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Herbicidal Activity of Rotation Crop Residues on Weeds and Selectivity to Crops

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윤작작물 잔류물의 제초활성 및 작물에 대한 선택성

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ABSTRACT

Allelopathic activity of rotation crop residues to common weeds and selectivity of crops were studied for developing an alternative weed control strategy in upland organic farming. All rotation crop residues with various ratios suppressed weed growth, but the growth of crop species stimulated a little when those were grown with the mixture of rotation crop residues except a few crop species. Among the rotation crop residues used in this study hairy vetch was the most effective, followed by Chinese milkvetch, barley and rye in suppression of weed growth. The 90:10 (crop:soil, v/v) treatments incorporation rate of crop residues such as hairy vetch and Chinese milkvetch suppressed completely the growth of all weed species tested in this study. The effect of crop residues on suppression of weed growth reduced to 90% when the incorporation rates decreased to 60% [60:40 (crop:soil, v/v). It was noticed that broadleaf weed species were more susceptible to rotation crop residues than grass weed species. In the influence of crop residues on the crop growth, no growth inhibition was found in red pepper, lettuce and perllia at any incorporation rates, but tomato, cucumber and corn were slightly inhibited in a few cases at their highest incorporation levels. This study demonstrated that rotation crop residues especially hairy vetch and Chinese milkvetch have high herbicidal effects against weeds without inhibiting the growth of crop species.

Key words : Allelopathy, Barley, Chinese milkvetch, Crop residue, Hairy vetch, Rye, Weed control

I. INTRODUCTION

Allelopathy is a natural and environment-friendly technique which may prove to be a unique tool for weed management and thereby increase crop yields. Allelopathy involves direct or indirect (harmful or beneficial) effects of one plant on another through the production of secondary chemical compounds that escape into the environment. Chemicals with allelopathic potential are present in virtually all plants and in most tissues, including leaves, stems, flowers, roots, seeds and buds.

Weed suppression has been in some cases attributed to physical interference (Teasdale 1996; Samarajeewa et al. 2006) and in others to chemical competition (Mohler and Teasdale 1993; Weston 1996; Caamal-Maldonado et al. 2001; Singh et al. 2003; Weston and Duke 2003). Growth inhibition or stimulation resulting from the release of secondary plant compounds is termed allelopathy (Molisch 1937). Allelopathy also includes plant derived compounds that possess allelopathic properties after microbial transformation. When released into the soil, either by root exudation or residue decomposition, allelochemicals have the potential to influence neighboring plant life, depending on the quantity and persistence of the chemical (Putnam 1988).

Changes from conventional to conservation tillage practices can cause shifts in weed species and densities (Wilson and Foy 1990). Similarly, changes in crop rotation sequences can also affect weed populations (Hume et al. 1991). Any agricultural practice may create changes in the weed flora on a given site (Holt and LeBaron 1990). Crop residues are defined as crop or its parts left in field for decomposition after it has been thrashed or harvested (Kumar and Goh 2000). Earlier these were regarded merely as waste, but now because of their usefulness they are considered an important resource that can bring significant physical, chemical, and biological

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changes in the agricultural soil after amendment. In the conservation tillage system, the retention of crop residues improves soil, increases water filtration, reduces labor, and suppresses weeds under some situations by bringing a shift in weed flora or directly suppressing them (Moody 1995; Jones et al. 1999). The presence of crop residues on the soil surface as mulch suppresses weeds through allelopathy and thus reduces a greater reliance on herbicides (White et al. 1989; Worsham 1991; Batish et al. 2001). However, additional management practices are required (Yenish et al. 1996). Some residues are also known to enhance the efficiency of herbicides (Teasdale et al. 1991); however, much depends on crop residues, its placement, environmental conditions, and cropping patterns.

Currently, there is an interest in legumes species especially hairy vetch and Chinese milkvetch for their easily decomposable potential to use as cover crop or rotational crop or use as crop residues to suppress weed growth. Information regarding crop residues of hairy vetch and Chinese milkvetch are very limited yet. Therefore, this study intends to determine herbicidal activity and crop injury of four different rotation crop residues.

II. MATERIALS AND METHODS

1. Plant materials

Barley, rye, Chinese milkvetch and hairy vetch were used in this study. Barley straw was collected from experimental farm of Chungnam National University in harvest period. Hairy vetch, Chinese milkvetch and rye were collected from Rural Development Administartion (RDA), Korea. Thirteen weed species i.e. grasses (*Echinochloa crusgalli*, *Digitaria sanguinalis*, *Arthraxon hispidus*, *Poa annua* and *Avena fatua*), sedge i.e. *Cyperus iria* and broadleaf i.e, *Galium spurium*, *Amaranthus retroflexus*, *Rumex japonicus*, *Chenopodium album*, *Bidens bipinnata*, *Plantago asiatica*, and *Aeschynomene indica* was collected from the experimental farm of Chungnam National University. Six different crop species i.e., red pepper, tomato, perllia, cucumber, lettuce and corn were purchased from market.

2. Preparations of plant material

After collection, the rotation crop residues were dried under shade in a polyethylenehouse of Chungnam National University. The studied crop residues were cut as small as possible and then used a disc type mill (Laboratory Mill 3600, Korea) to grind the samples. After grinding, the ratio of each rotation crop residues was mixed as a 0/100, 20/80, 40/60, 60/40, 80/20 and 90/10 of crop/soil by volume.

3. Weed control efficacy and crop injury

The allelopathic potential of different rotation crop residues against several weed and crop species were evaluated. Assays were performed by impregnating rotation crop residues/upland soil mixture (0:100, 20:80, 40:60, 60:40, 80:20, 90:10 v/v). Thirteen weed species and 6 different crop species i.e., red pepper, tomato, perllia, cucumber, lettuce and corn were grown in Wagner pots (1/5000 a). Each pot was filled up with upland cultivated dried soil up to 14.5 cm and then an amount of soil (that can cover 2 cm length of pot) was taken in a plastic bowl and 10 seeds of each weed species were mixed with this soil. After that these were seeded above 14.5 cm soil surface and then the next 0.5 cm portion was filled with above mentioned ratio of rotation crop residues and soil. Ten seeds of each crop species were sown in the pots. Treatments were replicated four times and arranged as a completely randomized design within the greenhouse. Pots were watered as required to prevent drying out and to allow sufficient moisture on the soil surface for germination of weed seeds. Thirty days after treatment, plant height of all crop species and shoots portion of weed and crop species were collected and kept separately in brown paper bags and then placed in an electric oven at 72°C for 3 days. The samples were weighed separately. Efficacy of different rotation crop residues was measured based on dry matter of weed and crop species. Percent inhibition as compared to the control was calculated for all data collected.

III. RESULTS

1. Weed control efficacy

All the rotation crop resides significantly reduced the growth of all tested weed species (Table 1 and 2). The degree of inhibition increased with increasing mixture ratio of crop residues (Table 2). Generally it was noticed that broadleaf weeds were suppressed more than grasses and sedge weeds. Among the four different rotation crop residues, hairy vetch was the most effective to inhibit weeds followed by Chinese milkvetch, barley and rye.

The growth inhibition was 61.1, 78.9, 95.5% using hairy vetch at the mixture ratio of 20:80, 40:60 and 60:40, respectively. At the highest mixture ratio of both hairy vetch and Chinese

Table 1. Effect of different rotation crop residues on dry weight of weeds by species.

Crop	Mixture ratio	Dry weight of weeds (g)												
		Grasses					Sedge	Broadleaf weeds						
	(crop: soil v/v)	EC	DS	Ah	Pa	Af	Ci	Gs	Ar	Rj	Ca	Bb	Pa	Ai
Barley	20:80	1.90	2.83	0.12	0.09	0.45	0.37	0.02	0.01	0.02	0.01	1.13	0.21	0.37
	40:60	1.34	1.21	0.01	0.07	0.24	0.12	0	0	0.01	0	0.35	0.14	0.13
	60:40	0.93	0.43	0	0.02	0.13	0	0	0	0	0	0.17	0	0.04
	80:20	0.01	0.04	0	0	0	0	0	0	0	0	0.03	0	0
	90:10	0.01	0.02	0	0	0	0	0	0	0	0	0.01	0	0
Rye	20:80	1.98	3.58	0.12	0.12	0.55	0.46	0.07	0.04	0.02	0.01	0.43	0.22	0.41
	40:60	1.79	3.08	0.08	0.11	0.39	0.33	0.01	0	0	0	0.38	0.13	0.21
	60:40	1.58	1.98	0.01	0.06	0.32	0.17	0	0	0	0	0.12	0.03	0
	80:20	1.33	0.59	0.01	0.05	0.26	0.11	0	0	0	0	0.08	0	0
	90:10	0.24	0.28	0	0.02	0.09	0	0	0	0	0	0.11	0	0
Hairy	20:80	1.46	1.83	0	0.10	0.39	0.55	0.06	0.05	0	0.01	0.14	0	0
vetch	40:60	1.00	0.94	0	0.05	0.28	0.19	0	0	0	0	0.03	0	0
	60:40	0.32	0.18	0	0	0	0.03	0	0	0	0	0	0	0
	80:20	0.01	0	0	0	0	0	0	0	0	0	0	0	0
	90:10	0	0	0	0	0	0	0	0	0	0	0	0	0
Chinese	20:80	1.64	2.73	0.10	0.19	0.49	0.58	0.07	0.06	0	0.01	0.23	0	0.03
milk	40:60	1.21	2.23	0.03	0.18	0.40	0.33	0.01	0.03	0	0	0.08	0	0
vetch	60:40	0.56	0.13	0	0	0	0.13	0	0	0	0	0	0	0
	80:20	0.01	0	0	0	0	0	0	0	0	0	0	0	0
	90:10	0	0	0	0	0	0	0	0	0	0	0	0	0
Control	100:0	2.32	4.43	0.27	0.25	0.73	0.77	0.12	0.20	0.06	0.06	1.35	0.50	0.72

Ec, *Echinochloa crus-galli;* Ds, *Digitaria saunganalis*; Ah, *Arthraxon hispidus;* Pa, *Poa annua*; Af, *Avena fatua*; Ci, *Cyperus iria;* Gs, *Galium spurium*, Ar, *Amaranthus retroflexus*; Rj, *Rumex japonicus*; Ca, *Chenopodium album*; Bb, *Bidens bipinnata*; Pa, *Plantago asiatica;* Ai, *Aeschynomene indica*

Table 2. Effect of different rotation crop residues on control of weeds by species.

Crop	Mixture ratio	Weed control efficacy (%)												
		Grasses					Sedge	Broadleaf weeds						
	(crop: soil v/v)	EC	DS	Ah	Pa	Af	Ci	Gs	Ar	Rj	Ca	Bb	Pa	Ai
Barley	20:80	14.8	34.5	53.8	60.9	36.6	43.1	80	93.3	66.7	85.7	15.7	56.3	49.3
	40:60	39.9	72	96.2	69.6	66.2	81.5	100	100	83.3	100	73.9	70.8	82.2
	60:40	58.3	90	100	91.3	81.7	100	100	100	100	100	87.3	100	94.5
	80:20	99.6	99.1	100	10	100	100	100	100	100	100	97.8	100	100
	90:10	99.6	99.5	100	100	100	100	100	100	100	100	99.3	100	100
Rye	20:80	16.8	16.6	58.6	36.8	26.7	36.1	36.4	77.8	60	83.3	68.6	54.2	41.4
	40:60	24.8	28.2	72.4	42.1	48	54.2	90.9	100	100	100	72.3	72.9	70
	60:40	33.6	53.8	96.6	68.4	57.3	76.4	100	100	100	100	91.2	93.8	100
	80:20	44.1	86.2	96.6	73.7	65.3	84.7	100	100	100	100	94.2	100	100
	90:10	89.9	93.5	100	89.5	88	100	100	100	100	100	92	100	100
Hairy	20:80	38.7	60.1	100	58.3	43.5	30.4	57.1	73.7	100	80	89.4	100	100
vetch	40:60	58	79.5	100	79.2	59.4	75.9	100	100	100	100	97.7	100	100
	60:40	86.6	96.1	100	100	100	96.2	100	100	100	100	100	100	100
	80:20	99.6	100	100	100	100	100	100	100	100	100	100	100	100
	90:10	100	100	100	100	100	100	100	100	100	100	100	100	100
Chinese	20:80	28.7	39.7	63	40.6	36.4	37	50	76.9	100	83.3	83	100	95.6
milk	40:60	47.4	50.8	88.9	43.8	48.1	64.1	92.9	88.5	100	100	94.1	100	100
vetch	60:40	75.7	97.1	100	100	100	85.9	10	100	100	100	100	100	100
	80:20	99.6	100	100	100	100	100	100	100	100	100	100	100	100
	90:10	100	100	100	100	100	100	100	100	100	100	100	100	100
Control	100:0	-	-	-	-	-	-	-	-	-	-	-	-	-

Ec, *Echinochloa crus-galli*; Ds, *Digitaria saunganalis*; Ah, *Arthraxon hispidus*; Pa, *Poa annua*; Af, *Avena fatua*; Ci, *Cyperus iria;* Gs, *Galium spurium*, Ar, *Amaranthus retroflexus*; Rj, *Rumex japonicus;* Ca, *Chenopodium album*; Bb, *Bidens bipinnata*; Pa, *Plantago asiatica;* Ai, *Aeschynomene indica*

milkvetch (80:20 of residues:soil v/v) completed weed control efficacy was obtained, but hairy vetch was more inhibitory effect to weeds (61.1%) at the lowest mixture (20:80 of residues:soil v/v) compared to Chinese milkvetch (48.1%) (Fig. 1). The growth inhibition of weeds was 48.1, 61.9 and 93.1% by Chinese milkvetch at the mixture ratio of 20:80, 40:60 and 60:40, respectively.

Almost all the weed species was suppressed by the mixture ratio of both hairy vetch and Chinese milkvetch at 80:20 and 90:10. At the ratio of 60:40 or 40: 60 greater than 90% weed growth was suppressed by hairy and Chinese milkvetch. The most susceptible weed species were *Arthraxon hispidus*, *Rumex japonicus*, *Plantago asiatica*, *Aeschynomene indica* for hairy vetch residues where 100% weed was suppressed by the lowest ratio mixture of hairy vetch (20:80 hairy vetch/soil mixture).

A few number of weed species was survived at the maximum level of rotation crop mixture of rye and barley. Between two grasses rotation crop residues, barley inhibited greater than rye. The growth inhibition of weeds was 36.2, 69.3 and 85.4% by barley residue at the mixture ratio of 20:80, 40:60 and 60:40, respectively, whereas the growth inhibition of weeds by rye residue was 32.1, 44.8 and 63.8% at the mixture ratio of 20:80, 40:60 and 60:40, respectively.

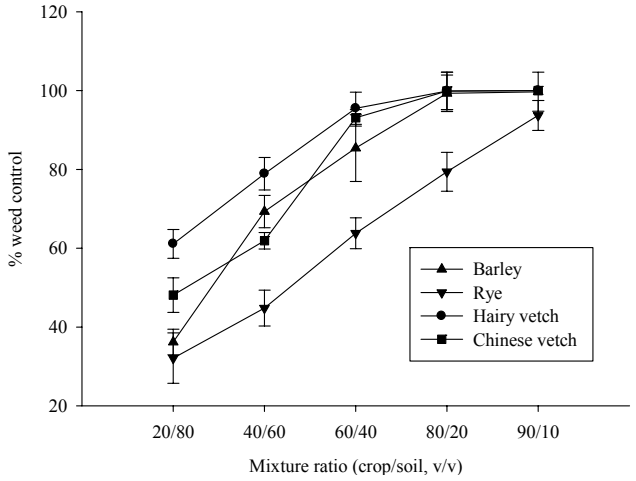

Fig. 1. Effect of different rotation crop residues on control of weeds.

2. Crop injury

A different scenario was found in case of rotation crop residues effect on crop species. The growth of crop species tested did not hamper by different rotation crop residues. Tomato was more susceptible among the crop species tested (Table 3 and 4). Corn was affected lesser at the highest mixture level of all the rotation crop residues. Cucumber was slightly affected at the highest level of Chinese milkvetch mixture.

IV. DISCUSSION

Plants affect the growth of neighboring or succession plants by releasing phytotoxic constituents into the soil. These phytochemicals are released either by root exudates from the living plant tissues or by decomposition of plant materials. Residue may play a role in affecting weed growth by reducing light and modifying soil temperature. However, in cases where residue was of a similar physical consistency, differences in weed dry matter production are more likely to be attributed to allelopathic activity. In this study we found inhibitory effect of different rotation crop residues on different weeds especially hairy vetch residues was most effective to suppress weed growth. Recently one study was done using methanol and ethanol extraction of hairy vetch and found inhibitory effect on different weeds (Hill et al. 2006). It seems that hairy vetch crop residues have allelochemicals thus help to reduce weed growth. Weed species exhibited greater phytotoxic responses to hairy vetch than to crimson clover (White et al. 1989) in the debris and extract studies. Weed growth was reduced using winter cereals and their cover crop mulch (Dhima et al. 2006). The annual medic residues reduced the density and dry weight of summer annual weeds (Fisk et al. 2001). The emergence, root and shoot growth, and root dry weight of the bioassay species were reduced when grown in soil mixed with the leaves of *L. radiate* (Iqbal et al. 2006). Aqueous extracts of the fresh leaves at various concentrations inhibited the root and shoot growth of all tested plant species. In this study we found the inhibitory effect of different rotation crop residues on different weeds especially hairy vetch residues was most effective to suppress weed growth. Thus, hairy vetch residue as cover mulch could be an alternate approach for weed management in upland organic farming.

V. 결 론

친환경유기농법 재배에서 적용될 수 있는 잡초방제법을 개발하기 위한 시험의 일환으로 윤작작물재배 후 지상부 잔류물의 제초활성을 검정하고 작물의 생육에 미치는 영향을 조사하였다. 윤작작물 잔류물은 모두 잡초의 생장을 억제하였으며, 윤작작물 중에서 헤아리벳치는 가장 높은

Table 3. Effect of different rotation crop residues on plant height of crops.

Crop	Mixture ratio (crop: soil v/v)	Plant height of various crops (cm)					
		Corn	Cucumber	Red pepper	Tomato	Lettuce	Perllia
Barley	20:80	52.2	27.6	5.9	7.3	3.5	4.3
	40:60	54.7	32.2	10.9	8.7	3.6	4.6
	60:40	57.3	27.1	9.9	7.1	3.8	4.8
	80:20	53.3	23.1	9.1	6.7	4.4	6.1
	90:10	50.9	23.0	8.8	6.6	3.5	8.3
Rye	20:80	54.1	28.7	6.0	9.8	3.7	7.9
	40:60	56.3	32.6	9.7	9.5	4.0	7.4
	60:40	58.6	37.3	9.0	9.5	3.9	8.1
	80:20	52.4	37.3	9.9	8.9	3.6	8.7
	90:10	48.7	34.6	10.3	9.2	3.7	8.5
Hairy vetch	20:80	57.5	20.5	7.8	7.4	3.5	4.8
	40:60	59.4	21.4	8.1	10.0	3.7	7.1
	60:40	61.8	30.6	10.6	8.2	3.9	6.0
	80:20	53.5	26.8	11.2	9.7	3.7	5.4
	90:10	51.0	25.0	10.5	10.8	3.6	6.2
Chinese milkvetch	20:80	57.8	31.9	7.0	10.9	3.8	4.5
	40:60	64.3	32.4	7.8	10.7	4.0	8.0
	60:40	63.3	27.0	9.3	12.3	3.9	10.7
	80:20	38.1	23.8	7.3	10.8	3.9	6.0
	90:10	26.3	17.2	6.5	10.2	3.6	5.2
Control	100:0	51.9	20.1	5.8	7.1	3.3	4.4

Table 4. Effect of different rotation crop residues on dry weight of crops.

Crop	Mixture ratio (crop: soil v/v)	Dry weight of crops (g/pot)					
		Corn	Cucumber	Red pepper	Tomato	Lettuce	Perllia
Barley	20:80	3.0	0.95	0.11	0.12	0.04	0.12
	40:60	3.0	1.39	0.14	0.16	0.05	0.12
	60:40	3.4	1.11	0.15	0.11	0.06	0.13
	80:20	2.9	0.96	0.17	0.07	0.07	0.14
	90:10	2.7	0.81	0.13	0.08	0.03	0.15
Rye	20:80	3.4	1.20	0.11	0.18	0.04	0.14
	40:60	3.5	1.35	0.10	0.21	0.06	0.14
	60:40	3.6	1.71	0.07	0.20	0.05	0.15
	80:20	3.1	1.70	0.10	0.17	0.04	0.16
	90:10	2.6	1.46	0.12	0.22	0.04	0.15
Hairy vetch	20:80	3.6	0.80	0.17	0.11	0.03	0.13
	40:60	4.3	0.82	0.01	0.21	0.04	0.15
	60:40	4.4	1.24	0.09	0.15	0.04	0.14
	80:20	3.5	0.94	0.06	0.14	0.04	0.13
	90:10	2.6	0.87	0.14	0.15	0.04	0.13
Chinese milkvetch	20:80	3.8	1.50	0.05	0.18	0.03	0.12
	40:60	5.3	1.79	0.07	0.15	0.04	0.15
	60:40	5.0	1.43	0.12	0.24	0.04	0.16
	80:20	1.4	0.86	0.08	0.17	0.04	0.14
	90:10	0.7	0.55	0.06	0.15	0.03	0.13
Control	100:0	2.93	0.80	0.05	0.09	0.02	0.11

제초활성을 보였고, 다음으로 자운영, 보리, 호밀 순이었다. 헤아리벳치와 자운영 잔류물과 토양 혼합비율 90:10에서 잡초는 100% 생장이 억제되었고, 혼합비율 60:40에서도 90%이상 생장이 억제되었다. 헤아리벳찌 40:60 비율에서도 잡초의 생장은 80% 억제되었다. 윤작작물 잔류물은 화본과잡초에 비하여 광엽잡초에서 높은 제초활성을 나타냈다. 윤작작물 잔류물은 들깨, 고추와 상추의 생장억제에 미치는 영향이 없었으나 옥수수, 오이, 토마토에서는 잔류물 고농도 수준에서 경미한 생장저해 현상을 보였다.

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