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Research Article

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# Performance of Mixed Cropping of Barley and Hairy Vetch as Green Manure Crops for Following Corn Production

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## Abstract

**BACKGROUND:** Mixed cropping of legume and grass was effective system in view point of providing organic matter and nitrogen or reducing the nitrogen starvation of following crop. The relation of the change of N and P constituents depending on the cropping types and those effects on the growth and nutrient uptake of the following crop were observed.
**METHODS AND RESULTS:** Three cropping types, hairy vetch mono cropping, barley mono cropping, and mixed cropping of hairy vetch and barley were applied. Soil properties, growth characteristics, and nitrogen production of green manure crops were observed. In additions, the effect of cropping types on the growth pattern of corn as the following crop was observed. In the mixed cropping system, creeping type hairy vetch climbed to the erect type barely for light utilization resulting in improvement of light interception rate and higher LAI (Leaf Area Index) than in mono cropping. Mixed cropping showed higher biomass production and soil nitrogen availability among the cropping types, indicating relatively much more nutrient supply and higher yield production of following crop.
**CONCLUSION:** Mixed cropping showed relatively higher LAI (dry matter) mainly because of intense competition for light utilization usually after flowering stage. Mixed cropping also showed relatively higher yield of corn, the following crop rather than other types, mainly due to the more biomass production potential and higher N and P production ability. Therefore, mixed cropping was adaptable method to reduce or replace chemical fertilizer application for environmentally-friendly agriculture.

**Key words:** Hairy vetch, LAI, Legume grass mixed cropping, Nitrogen fixation

## Introduction

Green manure crop is an environmentally friendly and labor saving organic fertilizer by soil fertility improvement and chemical fertilizer or composts application reduction (Jeon *et al.*, 2009, 2010). Hairy vetch is readily to decomposed and rapidly release nitrogen due to lower C/N ratio (Sarrantonio *et al.*, 1988; Varco *et al.*, 1989 ; Power *et al.*, 1991 ; Seo *et al.*, 2000). Legume crop (as green manure) is effective to reduce chemical nitrogen fertilizer requirement for the following crop due to atmospheric nitrogen fixation and releasing nitrogen into the soil (Campiglia *et al.*,

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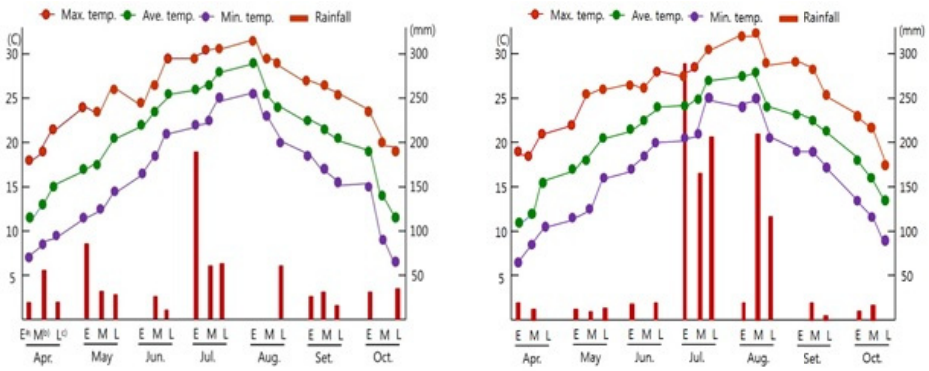


Fig. 1. Temperature and rainfall patterns during the crop cultivation period of 2016~2017. [a] E : Early month, [b] M : Middle month, [c] L : Late month

2010 ; Cazzato *et al.*, 2003). Mixed cropping was efficient system for biomass production by natural light utility improvement and nutrient provision to the following crops (Rauber *et al.*, 2001 ; Ramos *et al.*, 2011 ; Arata *et al.*, 2013). Recently, green manure crop has considered an important factor for environmentally -friendly agriculture. For example, input of gramineae crops such as barley, rye and wheat in soil reduced nitrogen (N) leaching from arable soil and could conserve organic matter and physical properties of soil (Astier *et al.*, 2006). Gramineae crops such as rye and barley with high carbon to nitrogen ratio (C/N ratio) would provide a little amount of N constituent to the following crop due to the N immobilization. Low C/N ratio of green manure crops such as hairy vetch symbiotically supply more N to soil by fixing atmospheric nitrogen and increase N availability during crop cultivation. Mixed cropping system of legume and grass would reduce nitrogen starvation by incorporating gramineae crops with higher C/N ratio (Rasmussen *et al.*, 2007 ; Arata *et al.*, 2013). There is little research on macro- nutrients mobilization in the mixed green manure cropping system. This study was tested nitrogen (N) and phosphorus (P) absorption of the succeeding crop corn in order to evaluate the effect of green manure in cropping systems in arable soil.

## Materials and Methods

### Experimental plot managements

This experiment was conducted at the experiment farm of National Institute of Crop Science, Suwon from 2016 to 2017. The experimental design was randomized complete block with three replications. Main treatments were three cropping types (hairy vetch mono cropping, barley mono cropping, mixed cropping of hairy vetch and barley). Each plot size was 10×15 m.

### Meteorological Analysis of Soil Chemical Properties

We got the meteorological data from Agriculture Meteorology Information Service, Rural Development Administration and analyzed the temperature and rainfall patterns during the experiment period. Temperature is one of the most important factors to determine crops yield potential. Monthly temperature and precipitation patterns were different year by year. Average temperature in 2016 (left diagram) was higher than that in 2017 by 0.7℃. But precipitation was 383 mm less than that of 2017 (Fig. 1).

### Soil Sample Collection and Analysis of Soil Chemical Properties

To analyze soil properties, porous cups was put at 20 cm depth from the soil surface and collect the soil sample after incorporating green manure crops. Inorganic soil N content was measured by micro diffusion method. For plant available soil P and K analysis, 0.5 M $NaHCO_3$, 1 M $NH_4C_2H_3O_2$ extraction were used respectively. Soil pH was analyzed with pH electrode in a 1:1 ratio of soil and water suspension. Soil organic matter was analyzed by weight loss on ignition at 360℃. General soil property of the plot was shown in the Table 1. Acidity was 5.5 and soil organic matter 12.0 g/kg. Total nitrogen and Available $P_2O_5$ was 1.05 and 385 mg/kg respectively.

### Plant Sampling and Maintenance

Hairy vetch and barley were sown at 10$^{th}$ October (2016). Mixed rate was hairy vetch 50% + barley 50%

Table 1. Soil chemical properties of experimental plot (0～15 cm soil depth) in 2016～2017

| pH (1:5, $H_2O$) | OM[a] (g/kg) | T-N[b] (g/kg) | Av. $P_2O_5$[c] (mg/kg) | Exchangeable cations ($cmol_c$/kg) | | |
|---|---|---|---|---|---|---|
| | | | | K | Ca | Mg |
| 5.5 | 12.0 | 1.05 | 385 | 1.1 | 5.5 | 1.5 |

[a] OM : organic matter, [b] T-N : total nitrogen, c) Av. $P_2O_5$ : available $P_2O_5$
Data are the means of two years

Table 2. Analysis of variance for total nitrogen (N), phosphate (P) content and dry weight (DW) of green manure crop and corn depending on cropping types

| Source | | | DF[d] | Mean square | *F*- value | Pr > P |
|---|---|---|---|---|---|---|
| Green Manure crops | B[a] HV[b] HV+B[c] | N | 4 | 1021.3611 | 14.17* | 0.0153 |
| | | P | 4 | 4.43625 | 8.84* | 0.0340 |
| | | DW | 4 | 10.10444 | 62.09** | 0.0010 |
| Corn | B HV HV+B | N | 4 | 10.76625 | 31.53** | 0.0036 |
| | | P | 4 | 1.58152 | 70.81** | 0.0008 |
| | | DW | 4 | 108573.9444 | 40.71** | 0.0022 |

[a] Mono barley cropping, [b] Mono hairy vetch cropping, [c] Mixed hairy vetch and barley cropping, [d] Degree of Freedom.
*P<0.05, **P<0.01

(100 seeds (spot sowing) + 200 seeds (line sowing)). Hairy vetch and barley shoot were harvested after 2 weeks flowering (about 10th May, 2017). After weighting total biomass, the samples were incorporated into the plot with rotatory machine. C and N constituent were measured one week interval after returning to the soil with nitrogen and carbon analyzer. For total P content, we used $HClO_4$ extraction and analyzed using ICP atomic emission spectrometer (720-ES Series, Varian Inc., Palo Alto, California, USA). After 4 weeks of incorporating green manure crops, corn was sown on 17th June by hand with 60 cm and 25 cm distance of inter-hill and inter-row distance respectively in each plot. Chemical fertilizer was not applied to all plots during corn cultivation period. SPAD value for chlorophyll contents was measured at the next leaf from the upper-most leaf at silk stage. About 110 days after sowing, thirty corn plants in each plot were chosen and sampled to measure total N and P constituents. Total fresh weight and ear weight of corn were measured from the thirty plants at maturity. Dry weight of the samples was measured after drying at 60℃ for 48 hours. Fresh weight and dry weight of samples was analyzed after drying at 60℃ for 48 hours before incorporating green manure crops to the soil. At maturity, thirty corn plants in each plot were chosen and sampled to measure yield potential of total fresh weight and ear weight. To measure dry weight, samples were treated at the condition of 60℃ for 48 hours.

### Statistical Analysis

The collected Data were subjected to analysis of variance (ANOVA) and the mean significant differences were compared by Duncan's multiple range test (DMRT) at $P \leq 0.05$. All data were analyzed using SAS package (Ver. 9.2).

## Results and Discussion

### Yield and nutrients of green manure

Table 2 showed that total nitrogen, phosphate content, dry weight of green manure crop and corn yield were statistically different depending on cropping types. The fresh weight of mixed hairy vetch and barley cropping (HV/B) was 6.1 ton per hectare which was 42～53% higher than those of mono green manure (Table 3). Also, amount of total nitrogen in HV/B plot was about 172 kg per hectare which is about 28, 272% higher than that of mono hairy vetch and barley cropping respectively. Mixed cropping such as hairy vetch and barley might be to improve soil fertility and yield production of following crop due to the input of C and N by the increased biomass.

Both hairy vetch and barely in mixed cropping

Table 3. Fresh weight of green manure crops and nitrogen production

| Cropping types | Fresh weight of green manure crops (ton/ha) | Nitrogen production amount (kg/ha) |
|---|---|---|
| mono barley cropping (B) | 4.3[b] | 63.0[b] |
| mono hairy vetch cropping (HV) | 3.3[b] | 134.2[ab] |
| mixed hairy vetch and barley cropping (HV/B) | 6.1[a] | 171.5[a] |

Means within a column followed by the same letter are not significantly different ($\alpha$=0.05) by Duncan multiple range test.

Table 4. LAI value before and after flowering of hairy vetch

| Cropping types | Before flowering[1)] | After flowering[2)] |
|---|---|---|
| Mono barley cropping (B) | 3.2[b] | 4.6[b] |
| Mono hairy vetch cropping (HV) | 5.7[a] | 7.9[ab] |
| Mixed hairy vetch and barley cropping (HV/B) | 4.3[ab] | 8.5[a] |

[1)] Before flowering : 12 April, [2)] After flowering : 12 May

would compete each other for light utilization which in turn caused to increase LAI (Leaf Area Index) value or higher SPAD (Soil Plant Analysis Development) value than mono cropping. According to the previous studies, hairy vetch climbed to the oat for light utilization in the mixed cropping resulting in improvement of light interception rate (Caballero *et al.*, 1986, 1995). Mono cropping showed lower the LAI value than that of mixed cropping (Table 4). It was observed that LAI would be sharply increased after flowering of hairy vetch. In many studies, gramineae crops showed positive effect for using nutrient, especially N and P uptake when mixed with legume crops (Rasmussen *et al.*, 2007 ; Jeon *et al.*, 2009). Table 3 also showed similar results that mixed cropping of hairy vetch and barley showed relatively higher LAI value than that of mono cropping of hairy vetch or barley especially after flowering of hairy vetch.

### Effect of cropping types on the growth pattern of corn as following crop

The nitrogen content in soil after incorporation of barley and hairy vetch in the mixed cropping was kept high until early June, while that in the mono barley was low (Fig. 2). Gradual decrease of nitrogen in all cropping after 29$^{th}$ June might be due to nitrogen uptake by following corn that grew dynamically during those days. According to the previous studies, higher C/N ratio of incorporated crops results in temporal nitrogen starvation during early growth of the following crop through decomposition of incorporated green manure by soil microorganisms (Chaves *et al*,

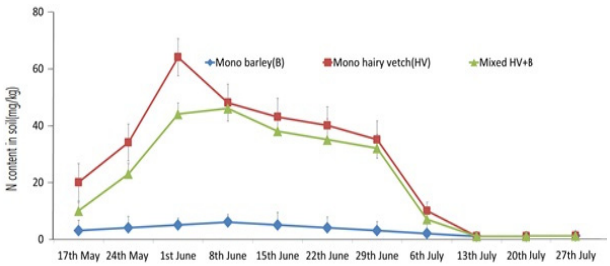


Fig. 2. Nitrogen concentration in soil after incorporating green manure crops. Each value shows the mean ± SEM of three replications.

2004). In our experiment, soil nitrogen content after incorporation of barley and hairy vetch was higher than that in mono barely cropping indicating that hairy vetch had a role of nitrogen supplier after incorporation.

Light utilization is very important factor to determine corn ear production potential in the reproductive stage. The SPAD values of corn leaves were relatively higher in the mono hairy vetch cropping than the others during the vegetative growth stage (Fig. 3). But as the growth stage was proceeding, the SPAD values of all cropping recorded to 45~46 indicating that cropping types could much affect the growth of corn in an early stage rather than late stage. Usually mono hairy vetch cropping is easily decomposed and increases soil nitrogen concentration in a short time after incorporation into the soil. In the vegetative growth stage of corn, mono hairy vetch cropping showed higher SPAD values than that of mixed. Otherwise, mixed cropping showed higher SPAD

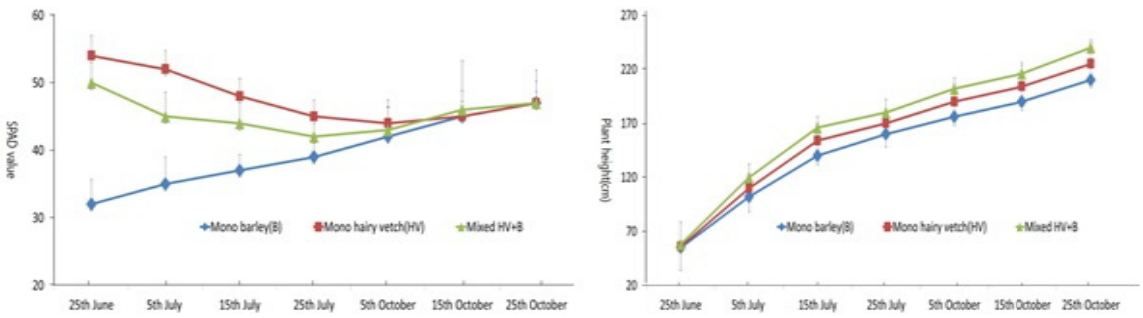


Fig. 3. SPAD value patterns and plant height of the following corn plant depending on growth stage. Each value shows the mean±SEM of three replications.

Table 5. Ear yield, nitrogen and phosphate constituent of corn depending on cropping types in 2016～2017

| Cropping types | Total N($g/m^2$) | Total P($g/m^2$) | Ear yield($g/m^2$) |
|---|---|---|---|
| Mono barley cropping (B) | $7.2^{b}$ | $1.7^{b}$ | $534^{b}$ |
| Mono hairy vetch cropping (HV) | $9.6^{ab}$ | $2.6^{a}$ | $759^{ab}$ |
| Mixed hairy vetch and barley cropping (HV/B) | $11.2^{a}$ | $3.1^{a}$ | $915^{a}$ |

values than mono cropping type due to the longer nitrogen providing potential in the reproductive stage. The change of plant height by cropping types showed similar pattern with that of SPAD value. Plant height showed relatively higher in the mono hairy vetch type than mono barley and mixed types. As the growth stage of corn was proceed, the difference of plant height was bigger, especially after 15$^{th}$ July even though no statistical difference was observed.

Ear yield of corn was different depending on cropping types (Table 5). Mixed cropping of hairy vetch and barley showed relatively higher corn yield rather than other types mainly due to the more biomass production potential and higher N and P production ability. The experiment result also showed that following corn easily uptake main constituents especially in mixed cropping through whole growth stage and, in turn, relatively higher N, P content and ear yield per plant. Of course, we have to study on the accurate nutrients movement mechanism to investigate the effect of cropping types on the main nutrients absorption of following crops.

## Discussion

The main purpose of this study is to find out whether green manure crops application can replace chemical fertilizer in upland crops (including corn) cultivation. It was observed that mixed cropping showed relatively higher LAI (dry matter) mainly because of intense competition for light utilization usually after flowering stage. We observed that mixed cropping contained higher total N and P constituent of barley than those of mono barley cropping and provided much more soil nutrients to the following crops. Of course, many factors might be involved in determining the growth and yield potential of following crops according to the cropping types. There were no previous studies relating to the main nutrients absorption, any scientific mechanism on nutrients movement in mixed cropping was not revealed. Further studies to investigate the mechanism of nutrition effect on the following crops through the soil as well as green manure crops are needed.

## Note

The authors declare no conflict of interest.

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