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Improvement of Hairy Vetch Seed Production by Mixture Cropping of Hairy Vetch and Triticale

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ABSTRACT : Demand for the domestic hairy vetch seed production will be increased with the increasing interest of environment-friendly agriculture in Korea. This study was conducted during from 2000 fall to 2003 spring at upland field of National Institute of Crop Science in Suwon, Korea to compare wheat and triticale (TC) as stake crop of hairy vetch (HV), and to know proper seeding rates and ratios between TC and HV for the maximum HV seed production. As supporting crop of HV, TC was superior to wheat at the points of higher HV seed yield, stronger TC stalk for supporting, consistence of ripening stage of two seeds. In seeding method, row seeding was superior to broadcast seeding at the points of less lodging and higher HV seed yield. HV seed yield decreased with the increase of TC seeding rate in mixture cropping (row seeding), particularly at TC seeding rates over 5 kg/10a. HV seed yield increased with the increase of HV seeding rate at the condition of TC seeding rates under 5 kg/10a in spite of higher lodging of mixed crops at higher HV seeding rate due to higher HV aboveground dry matter. Maximum HV seed yield was obtained at TC seeding rate of 1 ~ 1.5 kg/10a as indicating HV seed yield 176 kg/10a (CV. Madison) at seeding rate of TC 1 kg/10a + HV 2 kg/10a in 2001, and HV seed yield 96 kg/10a (CV. Common) at seeding rate of TC 1.5 kg/10a + HV 4.5 kg/10a in 2003. Use of all-purpose combine harvester for harvesting and appliance for separation of mixed seeds using centrifugal force, which are prerequisite for HV seed production, was excellent in the simultaneous seeds production system of HV and TC.

Keywords: hairy vetch, triticale, wheat, seed production, mixture cultivation, seed separation

The demand for green manure crop seeds in Korea will be increasing with the expansion of environment-friendly agriculture in which reduction of fertilization on crops, crop rotation and green manure for organic food production followed by CODEX guide-line are needed. Now also, that is urgently needed for the increase of chemical fertilizer price due to the diminished support of government and prohibition of use of imported seeds coated with chemicals in organic farming (Heuksalim Research Institute, 2004). But most seed of green manure crop is imported from foreign countries (USA, China, Australia and Canada *et al*) as much as rye - 5,968 ton, Chinese milk vetch - 1,316 ton, hairy vetch - 72 ton, But economical seed production of winter green manure crops such as hairy vetch and rye in Korea is difficult at the respects of poor climate condition at ripening and harvest stage (mainly middle and late June), high labor cost and poor equipments for harvesting and drying. To reduce the cost for importing the seeds, the development of techniques for seed production is urgent.

Cultivation of hairy vetch (HV) in company with grass crops, such as wheat, rye and oat, which have a rigid stem and act as a stake, is necessary to HV seed production because HV is viny plant (Park *et al*, 1989; Hujikuro, 1924). Before 1940s, HV was cultivated together with rye or mulberry to increase the efficiency of HV seed production (Hujikuro, 1923). Winter cereal crops such as wheat and rye could be used as a stake crop for HV cultivation in central or northern region in Korea. Both species, however, are not sufficient for this purpose. Due to the earlier ripening (wheat) and tall and poor rigidity as stake crop (rye), more appropriate species should be used. Triticlae (TC) seems to be superior to wheat or rye as stake crop for HV seed production because TC has stronger stalk than rye or wheat, and similar ripening stage with HV.

The aims of this experiment were to investigate the capabilities of TC as stake crop for HV seed production, to find out proper seeding rates of HV and TC for maximum HV seed production, and also to test multi-purpose combine harvester for harvest of mixed seeds and appliance for seed separation.

MATERIALS AND METHODS

This experiment was conducted at the upland field of National Institute of Crop Science from 2000 fall to 2003 spring. In the first year (2000 fall - 2001 spring), wheat and triticale (TC) were compared as stake crop for hairy vetch (HV) seed production. In addition, row seeding and broadcast seeding was compared for proper seeding method in fall. HV variety at the first year was 'Madison' (Pennington seed company, USA) which was originated in Nebraska,

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and varieties of TC and wheat were 'Sinyoungraimil' and 'Geurumil', respectively. Seeding rate of HV was 2 kg/10a, seeding rates of wheat and TC were 10 and 1 kg/10a, respectively. HV seed was mixed well with wheat or TC seed before seeding. Seeds at row seeding were spreaded and covered with soil by hand, and width between rows was 25 cm, and seeds at broadcast seeding were spreaded by hand and covered with soil by rotavator. Seeding date was October 5th. Phosphate and potassium was applied according to the standard fertilization guide of wheat. Application rate of nitrogen fertilizer was 6 kg/10a at seeding time, but additional nitrogen application after over-wintering was not conducted to reduce lodging at ripening stage. Heading dates and stalk heights of TC and wheat, flowering initiation date of HV were investigated in May, and lodging rate (%) was evaluated before harvesting, respectively. Mixed plant of 7.5 m^2 (5 row × 6 m) was harvested at the plot of row seeding and mixed plant of 7.8 m^2 (1.3 m × 6 m) was harvested at the plot of broadcast seeding, respectively at June 21th. After harvest for yield test, the rest of mixed plant was harvested by multi-purpose combine harvester (Yanmar, Japan) (Fig. 1). Dried mixed seeds were separated using centrifugal force by separation appliance which was made by National Institute of Crop Science and had capacity of 60

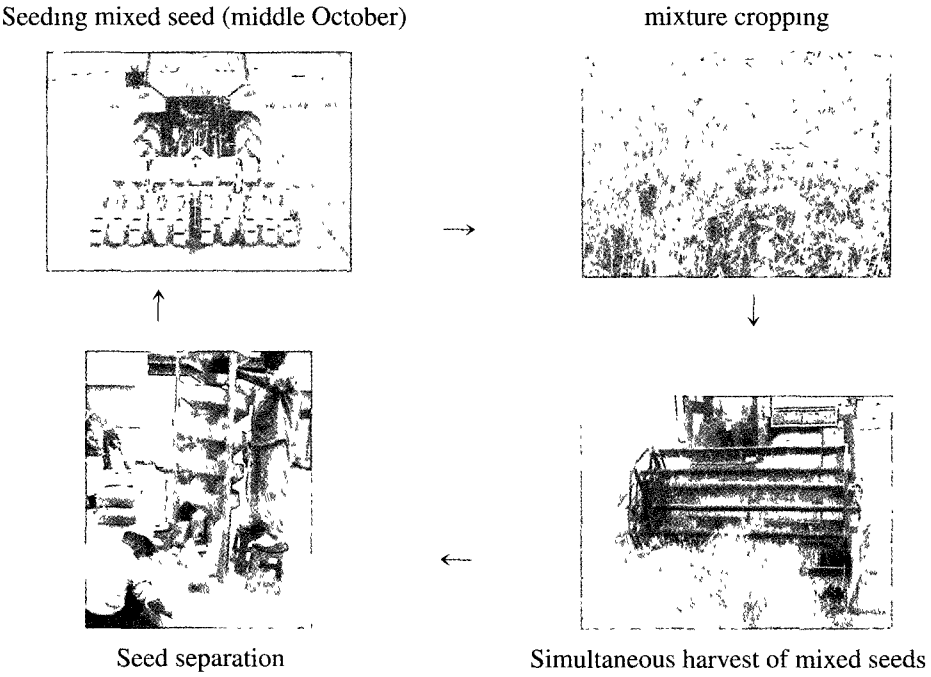
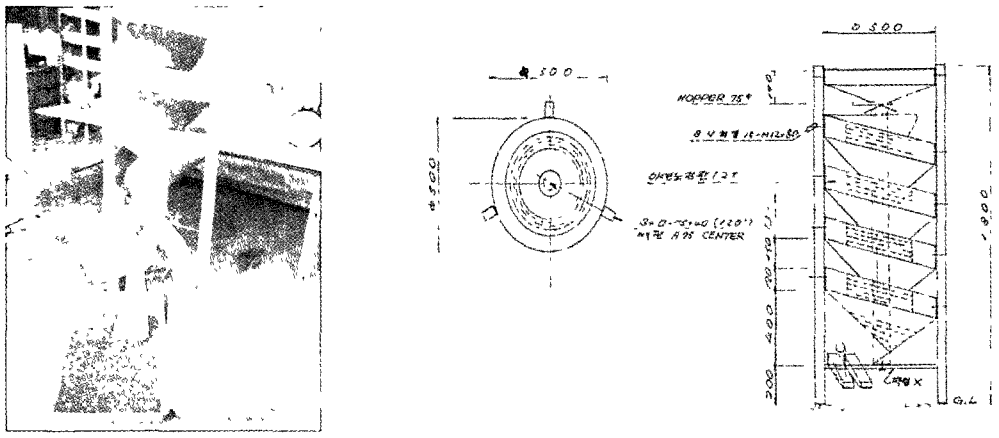


Fig. 1. Simultaneous seeds production system by the mixture cropping of hairy vetch with triticale.



(a) Separation appliance (b) Drawing of separation appliance

Fig. 2. Appliance for separation of seeds mixed with hairy vetch and triticale.

kg per hour to separate mixed seed (Fig 1, 2). After harvest by combine harvester, soybean was seeded as green manure for next year experiment.

During 2 years from 2001 fall to 2003 spring, experiments were conducted for verifying proper seeding rates or ratios in the mixture cropping (row seeding) between HV and TC. HV variety was 'Common' which was Oregon origin, and TC variety was 'Sinyoungraimil' which was bred in National Institute of Crop Science. Experimental plot was designed as split-plot with 5 replication during two years, in which main plot (3 levels) was TC seeding rate and sub plot (3 levels) was HV seeding rate, and area of one plot was 45 m^2 (5 × 9 m) and row spacing was 25 cm. During 2 years, nitrogen fertilizer was not applied because of soybean green manure. But phosphate and potassium were followed by standard fertilization guide of wheat. In 2001, TC and HV seeding rates were 5, 10, 15 kg/10a and 1, 2, 3 kg/10a, respectively. Seeding time was October 15. Number of seedling stand of TC and HV were measured in mid-November before over-wintering, and TC heading date and HV flowering initiation date were investigated in early May, respectively. Mixed plant was harvest on July 3rd from the center of each plot. Dried mixed seeds were separated by hand. In fall of 2002, TC and HV seeding rates were 1.5, 3, 4.5 kg/10a and 1.5, 3, 4.5 kg/10a, respectively. Dates of seeding and harvesting was October 11th and June 26th, respectively.

RESULTS AND DISCUSSIONS

Field test of triticale and wheat as stake crop for hairy vetch cultivation

Plant growths and seed yields in two mixture cropping (wheat + HV, TC + HV) in the first year (2000 fall ~2001 spring) are shown at Table 1. Heading date of triticale was 5 days later than wheat at which heading date was May 9th. TC stalk height after heading was 65 cm taller than that of wheat which was 85 cm. Flowering initiation date of HV was May 22th. So, much wheat seed was decayed before ripening of HV seed because ripening stage of wheat was earlier than that of HV or TC and wheat plant was covered by HV due to short stalk. In contrast to wheat, TC plant was not covered by HV because TC stalk was tall as much as 150 cm, and the seeds of two crops could be harvested at the same time without loss of TC seed because ripening stage of TC was similar with that of HV. Furthermore, TC could support HV robustly by much stronger stalk than wheat. In seeding method, row seeding was better than broadcast seeding in two mixture cropping of wheat + HV and TC + HV. HV seed yield was higher as 176 kg/10a at row seeding and 146 kg/10a at broadcast seeding in the mixture cropping with TC than wheat though TC seed yield was lower than wheat (Table 1). Considering that above results, it is thought that proper seeding method to get higher HV seed yield was to seed mixed TC + HV in rows.

Hairy vetch seed yields of according to seeding rates and ratios between hairy vetch and triticale

Table 2 shows seedling stands of two crops (before over-wintering), lodging at harvest and seed yields of two crops during the experiment from 2001 fall to 2002 spring. Seedling stands increased with the increase of seeding rate in two crops without influence of each companion crop. Lodging (93.3%) at harvest increased with lower TC seeding rate of 5 kg/10a. Seed yields during from 2001 fall to 2002 spring were shown at Table 2. TC seed yield decreased to 411 kg/10a lower TC seeding rate of 5 kg/10a. TC seed yield decreased less than 450 kg/10a with the increased HV seeding rate over 2 kg/10a. Higher HV seed yield was obtained at TC seeding rate 5 kg/10a because TC growth inhibited HV growth at TC seeding rates over 10 kg/10a. So, ratio of HV seed yield to total seed yield (TC + HV) also decreased with the increase of TC seeding rate over 10 kg/10a despite

Table 1. Growths and seed yields in the mixture cropping of hairy vetch+wheat and hairy vetch+triticale in spring of 2001.

Mixture†	Seeding-method	Heading date of wheat · TC	Flowering date of HV	Plant height of wheat · TC (cm)	Lodging at harvest (%)	Seed yield (kg/10a)		
						HV	wheat · TC	total
Wheat + HV	Row	5 9	5.21	84	3	69	498	567
	Broad -cast	5.9	5 22	85	90	125	276	401
TC+HV	Row	5.14	5.22	149	20	176	279	454
	Broad -cast	5.14	5 22	150	80	146	116	262
LSD0.05		-	-	-	-	41	59	68

†Variety . Hairy vetch(HV) - Madison (Nebraska origin), Triticale(TC) - Sinyoung, Wheat-Geuru
Seeding rate : Hairy vetch-2 kg/10a, Triticale-1 kg/10a, Wheat-10 kg/10a

Table 2. Growths and seed yields in mixture cropping of triticale + hairy vetch in 2002.

Seeding rate (kg/10a)		Plant number (No./m²)			Lodging at harvest	Seed yield (kg/10a)			
TC†	HV†	TC	HV	Ratio of HV ♪ (%)	(%)	TC	HV	total	Ratio of HV ♪ (%)
	1	118	29	19	94	490	34	524	7
5	2	126	64	33	94	420	55	475	12
	3	116	84	42	92	324	74	398	19
	1	169	31	15	80	502	16	518	3
10	2	192	46	19	84	454	32	486	7
	3	171	72	30	76	475	32	507	7
	1	210	28	12	74	584	11	595	2
15	2	243	48	17	78	494	22	516	5
	3	234	72	24	82	464	15	479	3
Mean 5		120	59	31	93.3	411	54	466	13
Mean 10		177	49	21	80.0	477	26	504	6
Mean 15		229	49	18	78.0	514	16	530	4
	1	166	29	15	82.7	525	20	546	4
	2	187	53	23	85.3	456	36	492	8
	3	174	76	32	83.3	421	40	461	10
LSD 0.05	ST ♩	15	ns	4	7.8	60	17	ns	5
	SV	12	10	5	ns	49	12	46	4
Significance of interaction‡		ns	ns	*	ns	ns	*	ns	**

†Variety : TC(triticale) - Sinyoung, HV(hairy vetch) - Common (Oregon origin)
‡ns , *, ** : Non-significant and significant at 0.05 and 0.01 probablity, respectively.
♩ST · Seeding rate of triticale, SV : Seeding rate of hairy vetch
♪Ratio of hairy vetch to total(triticale+hairy vetch)
※Heading date of triticale: May 1, Flowering beginning date of hairy vetch: May 15

higher HV seeding rate. The highest total seed yield (546 kg/10a) of TC+HV was obtained at HV seeding rate of 1 kg/10a due to the increase of TC seed yield by reduced HV seeding rates.

Table 3 shows growth status in the mixture cropping of HV + TC during 2002 fall to 2003 spring at which HV was planted with TC as 9 seeding rate combinations of HV 1.5, 3, 4.5 kg/10a by TC 1.5, 3, 4.5 kg/10a. Seedling stand after over-wintering (March 24) was in proportion to seeding rates of each crop. Ratio of HV stand to total stand increased with the increase of HV seeding rate, particularly at the condition of lowered TC seeding rate. HV crop stand at harvesting time decreased much (60% more or less) compared to that on March 30th. TC panicle numbers at harvest were not different among treatments. Lodging of mixed crops at harvest was influenced by HV seeding rate, but not by TC seeding rate.

Table 4 shows aboveground dry matters and seed yields at harvest according to the combinations of seeding rates of two crops. Dry matters of TC or HV were highly influenced by each companion crop showing that dry matter of each crop was decreased by the increase of seeding rate of each partner crop, respectively. Therefore, ratio of HV dry matter to total dry matter increased with higher HV seeding rates or lower TC seeding rates. Changes of seed yield of two crops showed similar trend with changes of dry matter. Ratio of HV seed yield to total seed yield, also increased with higher HV seeding rates or lower TC seeding rates. The highest HV seed yield (95 kg/10a) was obtained at the seeding combination of HV 4.5 kg/10a + TC 1.5 kg/10a in which the ratio of HV seed to total seed was also the highest as 26.7%.

In conclusion, out of winter cereal crops as stake crop of HV for higher HV seed production, TC was better than wheat with respect of consistency of ripening time and ability of physical supporting for HV. In considering two years' results about seeding rates between HV and TC for higher HV seed production, it was thought that TC seeding rates under 3 kg/10a (1 ~ 3 kg/10a) is proper because growth and seed production of HV was decreased due to higher TC growth at TC seeding rates over 3 kg/10a. At the same time,

Table 3. Growth status according to the combinations of different seeding rates in the mixture cropping with triticale and hairy vetch in 2003

Seeding rate (kg/10a)		Plant No. after wintering ♬ (No./m²)			Plant No. of HV at harvest (No./m²)	Panicle No. of TC at harvest (No./m²)	Lodging at harvest (%)
TC†	HV†	TC	HV	Ratio of HV ♪ (%)			
1.5	1.5	55	31	36	10	304	76
	3.0	57	59	51	21	320	81
	4.5	57	71	56	23	318	90
3.0	1.5	76	24	24	8	372	68
	3.0	77	48	38	19	298	54
	4.5	80	69	47	19	318	91
4.5	1.5	87	28	24	11	348	40
	3.0	94	60	38	18	348	81
	4.5	88	61	40	14	326	76
Mean 1.5		56	54	47	18	314	83
Mean 3.0		77	49	36	15	329	71
Mean 4.5		90	47	34	14	340	66
	1.5	73	27	28	10	341	61
	3.0	76	56	42	19	322	72
	4.5	75	67	47	19	321	86
LSD0.05	ST ♩	6	ns	4	ns	ns	ns
	SV	ns	8	3	4	ns	13
Significance of interaction‡		ns	ns	ns	ns	ns	ns

†, ‡, ♩, ♪ are the same with table 2, ♬ March 30th,
※ Heading date of triticale: May 14, Flowering beginning date of hairy vetch: May 25th
Plant height of triticale . 177cm

Table 4. Aboveground dry matters and seed yields according to the combinations of different seeding rates in the mixture cropping with triticale and hairy vetch in 2003

Seeding rate (kg/10a)		Dry matter (kg/10a)				Seed yield (kg/10a)				1000 seeds wt. of HV (g)
TC†	HV‡	TC	HV	total	Ratio of HV ♪ (%)	TC	HV	total	Ratio of HV ♪ (%)	
1.5	1.5	1,330	140	1,470	10	385	50	435	12	30.5
	3.0	1,226	172	1,398	12	344	74	417	18	29.2
	4.5	1,133	244	1,378	18	264	95	359	27	29.2
3.0	1.5	1,500	80	1,580	5	471	46	517	9	29.9
	3.0	1,175	137	1,312	10	365	58	423	14	30.1
	4.5	1,243	149	1,392	11	333	58	391	15	31.4
4.5	1.5	1,508	80	1,588	5	502	36	538	7	30.9
	3.0	1,518	88	1,605	5	449	42	491	9	30.1
	4.5	1,482	139	1,620	8	388	61	448	13	30.3
Mean 5		1,230	185	1,415	13	331	73	404	19	29.7
Mean 10		1,306	122	1,428	9	390	54	444	13	30.5
Mean 15		1,502	102	1,604	6	446	46	492	10	30.5
	1.5	1,446	100	1,546	7	453	44	496	10	30.5
	3.0	1,306	132	1,438	9	386	58	444	14	29.8
	4.5	1,286	177	1,463	12	328	71	400	18	30.5
LSD0.05	ST ♩	126	39	128	3	41	18	44	4	ns
	SV	104	32	ns	2	34	15	43	3	ns
Significance of interaction‡		ns	ns	ns	ns	ns	ns	ns	ns	ns

†, ‡, ♩, ♪ are the same as Table 2.

it was thought that HV seeding rates of 4 or 5 kg/10a would be proper because HV seed production was increased with the increase of HV seeding rate, but mixed crop could be lodged severely by higher HV seeding rates over 5 kg/10a due to the greater aboveground dry matter of HV. In the future, it is needed to develop shorter TC with stronger stalk to support HV with much HV aboveground dry matter. In the mixture cropping of between HV and TC having shorter and stronger stalk, HV seeding rate and ratio to TC could be increased because supporting strength of TC on HV would be increased.

Farmer's income from the mixture cropping of HV with TC tends to be much higher than those from rye or wheat mono-cultivation because HV seed price is much higher as 4,000 ₩/kg than that of winter cereal (wheat, rye, TC) as 800 ₩/kg. But machinery for harvesting and seed separation such as multi-purpose combine harveser and separation appliance using centrifugal force are needed additionally, so it is thought that this seed production system could be used at the large scale farm for green manure seed production.

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