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Weed Flora and Management Practices in Peach Orchard Fields in Korea

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ABSTRACT. This study was carried out two surveys in 2015 to monitor weed occurrence and determine the most troublesome weeds in peach orchards of Korea. The first survey identified 56 taxa belonging to 23 families including 27 annuals, 11 biennials, and 18 perennials. Based on importance values, *Conyza canadensis* (5.12%), *Plantago asiatica* (4.17%), and *Trifolium repens* (3.86%) were the dominant weeds in the first survey (from April to June). Seventeen exotic weeds were identified in the first survey, including *Conyza canadensis*, *Trifolium repens*, and *Chenopodium ficifolium*. The second survey (from September to October) identified 42 weeds belonging to 19 families including 23 annuals, 5 biennials, and 14 perennials. According to importance values, *Digitaria ciliaris* (8.00%) was the most dominant weed, followed by *Echinochloa utilis* (6.61%) and *Rorippa palustris* (6.48%). There were 12 exotic weeds, including *Taraxacum officinale*, *Rumex crispus*, and *Trifolium repens*. Additionally, according to Braun-Blanquet's scale showed that the dominance value was level 1 (41.98% and 46.43%, respectively) in two surveys. Currently, 40% of the total surveyed peach orchards applied herbicides for weed control. These results could provide basic data to assist orchardists in selecting the most suitable weed management methods; thereby, reducing labor inputs and effectively lowering costs while improving fruit yields in peach orchards of Korea.

***Key words*:** Dominant weed, Exotic weed, Weed control, Weed occurrence, Weed species

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Introduction

In Korea, fruit represents one of the main categories of economic crops. The country's fruit tree planted area was 155,000 ha in 2005, which is seven times larger than the acreage of orchards in 1955 (Ha and Chung, 2012). In particular, the area planted with peach trees has increased by around 3%, from 13,908 ha in 2011 to 14,210 ha in 2012. The yield of peaches ranked forefront in all fruits (Hong et al., 2012). In the face of the progressive increase in peach tree area, a series of problems have emerged in peach orchards, such as labor shortages, lagging product sales, and insufficient use of science-based management technologies. For these reasons, weed management methods are especially worthy of further study through surveys of weed flora.

Weed flora is a common component of orchard ecosystems. On the one hand, an abundance of weed species can increase population diversity in orchards. A previous survey of weeds was carried out in the Chungnam region; its results showed that 75 weed species belonging to 26 families were identified in orchard fields and that *Echinochloa crus-galli* was the most dominant of the weed species with high densities (Choi et al., 2009a). Additionally, Park et al. (2005) reported that weed ranking in orchards according to dominance had changed compared to that reported a decade ago. On the other hand, weeds bring about some serious adverse effects for peach trees. These negative impacts are mainly divided into environmental and biotic effects. Environmental effects can mean competition for light, water, and nutrients between weeds and peach trees (MacRae et al., 2007). Peach tree yields, rootstock, and leaves are affected by weed competition (Tworkoski and Glenn, 2001). In contrast, the term 'biotic effects' can imply that weed species are known favorable hosts

for insects and viruses (e.g. *Myzus persicae*, *Pantatomidae*, and beet mild yellowing virus) (Tamaki and Olsen, 1979; Leskey and Hogmire, 2005; Seo et al., 2011). Consequently, it is necessary to survey regularly for weed occurrence and to establish corresponding management methods.

In recent years, a large number of management methods have been applied to reduce weed emergence in orchards, such as hand mowing, mechanical tillage, mulching, herbicide application, and flame burning (Rifai et al., 2002; Lisek, 2014). However, these management methods have varying degrees of disadvantage. Thus, several different methods should be integrated as tactics to improve the effectiveness of weed control. Mechanical tillage in combination with hand mowing or herbicide application can effectively control weeds under the trees. Orchard floors treated with rice straw, glyphosate, and 80-mm plastic mulch caused a significant reduction in weed density and weed biomass (Abouziena et al., 2008). In addition, the simultaneous application of multi-herbicides can effectively deal with complex weed types in orchards. Glyphosate applied with oxyfluorfen or pelargonic acid obviously reduced number and fresh weight of weeds (Pyon and Lee, 1982; Wehtje et al., 2009). Carfentrazone-ethyl in combination with glyphosate or glufosinate can be used to simultaneously reduce monocotyledonous and dicotyledonous weed occurrence (Lee et al., 1997; Won et al., 2015).

The aim of the current study is to evaluate the frequency, type, and relative coverage of weeds occurring in peach orchards of Korea. Hereby, orchardists can rely on these survey results to select appropriate and effective weed management methods, decrease labor, and cost inputs in peach orchards. Also, data from the present survey can become the base for comparative studies with future surveys for the long-term monitoring of weed diversity.

Materials and Methods

Survey period and site

The study was carried out in peach orchards in Korea, from April to June 2015, for the first survey in spring, and from September to October 2015, for the second survey in autumn.

Survey methods

The frequency, species, number, and management method of weeds were investigated at each survey site. GPS (ICE CPS 100c) information and addresses of survey sites were recorded to ensure precise test field locations. As a result, exotic weed species locations could be known in each peach orchard. The area of each test field was estimated by pacing; counting the number of steps of a researcher from one end of the field to the other. Weed population and surrounding areas were recorded by photography with a camera (Canon100D) in the test fields.

Weed species were identified by visual observation in the surveyed fields. The covering ratio was calculated according to Braun-Blanquet (7-level system, 5, 4, 3, 2, 1, + and r) (1964). Braun-Blanquet's coverage scale for weed estimation was as follows: 5, covering more than 75% of the whole test fields; 4, any number of individuals covering 50-75% of the area; 3, any number of individuals covering 25-50% of the area; 2, very numerous or covering at least 5% of the area; 1, plentiful but of small cover value; +, sparsely present, cover small; r, very sparsely present, cover very small (Hwang et al., 2014).

Data analysis

The results of the weed survey were compiled into lists according to the Synonymic List of Vascular Plants of Korea (Korea National Arboretum, 2007). Exotic weeds (EW) were identified using "Colored Illustrations of Naturalized Plants of Korea" (Park, 2009) and with the paper describing upland field Flora (Jia et al., 2017). For classification into life cycles, weeds were divided into annuals, biennials, and perennials (Raunkiaer, 1934). Distribution proportion of each family of weeds was then calculated.

The importance values (IV) were analyzed based on the two surveys results (Curtis and McIntosh, 1950). Frequency was defined as the percentage of weed samples where the species are present in all the orchard fields under observation. The relative frequency (RF), relative coverage (RC), and importance value formula are as follows:

$$\text{o Relative frequency (RF)(\%)} = \frac{\text{Frequency of any species}}{\text{Total frequency of all species}} \times 100$$

$$\text{o Relative coverage (RC)(\%)} = \frac{\text{Coverage of any species}}{\text{Total cover of all species}} \times 100$$

$$\text{Important value (IV)(\%)} = (\text{RF} + \text{RC}) / 2$$

Results and Discussion

According to the results of the first survey, there were 56 taxa including 23 families, 45 genera, 50 species, and 6 varieties. The largest number of weed species belonged to the Compositae (11), followed by the Poaceae (9) and Scrophulariaceae (5). Seventeen exotic weeds were identified in the first survey, including *Conyza canadensis*, *Trifolium repens*, and *Chenopodium ficifolium* (Table 1). Meanwhile, there were 27 annual weeds, 11 biennial weeds, and 18 perennial weeds, which occupied 48.22%, 19.64%, and 32.14% of the total weed species, respectively (Fig. 1).

In the second survey, weeds were summarized as 42 taxa belonging to 19 families, 37 genera, 41 species, and 1 variety. The families were mainly classified as Compositae (8),

Table 1. Occurrence of weed species and exotic weeds in the first of two surveys of peach orchards in Korea in 2015.

Rank	Family	Scientific name	Life cycle	EW[z]
1	Compositae	*Artemisia princeps*	Perennial	
2		*Aster subulatus*	Annual	○
3		*Centipeda minima*	Annual	
4		*Conyza canadensis*	Biennial	○
5		*Crepidiastrum sonchifolium*	Biennial	
6		*Erechtites hieracifolia*	Annual	○
7		*Erigeron annuus*	Annual	○
8		*Lactuca scariola*	Annual	○
9		*Sonchus oleraceus*	Biennial	○
10		*Taraxacum officinale*	Perennial	○
11		*Taraxacum platycarpum*	Perennial	
12	Poaceae	*Agropyron tsukushiense*	Annual	
13		*Agropyron tsukushiense* var. *transiens*	Perennial	
14		*Agrostis stolonifera*	Perennial	
15		*Alopecurus aequalis*	Annual	
16		*Digitaria ciliaris*	Annual	
17		*Echinochloa utilis*	Annual	
18		*Eragrostis multicaulis*	Annual	
19		*Poa annua*	Annual	
20		*Poa sphondylodes*	Perennial	
21	Scrophulariaceae	*Lindernia procumbens*	Annual	
22		*Mazus pumilus*	Annual	
23		*Veronica arvensis*	Annual	○
24		*Veronica didyma* var. *lilacina*	Annual	○
25		*Veronica persica*	Biennial	○
26	Polygonaceae	*Persicaria hydropiper*	Annual	
27		*Rumex acetosa*	Perennial	
28		*Rumex acetosella*	Perennial	○
29		*Rumex crispus*	Perennial	○
30	Cruciferae	*Capsella bursa-pastoris*	Biennial	
31		*Lepidium apetalum*	Biennial	○
32		*Rorippa indica*	Perennial	
33		*Rorippa palustris*	Perennial	
34	Caryophyllaceae	*Arenaria serpyllifolia*	Annual	
35		*Stellaria aquatica*	Biennial	
36		*Stellaria media*	Biennial	

Table 1. Occurrence of weed species and exotic weeds in the first of two surveys of peach orchards in Korea in 2015 (continued).

Rank	Family	Scientific name	Life cycle	EW[z]
37	Chenopodiaceae	*Chenopodium album*	Annual	○
38		*Chenopodium album* var. *centrorubrum*	Annual	
39		*Chenopodium ficifolium*	Annual	○
40	Amaranthaceae	*Achyranthes fauriei*	Perennial	
41		*Amaranthus lividus*	Annual	○
42	Euphorbiaceae	*Acalypha australis*	Annual	
43	Convolvulaceae	*Calystegia sepium* var. *japonicum*	Perennial	
44	Papaveraceae	*Chelidonium majus* var. *asiaticum*	Biennial	
45	Commelinaceae	*Commelina communis*	Annual	
46	Cyperaceae	*Cyperus nipponicus*	Annual	
47	Rosaceae	*Duchesnea indica*	Perennial	
48	Rubiaceae	*Galium spurium* var. *echinospermon*	Biennial	
49	Cannabinaceae	*Humulus japonicus*	Annual	
50	Lamiaceae	*Leonurus japonicus*	Biennial	
51	Asclepiadaceae	*Metaplexis japonica*	Perennial	
52	Umbelliferae	*Oenanthe javanica*	Perennial	
53	Plantaginaceae	*Plantago asiatica*	Perennial	
54	Portulacaceae	*Portulaca oleracea*	Annual	
55	Solanaceae	*Solanum nigrum*	Annual	
56	Leguminosae	*Trifolium repens*	Perennial	○

[z]EW: exotic weed.

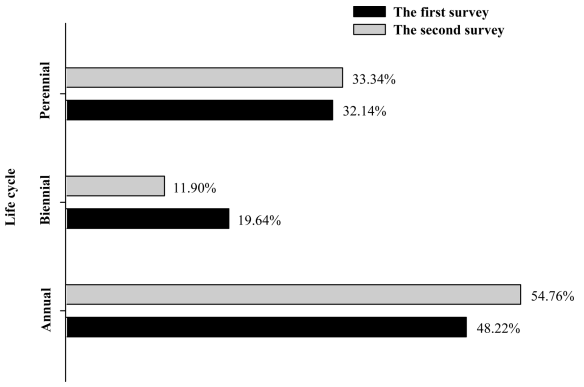

Fig. 1. Classification of all weed species occurring in peach orchards fields based on life cycle.

Poaceae (7), and Scrophulariaceae (4) in order of amount. There were 12 exotic weeds, including *Taraxacum officinale*, *Rumex crispus*, and *Trifolium repens* (Table 2). Concurrently, annual weeds (23), biennial weeds (5), and perennial weeds (14) were identified in the second survey. The annual weeds, biennial weeds, and perennial weeds occupied 54.76%, 11.90%, and 33.34% of the total weed species, respectively (Fig. 1).

Based on importance values of the two surveys, the most dominant noxious weeds were identified in peach orchards. *Conyza canadensis* (5.12%), *Plantago asiatica* (4.17%), and *Trifolium repens* (3.86%) were the dominant weeds in the first survey (Table 3). Choi et al. (2009b) previously reported that the most dominant exotic weed in the orchards of the Chungnam region was *Conyza canadensis*, which is similar to the first survey result of present study. In contrast, in the second survey, *Digitaria ciliaris* (8.00%) was the most dominant weed, followed by *Echinochloa utilis* (6.61%) and *Rorippa palustris* (6.48%) (Table 3). A similar previous study conducted to characterize the distribution of weeds in peach orchards in the Central Region of Korea showed that *Digitaria ciliaris* was the most dominant weed (Park et al., 2005). For the current two surveys, dominant weed occurrences were probably attributable to their strong fecundity and germination capacity. Furthermore, owing to the allelopathic effect of *Conyza canadensis*, the growth of other weeds could have been significantly inhibited (Djurdjević et al., 2011). In occasionally-tilled orchards, *Digitaria ciliaris* seeds can concentrate on the soil surface, which contributes to weed germination (Kobayashi and Oyanagi, 2005). In addition, the dominance value analysis according to Braun-Blanquet's scale showed that the covering ratio initially increased, and then

Table 2. Occurrence of weed species and exotic weeds in the second of two survey peach orchards in Korea in 2015.

Rank	Family	Scientific name	Life cycle	EW[z]
1	Compositae	*Artemisia princeps*	Perennial	
2		*Aster subulatus*	Annual	
3		*Conyza canadensis*	Biennial	○
4		*Eclipta alba*	Annual	○
5		*Erechtites hieracifolia*	Annual	○
6		*Lactuca scariola*	Annual	○
7		*Sonchus oleraceus*	Biennial	○
8		*Taraxacum officinale*	Perennial	○
9	Poaceae	*Agropyron tsukushiense*	Annual	
10		*Agrostis stolonifera*	Perennial	
11		*Alopecurus aequalis*	Annual	
12		*Digitaria ciliaris*	Annual	
13		*Echinochloa utilis*	Annual	
14		*Eragrostis multicaulis*	Annual	
15		*Poa annua*	Annual	
16	Polygonaceae	*Persicaria hydropiper*	Annual	
17		*Rumex acetosa*	Perennial	
18		*Rumex acetosella*	Perennial	○
19		*Rumex crispus*	Perennial	○
20	Cruciferae	*Capsella bursa-pastoris*	Biennial	
21		*Rorippa indica*	Perennial	
22		*Rorippa palustris*	Annual	
23	Amaranthaceae	*Achyranthes fauriei*	Perennial	
24		*Amaranthus mangostanus*	Annual	○
25	Caryophyllaceae	*Stellaria aquatica*	Biennial	
26		*Stellaria media*	Biennial	
27	Chenopodiaceae	*Chenopodium album* var. *centrorubrum*	Annual	
28		*Chenopodium ficifolium*	Annual	○
29	Convolvulaceae	*Calystegia sepium*	Perennial	
30		*Quamoclit coccinea*	Annual	○
31	Scrophulariaceae	*Mazus pumilus*	Annual	
32		*Veronica didyma*	Annual	
33	Commelinaceae	*Commelina communis*	Annual	
34	Rosaceae	*Duchesnea indica*	Perennial	
35	Rubiaceae	*Galium spurium*	Annual	
36	Cannabinaceae	*Humulus japonicus*	Annual	

Table 2. Occurrence of weed species and exotic weeds in the second of two survey peach orchards in Korea in 2015 (continued).

Rank	Family	Scientific name	Life cycle	EW[z]
37	Asclepiadaceae	*Metaplexis japonica*	Perennial	
38	Plantaginaceae	*Plantago asiatica*	Perennial	
39	Portulacaceae	*Portulaca oleracea*	Annual	
40	Solanaceae	*Solanum nigrum*	Annual	
41	Leguminosae	*Trifolium repens*	Perennial	○
42	Umbelliferae	*Oenanthe javanica*	Perennial	

[z]EW: exotic weed.

Table 3. Top 10 weed species ranked by importance values (IV) occurring in peach orchards in Korea in at different survey periods during 2015.

1th survey						2nd survey					
Rank	Scientific name	[w]R.F.	[x]T.C.	[y]R.C.	[z]I.V.	Rank	Scientific name	[w]R.F.	[x]T.C.	[y]R.C.	[z]I.V.
1	*Conyza canadensis*	4.97	24.00	5.27	5.12	1	*Digitaria ciliaris*	7.14	33.00	8.85	8.00
2	*Plantago asiatica*	3.73	21.00	4.62	4.17	2	*Echinochloa utilis*	6.25	26.00	6.97	6.61
3	*Trifolium repens*	3.11	21.00	4.62	3.86	3	*Rorippa palustris*	6.25	25.00	6.70	6.48
4	*Artemisia princeps*	3.73	18.00	3.96	3.84	4	*Plantago asiatica*	5.36	24.00	6.43	5.90
5	*Chenopodium ficifolium*	3.73	17.00	3.74	3.73	5	*Artemisia princeps*	4.46	19.00	5.09	4.78
6	*Erigeron annuus*	3.73	17.00	3.74	3.73	6	*Taraxacum officinale*	4.46	18.00	4.83	4.65
7	*Rorippa indica*	3.73	17.00	3.74	3.73	7	*Rumex crispus*	4.46	17.00	4.56	4.51
8	*Rorippa palustris*	3.73	17.00	3.74	3.73	8	*Trifolium repens*	3.57	18.00	4.83	4.20
9	*Portulaca oleracea*	3.11	15.00	3.30	3.20	9	*Poa annua*	3.57	14.00	3.75	3.66
10	*Digitaria ciliaris*	2.48	13.00	2.86	2.67	10	*Stellaria media*	3.57	14.00	3.75	3.66
	Others	63.98	275.00	60.44	62.21		Others	50.89	165.00	44.24	47.56

[w]R.F.: relative frequency.
[x]T.C.: total cover.
[y]R.C.: relative cover.
[z]I.V.: importance value.

decreased. In the two surveys, the dominance value was level 1 (41.98% and 46.43%, respectively) in peach orchards (Fig. 2).

In the present survey of peach orchards, orchardists adapted different control measures including herbicide application (He), mulching (Mu), herbicide with mulching (He + Mu), and mowing (Mo). Forty percent of the total number of surveyed peach orchards used herbicide for control weed, 30% adopted mulching exclusively, 20% applied herbicide along with mulching, and 10% adopted mowing (Fig. 3). A range of weed management methods are used for reducing dominant noxious weeds (e.g., *Conyza canadensis* and *Digitaria ciliaris*). Generally, hand mowing is a reliable method in peach orchards but it requires a great amount of labor force. Thus, this method is unfit for large-area peach orchards. Mechanical tillage for reducing weed occurrence can lessen the labor shortage problem. However, this mechanical method is also inadequate because it requires a lot of monetary input and

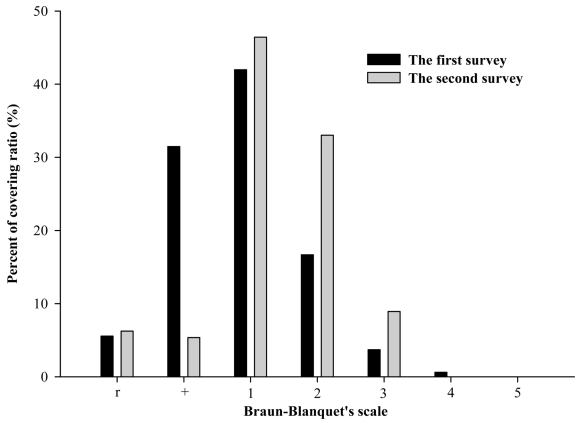

Fig. 2. Percent of covering ratio by Braun-Blanquet's cover-abundance scale (from r to 5) at total survey sites in the first and second surveys of 2015 (Braun-Blanquet's scale: "r", cover very small; "+", cover small; "1", plentiful but of small cover value; "2", cover at least 5%; "3", cover 25-50%; "4", cover 50-75%; "5", cover more than 75% of the area).

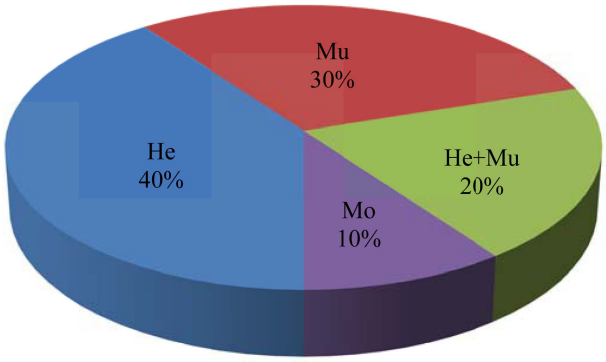

Fig. 3. Percentage of total number of surveyed peach orchards according to weed management method uses in Korea (Mo: Mowing; He: Herbicide application; Mu: Mulching).

professional technical operation knowledge. Currently, due to the stronger influence of economic benefits on orchardists' decision making process, herbicides are more widely used to control weeds in peach orchards because they can effectively control weeds with lower initial investment. Nevertheless, the long-term use of chemical herbicides comes with many negative consequences (e.g. water or soil pollution, threat to non-target crop, and increases in herbicide resistant weeds) (Zhang et al., 2005). In an attempt to employ more ideal weed control measures, natural mulches including rice straw and sawdust can be used in peach orchards. This method can not only effectively control weeds, but also contribute to improving soil porosity and water-holding capacity, as well as reduce runoff (Abdul-Baki and Teasdale, 1993).

The present study helped define difficult to control weed species (e.g. *Conyza canadensis* and *Digitaria ciliaris*) in peach orchards of Korea through two surveys throughout the year. Due to differences in weed growth and flowering periods, employing a two-survey methodology seems particularly meaningful for understanding weed types and establishing weed-free peach orchards. Meanwhile, the current article also discussed the differences between weed management methods. The above information can help orchardists to better manage peach orchards.

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