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Enhancing Forage Productivity and Organic Hanwoo Cattle Carrying Capacity through Growing Rye Legumes Mixed Fodder under Different Manure Levels

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ABSTRACT

This study was aimed to evaluate mixed sowing rye with legumes under different cattle manure levels for optimum forage yield and organic Hanwoo cattle carrying capacity from 2012-13 to 2014-15. Experiment was conducted under split plot arrangement having 3 main plots (Sole Rye, Rye with hairy vetch and rye with pea) and 4 sub-plots (0, 50, 100 and 150 kg N/ha). Findings showed if rye was mixed cropped with hairy vetch, dry matter (DM) and total digestible nutrient (TDN) yield was not different (P>0.05) from control, whereas rye-vetch mixture had increased (P<0.05) crude protein (CP) yield and carrying capacity for Hanwoo heifers than that of rye monoculture. DM and TDN yield under 100 kg manure was higher (P<0.05) than control and 50 kg N/ha levels but not different (P>0.05) with that of 150 kg N/ha. Manure levels did not affect (P>0.05) protein yield. The carrying capacity for Hanwoo heifers was not different among zero, 50 and 100 kg manure levels, whereas it was higher at 150 kg N/ha (P<0.05) than all other manure levels. Similarly, results depicted little different pattern when rye was mixed sown with pea that DM and TDN yield was not different (P>0.05) when compared with rye monoculture, whereas CP yield was higher in mixed forage than control but carrying capacity was higher (P<0.05) at all manure levels except 150 kg N/ha. It was concluded from findings of present study that mixed growing strategy of rye with local hairy vetch didn't need any manure application for optimum crude protein yield, whereas 100 kg N/ha manure would be adequate for overall optimum forage yield and 150 kg N/ha needed for obtaining optimum carrying capacity for Hanwoo heifers. Similarly, Rye pea mixed culture didn't need manure application for optimum crude protein yield but 50 kg N/ha manure would be needful for adequate dry matter yield and carrying capacity for Hanwoo heifers. However, 100 kg N/ha manure could be sufficient for optimal yield of digestible nutrients.

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Authors' Contribution
JIH designed and supervised the study. JIH and CKW executed experimental work and collected scientific data. MF analyzed the collected data and prepared the manuscript in coordination with others.

Key words
Rye mixed with legume, Forage yield, Total digestible nutrient and Hanwoo carrying capacity.

INTRODUCTION

Consequent upon high economic growth, food consumption pattern of people has been shifted progressively towards high quality livestock products in Republic of Korea. This upraised demand puts pressure on livestock industry to boost more livestock production and consequently, six livestock products (beef, milk, pork, chicken, eggs and duck) have been already included in top 10 Agro-forestry foods in country (Chung *et al*., 2014). In comparison to year of 1995, per capita consumption of meat and beef has been increased from 27 to 45 kg and 6.7 to 10.7 kg in 2014, respectively. Country is 42.8% self-sufficient in local beef production and rest is imported from America, Australia, Canada, New Zealand, Mexico and few other countries (Heo *et al*., 2014).

Hanwoo beef is predominantly preferred by consumer in-spite of fact that local Hanwoo beef is more expensive than the imported one. This factor might be attributed to freshness and good flavor (Jo *et al*., 2012). In addition to that local Hanwoo beef has low cholesterol, higher Omega 3 fatty acids, higher marbling percentage and adequate balance of meat and fat (Cho *et al*., 2005). Livestock industry desires to fulfill flourishing demand through innovative forage production techniques as green roughage is an essential feeding resource for livestock (Naseer *et al*., 2017). But unfortunately feed resources are not enough due to limited cultivatable land in country which is continuously decreasing and remained only 1679 thousand hectares for Agriculture (KOSTAT, 2015). Moreover, cropping pattern is also based on traditional techniques.

Rye (*Secale cereal* L.) is well recognized forage used

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for cattle feed as silage but inferior in certain ways to other cereal crops. It is coarsely stemmed and its straw is fibrous and less palatable than other forages for livestock feeding (Bushuk, 2001). So, it is desperately needed to implement revolutionized efforts for enhancing yield and nutritive value of available forages to boost organic beef production in country. Intercropping cereal crops with legumes might exhibit higher yield with better nutritive value for livestock feeding. It does not only improve yield through efficient rhizobial symbiosis between two intercropped species (Latati *et al*., 2013) but also enhance soil fertility through nitrogen fixation by leguminous specie (Li *et al*., 2001; Tsubo and Walker, 2002; Awal *et al*., 2006; Zhang *et al*., 2015). Another way that might prevent environmental pollution and enhance forage productivity is greater use of organic cattle manure along with introduction of leguminous plant in cropping systems (Ramesh *et al*., 2005; Sharma *et al*., 2004). The present study was designed with aim to evaluate influence of mixed sowing rye with legumes and different levels of cattle manure for optimum forage yield and organic Hanwoo cattle carrying capacity.

MATERIALS AND METHODS

Location of study

This study was conducted at Gyeongsan, Angang and Yeongju sites in Gyeongbuk Province of South Korea. Gyeongsan city have geographical coordinates Latitude: 35°49′23″ N, Longitude: 128°44′16″ E and second Angang city have geographical coordinates Latitude: 35.05444, Longitude: 126.60056, whereas geographical coordinates of 3rd Yeongju city are Latitude: 36.8057, Longitude: 128.6241 111 N 36 48’ 20”, E 128 37’ 27”.

Climate of research site

Climate in terms of temperature and rainfall of all three sites recorded during three years from 2013 to 2015 with 30 years history is given in Tables I and II.

Experimental treatments

The experiment was conducted at three different sites for 3 years from 2013 to 2015 under split plot arrangement having 3 main plots and 4 sub-plots. Monocrop rye (*Secale cereale* L.), mixed cropping rye with hairy vetch (*Vicia Villosa* L.; Hungvillosa) and winter pea (*Pisum sativum*; Ruby) were evaluated under three main plots treatments with 3 replicates: Treatment 1; Sole Rye (Control), Treatment 2; Rye mixed with hairy vetch and Treatment 3; rye mixed with pea. Four manure levels were evaluated under sub-plots with three replicates; 0 kg N/ha (control), 50, 100 and 150 kg N/ha.

Table I.- Average temperature (°C) of research sites during 2013 to 2015 with 30 years history.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Gyeongsan									
2013-2015	14.2	7.1	-0.3	-0.3	1.9	7.4	12.2	18.7	21.7
1982-2011	9.3	4	-1.9	-3.9	-1.6	3.4	9.9	15.2	19.4
Angang									
2013-2015	14.5	7.6	0.3	-0.3	1.7	7.3	12.2	18.5	22.1
1982-2011	15.1	8.7	3.0	0.8	2.6	7.1	13.2	17.6	20.7
Yeongju									
2013-2015	12.8	5.6	-2.2	-2.0	0.6	6.3	11.6	18.2	22.0
1982-2011	12.6	5.8	-5.6	-2.9	-0.2	4.8	11.6	16.9	21.0

Table II.- Average rainfall (mm) of research sites during 2013 to 2015 with 30 years history.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Gyeongsan									
2013-2015	85.6	39.7	20.3	14.0	18.0	80.7	90.4	51.0	67.2
1982-2011	19.9	33.7	19.6	20.8	27.6	54.1	72.7	109	156.6
Angang									
2013-2015	92.0	43.0	22.0	15.1	29.5	69.3	93.4	53.8	64.2
1982-2011	52.4	43.0	22.0	80.9	37.1	53.8	68.3	86.6	148.8
Yeongju									
2013-2015	92.4	53.3	31.8	21.4	29.4	43.6	76.0	97.7	137.4
1982-2011	43.1	4.2	18.2	19.4	30.8	53.3	86.8	120.6	180.9

Table III.- Effect of mixed sowing rye with legumes under different manure levels on dry matter yield (tons/ha) of forage in three places of Gyeongbuk province South Korea.

Manure levels (kg N/ha)	Culture type					
	Rye sole (control)		Rye hairy Vetch Mix		Rye Pea Mixture	
Gyeongsan						
0	3.69 ± 0.51 [a]	B	3.45 ± 0.40 [a]	B	3.84± 0.15 [a]	B
50	5.24 ± 0.65 [a]	AB	4.31 ± 0.42 [a]	AB	4.49 ± 0.49 [a]	AB
100	6.04 ± 0.72 [a]	A	5.45 ± 0.46 [a]	A	5.1 ± 0.42 [a]	A
150	7.13 ± 0.88 [a]	A	5.64 ± 0.46 [a]	A	5.37 ± 0.28 [a]	A
Angang						
0	5.74 ± 0.9 [a]	A	7.33 ± 0.5 [a]	A	7.66 ± 0.8 [a]	A
50	5.85 ± 0.9 [a]	A	6.94 ± 0.5 [a]	A	8.08 ± 0.8 [a]	A
100	6.99 ± 0.9 [a]	A	7.41 ± 0.3 [a]	A	7.98 ± 0.7 [a]	A
150	7.86 ± 1.0 [a]	A	7.37 ± 0.3 [a]	A	9.37 ± 0.6 [a]	A
Yeongju						
0	4.38 ± 0.41 [a]	C	4.31 ± 0.31 [a]	C	5.21 ± 0.60 [a]	B
50	5.54 ± 0.50 [a]	BC	5.40 ± 0.46 [a]	BC	6.19 ± 0.77 [a]	AB
100	6.73 ± 0.70 [a]	AB	6.89 ± 0.63 [a]	AB	7.57 ± 0.94 [a]	AB
150	7.62 ± 0.60 [a]	A	8.07 ± 0.74 [a]	A	8.17 ± 0.88 [a]	A
Overall mean of all 3 places						
0	4.60 ± 0.61 [a]	C	5.03 ± 0.41 [a]	B	5.57 ± 0.45 [a]	B
50	5.54 ± 0.39 [a]	BC	5.55 ± 0.33 [a]	B	6.25 ± 0.48 [a]	AB
100	6.59 ± 0.45 [a]	AB	6.58 ± 0.31 [a]	A	6.89 ± 0.47 [a]	AB
150	7.54 ± 0.47 [a]	A	7.03 ± 0.36 [a]	A	7.63 ± 0.48 [a]	A

[abc] Variables among culture types having different superscripts in columns are different (P<0.05). ABC, variables among nitrogen levels having different letters in rows are different (P<0.05).

Land preparation, seeding and time period

In each replicate, plot having length and width measurement (4 × 2 meters) was prepared for sowing rye mixed with legumes under four different manure levels. Six months old fermented cattle manure was used. Half of cattle manure was fertilized at seeding day and other half manure was used in thawing season. Seeding was carried out through broadcast method. First experiment was conducted from Oct. 17, 2012 to May 16, 2013, whereas 2nd experiment was performed from Oct. 17, 2013 to May 20, 2014 and 3rd was executed from Oct. 17, 2014 to May 18, 2015.

Parameters studied

Effect of sowing rye mixed with hairy vetch and pea under four different manure levels was determined in terms of following parameters: (1) Dry matter yield (tons/ha), (2) Crude protein yield (kg/ha), (3) Total digestible nutrients yield (tons/ha), and (4) Carrying capacity for Hanwoo heifers (heads/ha).

Data collection

Two samples from each replicate were taken for dry matter yield, initially weighed, dried in oven at 70° C for 72 h and then again weighed after drying. The kg dry matter yield was also converted into tons per hectare. Proximate analysis was performed according to scientific methods of AOAC (1995) and crude protein was determined through Kjeldahl digestion method using quantitative determination of organic nitrogen. Fiber analysis like Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) was made by Van-Soest (1991) method. The carrying capacity (heads/ha) was calculated based on dry matter yield for Hanwoo heifer gaining 400 g daily for 450 kg body weight based on RDA (2012). Total digestible nutrients (TDN) were calculated by following formula of Nahm (1992) and Linn and Martin (1989):

$$TDN = \{88.9 - (0.79 \times ADF\ \%)\}$$

Statistical analysis

Data were analyzed using ANOVA technique through SAS 9.3 software. The difference between two treatment means was tested through Duncan Multiple Range Test.

RESULTS AND DISCUSSION

Effect of mixed sowing rye with hairy vetch under different manure levels

Dry matter yield

The overall results in Table III indicated that DM yield was not different (P>0.05) between monocrop rye and rye-vetch mixed cultures. In case of rye as sole crop,

increasing trend in DM yield was observed with increasing manure level as depicted by results in research sites except Angang. The overall results in Table III denoted that DM yield in rye vetch mixture with 100 kg manure was higher ($P<0.05$) than control and 50 kg N/ha level but not different ($P>0.05$) with that of 150 kg N/ha.

In case of Gyeongsan, DM yield in rye vetch mixture was higher with 100 kg N/ha than control and had tendency to increase from 50 to 100 kg N/ha but not different with 150 kg N/ha level. The pattern was different in Angang where DM yield was not influenced ($P>0.05$) by manure levels. However, out of Yeongju site, DM yield of hairy vetch mixture with 100 kg N/ha was higher ($P<0.05$) than control and had tendency to increase from 50 to 100 kg N/ha but not different ($P>0.05$) with highest manure level *i.e.* 150 kg N/ha.

It is depicted from overall results that optimum dry matter yield may be achieved with 100 kg N/ha manure level. Low requirement of N fertilizer for optimum yield of rye-vetch mixture might be attributed to potential of hairy vetch for improvement of soil nitrogen fertility while increasing N availability to crop production (Kuo and Sainju, 1998; Clark *et al*., 2007) and consequently reduces N fertilizer requirements (Sullivan *et al*., 1991).

Crude protein yield

Effect of different cultures on crude protein (CP) yield under different nitrogen levels is presented in Table IV. The overall results indicated that CP of rye vetch mixture with 100 kg N/ha was higher than control and there was tendency to increase CP yield when manure levels was increased from 50 to 100 and 100 to 150 kg N/ha. In rye monoculture, CP yield increased at increasing rate of nitrogen levels except at Angang site.

In Gyeongsan site, CP yield in hairy vetch mixture was higher with 100 kg N/ha than that of control and 50 kg N/ha but not different with 150 kg N/ha level, whereas at Angang site, nitrogen levels did not affect ($P>0.05$) protein yield in rye-hairy vetch mixture. However, CP yield in hairy vetch biculture at Yeongju site with 100 kg nitrogen was higher than that of control and 50 kg nitrogen but lower ($P<0.05$) than that of 150 kg N/ha level.

Table IV.- Effect of mixed sowing rye with legumes under different manure levels on crude protein yield (kg/ha) of forage in three places of Gyeongbuk province Korea.

Manure levels (kg N/ha)	Culture type					
	Rye sole (control)		Rye hairy Vetch Mix		Rye Pea Mixture	
Gyeongsan						
0	210.1 ± 24 ^{a}	C	232.3 ± 23 ^{a}	B	257.9 ± 16 ^{a}	A
50	278.91 ± 36 ^{a}	BC	265.49 ± 31 ^{a}	B	298.32 ± 40 ^{a}	A
100	357.24 ± 30 ^{a}	AB	389.97 ± 35 ^{a}	A	363.62 ± 46 ^{a}	A
150	388.22 ± 26 ^{a}	A	405.13 ± 50 ^{a}	A	366.19 ± 37 ^{a}	A
Angang						
0	287 ± 45 ^{b}	A	714 ±76 ^{a}	A	556 ±63 ^{a}	A
50	320 ± 65 ^{b}	A	715 ± 112 ^{a}	A	704 ± 56 ^{a}	A
100	347 ± 56 ^{b}	A	688 ± 100 ^{a}	A	687 ± 79 ^{a}	A
150	380 ± 50 ^{b}	A	631 ± 76 ^{ab}	A	768 ± 126 ^{a}	A
Yeongju						
0	219.45 ± 18 ^{b}	C	213.98 ± 13 ^{b}	C	327.07 ± 44 ^{a}	A
50	290.14 ± 28 ^{ab}	BC	253.59 ± 14 ^{b}	C	341.60 ± 36 ^{a}	A
100	335.64 ± 29 ^{a}	AB	334.37 ± 20 ^{a}	B	397.70 ± 39 ^{a}	A
150	373.68 ± 29 ^{a}	A	425.87 ± 34 ^{a}	A	406.65 ± 30 ^{a}	A
Overall mean of all 3 places						
0	238.9 ± 18 ^{b}	C	386.7 ± 52 ^{a}	A	380.6 ± 35 ^{a}	A
50	296.3 ± 25^{b}	BC	411.5 ± 56 ^{ab}	A	448.2 ± 43 ^{a}	A
100	346.6 ± 22^{b}	AB	471.0 ± 46 ^{a}	A	483.0 ± 42 ^{a}	A
150	380.0 ± 20 ^{b}	A	487.5 ± 37 ^{ab}	A	513.7 ± 56 ^{a}	A

^{abc} Variables among culture types having different superscripts in columns are different ($P<0.05$). ABC, variables among nitrogen levels having different letters in rows are different ($P<0.05$).

It was depicted from overall results that optimum CP yield could be achieved through mixed cropping rye with legumes even under zero cattle manure. Because, CP yield under zero kg N/ha was not different from those of 50, 100 and 150 kg N/ha levels. Improvement in CP yield of rye-vetch biculture over rye crop monoculture might be due to leguminous nature of hairy vetch which might increase N content of mixture (Odhiambo and Bomke, 2001). Previously, similar findings were reported by other workers (Clark *et al*., 1994, 2007; Parr *et al*., 2011; Hayden *et al*., 2014) that hairy vetch and rye mixed cropping fetched greater above ground nitrogen content than that of rye monoculture. The optimum CP yield in mixed forage might be attributed to leguminous factor of hairy vetch which can supply nitrogen for companion crop (Kim *et al*., 2002).

Total digestible nutrients yield

Response of different culture and nitrogen levels is presented in Table V. The overall results indicated that yield of total digestible nutrients (TDN) was not influenced by rye vetch mixed culture. Yield of TDN was highest under 150 kg N/ha in rye sole monocrop, followed by 100, 50 and 0 kg N/ha levels.

In Gyeongsan site, TDN yield in rye vetch mixture with 100 kg nitrogen was higher (P<0.05) than control but had tendency to increase from 50-100 kg nitrogen and tend to decrease from 150 to 100 kg N/ha manure level. The same pattern was followed in case of Yeongju site, whereas manure levels didn't influence TDN yield at Angang site.

The overall results indicated that TDN yield in rye vetch mixture with 100 kg N/ha was higher (P<0.05) than 50 kg and control but not different with that of 150 kg N/ha manure level. So, it was depicted from overall results that optimum TDN yield in rye-vetch mixture could be achieved with 100 kg N/ha manure level. Previously, Lee *et al*. (2013) also reported optimum TDN yield under Rye hairy vetch mixed cropping with 80 kg N/ha of composted cattle manure. Similarly, Hwangbo and Jo (2013) also patronized results of present study that mixed sowing with legumes might increase feed value including TDN. The optimum TDN yield in rye-vetch mixture might be attributed to adequate level of its dry matter yield at 100 kg N/ha manure level.

Table V.- Effect of mixed sowing rye with legumes under different manure levels on total digestible nutrients yield (ton/ha) of forage in three places of South Korea.

Manure levels (kg N/ha)	Culture type					
	Rye sole (control)		Rye hairy Vetch Mix		Rye Pea Mixture	
Gyeongsan						
0	1.80 ± 0.24 [a]	B	1.71± 0.19 [a]	C	1.97± 0.07 [a]	C
50	2.66 ± 0.32 [a]	AB	2.18 ± 0.21 [a]	BC	2.29 ± 0.26 [a]	BC
100	2.88 ± 0.31 [a]	AB	2.79 ± 0.20 [a]	AB	2.63 ± 0.24 [a]	AB
150	3.69 ± 0.50 [a]	A	2.99 ± 0.23 [a]	A	2.90 ± 0.16 [a]	A
Angang						
0	2.61 ± 0.3 [b]	B	3.77 ± 0.3 [a]	A	3.73 ± 0.3 [a]	B
50	2.67 ± 0.3 [b]	B	3.48 ± 0.2 [ab]	A	3.88 ±0.3 [a]	B
100	3.28 ± 0.4 [a]	AB	3.75 ± 0.1 [a]	A	4.03 ± 0.3 [a]	B
150	3.99 ± 0.5 [ab]	A	3.83 ± 0.1 [b]	A	5.06 ± 0.3 [a]	A
Yeongju						
0	2.19 ± 0.22 [a]	C	2.17 ± 0.18 [a]	C	2.67 ± 0.31 [a]	B
50	2.88 ± 0.27 [a]	BC	2.74 ± 0.25 [a]	BC	3.16 ± 0.39 [a]	AB
100	3.37 ± 0.34 [a]	AB	3.49 ± 0.34 [a]	AB	3.85 ± 0.46 [a]	AB
150	3.89 ± 0.36 [a]	A	4.15 ± 0.38 [a]	A	4.10 ± 0.43 [a]	A
Overall mean of all 3 places						
0	2.20 ± 0.61 [a]	C	2.55 ± 0.22 [a]	B	2.79 ± 0.20 [a]	C
50	2.74 ± 0.17 [a]	BC	2.80 ± 0.16 [a]	B	3.11 ± 0.22 [a]	BC
100	3.18 ± .20 [a]	B	3.34 ± 0.15 [a]	A	3.5 ± 0.23 [a]	AB
150	3.86 ± 0.26 [a]	A	3.66 ± 0.18 [a]	A	4.02 ± 0.25 [a]	A

[abc] Variables among culture types having different superscripts in columns are different (P<0.05). ABC, variables among nitrogen levels having different letters in rows are different (P<0.05).

Table VI.- Effect of mixed sowing rye with legumes under different manure levels on carrying capacity (heads/ha) for organic Hanwoo heifers (450 kg) with 400 g of daily gain fed diets comprising 70% rye or mixed forage.

Manure levels (kg N/ha)	Culture type					
	Rye sole (control)		Rye hairy Vetch Mix		Rye Pea Mixture	
Gyeongsan						
0	1.30 ± 0.15 [a]	C	1.33 ± 0.14 [a]	B	1.51± 0.06 [a]	B
50	1.84 ± 0.21 [a]	BC	1.61 ± 0.17 [a]	B	1.75 ± 0.21 [a]	AB
100	2.15 ± 0.19 [a]	AB	2.21 ± 0.17 [a]	A	2.07 ± 0.22 [a]	A
150	2.55 ± 0.25 [a]	A	2.33 ± 0.22 [a]	A	2.18 ± 0.15 [a]	A
Angang						
0	1.84 ± 0.2 [b]	A	3.54 ± 0.3 [a]	A	3.06 ± 0.2 [a]	B
50	1.96 ± 0.3 [b]	A	3.43 ± 0.4 [a]	A	3.55 ± 0.2 [a]	AB
100	2.27 ± 0.3 [b]	A	3.46 ± 0.3 [a]	A	3.56 ± 0.3 [a]	AB
150	2.64 ± 0.3 [b]	A	3.32 ± 0.2 [ab]	A	4.19 ± 0.47 [a]	A
Yeongju						
0	1.48 ± 0.13 [a]	C	1.46 ± 0.10 [a]	C	1.98 0 ± 0.25 [a]	A
50	1.95 ± 0.18 [a]	BC	1.79 ± 0.13 [a]	C	2.21 ± 0.25 [a]	A
100	2.27 ± 0.22 [a]	AB	2.32 ± 0.19 [a]	B	2.64 ± 0.28 [a]	A
150	2.58 ± 0.22 [a]	A	2.84 ± 0.24 [a]	A	2.76 ± 0.24 [a]	A
Overall mean of all 3 places						
0	1.54 ± 0.11 [b]	C	2.11 ± 0.23 [a]	B	2.18 ± 0.17 [a]	B
50	1.92 ± 0.13 [b]	BC	2.28 ± 0.21 [ab]	AB	2.51 ± 0.20 [a]	AB
100	2.23 ± 0.14 [b]	AB	2.66 ± 0.17 [ab]	AB	2.76 ± 0.20 [a]	AB
150	2.59 ± 0.15 [a]	A	2.83 ± 0.15 [a]	A	3.05 ± 0.24 [a]	A

[abc] Variables among culture types having different superscripts in columns are different (P<0.05). ABC, variables among nitrogen levels having different letters in rows are different (P<0.05).

Carrying capacity for Hanwoo heifers

Table VI indicates response of different treatments on carrying capacity for Hanwoo heifers. The carrying capacity for organic Hanwoo heifers was increased by rye-hairy vetch culture higher (P<0.05) as compared to that of rye monocrop. Previously, Lee *et al*. (2013) also substantiated that rye-hairy vetch mixture might be most adaptable mixed combinations for roughage production at Gang-wondo area of South Korea in terms of stock carrying capacity. The carrying capacity for organic Hanwoo heifers was maximum under 150 kg N/ha level, followed by 100, 50 and 0 kg N/ha levels in case of rye monocrop at all research sites except Angang.

In Gyeongsan site, carrying capacity in rye vetch mixture with 100 kg N/ha was higher (P<0.05) than control and 50 kg nitrogen but not different from 150 kg N/ha level. However, at Angang site, different manure levels didn't influence carrying capacity in rye vetch biculture, whereas at Yeongju site carrying capacity with 150 kg nitrogen level was higher (P<0.05) than 50, 100 and zero kg N/ha (control). As per overall results, carrying capacity in rye vetch mixture with 150 kg N/ha was found optimum because it was higher (P<0.05) than 0, 50 and 100 kg N/ha levels. There was tendency to increase carrying capacity when manure level was increased from zero to 50 kg N/ha. Previously, Hwangbo and Jo (2014) also reported that 100-150 kg/ha could be adequate cattle manure level for optimum carrying capacity of Hanwoo if cereal is mixed with hairy vetch crop.

Effect of mixed sowing rye with pea under different manure levels

Dry matter yield

Response of mixed sowing rye with pea under different cattle manure levels on dry matter yield of mixed forage is presented in Table III. Dry matter (DM) yield was found not different (P>0.05) between rye-pea mixed and rye monoculture. In Gyeongsan site, DM yield in rye pea mixture with 100 kg nitrogen level was higher than control and had tendency to increase DM yield from 50 to 100 kg

N/ha but it was not different (P>0.05) from 150 kg N/ha level. In Angang site, manure levels didn't affect DM yield in rye pea mixture. The DM yield was found higher with 150 kg manure than control and had tendency to increase DM yield when manure was increased from 50 and 100 to 150 kg N/ha.

The overall DM yield in rye pea mixture with 50 kg nitrogen was not different from that of 100 kg N/ha level, whereas there was tendency to increase DM yield when manure level was enhanced from 100 to 150 kg N/ha and tendency to decrease DM yield if manure level was reduced from 50 to zero kg N/ha level. It was depicted from overall results that optimum DM yield could be achieved in rye-pea mixed cropping under 50 kg N/ha manure level. The reason might be due to factor that pea would be right choice for mixed cropping with cereals which might adequately enhance biomass production (Salawu *et al*., 2001). Pea can not only be high nitrogen fixer but also improve soil conditioning through nitrogen contribution to soil as broken forage (Sarrantonio, 1994). Enhancing yield in mixed forage might be due to factor that pea might be quite moisture efficient crop for increasing biomass production (Sims, 1996).

Crude protein yield

Effect of mixed sowing rye with pea under different cattle manure levels on crude protein yield is also presented in Table IV. Rye mixed with pea strategy didn't (P>0.05) influence crude protein yield in Gyeongsan and Yeongju sites, whereas rye pea biculture at Angang site increased CP yield higher (P<0.05) than rye monoculture. However, different manure levels didn't influence (P>0.05) CP yield in rye pea mixture in all three sites.

The overall results depicted that optimum CP yield might be achieved through rye-pea intercropping culture even under zero kg N/ha manure level. The possible reason might be due to high potential of pea crop for efficient nitrogen fixation. Previously, it was also substantiated that above ground nitrogen accumulation efficiency was increased from 70% to 90% in pea if mixed with cereals (Hauggaard-Nielse *et al*., 2003). When rye and pea were mixed cropped, pea not only contributed nitrogen adequately to rye (Urbatzka *et al*., 2011) but also contribute to subsequent crops after harvesting (Karpenstein-Machan and Stülpnagel, 2000). Mixed cropping cereal with pea might improve amino acid profile of mixed forage through increasing concentrations of some amino acids (Pozdíšek *et al*., 2011).

Total digestible nutrients yield

Response of mixed sowing rye with pea under different cattle manure levels on total digestible nutrients (TDN) of mixed forage is also presented in Table V. In case of sole rye crop, TDN yield under 150 kg N/ha was found higher (P<0.05) amongst all manure levels, whereas TDN yield with 100 kg N/ha was also higher (P<0.05) than 50 and zero kg N/ha levels. The TDN yield in rye pea mixture was not influenced by mixed cropping strategy in all three sites except at Angang site where TDN yield was found higher under zero and 50 kg N/ha levels only.

In Gyeongsan site, TDN yield in rye pea mixture with 100 kg nitrogen level was higher than control and had tendency to increase TDN yield from 50 to 100 kg N/ha but not different from that of 150 kg N/ha level. At Angang site, TDN yield in rye pea mixture was found higher with 150 kg N/ha than all other manure levels.

In case of Yeongju site, TDN yield was tended to increase when manure level was increased from zero to 50, 100 and 150 kg N/ha levels. The overall results indicated that TDN yield in rye pea mixture with 100 kg N/ha was higher (P<0.05) than control and tended to increase when manure was enhanced from 100 to 150 kg N/ha, whereas TDN yield was tended to decrease when manure level reduced from 100 to 50 kg N/ha level. So, overall it was depicted that optimum TDN yield in rye pea mixture could be achieved with 100 kg N/ha. The possible reason might be that rye-pea mixed culture could be adequate for optimum CP yield but not for optimum TDN yield and required higher manure level. The finding of present study was also supported previously (Hwangbo and Jo, 2014) through recommendation of applying 100~150 kg N/ha manure for optimum forage nutritive value.

Carrying capacity for Hanwoo heifers

Effect of mixed sowing rye with pea under different cattle manure levels on stock carrying capacity for organic Hanwoo heifers is presented in Table VI. In Gyeongsan site, carrying capacity for Hanwoo heifers in rye pea mixture with 100 kg nitrogen was higher than control and had tendency to increase from 50 to 100 kg N/ha, whereas it was not different (P>0.05) form that of 150 kg N/ha level. At Angang site, carrying capacity with 150 kg N/ha was higher than control and was tended to increase when manure level was enhanced from 50 to 100 and 100 to 150 kg N/ha. In Yeongju site, different manure levels didn't influence carrying capacity in rye pea mixture. The overall mixed sowing rye with pea increased stock carrying capacity higher (P<0.05) as compared to that of rye mono-cropping under all manure levels except 150 kg N/ha.

The overall carrying capacity for Hanwoo heifers in rye pea mixture with 50 kg nitrogen was not different (P>0.05) from that of 100 kg N/ha level, whereas there was tendency to increase carrying capacity when manure level was enhanced from 100 to 150 kg N/ha and tendency to

decrease if manure level was reduced from 50 to zero kg N/ha level. It was depicted from overall results that optimum carrying capacity could be achieved in rye-pea mixed cropping under 50 kg N/ha manure level. Enhancement in carrying capacity in rye-pea mixed cropping might be attributed to factor of leguminous nature of pea which can improve stock carrying capacity of forages and pastures with higher protein content (Sullivan, 2013). The optimum carrying capacity of rye-pea mixed culture under 50 kg N/ha manure level might be due to enhanced dry matter yield in mixed forage at this fertilizer level.

CONCLUSION

It was concluded from findings of present study that mixed growing strategy of rye with local hairy vetch didn't need any manure application for optimum crude protein yield, whereas 100 kg N/ha manure would be adequate for overall optimum forage yield and 150 kg N/ha needed for obtaining optimum carrying capacity for Hanwoo heifers. The pattern in case of rye pea mixture was found little different. Likewise, rye pea mixed culture didn't need manure application for optimum crude protein yield but 50 kg N/ha manure would be needful for adequate dry matter yield and carrying capacity for Hanwoo heifers. However, 100 kg N/ha manure could be sufficient for optimal yield of digestible nutrients.

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Statement of conflict of interest

Authors of this manuscript named Prof. Jo Ik-Hwan, Choi Kwang-Won and Dr. Muhammad Fiaz hereby clearly declare that there is no conflict of interests regarding publication of this article.

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