Research Article

Effect of Triticale Legume Mixed Cropping with Various Manure Levels on Forage Production for Hanwoo Cattle

Jo Ik-Hwan[1], Choi Kwang-Won[1], Muhammad Yaqoob[2] and Muhammad Fiaz[3*]

[1]Department of Animal Resources, College of Life and Environment Sciences, Daegu University, South Korea; [2]Department of Clinical Studies, KBCMA-College of Veterinary and Animal Sciences Narowal, Pakistan; [3]Department of Livestock Production & Management, PMAS-Arid Agriculture University Rawalpindi, Punjab, Pakistan.

Abstract | The aim of this work was to evaluate mixed cropping triticale with legumes using different cattle manure levels for optimum forage productivity in a split plot arrangement having 3 main plots and 4 sub-plots with three replicates. Triticale was cultivated as monocrop, mixed cropped with hairy vetch and winter pea under 3 main plots. Four manure levels were also evaluated under 4 sub-plots: 0 kg N (nitrogen)/ha (control), 50, 100 & 150 kg N/ha. The collected data were analyzed using general linear model procedure through Statistical Analysis Software (SAS). Dry matter (DM) yield of triticale-vetch mixed crop was higher ($P<0.05$) at 150 kg N/ha level than that of control and not different ($P>0.05$) from that of 50 and 100 kg N/ha. The DM yield of triticale-pea was not different ($P>0.05$) from that of control and triticale-vetch mixed crop at all manure levels. Crude protein (CP) yield of triticale hairy vetch and pea mixtures was not different ($P>0.05$) across all manure levels. Yield of total digestible nutrients (TDN) was highest at 150 kg N/ha in triticale sole monocrop, followed by 100, 50 and 0 kg N/ha levels. The overall TDN yield in triticale vetch mixture with 100 kg N/ha was higher ($P<0.05$) than control and not different ($P>0.05$) from 50 and 150 kg N/ha levels. However, TDN yield of triticale-pea mixture was greater ($P<0.05$) than triticale monocrop. Carrying capacity for Hanwoo cows in triticale with vetch and pea were also not different ($P>0.05$) from triticale-vetch mixed crop at all nitrogen levels. Mixed cropping produced optimum CP yield and carrying capacity for Hanwoo cows even without manure application, whereas 50 kg N/ha manure could be needed for optimal DM and TDN yield. It was concluded that optimum forage productivity could be achieved by application of 50 kg N/ha from animal manure and mixed sowing of triticale with hairy vetch or winter pea.

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***Correspondence** | Muhammad Fiaz, Assistant Professor, PMAS-Arid Agriculture University Murree Road, 46300 Rawalpindi, Pakistan; **Email:** dr.fiaz@uaar.edu.pk; drfiazlm@gmail.com
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Introduction

Food consumption pattern in South Korea has progressively changed towards livestock products. As per capita meat consumption increased from 19.9 to 49.5 kg over a period of years from 1990 to 2016 (KOSTAT, 2017). In response to increasing domestic demand, meat import has increased, and native self-sufficiency of meat production is reduced to 41% till the end of year 2016 (Chang, 2018). The favorite meat component is beef which is being produced from Korean native cattle as well as imported, mainly from USA. The United States is exporting beef to South Korea as second-largest market by value and quantity (Hopkinson, 2018). South Korea is blessed with local Hanwoo beef cattle whose farming must be flourished through innovative forage cultivation techniques and efficient feeding resource management which may eventually enhance the self-sufficiency of local meat production within country.

Green roughages are an essential feeding resource for livestock (Naseer *et al*., 2017). Unfortunately feeding resources in Korea are not adequate due to limited cultivatable land in country which is continuously decreasing and remained 1.596 million hectares in 2018 (KOSTAT, 2018). Feeding cost is main part of production costs, of which 75% concentrates and 96.4% of forages were imported in Korea, which concentrates account for 75% and 96.4% of crop roughages were imported in Korea which indeed a matter of concern for technocrats and Korean Government (Sung and Yoon, 2013). The surge in cost of international crops and feeds may affect Korean livestock feed operations. Feed cost has a greater impact on profitability than any other cost component due to its large influence on production costs. Thus, it is desperately needed to implement revolutionized efforts for enhancing yield and nutritive value of available forages to boost organic beef production in country.

Triticale is one of great cereal crops widely grown in Korean conditions because it is hardy crop having adequate growth and adaptability to numerous environmental conditions. It has dual advantage with nutrient-use efficiency of rye and adequate yield of wheat (Furman *et al*., 1997; Dennett *et al*., 2013) however, disadvantage of triticale is that it tends to be a little more susceptible to winter injury. Intercropping cereal crops with legumes might exhibit higher yield with better nutritive value in both protein (15%) and energy (9.5 MJ ME/kg DM) (ILRI, 2009) for livestock feeding. It improves yield through efficient rhizobial symbiosis between two intercropped species (Peoples *et al*., 2009; Oldroyd *et al*., 2011; Latati *et al*., 2013) and also enhance soil fertility through nitrogen fixation by leguminous species (Li *et al*., 2001; Tsubo and Walker, 2002; Awal *et al*., 2006; Zhang *et al*., 2015). Another way to prevent environmental pollution and enhance forage productivity is greater use of organic cattle manure along with introduction of leguminous plant in cropping systems (Sharma *et al*., 2004; Ramesh *et al*., 2005). The use of cattle manure can be an economical source of fertilizer for plant growth (Newton *et al*., 2003). The present study was designed to evaluate influence of mixed sowing triticale with legumes and different levels of cattle manure on forage yield and organic Hanwoo cattle carrying capacity.

Materials and Methods

Location of study

The study was performed at Gyeongsan, Angang and Yeongju sites in Gyeongbuk Province of South Korea. The Gyeongsan city have geographical coordinates Latitude: 35°49′23″ N, Longitude: 128°44′16″ E, whereas Angang city have geographical coordinates Latitude: 35.05444, Longitude: 126.60056.

The geographical coordinates of Yeongju city are Latitude: 36° 51' 59.99" N and Longitude: 128° 31' 59.99" E.

Climate of research site

The recorded climate data regarding temperature and rainfall about three research sites during trials from 2013 to 2015 along with 30 years history is given in Table 1 and Table 2. The soil characteristics of research sites are shown in Table 3.

Table 1: *Average temperature (°C) of research site during 2013 to 2015 with 30 years history.*

Region	Oct	Nob	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	0.8	2.6	7.1	13.2	17.6	20.7
Yeongju									
2013-2015	12.8	5.6	-2.2	-2	0.6	6.3	11.6	18.2	22
1982-2001	12.6	5.8	-5.6	-2.9	-0.2	4.8	11.6	16.9	21

Table 2: *Average rainfall (mm) of research sites during 2013 to 2015 with history.*

Region	Oct	Nob	Dec	Jan	Feb	Mar	Apr	May	June
Gyeongsan									
2013-2015	85.6	39.7	20.3	14	18	80.7	90.4	51	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	43	22	15.1	29.5	69.3	93.4	53.8	64.2
1982-2011	52.4	43	22	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	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 3: *Chemical characteristics of the soil at experimental site in 2013~2015.*

Region	pH	EC (dS/m)	Available P2O5 (mg/kg)	T-N (%)	OM (Cmol +/kg)	CEC	Ca2+	K+	Mg2+
Gyeongsan	6	0.11	211.34	0.021	3.16	13.06	8.47	2.51	2.6
Angang	7.06	0.59	843.06	0.017	5.26	19.16	8.42	0.65	2.99
Yeongju	5.1	0.54	352.01	0.015	6.65	17.68	4.61	0.22	0.99

EC: *electrical conductivity,* **T-N:** *Total nitrogen,* **OM:** *organic matter and* **CEC:** *cation exchange capacity.*

Experimental treatments

The field trials were performed at three different sites for 3 years from 2013 to 2015 in a split plot arrangement having 3 main plots and 4 sub-plots. Mixed cropping cultivation of Triticale (*X Triticosecale Wittm*;sin young) with leguminous crops; hairy vetch (*Vicia Villosa* L.; Hungvillosa) and winter pea (*Pisum sativum*; Ruby) was made with 3 replicates under three main plot treatments. The first main plot treatment was fixed as control treatment; triticale alone, whereas 2nd and 3rd main plot treatments were triticale mixed with hairy vetch and triticale mixed with pea. Four manure levels were evaluated under sub-plots: 0 kg N (nitrogen)/ha (control), 50, 100 & 150 kg N/ha with three replicates.

Land preparation, seeding and time period

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

Parameters studied

Effect of sowing triticale mixed with leguminous crops; hairy vetch and pea at four different manure levels was determined in terms of following parameters: (1) dry matter yield (tons/ha), (2) crude protein (CP) yield (kg/ha), (3) total digestible nutrients yield (tons/ha), and (4) carrying capacity for Hanwoo cows (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 dry matter (DM) yield (kg) was also converted into tons per hectare. Proximate analysis was performed according to scientific methods of AOAC (1995) and CP was determined through Kjeldahl digestion method using quantitative determination of organic nitrogen. Fiber analysis such as neutral detergent fiber (NDF) and acid detergent fiber (ADF) was made as described by Van-Soest (1991) method. The carrying capacity (number of animal units grazed per hectare for specific time period; heads/ha) was calculated based on dry matter yield for Hanwoo cows gaining 400 g daily for 450 kg body weight based on Rural Development Administration (2012). The total digestible nutrients was calculated using NRC (2001) formula for TDN;

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

Statistical analysis

The collected data were analyzed using General Linear Model Procedure through Statistical Analysis Software (SAS) under split plot arrangement having 3 main plots and 4 sub-plots. Main plots were triticale monocrop (control), triticale mixed cropping with hairy vetch and triticale mixed cropping with pea, whereas 4 sub-plots were 0 kg N/ha (control), 50, 100 & 150 kg N/ha. The mean comparison was made through Least Significant Difference (LSD) test at P<0.05.

Results and Discussion

Dry matter yield

Table 4 showed that overall DM yield was not different (P>0.05) between monocrop triticale and triticale-vetch mixed crops. In triticale as sole crop, DM yield at 100 kg N was higher (P<0.05) than that of control and not different (P>0.05) from 50 and 150 kg N/ha levels. Whereas, the DM yield of triticale-vetch mixed crop was higher (P<0.05) at 150 kg N/ha level than that of control and not different (P>0.05) with 50 and 100 kg N/ha levels. This pattern of DM yield in triticale-hairy vetch mixed cropping was also

Table 4: *Effect of mixed sowing triticale with legumes under different manure levels on dry matter yield (tons/ha) of forage in three places of Gyeongbuk province South Korea.*

Place-1: Gyeongsan						
Manure Levels (Kg N/ha)	Triticale mixed cropping with legumes					
	Triticale sole (control)		Triticale hairy Vetch Mix		Triticale Pea Mixture	
0	3.89 ± 0.76[a]	C	4.18 ± 1.46[a]	B	4.48± 1.09[a]	A
50	4.64 ± 1.45[a]	BC	5.64 ± 1.84[a]	A	5.24 ± 2.16[a]	A
100	5.49 ± 1.21[a]	AB	5.30± 1.28[a]	AB	5.46± 1.77[a]	A
150	6.16 ± 1.31[a]	A	6.03 ± 1.31[a]	A	5.90 ± 2.19[a]	A
Place-2: Angang						
0	6.72± 1.83[b]	A	8.06 ± 0.66[a]	B	8.04 ± 1.26[a]	A
50	7.30 ± 2.05[a]	A	8.16 ± 1.51[a]	AB	8.08 ±1.56[a]	A
100	7.86 ± 1.81[a]	A	8.29 ± 0.86[a]	AB	8.75 ± 0.72[a]	A
150	8.26 ± 1.00[a]	A	9.11 ± 1.02[a]	A	9.00 ± 1.28 [a]	A
Place-3: Yeongju						
0	4.33 ± 1.40[a]	A	4.11± 0.59[a]	B	4.51 ± 0.75[a]	A
50	4.77 ± 1.33[a]	A	4.67 ± 1.32[a]	AB	5.65 ± 1.45[a]	A
100	5.52± 1.90[a]	A	5.30 ± 1.75[a]	AB	5.68 ± 1.49[a]	A
150	5.94 ± 2.29[a]	A	5.60 ± 1.78[a]	A	5.76 ± 1.81[a]	A
Overall mean of all 3 places						
0	4.98 ± 1.33[a]	C	5.45 ± 0.90[a]	B	5.67 ± 1.03[a]	B
50	5.57 ± 1.61[a]	BC	6.16 ± 1.56[a]	AB	6.32 ± 1.72[a]	AB
100	6.29 ± 1.64[a]	AB	6.30 ± 1.29[a]	AB	6.32 ± 1.33[a]	AB
150	6.78 ± 1.53[a]	A	6.91 ± 1.37[a]	A	6.89 ± 1.76[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).

followed in all three research sites: Gyeongsan, Angang and Yeongju. It was shown from results that optimum production of triticale-hairy vetch could be met at 50 kg N/ha level.

In triticale-pea legume mixture, DM yield of triticale-pea was not different (P>0.05) from that of control and triticale-vetch mixed crop at all manure levels. When DM yield of triticale-pea was compared under different manure levels, it was found that DM yield at 150 kg N/ha level was higher (P<0.05) than control treatment and not different (P>0.05) from 50 and 100 Kg N/ha. Thus, it was shown that optimum DM yield of triticale mixed with pea legume could be achieved at 50 kg N/ha.

The optimum DM yield in current study was achieved in both mixed crops; triticale-hairy vetch and triticale-pea legume at 50 kg N/ha level. The possible reason behind improved yield might be due to efficient rhizobial symbiosis between two cereal and leguminous intercropped species (Latati *et al*., 2013). However, optimum yield benefit could be fetched at 50 kg N/ha manure level. Low requirement of nitrogen level for optimum DM yield might be attributed to the nitrogen fixation ability of leguminous species in growing mixed crops (Li *et al*., 2001; Tsubo and Walker, 2002; Awal *et al*., 2006; Zhang *et al*., 2015). However, different legume species have variable capacity to fix atmospheric nitrogen (Sprent and Gehlot, 2010), whereas certain legumes receiving manure may fix more atmospheric nitrogen (Freitas *et al*., 2011) and it is also ascertained that long term application of organic fertilizer can play significant role in maintaining nutrient balance and soil physical properties (Liang *et al*., 2013).

Crude protein yield

Table 5 indicated that overall CP yield of triticale hairy vetch mixed crop was higher (P<0.05) than that of triticale sole crop under all manure levels from 0 to 150 kg N/ha. When CP yield of triticale hairy vetch mixture was compared at different manure levels, it was found not different (P>0.05) across all manure

Table 5: *Effect of mixed sowing triticale with legumes under different manure levels on crude protein yield (kg/ha) of forage in three places of Gyeongbuk province Korea.*

Place-1: Gyeongsan						
Manure Levels (Kg N/ha)	**Triticale mixed cropping with legumes**					
	Triticale sole (control)		Triticale hairy Vetch Mix		Triticale Pea Mixture	
0	269.69 ± 65[b]	C	288.67 ± 112[ab]	B	377.11± 105[a]	A
50	306.82 ± 94[a]	BC	374.54 ± 136[a]	AB	389.66 ± 163[a]	A
100	361.70 ± 62[a]	AB	393.44 ± 11[a]	AB	418.91 ± 107[a]	A
150	429.59 ± 83[a]	A	427.96 ± 73[a]	A	446.96± 157[a]	A
Place-2: Angang						
0	394.28± 122[b]	A	836.1 ±231[a]	A	802.7±279[a]	A
50	464.19 ± 115[b]	A	912.5 ± 388[b]	A	696 ± 240[b]	A
100	464.37 ± 118[b]	A	898 ± 313[a]	A	773.8 ± 230[a]	A
150	468.33 ± 100[b]	A	990.0 ± 378[a]	A	885.3 ± 359[a]	A
Place-3: Yeongju						
0	275.37 ± 108[a]	A	252.93 ± 41[a]	B	328.10 ± 106[a]	A
50	276.12 ± 68[b]	A	276.60 ± 74[b]	AB	389.95 ± 156[a]	A
100	324.81 ± 124[a]	A	296.69± 115[a]	AB	428.61 ± 171[a]	A
150	362.13 ± 134[a]	A	347.46 ± 105[a]	A	465.74 ± 237[a]	A
Overall mean of all 3 place						
0	313.11 ± 114[b]	C	459.25 ± 308[a]	A	502.64 ± 279[a]	A
50	349.05 ± 124[b]	BC	547.52 ± 387[a]	A	491.88± 234[ab]	A
100	383.63 ± 118[b]	AB	523.36 ± 336[a]	A	540.44 ± 239[a]	A
150	420.02 ± 113[b]	A	588.48 ± 366[a]	A	599.34± 327[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)

levels. Whereas, in triticale alone, CP yield in triticale monocrop with 100 kg N/ha manure was greater (P<0.05) than control and not different (P>0.05) from that of 50 and 150 kg N/ha levels.

For triticale-pea mixture, CP yield of triticale-pea mixed crop was higher (P<0.05) than that of triticale monocrop at all manure levels except 50 kg N/ha. However, CP yield of this mixture was not different (P>0.05) from that of triticale-vetch mixed crops. When CP yield of triticale-pea legume was compared among different manure levels, it was not different (P>0.05) across all manure levels. Thus, it was shown that optimum CP yield could be achieved without application of manure.

For CP yield of triticale-vetch and triticale-pea mixed crops, it was not different (P>0.05) across all manure levels, showing that optimum CP yield could be achieved through mixed cropping triticale with legumes even without manure application. These findings were also in line to previous report of BenYoussef *et al.* (2019) while studying influence of nitrogen fertilizer on forage yields in hairy vetch and triticale mixtures. They found out that CP of intercrops with various N levels was not different from zero N application and it might be due to hairy vetch contribution in the mixed cropping. This increase in CP yield might be attributed to leguminous factor of hairy vetch and pea crops that might increase N content of mixture (Odhiambo and Bomke, 2001). It might be a character of legumes to biologically fix nitrogen and accumulate higher tissue N in mixture (Padulosi *et al.*, 2002) as well as reduce requirement of N fertilizer inputs into the system (Liu *et al.*, 2011). Crops of leguminous nature may contribute 15% of the N if intercropped with cereals (Li *et al.*, 2009). That's why herbaceous legumes may support mixed cropping and contribute greater quantities of protein (Weller and Cooper, 2001; King *et al.*, 2012).

Total digestible nutrients yield

Table 6 showed overall results indicated that yield of total digestible nutrients (TDN) was not influenced

Table 6: *Effect of mixed sowing Triticale with legumes under different manure levels on total digestible nutrients yield (ton/ha) of forage in three places of South Korea.*

Place-1: Gyeongsan						
Manure Levels (Kg N/ha)	Triticale mixed cropping with legumes					
	Triticale sole (control)		Triticale hairy Vetch Mix		Triticale Pea Mixture	
0	2.10 ± 0.42 [a]	C	2.27± 0.76 [a]	B	2.47± 0.51 [a]	A
50	2.44 ± 0.78[a]	BC	3.05 ± 0.91[a]	A	2.86 ± 1.90[a]	A
100	2.86 ± 0.63[a]	AB	2.86 ± 0.71[a]	AB	3.03 ± 0.88[a]	A
150	3.35 ± 0.78[a]	A	3.28 ± 0.39[a]	A	3.16 ± 1.06 [a]	A
Place-2: Angang						
0	350 ± 0.80[b]	B	4.18 ± 0.46[ab]	A	4.23 ± 0.85[a]	A
50	3.77 ± 0.84[a]	AB	4.27 ± 0.81[a]	A	4.17 ±0.87[a]	A
100	4.16 ± 0.75[a]	AB	4.39 ± 0.71[a]	A	4.70 ± 0.67[a]	A
150	4.27 ± 0.47[a]	A	4.71 ± 0.64[a]	A	4.62 ± 0.65[a]	A
Place-3: Yeongju						
0	2.41 ± 0.88[a]	A	2.29 ± 0.42[a]	A	2.55 ± 0.56[a]	A
50	2.64 ± 0.84[a]	A	2.73 ± 0.95 [a]	A	3.26 ± 1.06[a]	A
100	3.12 ± 1.20[a]	A	3.01 ± 1.18[a]	A	3.21 ± 0.94[a]	A
150	3.39 ± 1.14[a]	A	3.21 ± 1.19 [a]	A	3.29 ± 1.18[a]	A
Overall mean of all 3 places						
0	2.67± 0.92[a]	C	2.91 ± 1.07[a]	B	3.82 ± 1.05[a]	B
50	2.95 ± 0.99[a]	BC	3.35 ± 1.10[a]	AB	3.43 ± 1.14[a]	AB
100	3.38 ±1 .03[a]	AB	3.42 ± 1.11[a]	AB	3.65 ± 1.11[a]	AB
150	3.67 ± 1.04[a]	A	3.73± 1.05[a]	A	3.69 ± 1.17[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)

by triticale-vetch mixed crops. Yield of TDN was highest at 150 kg N/ha in triticale sole monocrop, followed by 100, 50 and 0 kg N/ha levels. The overall results indicated that TDN yield in triticale vetch mixture with 100 kg N/ha was higher (P<0.05) than control and not different (P>0.05) from 50 and 150 kg N/ha levels. Therefore, it was shown from overall results that optimum TDN yield in triticale-vetch mixture could be achieved at 50 kg N/ha manure level. In triticale-pea mixed crops, the TDN yield of triticale-pea mixed crop was not different (P>0.05) from triticale monocrop and triticale-vetch. However, TDN yield of triticale-pea mixture was greater (P<0.05) than triticale monocrop. Yield was not different (P>0.05) between 50 and 100 kg N/ha levels. It was shown that optimum TDN yield in triticale-pea mixed cropping could be achieved with application of only 50 kg N/ha.

In follow up of DM yield, the optimum TDN yield in both mixed crops; triticale-vetch and triticale-pea could be achieved at 50 kg/ha N level and it might be attributed to the adequate level of DM yield in the same treatment. Mixed cropping with legumes might increase DM yield (Finn *et al*., 2013) and positively influenced nutritive value (Papadopoulos *et al*., 2001; Sturludottir *et al*., 2013). The DM yield of the crop has significant positive correlation with its TDN yield (Omokanye *et al*., 2020). More nutrients may be available in response to mixed cropping strategy in current study might be reason for higher determination of TDN yield.

Carrying capacity for Hanwoo cows

Table 7 indicates response of different treatments on carrying capacity for Hanwoo cows. The carrying capacity for organic Hanwoo cows was higher (P<0.05) in triticale-hairy vetch mixed crops than triticale monocrop at only 50 kg N/ha manure level. In triticale as monocrop, carrying capacity at 100 kg N/ha was higher (P<0.05) than monocrop. It was not different (P>0.05) between 50 and 150 kg N/ha levels. When carrying capacity of Hanwoo was compared in triticale-vetch mixed cropping, it was found that

Table 7: *Effect of mixed sowing triticale 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% triticale or mixed forage.*

Manure Levels (Kg N/ha)	Triticale mixed cropping with legumes					
	Triticale sole (control)		Triticale hairy Vetch Mix		Triticale Pea Mix	
Place-1: Gyeongsan						
0	1.60 ± 0.35[a]	C	1.72 ± 0.60[a]	B	2.05± 0.53[a]	A
50	1.84 ± 0.57[a]	BC	2.33 ± 0.76[a]	A	2.24 ± 0.93[a]	A
100	2.16 ± 0.42[a]	AB	2.20 ± 0.61[a]	AB	2.39 ± 0.65[a]	A
150	2.54 ± 0.54[a]	A	2.51± 0.32[a]	A	2.52 ± 0.87[a]	A
Place-2: Angang						
0	2.50 ± 0.64[b]	A	4.06 ± 0.84[a]	A	3.98 ± 1.13[a]	A
50	2.81 ± 0.65[b]	A	4.50 ± 1.35[a]	A	3.64 ± 1.04[ab]	A
100	2.96 ± 0.62[b]	A	4.33 ± 0.61[a]	A	4.07 ± 0.88[a]	A
150	3.01 ± 0.38[b]	A	4.71 ± 1.27[a]	A	4.37 ± 1.20[a]	A
Place-3: Yeongju						
0	1.73 ± 0.65[a]	A	1.62 ± 0.27[a]	B	1.94 ± 0.47[a]	A
50	1.82 ± 0.52[a]	A	1.86 ± 0.57[a]	AB	2.39 ± 0.82[a]	A
100	2.15 ± 0.80[a]	A	2.02 ± 0.76[a]	AB	2.49 ± 0.85[a]	A
150	2.36± 0.94[a]	A	2.25 ± 0.75[a]	A	2.63 ± 1.12[a]	A
Overall mean of all 3 places						
0	1.94 ± 0.68[b]	C	2.46 ± 1.29[ab]	A	2.66 ± 1.20[a]	A
50	2.16± 0.73[b]	BC	2.89 ± 1.49[a]	A	2.76 ± 1.10[ab]	A
100	2.42 ± 0.72[a]	AB	2.85± 1.36[a]	A	2.99± 1.10[a]	A
150	2.64 ± 0.70[a]	A	3.16 ± 1.41[a]	A	3.17 ± 1.34[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 was not different (P<0.05) among all manure levels. It was shown that growing triticale-vetch mixed crop could achieve optimum carrying capacity for Hanwoo cows even without N application. In triticale-pea mixed cropping, carrying capacity was higher (P<0.05) even without manure application than triticale monocrop, whereas not different (P>0.05) from other manure levels. Carrying capacity for Hanwoo cows in triticale-pea was also not different (P>0.05) from triticale-vetch mixed crop at all nitrogen levels. When carrying capacity was compared in triticale-pea mixture, it was not different (P>0.05) among all manure levels. Thus, optimum carrying capacity for Hanwoo heifers could be achieved even without manure application.

However, for carrying capacity of Hanwoo cows, optimum number of carrying capacity could be brought in mixed cropping with legumes (Hairy vetch and pea) even at no manure level. Application of 50 kg N/ha level could improve carrying capacity for Hanwoo cows numerically. The higher carrying capacity in mixed cropping with legumes might be attributed to the factor of leguminous nature of hairy vetch and pea crops which might yielded more DM. The higher DM yield could increase carrying capacity because dry matter accounts for 84% in variability of carrying capacity (Andrade *et al*., 2012). Moreover, measurement of carrying capacity is also based quantity of edible dry matter in forage content (Wangchuk *et al*., 2015). The leguminous forage may be more edible for animals and ultimately increase carrying capacity even in rangeland management (Muir *et al*., 2019).

Conclusions and Recommendations

Findings of present study indicated that mixed growing strategy of triticale with legumes; hairy vetch and winter pea needs no manure application for optimum CP yield and carrying capacity for Hanwoo cows, whereas 50 kg N/ha manure could be needed for optimal dry matter and total digestible nutrients yield. It was concluded that optimum forage productivity could be achieved by application of 50 kg N/ha from animal manure and mixed sowing of triticale with hairy vetch or winter pea.

Implications

Mixed cropping strategy of cereals with leguminous crops may be applied in other regions of the world having shortage of protein sources. The optimum forage productivity in terms of dry matter and digestible nutrients yield can be achieved by application of 50 kg N/ha from animal manure, whereas mixed cropping cereals with legumes needs no manure application for optimum CP yield and carrying capacity for cows.

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Statement of Animal Rights

It is hereby stated with assurance that our research team did not use any animal as research material in the course of this experiment.

Novelty Statement

It was an innovative approach to gear up forage productivity within limited land availability of South Korea through using economical organic cattle manure as fertilizer which could bring economic benefits and reduce environmental pollution.

Author's Contributions

Jo Ik-Hwan: Principal author who designed the study and overall supervised every activity in conduct of research work.

Choi Kwang-Won: Assisted first author (Jo Ik-Hwan) through practically conduct of research trials at different research sites and later on collected scientific data.

Muhammad Yaqoob: Made statistical analysis of the collected data.

Muhammad Fiaz: Summarized the collected data and prepared the whole manuscript under close coordination with other research team.

Conflict of interest

Authors declare that there is no conflict of interests regarding publication of this article.

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