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The basic performance and field application test of newly developed flower thinning system for peach cultivation

Young-Sik Park[1], Sang-Hyeon Im[1] and Jae-Yun Heo[2]*

[1]*Horticultural Crops Research Unit, Gangwondo Agricultural Research and Extension Services, Chuncheon, 24226, Korea.*
[2]*Deptartment of Plant Science, Gangneung-Wonju National University, Gangneung 25457, Korea.* **E-mail*: jyheo@gwnu.ac.kr

Abstract

We developed a pulsatory water spray gun system aimed at improving the efficiency of fruit setting management in peach cultivation and evaluated its feasibility for field application. In order to select the optimum water spray conditions and developmental stages of a flower for field applications, the influence of varying pressures of the power sprayer, nozzle diameters, and spray distances on flower and leaf bud thinning rate was investigated under four different developmental stages of flower such as bud sprouting, pink, balloon and flowering period using the water cut bearing branch of “Kawanakawase Hakuto” peach. The optimum conditions for the application of the pulsatory water spray gun were identified as a power sprayer pressure of 2 MPa at a nozzle diameter of 2 mm and spraying distance of 1 m in the ballooning and flowering stages. A flower bud thinning rate greater than 60 % and a leaf bud thinning rate lower than 7 % were observed under these conditions. In the field application test based on the selected conditions, the flower and leaf bud thinning rates were ideal for fruit production and showed higher fruit characteristics compared with fruits produced by a conventional fruit setting management method. In addition, the application of this system for flower thinning could considerably reduce the total work time compared with the conventional method. Hence, it is also expected that the newly developed system can be used for labor savings during fruit setting management in peach cultivation.

Key words: Flower developmental stages, fruit characteristics, fruit setting management, labor saving, *Prunus persica* L. Batsch

Introduction

Peach is one of the popular fruit crops for consumers because it is highly nutritious and contains a large amount of physiological active substances such as pectin and free amino acids (Oliveira *et al.*, 2016; Jung *et al.*, 2017). It also attracts the attention of farmers as substitute fruit crop because it is relatively easier to manage tree than other fruit crops and has low fruit storage capacity not enough to import from other countries (Yu *et al.*, 2016; Chang *et al.*, 2017). The cultivation area of peaches was 13,876 hectares and 170,044 tons of peaches were produced in 2000 in Korea, but owing to the increased consumption of peaches and interest in cultivation, the cultivation area and production of peaches increased to 19,877 hectares and 280,870 tons, respectively, in 2016.

In peach cultivation, flower or fruit thinning is required for preventing biennial bearing and stabilizing tree vigor (Southwick *et al.*, 1995), but the efficiency related to this process has decreased sharply owing to the recent reduction in labor force in the rural society, which has led to increased labor costs, thus undermining the competitiveness of peach cultivation in the market. Hence, the development of alternative technologies to reduce production costs as well as solve labor problems related to fruit setting management is needed for sustainable peach cultivation. In Korea, fruit setting management for some crops has been conducted through chemicals to cut the production costs (Lee *et al.*, 2015; Yoo *et al.*, 2016). However, for peach, fruit setting management is done using hands because the effect of chemicals on flower or fruit thinning in peach is inconsistent depending on meteorological conditions, which leads to the production of malformed fruits. Recently, mechanical systems for flower or fruit thinning have been introduced for some fruit crops (Lyons *et al.*, 2015; McClure and Cline, 2015; Theron *et al.*, 2017). Since these systems are not affected by varying environments and requires less labor forces, they have contributed toward reducing production costs and work duration.

Hence, it can be important to establish mechanical systems for fruit setting management to maintain the competitiveness of peach cultivation. For this reason, our research team developed a pulsatory water spray gun system that can be used for flower thinning in peaches and carried out a basic performance test. In addition, we experimented to investigate its feasibility for practical applications in the field. This paper reports the results of these experiments, which confirmed that newly developed system could be used as a labor saving system during fruit setting management in peach cultivation.

Materials and methods

Configuration of pulsatory water spray gun system: The pulsatory water spray gun system developed for peach flower bud-pinching/thinning consists of a spray gun that uses the hydraulic pressure of a 3-HP agricultural power sprayer and a hydraulic booster that amplifies the hydraulic pressure of the power sprayer (Fig. 1). The spray gun is made of lightweight and durable PE material and can withstand pressures up to 5 MPa. The hydraulic booster consisted of the inlet of the agricultural chemical hose connected with the power sprayer, a body part for amplifying the water pressure, and an outlet for the amplified water pressure,

Fig. 1. Newly developed pulsatory water spray gun system.

considering the convenience of the user.

Performance factor test of pulsatory water spray gun system: The basic performance of the pulsatory water spray gun system was evaluated by comparing the impact and concentration of the spray that was influenced by the pressure of the power sprayer, nozzle diameter, and spray distance. These aspects were tested in three sections and five sections, respectively. For each experimental condition, the spray impact was obtained by measuring the maximum load when the digital scale was mounted on the wall at right angles and spraying the gun for 10 s. Further, the spray concentration was obtained by the magenta grade measured by scanning the diameter of the pressure film part that was changed to red after spraying.

Setting of spray condition for pulsatory water spray gun system: The purpose of this experiment was to obtain the optimum spray pressure and flowering stage for field application of the pulsatory water spray gun system. The water cutting (approximately 30 cm) of the 5-year-old "Kawanakawase Hakuto," which was manually obtained at the Fruit Research Center of Gangwon Agricultural Research and Extension Service in 2016, was fixed on the table at an angle of 45°. Water was sprayed on the flowers under specific spraying conditions for 3 s. Then, the flower thinning rate and leaf bud thinning rate were examined after a day. In this experiment, the spraying distance and nozzle diameter used in water spraying were the conditions with the best spray impact and concentration in the pulsatory water spray gun system performance test. The tested pressure conditions were 1 MPa, 2 MPa, and 3 MPa. The developmental stages of flower buds considered in the experiment were bud sprouting period, pink period, balloon period, and flowering period. In each treatment, 10 bearing branches were used for the test.

Field application test of pulsatory water spray gun system: In the field, the effects of the pulsatory water spray gun system on flower thinning and fruit characteristics were also examined. Experiments were carried out at a peach farm in Sinchon-ri, Chuncheon, based on the optimum spray conditions determined in the manual flower thinning factor test. A 7-year-old "Kawanakawase Hakuto" (7 m x 4 m, Y-shaped) was used for the experimental test, and the test was conducted in the balloon and flowering periods, which were influenced by flower thinning through the spray gun. In particular, it was essential to know whether spraying using the water gun had a negative effect on the fruit. Therefore, additional experiments were performed to compare the main fruit characteristics of the cultivated fruits with fruit thinning, using 30 fruits during the harvest period. The fruit characteristics examined were fruit weight, soluble solid content, and acidity. The effect of field application of the pulsatory water spray gun system on the reduction of the labor force was examined by comparing working distance, working radius and total work duration for conventional fruit setting management method.

Statistical analysis: A basic statistical analysis was conducted using Microsoft Excel 2013, and IBM SPSS statistics V21.0 was also used for Duncan's multiple range tests.

Results and discussion

The effect of pressure, nozzle diameter, and spray distance of the pulsatory water spray gun on the spray impact amount and concentration is shown in Fig. 2. The range of the impingement force for each pressure observed after the shot of a pulsatory water spray gun was 0.1 to 0.2 kg at 1 MPa, 0.22 to 0.38 kg at 2

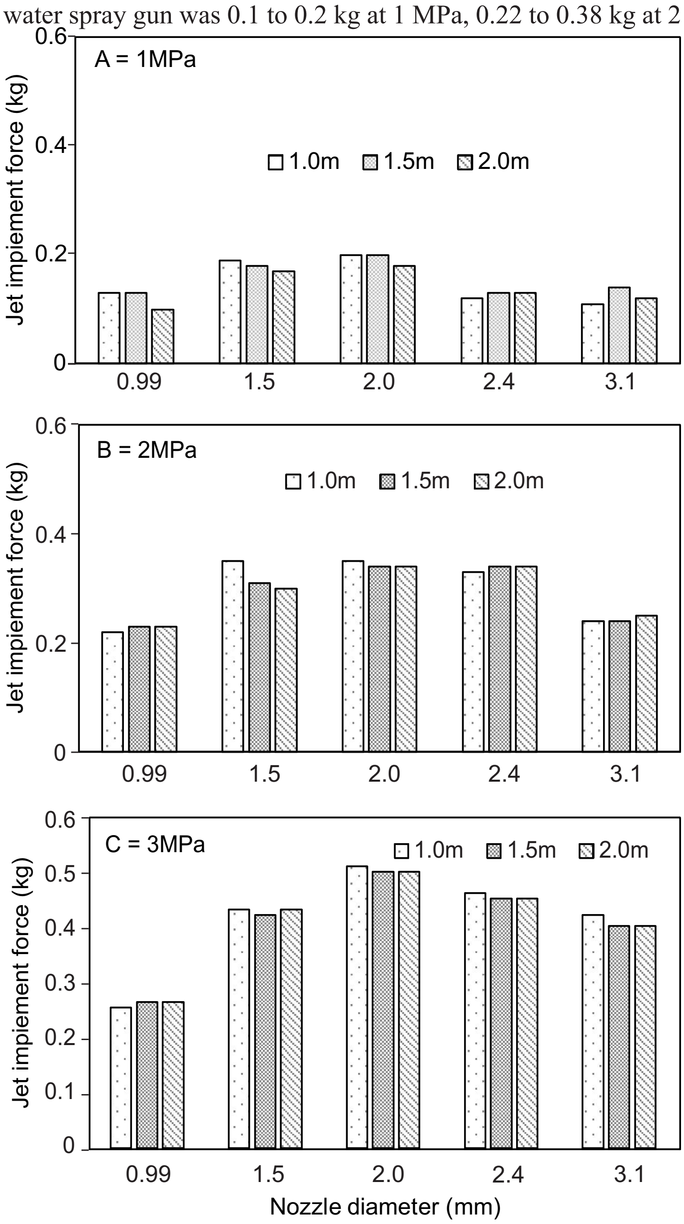

Fig. 2. Impingement forces evaluated by performance factors. Different bar graphic types indicate spray distance. A, B and C indicate 1 MPa, 2 MPa and 3 MPa of pressure, respectively.

MPa, and 0.24 to 0.5 kg at 3 MPa (Fig. 2). Therefore, the spray impingement force increased as the spray gun pressure increased. The observed spray impact based on the nozzle diameter was found to be the maximum critical point at 2.0 mm under all pressure conditions. The impingement force generally increased as the spraying distance decreased, and it was observed that the spray impingement force at all pressure conditions was high at a nozzle diameter of 2.0 m and spraying distance of 1.0 m. In particular, the maximum spray impingement force of 0.5 kg was observed at 3 MPa. The magenta grades at each diameter of the observed circle after spraying showed the best values at a nozzle diameter of 2.0 m and spraying distance of 1.0 m, at all spraying pressures (Fig. 3). Because a higher spray concentration and magenta grade imply a higher concentration (Park *et al.*, 2017), the best performance of the pulsatory water spray gun was obtained when a spraying pressure of 2 MPa or 3 MPa was used at a nozzle diameter of 2.0 m and spraying distance of 1.0 m.

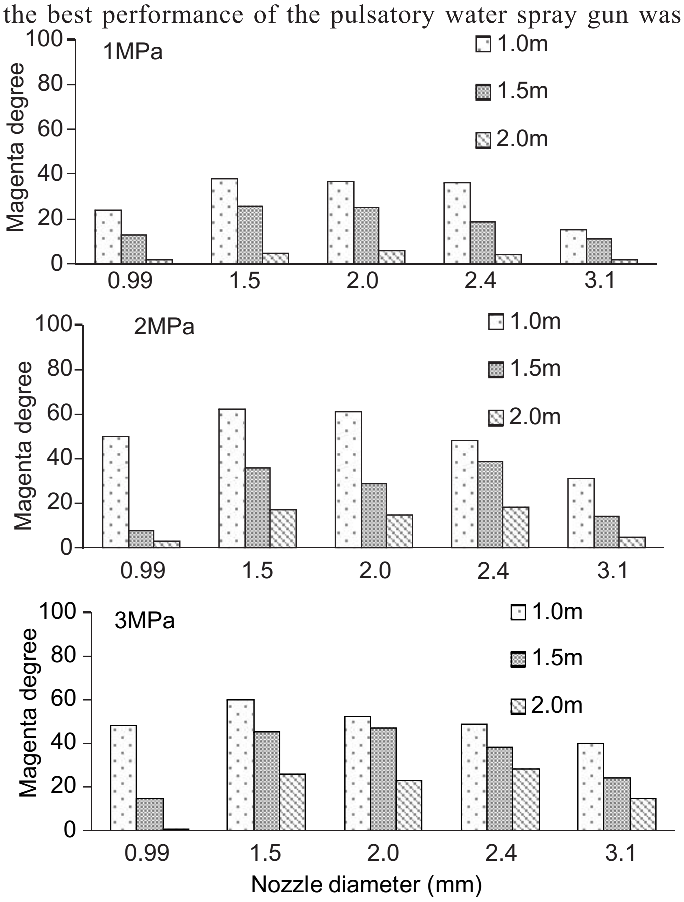

Fig. 3. Magenta grade measured at performance factors. Different bar graphic types indicate spray distance.

When the pulsatory water spray gun system was used under spraying conditions of a nozzle diameter of 2 mm and spraying distance of 1 m, the flower thinning rate increased, as the spraying pressure increased or the development stage of the flower bud was closer to the flowering period. At a pressure of 1 MPa, the leaf bud thinning rate was observed to be 0 % under all conditions, irrespective of the flower bud growth period. However, the rate of flower thinning was less than 60 %; thus, the pressure was not suitable for high quality fruit production. In case of a spray pressure of 3 MPa, the flower thinning rate was more than 70 % from the pink to the flowering periods (Table 1). However, the leaf bud thinning rate was higher than 23.9 % and the bark was peeled off, thereby resulting in problems of securing early leaves and production rate. Moreover, a flower thinning rate of 60 % was observed only in the balloon and flowering periods at a power spraying pressure of 2 MPa. The leaf bud thinning rate varied within 0-6.8 % according to the development stage of the flower bud. According to the report of Costa and Vizzotto (2000), the flower thinning rate should vary between 60-80 % and the leaf bud thinning rate should be 13 % or less to produce high-quality peaches. Therefore, the optimum conditions for using the pulsatory water spray gun are a power sprayer pressure of 2 MPa, nozzle diameter of 2 mm, and spraying distance of 1 m in the balloon and flowering periods.

The results of the determined leaf and flower thinning rates and fruit characteristics obtained after the field application of the developed system are listed in Table 2. In the field application test, the leaf thinning rate at the balloon and flowering periods was 5.8 and 7.9 %, respectively, which confirm that the leaf thinning rate was optimum for production of high-quality peaches, although it increased compared with the values of the internal test. Interestingly, the flower thinning rate during the balloon and flowering periods also increased and the efficiency of application for flower thinning during the balloon period was better than that during the flowering period. The highest fruit weight was obtained when applying the spray gun during the balloon period, while a significantly lower fruit weight was obtained using manual control (hand fruit thinning). These results suggest that an earlier application time of the pulsatory water spray gun system might affect fruit weight compared with manual control. Myers *et al.* (1993), Blanco (1987), and Miller *et al.* (2011) also reported that the timing of flowering or fruit thinning has a considerable

Table 1. Flower and leaf bud thinning rates for different power sprayer pressures and flower bud developmental stages in water cutting of the 5-year-old “Kawanakawase Hakuto” at a nozzle diameter of 2.0 m and spraying distance of 1.0 m.

Pressure	Flower bud thinning rate (%)				Leaf bud thinning rate (%)			
(MPa)	Bud sprouting	Pink	Balloon	Flowering	Bud sprouting	Pink	Balloon	Flowering
1	3.5±2.0 [z]	48.1±6.7	51.3±4.7	53.6±6.7	0.0±0.0	0.0±0.0	0.0±0.0	0.4±0.6
2	5.5±7.1	50.2±9.0	63.5±3.3	67.5±6.8	0.0±0.0	2.6±4.2	3.8±2.7	6.8±7.2
3	11.1±7.5	71.0±4.6	73.9±3.3	81.7±4.3	0.0±0.0	23.9±6.5	35.1±7.6	37.9±2.2

[z] Means ± SE (n=10)

Table 2. Effect of pulsatory water spray gun system on flower and leaf bud thinning rates and fruit characteristics in field grown “Kawanakawase Hakuto”

Thinning method	Developmental stage of flower	Flower bud thinning rate (%)	Leaf bud thinning rate (%)	Fruit weight (g)	Fruit firmness (kg/5 mm)	Soluble sugar content (°B)	Acidity (%)
Pulsatory water spray gun system	Balloon	74.5 a[z]	5.8 b	388.2 a	0.32 a	12.0 a	0.45 a
	Flowering	68.5 b	7.9 a	366.2 b	0.34 a	10.3 b	0.43 a
Conventional method (hand)	After flowering	-	-	358.6 b	0.36 a	9.8 b	0.48 a

effect on the weight of peach. Especially, Havis (1962) obtained similar results of the impact of flower thinning on the weight of peach; an earlier flower thinning process can result in a 7 to 30 % increase in fruit weight when compared with fruit thinning. In addition, the chemical properties of peach differed depending on the applications, and statistically significant difference was observed between applications in the analyzed fruit soluble solids. The highest soluble solid was observed when applying the spray gun during the balloon period, while the lowest was obtained in manual control. The results of this study indicate a significant difference in fruit soluble solids and the positive effect of the application of the developed system. These results may be a consequence of early flower removal that enable conserving photosynthetic reserves by reducing competition between all organs throughout the tree, which lead to fruit production with high quality (Byers *et al.*, 2010).

The effect of field application of the pulsatory water spray gun system on the reduction of labor force is shown in Table 3. The working distance for conventional method and newly developed system could be set as 0.6 m (the length in the arms of the humans) and 1.6 m (the length in the arms of the humans plus the effective water injection distance), respectively. As a result, the working radius of conventional method and newly developed system were calculated as 1.1 m^2 and 8.0 m^2, based on the circular area (Fig. 4), and the number of movements for flower thinning per hectare were analyzed at 1,243 and 8,841 times, respectively. When this system was applied in a peach orchard having a cultivation area of 1 hectare, the number of workers required is 6 and the total work duration is 48 h for fruit setting management, while the corresponding figures are 37 and 296 h, respectively, for the same area, when performing fruit setting management by hand. Hence, it has been found that the proposed system can reduce the total work duration compared with the conventional method. As we have already demonstrated, fruit characteristics observed during the developed thinning process were similar to the ones reported from hand flowering thinning studies on peaches and had no negative effect on fruit characteristics. Overall, these results suggest that newly developed pulsatory water spray gun system for flower thinning can be efficiently used in peach cultivation.

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Table 3. Effect of pulsatory water spray gun system on the number of movements and the total work duration for flower thinning of peaches per ectare

Thinning method	The number of movements			Total work duration		
	Working distance (m)	Working radius (m^2)	The number of movements	The number of workers	Working hours per day	Total work duration
Pulsatory water spray gun system	1.6	8.0	1243.3	6.0	8.0	48.0
Conventional method (hand)	0.6	1.1	8,841.9	37.0	8.0	296.0

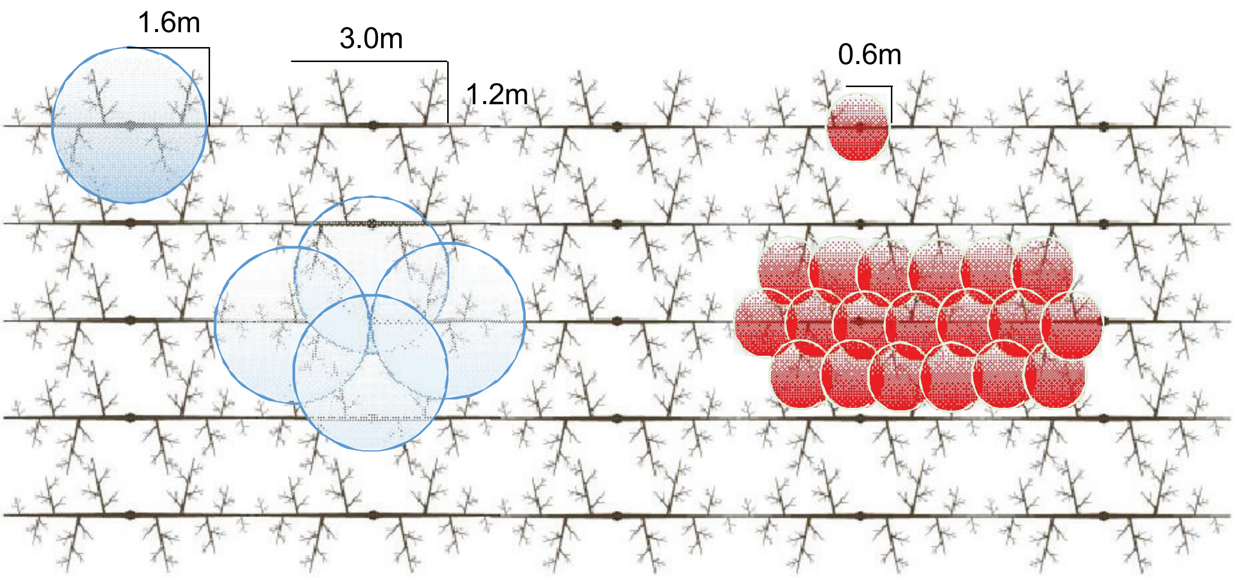

Fig. 4. Working radius of newly developed system (blue) and conventional flower thinning method (red).

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