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Evaluation of Carfentrazone-ethyl Alone and in Combination with Glyphosate or Glufosinate for Weed Control in Orchards

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Carfentrazone-ethyl의 단제와 Glyphosate 및 Glufosinate와의 혼합처리에 의한 과수원에서의 잡초방제효과

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ABSTRACT

Effect of a new postemergence herbicide carfentrazone-ethyl on controlling weeds in pear orchards was examined and compared with that of glyphosate and glufosinate. Herbicides tested were applied in mid June when weeds had reached at an average height of 15 to 20cm. The experimented orchards were infested mainly by dicots of *Artemisia princeps, Chenopodium album, Polygonum hydropiper, Erigeron canadensis, Commelina cummunis, Calystegia japonica,* and *Amaranthus ascendens*, and monocots of *Echinochlor crus-galli, Digitaria sangunalis, Setaria viridis*, and several sedges, Carfentrazone-ethyl alone effectively controlled dicot weeds in the orchards, but not monocot weeds. Especially, sedges were not adequately controlled by carfentrazone-ethyl alone at any application rates examined. Glyphosate or glufosinate was more effective to control monocot weeds than carfentrazone-ethyl, whereas carfentrazone-ethyl exhibited higher effect on dicot weeds than glyphosate or glufosinate. Carfentrazone-ethyl mixed with glyphosate of the half recommended rate exhibited a higher degree of weed control, especially of *E. crus-galli*, as compared to the herbicide mixture of carfentrazone-ethyl with glufosinate of the half recommended rate. However, no phytotocixity of the herbicides to pear trees was observed. Our results demonstrate that carfentrazone-ethyl is useful to reduce the application rates and to accelerate the weed controlling effect of glyphosate or glufosinate. Thus, carfentrazone-ethyl in combination with glyphosate or glufosinate can successfully be used to control the most important weeds in orchards.

Key words : carfentrazone-ethyl, glyphosate, glufosinate, orchard, herbicide mixture.

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INTRODUCTION

In Korea, several herbicides such as paraquat, glyphosate, and glufosinate have routinely been used as postemergence herbicides for controlling weeds in orchards[2,4]. However, multiple applications are often needed to maintain an acceptable weed control level in orchards, since a single application of the individual herbicides does not provide complete weed control[2,3,4]. Furthermore, a few weed species, which are difficult to control with the above herbicides, continue to be a problem[3].

Carfentrazone-ethyl(F8426), a new postemergence herbicide discovered[7] and being developed by FMC Corporation, is a low dosage, nonresidual, contact herbicide that effectively controls many important weeds in cereal culture[11]. Carfentrazone-ethyl can be used as an effective postemergence herbicide to control weeds in orchards. Since carfentrazone-ethyl is a rapid acting herbicide[11], the new herbicide might substitute for paraquat of which use is now banned in some countries and becoming increasingly limited in others due to its high toxicity to mammals.

In the present study, we examined the effect of carfentrazone-ethyl on controlling weeds in orchards and compared with that of glyphosate and glufosinate if the new herbicide would successfully be used to control many problem weeds in orchards. We also examined the effect of herbicide mixtures of carfentrazone-ethyl plus glyphosate or glufosinate if the herbicide mixtures would provide a higher and longer period of weed control than the herbicides applied alone in the orchards, and if lower herbicide rates could be used in the herbicide mixtures.

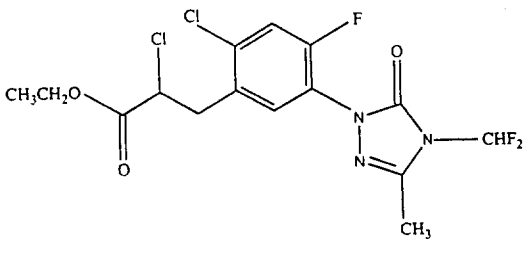

Fig. 1. Chemical structure of carfentrazone-ethyl.

MATERIALS AND METHODS

Field experiments were conducted in the orchards at three different locations of Korea. Ten- to fifteen-year-old pear trees(*Pyrus pyrifolia* cv. Niitaka) were growing in the orchards. Each experimental plot was 4×4m and contained at least one pear tree to examine if herbicides cause any phytotoxicity to the trees. Just prior to herbicide treatments, weed distribution in the orchards was examined with respect to emergence frequency of individual weed species and its coverage rate.

Herbicides tested were applied in mid June when weeds had reached at an average height of 15 to 20cm. Carfentrazone-ethyl [ethyl 2-chloro-3 {2-chloro-4-fluoro-5-(4-difluoromethyl-4,5-dihydro-3-methyl-5-oxo-1H-1,2,4-triazol-1-yl)phenyl}propionate] depicted in Fig. 1 was applied at various rates alone or in combination with glyphosate or glufosinate at a half of the recommended rate using a laboratory belt sprayer delivering 1,000 L/ha spray volume. For comparison, glyphosate or glufosinate at the recommended rate was also applied to the orchards. Emulsifiable concentrate of carfentrazone-ethyl(24% ai) was used, whereas soluble concentrates of glyphosate(41% ai) and glufosinate ammonium(18% ai) were used. The rates for all treatments were given in Table 1. After the herbicide application, visual herbicide efficacy ratings were made at various time intervals using a 0~100 scale with 0 equal to no control and 100 being equivalent to complete control. On this scale, acceptable weed control is a rating of greater than 80%. At 30 days after

Table 1. Rates for herbicide treatments used in the study.

Treatment	Herbicide	Rate (g ai/ha)
1	Untreated	-
2	Carfentrazone-ethyl	12.5
3	Carfentrazone-ethyl	25
4	Carfentrazone-ethyl	50
5	Glyphosate	1230
6	Glufosinate	540
7	Carfentrazone-ethyl + Glyphosate	12.5 + 615
8	Carfentrazone-ethyl + Glyphosate	25 + 615
9	Carfentrazone-ethyl + Glyphosate	50 + 615
10	Carfentrazone-ethyl + Glufosinate	12.5 + 270
11	Carfentrazone-ethyl + Glufosinate	25 + 270
12	Carfentrazone-ethyl + Glufosinate	50 + 270

Table 2. Weed distribution in the experimented orchards in mid June.

Weed species		Emergence frequency	Biomass	Relative biomass
		%	g/m^2	%
Dicots	Artemisia princeps	100	216.5	28
	Chenopodium album	62.5	106.6	14
	Erigeron canadensis	100	84.5	11
	Commelina communis	62.5	42.75	6
	Polygonum hydropiper	35	40.5	5
	Acalypha australis	37.5	27.75	4
	Calystegia japonica	75	22.5	3
	Stellaria media	50	17.5	2
	Amaranthus ascendens	50	10.75	1.4
	Trifolium repens	25	3	0.4
	Sonchus oleraceus	50	2.5	0.3
	Humulus japonicus	37.5	0.75	0.1
	Plantago asiatica	38.5	0.75	0.1
	Galium spurium	25	0.75	0.1
Monocots	*Digitaria. sangunalis*	100	90.5	12
	Setaria viridis	100	64.75	9
	Echinochlor crus-galli	75	20.5	3
	Cyperus spp.	30	10.75	1.4

application(DAA), fresh weights of each survival weed species were measured to calculate weed control value. The experimental design was a randomized complete block with three replications.

RESULTS AND DISCUSSION

The experimented orchards in mid June were infested mainly by dicots of *Artemisia princeps, Chenopodium album, Polygonum hydropiper, Erigeron canadensis, Commelina communis, Calystegia japonica*, and *Amaranthus ascendens*, and monocots of *Echinochlor crus-galli, Digitaria sangunalis, Setaria viridis*, and several sedges(Table 2). Dicots of *Acalypha australis, Stellaria media, Trifolium repens, Sonchus oleraceus, Humulus japonicus, Plantago asiatica*, and *Galium spurium* were also found in the orchards.

Table 3. Effect of carfentrazone-ethyl alone and in combination with glyphosate or glufosinate on the biomass of major weed species in orchards.

Treatment[1]	Weed species[2]							Dicots	Weed species[2]				Monocots
	Aa	Ap	Ca	Ph	Ec	Cc	Cj		Ecg	Ds	Sv	Sedges	
	biomass(g/m^2)[3]							(%)[4]	biomass(g/m^2)[3]				(%)[4]
1	82.3	277	98.5	62.5	127	29.3	63.8	0	235	93.7	86.5	69.8	0
2	17.6	72	21.3	14.6	33.6	14.3	26.6	73	177	106	56.3	46.3	18
3	0	58.6	0	0	11.3	0	0	91	184	72	48.6	40.6	27
4	0	13.3	0	0	0	0	0	98	135	55.6	35.6	21.6	46
5	0	13	0	0	9	0	0	97	29.6	10.3	14	0	87
6	0	0	0	0	9.3	0	0	99	42.3	16	18.6	0	82
7	0	21.6	0	0	9.6	0	0	96	70.3	42	25.3	0	67
8	0	0	0	0	0	0	0	100	31	22.3	12.3	0	84
9	0	0	0	0	0	0	0	100	22.6	15.6	8.6	0	89
10	12.6	28.3	0	10.3	14.6	3.3	14	89	115	49	33	0	53
11	0	0	0	0	0	0	0	100	62	30.3	17.6	0	74
12	0	0	0	0	0	0	0	100	45.3	21	12.6	0	81

[1] Treatment numbers are the same as in Table 1.
[2] Major weed species examined were Aa, *Amaranthus ascendens* ; Ap, *Artemisia princeps* ; Ca, *Chenopodium album* ; Ph, *Polygonum hydropiper* ; Ec, *Erigeron canadensis* ; Cc, *Commelina communis* ; Cj, *Calystegia japonica* ; Ecg, *Echinochlor crus-galli* ; Ds, *Digitaria sangunalis* ; Sv, *Setaria viridis* ; and sedges.
[3] At 30 DAA, fresh weights of each survival weed species were measured.
[4] Weed control value compared to untreated control.

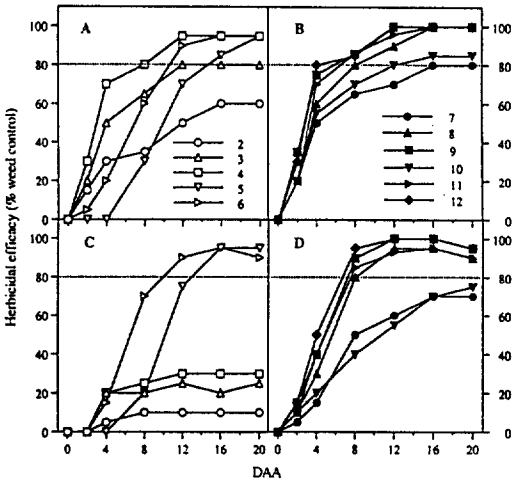

Fig. 2. Effect of carfentrazone-ethyl alone and in combination with glyphosate or glufosinate for the control of dicot weeds (A, B) and monocot weeds (C, D) in orchards. Treatment numbers are the same as in Table 1. A rating of 0 represents no weed control and 100 indicates complete control. Effects of the individual herbicides are the unfilled symbols, whereas effects of the herbicide mixtures are presented in the filled symbols.

Carfentrazone-ethyl alone effectively controlled most dicot weeds in the orchards, but not monocot weeds(Table 3, Fig. 2). This result might be due to the fact that carfentrazone-ethyl is a contact herbicide[11] and thus does not kill the protected growing point of monocot weeds. Carfentrazone-ethyl has been reported to control a wide range of dicot weeds, particularly of *Abutilon theophrasti, Salsola kali, Amarathus* spp., *Ipomea* spp., *C. album, Solanum nigrum*, and several important mustard species, with good tolerance to wheat, barley, and rice[11]. Glyphosate or glufosinate was more effective to control monocot weeds than carfentrazone-ethyl, whereas carfentrazone-ethyl at 50g ai/ha application rate exhibited higher effect on dicot weeds than glyphosate or glufosinate(Table 3, Fig. 2). Although glyphosate or glufosinate alone completely controlled sedges in the orchards, the sedges were not adequately controlled by carfentrazone-ethyl alone at any application rates examined(Table 3).

Effect of carfentrazone-ethyl on controlling dicot weeds was found to be much faster than that of glyphosate or glufosinate(Fig. 2). Acceptable weed control of 80% on dicot weeds was achieved at 8 DAA by carfentrazone-ethyl at 50g ai/ha application rate, but glufosinate and glyphosate of the recommended rates provided the acceptable weed control at 11 and 15 DAA, respectively(Fig. 2). Carfentrazone-ethyl is a fast acting herbicide which is known to exert its herbicidal effect by causing rapid membrane disruption[11]. Carfentrazone-ethyl is also known to have the same mechansim of action as the diphenyl ethers and as sulfentrazone(F6285) in which membrane disruption is due to the inhibition of protoporphyrinogen oxidase, the last common enzyme in the biosynthesis of both heme and chlorophylls, leading to the accumulation of abnormally high level of phytotoxic intermediate, protoporphyrin IX[1,5,6,8,11].

Carfentrazone-ethyl is a low dosage herbicide at field application rates between 4 and 35g ai/ha[11], and the recommended rates of glyphosate and glufosinate are at least 35- and 15-fold higher than that of carfentrazone-ethyl, respectively. If the herbicide mixtures of carfentrazone-ethyl plus glyphosate or glufosinate at half the recommended rate can control the weeds in the orchards as effectively as glyphosate or glufosinate alone applied at their full recommended rates, carfentrazone-ethyl might be useful to reduce the application rates of glyphosate or glufosinate. Carfentrazone-ethyl mixed with glyphosate or glufosinate of the half recommended rate controlled monocot weeds as well as dicot weeds more effectively than the herbicides applied alone(Table 3). Carfentrazone-ethyl mixed with glyphosate had higher effect on controlling weeds, especially on *E. crus-galli*, as compared to the mixture of carfentrazone-ethyl with glufosinate(Table 3). Although reason for this observation is not known, carfentrazone-ethyl might increase leaf penetration of glyphosate and thereby enhance the herbicidal effect of glyphosate on monocot weeds. Similarly, it has been reported that the herbicide mixture of glyphosate with oxyfluorfen, a well-known protoporphyrinogen oxidase-inhibiting herbicide[1], greatly increased glyphosate injury to junipers apparently due to the increased leaf penetration[9].

Along with the fact that carfentrazone-ethyl could be used to reduce the application rates of glyphosate or glufosinate, carfentrazone-ethyl was found to accelerate the weed controlling effect of glyphosate or glufosinate. Acceptable weed control of 80% on dicot and monocot weeds was achieved at 4 and 8 DAA, respectively, by the herbicide mixtures of carfentrazone-ethyl at 50g ai/ha plus glyphosate or glufosinate of the half recommended rate(Fig. 2). For example, the acceptable weed control on dicot and monocot weeds was attained 11 and 5 days earlier, respectively, by the herbicide mixture of carfentrazone-ethyl plus glyphosate than by glyphosate applied alone. During the experiments, however, no phytotocixity of the herbicides to pear trees was observed(data not shown).

Weed control is often higher and longer from herbicide mixtures than from a single herbicide[2,10]. By using herbicide mixtures, the buildup of resistant weed species and the development of herbicide resistant weed biotypes could also be prevented or slowed. In addition, application cost could considerably be reduced. Based on our results, it can be concluded that carfentrazone-ethyl in combination with glyphosate can successfully be used to control the most important weeds in orchards.

적 요

배 과수원에 발생하는 잡초종을 잡초생장기인 6월 중순에 조사한 결과 광엽초종은 쑥, 명

아주, 여뀌, 망초, 닭의장풀, 메꽃, 비름 등이 우점발생하였고 화본과초종은 피, 바랭이, 강아지풀 등이 발생빈도가 높은 경향으로 나타나 우리나라 과수원에 발생하는 대표적인 잡초종들이 거의 분포하였다. 새로운 경엽처리 제초제인 carfentrazone-ethyl의 단제와 glyphosate 및 glufosinate의 약량에 따른 혼합처리시 과수에 대한 약해증상은 나타나지 않았으며 carfentrazone-ethyl의 단제처리구에서는 광엽초종에 대한 살초효과는 뚜렷하였으나 화본과 및 사초과초종에 대한 효과는 미약하였다. Glyphosate나 glufosinate의 단제처리구에서보다 carfentrazone-ethyl과의 혼합처리구에서 glyphosate나 glufosinate를 표준약량의 절반으로 혼합하더라도 약효발현이 빠르게 나타났으며 혼합처리에 의해 화본과 및 사초과초종에 대한 살초효과가 상승하는 경향이었다. 처리후 10일까지 carfentrazone-ethyl은 glyphosate와의 혼합처리구에서보다 glufosinate와의 혼합처리구에서 광엽 및 화본과초종에 대한 살초효과가 높았으나 시간이 경과할수록 glyphosate와의 혼합처리구에서 약효의 지속기간이 길어짐에 따라 후발초종에 대한 방제효과도 높은 것으로 판단되어 carfentrazone-ethyl은 glyphosate와 혼합처리시 과수원에 발생하는 잡초종을 효과적으로 방제할 수 있을 것으로 생각되었다.

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