procedures and practices were those normally used in this region, e.g. regular watering, weeding, thinning, etc. All the cranberry plants were grown for 3 years under the above experimental conditions.

Determination of growth and fruit parameters

The diameter of cranberry fruit was measured using Vernier calipers; the 100-seed weight and fruit yield were determined by weighing. The number of fruit set and the number of erect stems were counted manually. Data were analyzed and figures were drawn using SPSS 19.0 (SPSS Inc., Chicago, IL, USA) and Excel 2013.

Statistical analysis

Data were analyzed using SPSS 19.0 (SPSS Inc., Chicago, IL, USA) and Excel 2013. The figures were drawn using Sigmaplot 10.0. The one-way ANOVA and Duncan’s test were used to analyze the difference at the $P < 0.05$ level.

Results

Effect of different fertilizer on the number of erect stems of cranberry plants

The number of erect stems on cranberry plants is an important yield component. As shown in *Table 2,* the number of erect stems was significantly higher in all treatments, except for the low nutrient level organic-inorganic composite solid fertilizer (T1 treatment) than in CK ($P < 0.05$). The highest numbers of erect stems were in the high nutrient level inorganic liquid fertilizer (T7 treatment) (*Table 2*).

As shown in *Figure 1a,* the number of erect stems of cranberry per unit area increased with increasing amounts of fertilizer, whether it was in liquid or solid form. Within each nutrient level, there was no significant difference in the number of erect stems between the solid and liquid fertilizer treatments. There were significant differences in the number of erect stems between low and high nutrient levels (A and C, respectively, in *Figure 1*). At the medium nutrient level, the number of erect stems of cranberry was not significantly different between the medium nutrient level inorganic composite solid fertilizer (T4 treatment) and the medium nutrient level inorganic liquid fertilizer (T6 treatment) (*Fig. 1b; Table 2*).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_49114929

Table 2. *Effects of different fertilizer treatments on the number of erect stems of cranberry plants*

Treatment	Mean no. of erect stems/m^2	Standard deviation	Duncan's test
CK	348.0	106.1	a
T1	470.3	42.2	ab
T2	781.3	122.7	de
T3	874.0	17.3	e
T4	715.0	73.8	cd
T5	592.7	94.6	bc
T6	733.0	91.0	cd
T7	914.7	38.6	e
T8	711.0	39.7	cd
T9	633.3	88.4	c
T10	607.0	54.8	c

T1, low nutrient level (NPK 3.30 kg + 4 kg HA/667 m^2) organic-inorganic composite solid fertilizer; T2, medium nutrient level (NPK 6.00 kg + 4 kg HA/667 m^2) organic-inorganic composite solid fertilizer; T3, high nutrient level (NPK 9.90 kg + 4 kg HA/667 m^2) organic and inorganic composite solid fertilizer; T4, medium nutrient level (NPK 6.00 kg/667 m^2) inorganic composite solid fertilizer; T5, low nutrient level (NPK 3.30 kg/667 m^2) inorganic liquid fertilizer; T6, medium nutrient level (NPK 6.00 kg/667 m^2) inorganic liquid fertilizer; T7, high nutrient level (NPK 9.90 kg/667 m^2) inorganic liquid fertilizer; T8, medium nutrient level (NPK 6.00 kg + 4 kg HA/667 m^2) organic-inorganic compound liquid fertilizer; T9, inorganic multi-component solid commercial fertilizer (NPK 3.30 kg/667 m^2); T10, organic-inorganic composite liquid commercial fertilizer (NPK 6.00 kg + 4 kg HA/667 m^2)

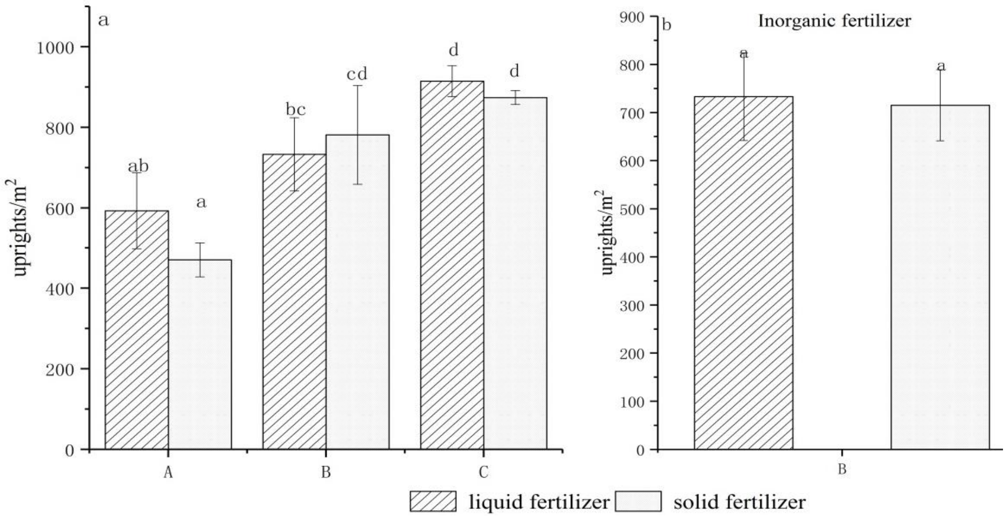

Figure 1. *Effects of different forms of fertilizer on number of erect stems of cranberry plants. Left panel: A, low nutrient level (NPK 3.30 kg/667 m^2) organic-inorganic solid fertilizer (T1) and liquid fertilizer (T5); B, medium nutrient level (NPK 6.00 kg + 4 kg HA/667 m^2) organic-inorganic composite solid fertilizer (T2) and liquid fertilizer (T8); C, high nutrient level (NPK 9.90 kg/667 m^2) organic-inorganic solid fertilizer (T3) and liquid fertilizer (T7). Right panel: B, medium nutrient level (NPK 6.00 kg/667 m^2) applied as inorganic solid fertilizer (T4) or liquid fertilizer (T6). Different letters above bars indicate significant differences (P < 0.05)*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_49114929

As shown in *Figure 2,* the addition of HA to solid or liquid inorganic fertilizer had no significant effect on the number of erect stems of cranberry.

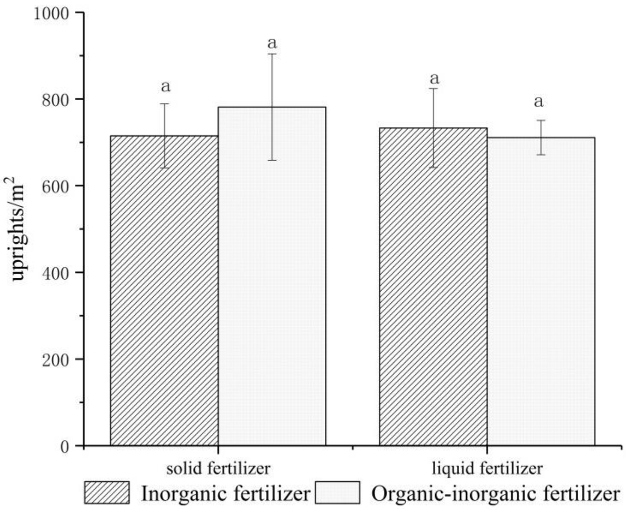

Figure 2. *Effect of adding HA to solid or liquid fertilizer on number of erect stems of cranberry. Solid fertilizer treatments: organic-inorganic compound fertilizer (T2) and inorganic fertilizer (T4); liquid fertilizer treatments: organic-inorganic compound fertilizer (T8) and inorganic fertilizer (T6).*

Effects of different fertilizers on cranberry fruit diameter

The average cranberry fruit diameter in the treatments ranged from 15.4 mm to 20.0 mm, which was significantly higher than that in CK (12.1 mm). The average fruit diameters in the high nutrient level organic and inorganic composite solid fertilizer (T3 treatment) and high nutrient level inorganic liquid fertilizer (T7 treatment) were 19.7 mm and 20 mm, respectively, which were significantly different from those in the other treatments, but not significantly different from each other. There were significant differences in the mean fruit diameter between the medium nutrient level organic-inorganic composite solid fertilizer (T2 treatment) and medium nutrient level inorganic liquid fertilizer (T6 treatment) and the low nutrient level organic-inorganic composite solid fertilizer (T1 treatment), medium nutrient level inorganic composite solid fertilizer (T4 treatment), low nutrient level inorganic liquid fertilizer (T5 treatment), and inorganic multi-component solid commercial fertilizer (T9 treatment), but not among the low nutrient level organic-inorganic composite solid fertilizer (T1 treatment), medium nutrient level inorganic composite solid fertilizer (T4 treatment), low nutrient level inorganic liquid fertilizer (T5 treatment), and inorganic multi-component solid commercial fertilizer (T9 treatment) (*Table 3*).

Figure 3a compares fruit diameter under three different nutrient levels between solid and liquid fertilizer treatments. As shown in *Figure 3a,* the average fruit diameter in the low nutrient level organic-inorganic composite solid fertilizer (T1)– high nutrient level organic and inorganic composite solid fertilizer (T3) treatments (with HA) was slightly smaller than that in the liquid fertilizer treatments low nutrient level inorganic liquid fertilizer (T5)– high nutrient level inorganic liquid fertilizer (T7) (without HA), but the difference was not significant. As shown in *Figure 3b,* at the medium nutrient level, the

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_49114929

average fruit diameter was 10.48% higher in the liquid fertilizer treatment (T6) than in the solid fertilizer treatment (T4), and this difference was significant (*Table 3*).

Table 3. *Effects of different fertilizer treatments on mean cranberry fruit diameter*

Treatment	Mean fruit diameter (mm)	Standard deviation	Duncan's test
CK	12.1	0.3	a
T1	15.4	0.3	b
T2	17.7	0.6	d
T3	19.7	1.3	e
T4	16.1	0.8	bc
T5	15.7	0.6	b
T6	17.8	0.9	d
T7	20.0	0.3	e
T8	17.4	0.6	cd
T9	15.9	1.1	b
T10	16.7	0.8	bcd

Different letters indicate significant differences among treatments ($P < 0.05$). See note of *Table 2* for detailed descriptions of treatments

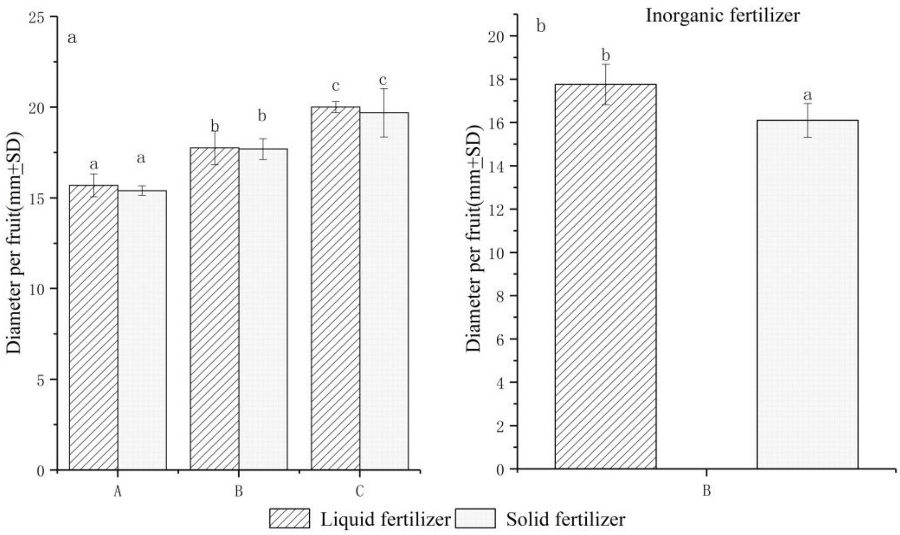

Figure 3. *Effects of different forms of fertilizers on the diameter of cranberry fruit. See legend of Figure 1 for descriptions of different treatments*

The medium nutrient level organic-inorganic composite solid fertilizer (T2 treatment) and medium nutrient level inorganic composite solid fertilizer (T4 treatment) had the same inorganic nutrient content supplied as solid fertilizer, but the medium nutrient level organic-inorganic composite solid fertilizer (T2 treatment) had additional HA. Compared with the medium nutrient level inorganic composite solid fertilizer (T4 treatment), the medium nutrient level organic-inorganic composite solid fertilizer (T2 treatment) increased the fruit diameter significantly by 9.94%. The medium nutrient level inorganic liquid fertilizer (T6) and medium nutrient level organic-inorganic

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_49114929

compound liquid fertilizer (T8) treatments had the same inorganic nutrient content supplied as liquid fertilizer, but the medium nutrient level organic-inorganic compound liquid fertilizer (T8) treatment had additional HA. There was no significant difference in the average fruit diameter between the medium nutrient level inorganic liquid fertilizer (T6) and medium nutrient level organic-inorganic compound liquid fertilizer (T8) (*Fig. 4; Table 3*).

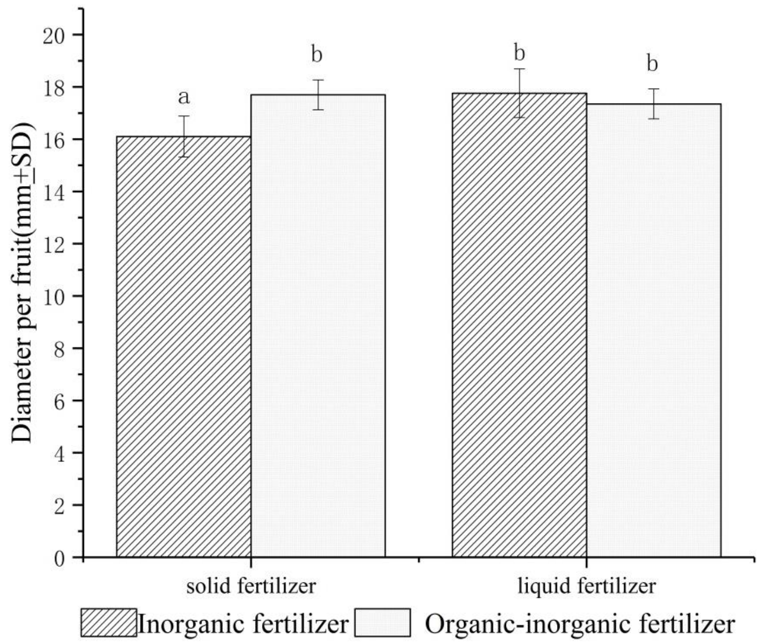

Figure 4. *Effect of HA addition to fertilizer on diameter of cranberry fruit. See legend of Figure 2 for descriptions of different treatments*

Effects of different fertilizers on fruit set

As shown in *Table 4,* the number of fruit set was significantly lower in CK than in all the treatments, except for the low nutrient level organic-inorganic composite solid fertilizer (T1) treatment. The number of fruit set ranged from 11.0 (CK) to 550.0 high nutrient level inorganic liquid fertilizer (T7). The number of fruit set was not significantly different among the medium nutrient level inorganic composite solid fertilizer (T4 treatment), low nutrient level inorganic liquid fertilizer (T5 treatment), and inorganic multi-component solid commercial fertilizer (T9 treatment) and organic-inorganic composite liquid commercial fertilizer (T10 treatment). The number of fruit set was the highest in the high nutrient level inorganic liquid fertilizer (T7) treatment, followed by the high nutrient level organic and inorganic composite solid fertilizer (T3), medium nutrient level organic-inorganic compound liquid fertilizer (T8), the medium nutrient level organic-inorganic composite solid fertilizer (T2), and medium nutrient level inorganic liquid fertilizer (T6) treatments; and was significantly higher in all those treatments than in the medium nutrient level inorganic composite solid fertilizer (T4 treatment), low nutrient level inorganic liquid fertilizer (T5 treatment), and inorganic multi-component solid commercial fertilizer (T9 treatment) and organic-inorganic composite liquid commercial fertilizer (T10 treatment). The number of fruit set was not significantly different between the medium nutrient level organic-inorganic composite

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_49114929

solid fertilizer (T2) and medium nutrient level inorganic liquid fertilizer (T6) treatments. The number of fruit set per unit area increased significantly with increasing nutrient levels (low to medium to high).

Table 4. *Effects of different fertilizer treatments on the number of cranberry fruit set*

Treatment	Mean no. of fruit/m^2	Standard deviation	Duncan's test
CK	11.0	1.0	a
T1	40.3	16.8	ab
T2	194.3	6.4	d
T3	359.3	45.8	f
T4	91.7	6.4	bc
T5	102.7	6.4	c
T6	227.3	22.9	d
T7	550.0	77.0	g
T8	289.7	45.8	e
T9	77.0	11.0	bc
T10	88.0	11.0	bc

Different letters indicate significant differences among treatments ($P < 0.05$). See note in *Table 2* for descriptions of different treatments

As shown in *Figure 5a*, as the nutrient level increased, the number of fruit set per unit area (m^2) significantly increased in the liquid fertilizer and solid fertilizer treatments. At the low and high nutrient levels, the number of fruit set differed significantly between the solid and liquid fertilizer treatments. At the medium nutrient level, the average number of fruit set was 1.5 times higher in the liquid fertilizer treatment (T6) than in the solid fertilizer treatment (T4), and this difference was significant (*Fig. 5b; Table 4*).

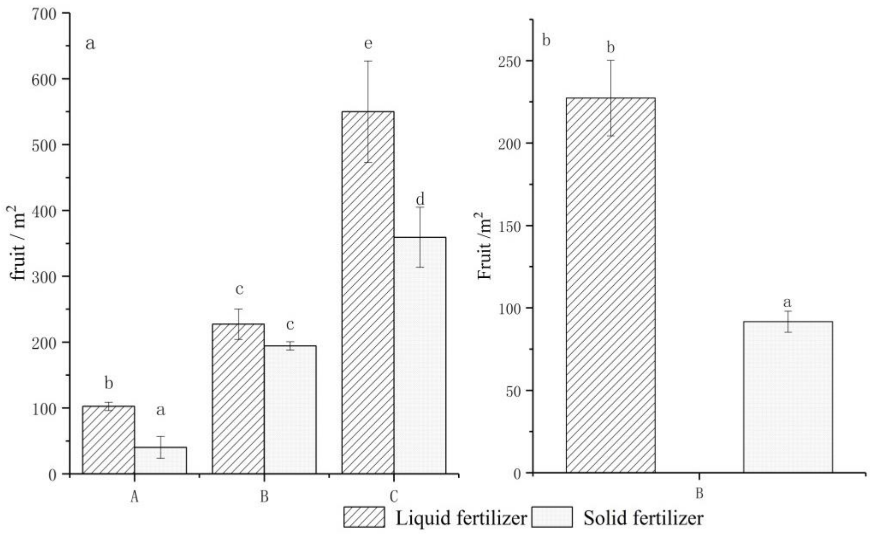

Figure 5. *Effects of different forms of fertilizers on the number of cranberry fruit set. See legend of Figure 1 for descriptions of different treatments*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_49114929

The inorganic nutrient contents were the same in the medium nutrient level organic-inorganic composite solid fertilizer (T2) and medium nutrient level inorganic composite solid fertilizer (T4) solid fertilizer treatments, but the medium nutrient level organic-inorganic composite solid fertilizer (T2) treatment had additional HA. Similarly, the inorganic nutrient contents were the same in the medium nutrient level inorganic liquid fertilizer (T6) and medium nutrient level organic-inorganic compound liquid fertilizer (T8) liquid fertilizer treatments, but the T8 treatment had additional HA. The number of fruit set was significantly higher in the T2 treatment than in the T4 treatment, and significantly higher in the medium nutrient level organic-inorganic compound liquid fertilizer (T8) treatment than in the medium nutrient level inorganic liquid fertilizer (T6) treatment. These results show that the addition of HA to solid or liquid inorganic fertilizer resulted in increased fruit set (*Fig. 6, Table 4*).

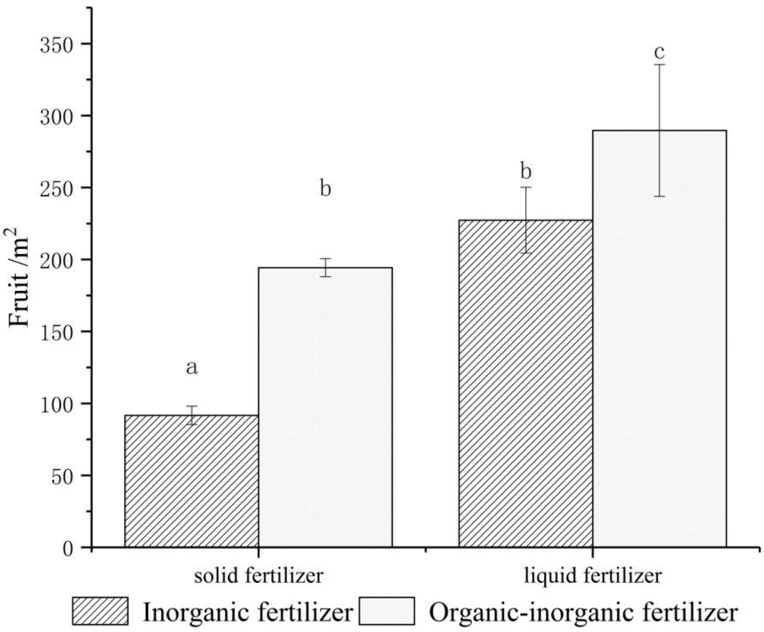

Figure 6. *Effect of adding HA to formula fertilizer on the number of cranberry fruit set. See legend of Figure 2 for descriptions of different treatments*

Effect of different formula fertilizers on 100-grain weight of cranberry fruit

As shown in *Table 5,* the 100-grain weight of cranberry fruit ranged from 153.33 g to 250 g in the treatments, compared with 102 g in CK. The 100-grain weight in the high nutrient level organic and inorganic composite solid fertilizer (T3) treatment was significantly different from those in the low nutrient level organic-inorganic composite solid fertilizer (T1) and low nutrient level inorganic liquid fertilizer (T5) treatments; and that in the high nutrient level inorganic liquid fertilizer (T7) treatment was significantly different from those in the T1, low nutrient level inorganic liquid fertilizer (T5), inorganic multi-component solid commercial fertilizer (T9), and organic-inorganic composite liquid commercial fertilizer (T10) treatments. The difference in 100-grain weight between high nutrient level organic and inorganic composite solid fertilizer (T3) and high nutrient level inorganic liquid fertilizer (T7) treatment was not significant.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_49114929

Table 5. *Effects of fertilizer treatments on 100-grain weight of cranberry*

Treatment	Mean no. fruit/m^2	Standard deviation	Duncan's test
CK	102.00	8.19	a
T1	153.33	28.87	abc
T2	190.00	10.00	bcde
T3	236.67	5.77	de
T4	185.00	7.07	ab
T5	160.00	10.00	abc
T6	193.33	5.77	cde
T7	250.00	26.46	e
T8	200.00	10.00	cde
T9	170.00	17.32	bcd
T10	170.00	10.00	bcd

Different letters indicate significant differences among treatments ($P < 0.05$). See note in *Table 2* for descriptions of different treatments

As shown in *Figure 7a*, as the nutrient level increased, the 100-grain weight of cranberry fruit increased, regardless of whether the fertilizer was in solid or liquid form. The yield in the high-nutrient liquid fertilizer treatment was significantly higher than those in the low-nutrient liquid and solid fertilizer treatments, but not significantly different from those in the medium-nutrient solid and liquid fertilizer treatments. At each nutrient level, the yield was slightly higher in the liquid fertilizer treatment than in the solid fertilizer treatment, but the differences were not significant (*Fig. 7a*). At the medium nutrient level, medium nutrient level inorganic composite solid fertilizer (T4) and medium nutrient level inorganic liquid fertilizer (T6) treatments, the 100-grain weight was significantly higher in the liquid fertilizer treatment than in the solid fertilizer treatment (*Fig. 7b; Table 5*).

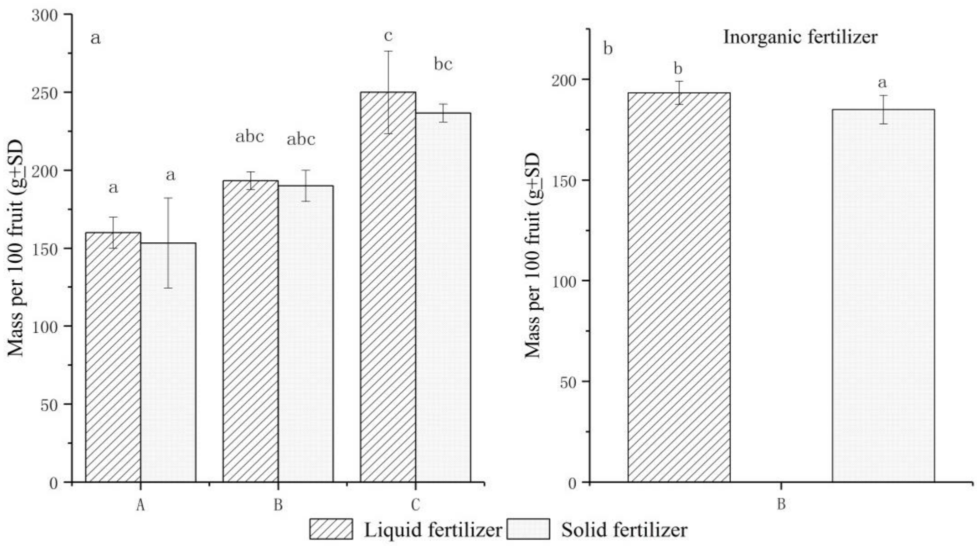

Figure 7. *Effects of different forms of formula fertilizers on 100-grain weight of cranberry fruit. See legend of Figure 1 for descriptions of different treatments*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_49114929

The nutrient levels were the same in the medium nutrient level organic-inorganic composite solid fertilizer (T2) and medium nutrient level inorganic composite solid fertilizer (T4) solid fertilizer treatments, but the medium nutrient level organic-inorganic composite solid fertilizer (T2) treatment had additional HA. The 100-grain weight was not significantly different between the medium nutrient level organic-inorganic composite solid fertilizer (T2) and the medium nutrient level inorganic composite solid fertilizer (T4) treatments. Similarly, the nutrient levels were the same in the medium nutrient level inorganic liquid fertilizer (T6) and medium nutrient level organic-inorganic compound liquid fertilizer (T8) treatments, but the medium nutrient level organic-inorganic compound liquid fertilizer (T8) treatment had additional HA. The 100-grain weight was not significantly different between the T8 and T6 treatments. These results show that the addition of HA to solid or liquid fertilizers did not significantly increase the 100-grain weight of cranberry. In general, the 100-grain weight was higher in the liquid fertilizer treatments than in the solid fertilizer treatments (*Fig. 8; Table 5*).

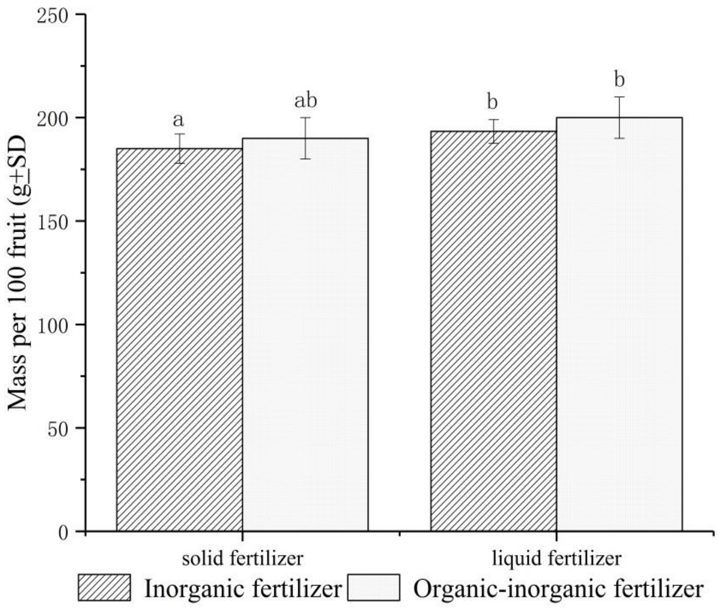

Figure 8*. Effect of adding HA to formula fertilizer on 100-grain weight of cranberry. See legend of Figure 2 for descriptions of different treatments*

Effects of different formula fertilizer treatments on cranberry yield

As shown in *Table 6*, the cranberry yield was not significantly different between CK and the low nutrient level organic-inorganic composite solid fertilizer (T1), medium nutrient level inorganic composite solid fertilizer (T4), low nutrient level inorganic liquid fertilizer (T5), and inorganic multi-component solid commercial fertilizer (T9) treatments. However, the yield differed significantly between CK and the medium nutrient level organic-inorganic composite solid fertilizer (T2), high nutrient level organic and inorganic composite solid fertilizer (T3), medium nutrient level inorganic liquid fertilizer (T6), high nutrient level inorganic liquid fertilizer (T7), and medium nutrient level organic-inorganic compound liquid fertilizer (T8) treatments. The treatments and CK were ranked, from highest cranberry yield to lowest, as follows: high nutrient level inorganic liquid fertilizer (T7) (918.84 kg/667 m^2) > high nutrient level

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_49114929

organic and inorganic composite solid fertilizer (T3) (568.38 kg/667 m^2) > medium nutrient level organic-inorganic compound liquid fertilizer (T8) (385.93 kg/667 m^2) > medium nutrient level inorganic liquid fertilizer (T6) (293.72 kg/667 m^2) > medium nutrient level organic-inorganic composite solid fertilizer (T2) (246.52 kg/667 m^2) > medium nutrient level inorganic composite solid fertilizer (T4) (115.19 kg/667 m^2) > low nutrient level inorganic liquid fertilizer (T5) (109.32 kg/667 m^2) > organic-inorganic composite liquid commercial fertilizer (T10) (99.54 kg/667 m^2) >inorganic multi-component solid commercial fertilizer (T9) (99.05 kg/667 m^2) > low nutrient level organic-inorganic composite solid fertilizer (T1) (30.08 kg/667 m^2) > CK (7.45 kg/667 m^2). There was no significant difference in yield between the medium nutrient level organic-inorganic composite solid fertilizer (T2) and medium nutrient level inorganic liquid fertilizer (T6) treatments, but the yields in those treatments differed significantly from the yields in the other treatments [except for medium nutrient level organic-inorganic compound liquid fertilizer (T8)]. The highest yield was in the high nutrient level inorganic liquid fertilizer (T7) treatment, followed by high nutrient level organic and inorganic composite solid fertilizer (T3) and then medium nutrient level organic-inorganic compound liquid fertilizer (T8), and the differences were significant among those three treatments (*Table 6*).

Table 6. *Effects of different fertilizer formula treatments on cranberry yield*

Treatment	**Mean yield (mg/667 m^2)**	**Standard deviation**	**Duncan's test**
CK	7.45	0.14	a
T1	30.08	7.26	a
T2	246.52	20.17	b
T3	568.37	84.87	d
T4	115.19	5.19	a
T5	109.32	3.36	a
T6	293.72	38.55	bc
T7	918.84	182.27	e
T8	385.93	59.80	c
T9	99.05	9.34	a
T10	99.54	10.59	a

Different letters indicate significant difference among treatments at $p < 0.05$. See note in *Table 2* for descriptions of different treatments

As the nutrient level increased from low to high, the fruit yield increased, regardless of whether the fertilizer was in liquid or solid form (*Fig. 9a*). The fruit yields were significantly higher in the high-nutrient treatments than in the medium-nutrient treatments; and significantly higher in the medium-nutrient treatments than in the low-nutrient treatments. At each nutrient level, the yield was higher in the liquid fertilizer treatment than in the solid fertilizer treatment, and this difference was significant in the high-nutrient treatment (*Fig. 9a*). Comparing the solid and liquid fertilizers at the medium nutrient level [the medium nutrient level inorganic composite solid fertilizer (T4) and medium nutrient level inorganic liquid fertilizer (T6) treatments, respectively], the fruit yield was significantly higher (2.5 times higher) in the liquid fertilizer treatment than in the solid fertilizer treatment (*Fig. 9b; Table 6*).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_49114929

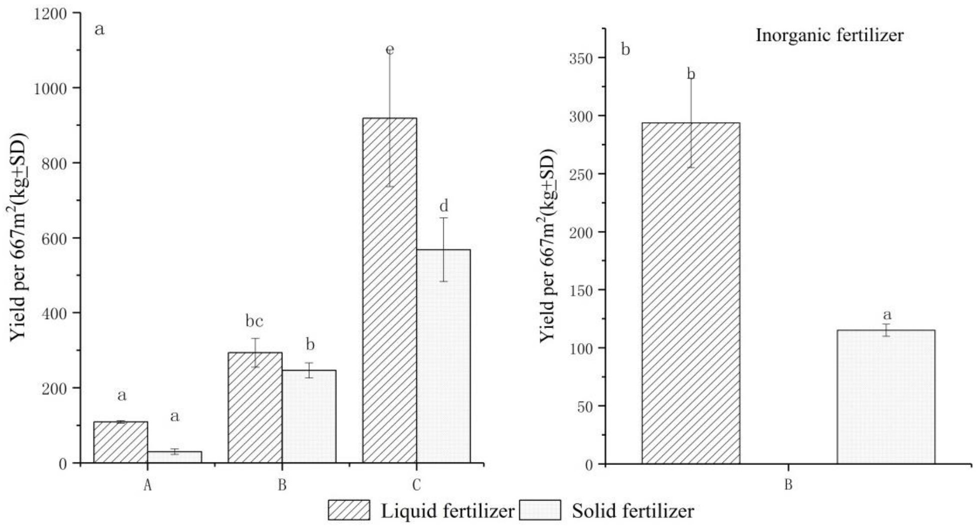

Figure 9. *Effects of different forms of fertilizer on cranberry yield. See caption of Figure 1 for descriptions of different treatments*

The addition of HA to solid or liquid fertilizers resulted in increased fruit yields. The treatments were ranked, from highest fruit yield to lowest, as follows: organic-inorganic composite liquid fertilizer (T8) > inorganic liquid fertilizer (T6) > organic-inorganic composite solid fertilizer (T2) > inorganic nutrient solid fertilizer (T4). There were significant differences in fruit yield among all those treatments, except between the organic-inorganic composite solid fertilizer (T2) and the inorganic nutrient liquid fertilizer (T6) treatment (*Fig. 10; Table 6*).

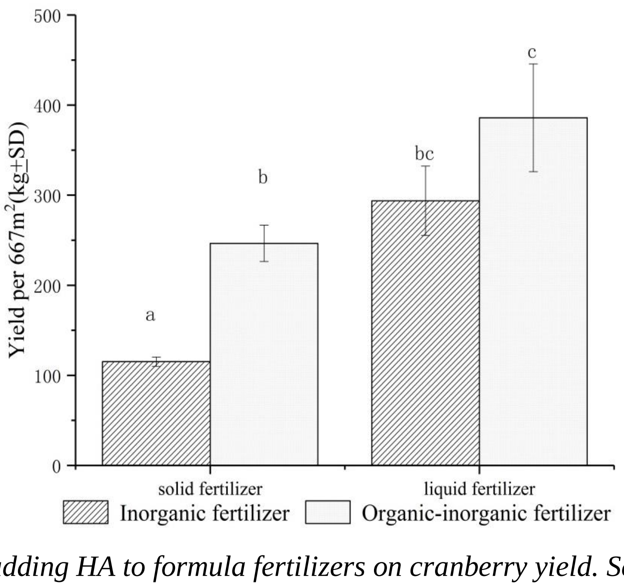

Figure 10. *Effect of adding HA to formula fertilizers on cranberry yield. See legend of Figure 2 for descriptions of different treatments*

Discussion

The application of solid and liquid multi-fertilizers positively affected cranberry growth and yield. In this study, we tested the effects of different nutrient levels (low, medium, high)

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_49114929

and different fertilizer forms (solid or liquid) with and without HA as an additive. All of these factors affected the growth and yield of cranberry, as discussed below.

Effect of different nutrient application levels on cranberry

There is a long history of research on the fertilizer requirements of different crops, and many studies have sought to establish a general method to find the optimal amount of fertilizer and nutrient ratio for crops (Ming, 2016). Nutrients are consumed by plants during growth. To optimize crop fertilization, the fertilizer ratio and nutrient gradient levels are usually determined after measuring the soil nutrient content and/or nutrient contents in the crop plants. In this study, we applied fertilizer at three nutrient levels; low (NPK 3.30 kg/667 m^2), medium (NPK 6.0 kg/667 m^2), and high (NPK 9.90 kg/667 m^2), and compared their performance with those of two commercially available fertilizers, T9 (NPK 3.30 kg/667 m^2) and T10 (NPK 6.00 kg/667 m^2). The results showed that different nutrient levels had very different effects on crop growth and development. For most indices, there was no significant difference between the low nutrient level (NPK 3.30 kg/667 m^2 in the T1, T5, and T9 treatments) and CK. Only fruit diameter and the number of fruit set differed significantly between these low nutrient level treatments and CK. The effects of the low nutrient level (NPK 3.30 kg/667 m^2) were significantly different from those of the medium and high nutrient levels (NPK 6.0 kg/667 m^2 and NPK 9.90 kg/667 m^2). This is because nutrient levels in the soil affect the osmotic pressure in the root zone, resulting in differences in crop root absorption capacity (Ji et al., 2021). For most of the indicators, their values were significantly higher in the high-nutrient treatments (NPK 9.90 kg/667 m^2 in the T3 and T7 treatments) than in the medium- and low-nutrient treatments. This result indicates that the root system absorbed nutrients and grew quickly. However, we also observed typical growth characteristics of cranberry under excessive fertilization. For example, the erect stems were slender and long, and the branches and leaves were lush and dense, resulting in insufficient sunlight for cranberry fruits, and causing poor fruit coloration with low quality, and high incidence of fruit rot. In severe cases, the incidence of cranberry disease can reach more than 10%. Therefore, we concluded that the high nutrient level (NPK 9.90 kg/667 m^2) is not suitable for cranberry plants under large-scale cultivation, consistent with the results of another study (Carolyn, 2014). Compared with the other fertilizer treatments, the commercial fertilizer treatment (T10) with a medium nutrient level (NPK 6.00 kg/667 m^2) had a weaker positive effect on cranberry growth and yield. This is because the nutrient distribution ratio differed between T10 and the other treatments (see *Table 1*). The purpose of multi-compound fertilization is to provide balanced and sustainable nutrition for cranberry plants, and to provide nutrients at optimum levels for crop yield and quality. This requires optimization of nutrient levels and proportions to provide the best economic, ecological and social benefits.

Effect of different forms of fertilizer on cranberry

As mentioned above, it is important to provide balanced nutrients to plants, because nutrients function together to promote growth and development. There is a synergistic regulation mechanism among N, P, and K, and the balance of different nutrients can only be achieved by adjusting the composition of fertilizer to meet the requirements of the crop.

DeMoranville (1992) and Carolyn (2014) studied the effects of different types of NPK application, and found that the ratio of nutrients affected the rate of N release.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_49114929

When a low N level is required, it is recommended that no fertilizer is added, or an NPK fertilizer with a ratio of 5-5-20. It has been reported that the growth index of cranberry is ideal when the N:P ratio is 1:1 or close to 2:1 (for example, NPK = 18-8-18). This is because a reasonable P supply can accelerate cell division and proliferation and promote plant growth and development, especially in the early growth stage. If P is insufficient, protein synthesis will be affected. In severe cases of P deficiency, proteins are degraded, thereby affecting N homeostasis. An adequate N supply increases not only the number of erect stems, but also photosynthesis (DeMoranville, 1992; Carolyn, 2014). This is consistent with HuB's view that nitrate acts as a signaling molecule through NRT1.1B-SPX4-NBIP1, which synergistically activates nitrate-responsive genes and P-starvation-inducible genes. Thus, nitrate signaling affects the balance of N and P (Hu et al., 2019). Some nutrients (e.g., P) in fertilizers have low mobility and a high fixation rate in soil, and so diffusion is the main way that they move to the root surface (Tinker and Nye, 2020). The diffusion of P in the soil, i.e., P availability, is affected by the soil moisture content (Mahtab et al., 1971). In this way, soil moisture conditions strongly affect nutrient uptake by crops' roots. In this study, we detected significant differences in fruit diameter, fruit set, 100-grain weight, and fruit yield between the liquid and solid fertilizer treatments. This is mainly because the multi-component compound liquid fertilizer was a small-molecule aqueous solution, which could be directly absorbed and utilized by the crop root system, so the nutrient utilization efficiency was high. In contrast, the multi-component compound solid fertilizer needed to dissolve in water in the soil before it could be absorbed and utilized by the plants. During the dissolution process, some nutrients would have been fixed and some would have diffused or volatilized in the soil, so the nutrient utilization rate would be lower. This is consistent with the findings of several previous studies (Wu, 2014; Zhan, 2015; Li et al., 2019).

Effect of adding an organic component, HA, on fertilization efficiency

Peat HA is a natural macromolecular organic acid. Because it has hydroxyl and phenolic hydroxyl groups in its structure, it can form chelates with some insoluble divalent or trivalent metal ions, and this improves nutrient utilization by plants. In addition, the HA molecule contains a variety of functional groups and phenolic quinone structures that enhance oxidase activity in plants. Increased oxidase activity leads to greater nutrient adsorption and increased synthesis of enzymes. The increased nutrient uptake results in accelerated plant growth, early emergence, and early maturity, which not only increases yield but also improves crop quality. In addition, the addition of HA to soil can affect the temperature and humidity conditions, thereby promoting microbial activity and regulating the soil N content (Zhang et al., 2014).

In another study, the application of HA and inorganic fertilizer at an appropriate ratio significantly increased the yield, vitamin C content, and soluble sugars content of seeded white grapes, and improved fruit quality and commercial performance (Mirjegi et al., 2011). Similarly, a peat fulvic acid compound fertilizer was shown to increase the volume and quality of blueberry fruit, the fruit soluble sugar content, vitamin C content, and sugar-acid ratio, as well as the contents of chlorophyll a, chlorophyll b, total chlorophyll, and soluble sugars in blueberry leaves. It also significantly increased the activity of superoxide dismutase and the free proline content in blueberry leaves, and significantly decreased the levels of the lipid peroxidation product, malondialdehyde (Yang, 2018). In this study, the fruit diameter, number of fruit set, and yield of cranberry were significantly

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_49114929

higher in the organic-inorganic compound fertilizer treatments (fertilizers containing HA) than in the inorganic fertilizer treatments (no HA). This result demonstrates that the combined application of HA and NPK fertilizers is the optimal fertilization method for sustainability of the system, as it achieves a high and stable crop yield. The reason for the increased yield may be the slow release of nutrients in the presence of HA; the greater soil nutrient pool; and increased stress resistance of cranberry plants. As a natural organic acid, HA may increase the mineralization process of organic nutrients in the soil, thereby promoting the release of insoluble nutrients and increasing the contents of total and available nutrients in the soil, which has the same effect as adding more minerals (Zhao et al., 2009; Luo et al., 2012). These findings indicate that an organic-inorganic fertilizer can supply balanced nutrients to plants and increase the nutrient supply, consistent with the results of other studies (Li et al., 2018).

Conclusion

Our results show that various fertilizer treatments can promote the growth and yield of cranberry. Most of the treatments significantly increased the number of erect stems, fruit diameter, number of fruit set, and 100-grain weight. Except for the number of erect stems and the number of fruit set, all other parameters were not significantly different between CK and the low-nutrient fertilizer treatment (NPK 3.30 kg + 4 kg HA/667 m^2). Among the other treatments, those resulting in the largest differences in cranberry growth, compared with that in CK, were NPK 6.00 kg + 4 kg HA/667 m^2 solid fertilizer, NPK 9.90 kg + 4 kg HA/667 m^2 solid fertilizer, NPK 9.90 kg/667 m^2 liquid fertilizer, and NPK 6.00 kg + 4 kg HA/667 m^2 liquid fertilizer. The cranberry yield was significantly increased by three fertilizer treatments (NPK 9.90 kg + 4 kg HA/667 m^2 solid fertilizer, NPK 9.90 kg/667 m^2 liquid fertilizer, and NPK 6.00 kg + 4 kg HA/667 m^2 liquid fertilizer) but not by the other five fertilizer treatments (NPK 3.30 kg + 4 kg HA/667 m^2, NPK 6.00 kg/667 m^2 solid fertilizer, NPK 3.30 kg/667 m^2 liquid fertilizer, NPK 6.00 kg/667 m^2 solid commercial fertilizer, and NPK 6.00 kg + 4 kg HA/667 m^2 liquid commercial fertilizer). Compared with solid fertilizer treatments, liquid fertilizer treatments resulted in significantly increased fruit diameter, fruit set, 100-grain weight, and yield. The effect of organic-inorganic compound fertilizer was significantly better than that of inorganic formula fertilizer in terms of fruit diameter, fruit set number, and yield of cranberry. Compared with the multi-component compound fertilizers, the two commercial fertilizers had weaker effects to promote cranberry growth. On the basis of our results, we recommend NPK 6.00 kg + 4 kg HA/667 m^2 solid fertilizer or NPK 6.00 kg + 4 kg HA/667 m^2 liquid fertilizer for the large-scale cultivation of cranberry.

Acknowledgments. This study was supported by the National Key R&D Project Provincial Funding (Project No. GX17B008); Heilongjiang Academy of Sciences pilot ripening project “Cranberry Nutrient Control Technology Ripening and Scale Demonstration (HSSH2022ZR01).

REFERENCES

[1] Cao, H. Y., Ji, X. H., Zhang, Y. (2019): Effects of different content of humic acid compound fertilizer on grape yield and quality. – Soil Bull 50(3): 670-674.

DOI: http://dx.doi.org/10.15666/aeer/2105_49114929

[2] Carolyn, J. (2014): DeMoranville. Nutrition management for producing. – Nutrition 47-57.
[3] Davenport, J. R. (1996): The effect of nitrogen fertilizer rates and timing on cranberry yield and fruit quality. – J Am Soc Hortic Sci 121(6): 1089-1094.
[4] Davenport, J., Provost, J. (1994): Cranberry tissue nutrient levels as impacted by three levels of nitrogen fertilizer and their relationships to fruit yield and quality. – J Plant Nutr 17: 1625-1634.
[5] Davenport, J. R., Pitts, M. T., Provance, W., DeMoranville, C. (1997): Influence of soil iron and aerobic status on phosphorus availability in cranberry (Vaccinium macrocarpon Ait.) soils. – Acta Hortic 446: 369-379.
[6] DeMoranville, C. J. (1992): Cranberry nutrients, phenology, and NPK fertilization. – Doctoral Dissertation, University of Massachusetts, Amherst.
[7] DeMoranville, C. J., Davenport, J. R. (1997): Phosphorus forms, rates, and timing in Massachusetts cranberry production. – Environ Sci 446: 381-388.
[8] Doehlert, C. A. (1972): Composition and timing of cranberry fertilizers. – Proc. 84th Ann. Mtg. Amer. Cranberry Grower's Assoc, pp. 9-17.
[9] Doughty, C. C. (1984): Some effects of minor elements on cranberry (Vaccinium macrocarpon Ait.) growth. – Canadian Journal of Plant Science 64(2): 339-348.
[10] Eaton, G. W. (1971): Effect of N, P and K fertilizer applications on cranberry leaf nutrient composition, fruit color, and yield in a mature bog. – Journal of the American Society for Horticultural Science 96: 431-433.
[11] Eaton, G. W., Meehan, C. N. (1976): Effects on N and K applications on the leaf composition, field, and fruit quality of bearing `McFarlin' cranberries. – Canadian Journal of Plant Science 56: 107-110.
[12] Gai, Y. Z. (2017): Biological activity and metabolomics of cranberry. – Fruit Trees in Southern China 46(3): 184-188.
[13] Geng, J. M. (2017): Development and Identification of Novel EST-SSR Markers Based on the Transcriptome of Cranberry Fruit. – Jilin Agricultural University, Changchun.
[14] Guédot, C., McManus, P., Colquhoun, J., Nice, G. (2019): Pest Management in Wisconsin. – University of Wisconsin-Extension.
[15] Han, Z. Y., Liu, J. Q., Lan, Z. Q., Tian, X. W. (2019): Effects of different organic material ratios on the growth and soil nutrients of cherry tomato. – North Horticul 13: 23-29.
[16] Hu, B., Jiang, Z., Wang, W., Qiu, Y., Zhang, Z., Liu, Y., Chu, C. (2019): Nitrate - NRT1. 1B - SPX4 cascade integrates nitrogen and phosphorus signalling networks in plants. – Nat plants 5(4): 401-413.
[17] Ji, L., Yang, Y. C., Wang, J., Luo, Y. (2021): Effects of different light substrate ratios on root morphology and nutrient accumulation of walnut catalpa seedlings in containers. – Western Forestry Science 50(1): 42-49.
[18] Jiang, J., Wu, L. et al. (2006): Preliminary report on the performance of four cranberry varieties introduced. – China Fruit Tree 4: 28-30.
[19] Li, H. Y., Wang, Y., Sun, G. X., et al. (2018b): Study on the correlation between fertilization and quality and yield of pan peach. – Shihezi Science and Technology 2: 1-7.
[20] Li, P., Su, X. D., Wang, J. J., Guo, S. J. (2018a): Effects of combined application of humic acid fertilizer and bacterial fertilizer on orchard soil properties and grape yield and quality. – China Soil and Fertilizer 1: 121-126.
[21] Luo, H., Li, M., Hu, D. G. (2012): Effects of different organic fertilizers on fruit yield and quality of Feicheng peach. – J Plan Nutr Fer 18(4): 955-964.
[22] Mahtab, S. K., Godfrey, C. L., Swoboda, A. R., Thomas, G. W. (1971): Phosphorus diffusion in soils: I. The effect of applied P, clay content, and water content. – Soil Sci Soc Am J 35: 393~397.
[23] Ming, D. X. (2016): Field Experiment and Statistical Analysis. – Science Press, Beijing.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_49114929

[24] Mirjegi, K. A., Ziman, Yunus., Yushan, Kulban. (2011): Effect of organic-inorganic compound fertilizer on yield and fruit quality of kernelless white grapes. – Xinjiang Agricultural Science 48(12): 2294-2298.
[25] Pappas, E., Schaich, K. M. (2009): Phytochemicals of cranberries and cranberry products: characterization, potential health effects, and processing stability. – Crit Rev Food Sci 49(9): 741-781.
[26] Qu, L. P., Li, Y. D. (2014): Study on the chromosome number of bilberry plants in Northeast China. – South Agricul 8(31): 24-25.
[27] Tang, Q. (2019): Effects of humic acid on blueberry yield and fruit quality. – Fruit Trees in Southern China 48(3): 128-130.
[28] Tinker, B. T., Nye, P. H. (2000): Solute Movement in the Rhizosphere. – Oxford University Press, Oxford.
[29] Vorsa, N., Cunningham, J. Roderick, R., Howell, A. B. (2002): Evaluation of fruit chemistry in cranberry germplasm: potential for breeding varieties with enhanced health constituents. – Acta Hortic 574: 215-219.
[30] Vorsa, N., Polashock, J., Cunningham, D., Roderick, R. (2005): Genetic inferences and breeding implications from analysis of cranberry germplasm anthocyanin profiles. – J Am Soc Hortic Sci128: 691-697.
[31] Wei, Y., Zhan, Z. Y., Zhang, Y. (2017): Research progress of cranberry bioactive substances and main physiological functions. – Food Res Devel 38(10): 219-224.
[32] Wu, C. X., Yang, J. H. (2010): Construction methods and technical points of cranberry orchards. – J Tianjin Agricul U 17(1): 26-29.
[33] Wu, H. L. (2014): Effects of Water and Fertilizer Integration on Nutrient Dynamics, Quality and Yield of Jujube Leaves. – Northwest A&F University, Xianyang.
[34] Yan, J. (2018): Effects of Different Fertilizer Species on Blueberry Physiology and Fruit Quality. – Guizhou University, Guiyang.
[35] Zhan, A. (2015): Root Morphology and Physiological Regulation to Improve Nutrient and Water Absorption. – Northwest A&F University, Xianyang.
[36] Zhang, Z. Y. (2004): Theoretical basis and application prospect of developing peat humic acid nutrient matrix products. – Humic Acid 4: 7-12.
[37] Zhao, S. M., Liu, H. Y., Gu, L. W. (2020): American cranberries and health benefits—an evolving story of 25 years. – Journal of the Science of Food and Agriculture 100(14): 5111-5116.
[38] Zhao, Z. P., Tong, Y. A., Gao, Y. M. et al. (2009): Effects of different ratios of fertilization on the yield and quality of Fuji apples in Weibei dry source. – Journal of Plant Nutrition and Fertilizers 15 (5): 1130-1135.
[39] Zou, Y., Hu, W. Z., Jiang, A. L. et al. (2013): Research progress on bioactive substances in cranberry and their functional properties. – China Food Science and Technology 37(19): 396-398.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_49114929