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Research Article

Enhancing yield and nutritive value of forage through corn soybean intercropping strategy at seventeen different places in Republic of Korea

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ABSTRACT

Corn is basal forage for livestock species in Republic of Korea but it lacks protein and needs nitrogenous fertilizer. This study was designed with main objective to achieve optimum growth, yield & nutritive value of forage for livestock through implementing corn-soybean intercropping strategy at 17 different places under Korean condition. Two treatments; corn as monocrop (control treatment) and corn-soybean intercrop were compared under Randomized Block Design from 28th May to 8th October, 2015. Each treatment had three replicates in each block, whereas seventeen different places were considered as blocks. Data were analyzed through SAS-9.1.3 software. Difference between two treatment means was tested through T-test. Findings depicted that intercropping pattern could not influence (P>0.05) corn plant & ear height, corn lodged stalk No. and corn stalks number. However, corn-soybean intercropping enhanced (P<0.05) forage productivity in terms of total fresh yield (16.4±0.7^{b} vs. 19.9±0.7^{a} tons ha^{-1}), total dry matter yield (5.38±0.25^{b} vs. 6.41±0.31^{a} tons ha^{-1}) and total digestible nutrients yield (3.94±0.17^{b} vs. 4.59±0.21^{a} tons ha^{-1}). Dry matter percentage in corn stalks and corn ears was not different (P>0.05) between two treatments. It was concluded that corn-soybean intercropping strategy was promising technique in enhancing forage productivity though positive symbiotic relation between two crops.
(**Key words** : Corn-soybean, Intercropping, Forage yield, Total digestible nutrient)

Ⅰ.INTRODUCTION

Consequent upon high economic development, importance of livestock industry has been significantly increased as food consumption pattern is massively shifted towards livestock products in South Korea. Considering the base of production, six livestock products (beef, milk, pork, chicken, eggs and duck) have been already included in top 10 Agro-forestry food items (Chung et al., 2014). The country is bestowed with dynamic livestock species; pigs 9921, cattle 3339.6, goat 264.6 and poultry 151930.6 thousand heads during the year of 2014 (AAFC, 2015). However, unfortunately needful feeding resources are not sufficiently available as two third of national land is comprised on mountains. Increasing trend of urbanization is also continuously depleting cultivatable land leaving only 1,679 thousand hectares for Agriculture (KOSTAT, 2015). Corn forage crop is predominantly preferred by many farmers as it is palatable energy feeding source for livestock. Although corn is protein deficient fodder and needs lot of nitrogen in growing process but it can be easily processed and suitable for silage making. Being most preferred forage, improving its yield and nutritive value could be a revolutionized effort to overcome the shortage problems of feeding resources in country. So it is desperately needed to develop and implement innovative forage production technique at farmer level. Corn-soybean intercropping would be an innovative forage production technique for eminent yield and nutritive value of fodder employing complementary growth resources of mixed crops under limited land resources (Seo et al., 2014). It may enhance not only forage yield through efficient rhizobial symbiosis between two intercropped species (Latati et al., 2013) but also improves soil fertility through nitrogen fixation by leguminous specie (Awal et al., 2006; Li et al., 2001; Tsubo and Walker, 2002; Zhang et al., 2015). Keeping in view the salient importance of biculture, this study was designed with main objective to achieve optimum growth, yield & TDN value of forage for livestock through implementing corn-soybean intercropping strategy at farmer's level under Korean environment conditions.

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Ⅱ. MATERIAL AND METHODS

1. Location of study and its climate

In achieving objectives of this study, private progressive farmers were involved for implementation and execution of corn-soybean intercropping strategy. The experiment was launched at 17 different site with 11, 2, 2 & 2 private farmlands of Gyeongbuk, Chungbuk, Chungnam and Gyeonggi provinces of South Korea, respectively. Addresses of experimental sites are given in Table 1. Ambient temperature (°C) and rain fall (mm) of each month during study are mentioned in Table 2.

2. Experimental treatments

Corn alone *vs*. corn- soybean mixed cropping was compared under two treatments with three replicates in each block (experiment site) employing randomized block design. Treatment 1; Corn monocrop was considered as control, whereas Treatment 2; corn-soybean intercropping was alternate treatment in comparison. Experimental sites (n = 17) were specified as blocks in this research trial.

3. Land preparation, seeding and harvesting

In each block (site), six similar plots having length and width measurement (5 × 2.8 meters) were prepared for comparison of two treatments with three replicates. For this trial, Pioneer (P1184) and crossbred (PI483463 × Hutcheson) seed varieties were used for corn and soybean crops, respectively. In case of sole corn as monocrop, seeding was executed in each plot on four lines having 70 centimeter interline distance. In each plot, sidelines on both sides were considered to check border effect only. Corn seeding was performed in lines keeping corn to corn distance 20 cm. However, in case of corn-soybean intercropping, same arrangement was followed with addition of soybean seeding on same corn seeded lines with inter seed distance of 10 centimeter. A mixture of Alachlor and Simazine herbicides was used soon after seeding activity. Harvesting of both monocrop and intercropping forage was conducted 120 days after seeding date. The detail of seeding and thereafter harvesting time of seventeen different places is shown in Table 1.

Table 1. Location of research sites with cropping schedule

Site No.	Address of Experimental Site	Seeding Date	Harvesting Date
1	1879-14, Yuktong-ri, Angang-eup, Gyeongju-si, Gyeongbuk (P1)	05 June, 2015	23 Sep, 2015
2	1855-3, Yuktong-ri, Angang-eup, Gyeongju-si, Gyeongbuk (P2)	05 June, 2015	23 Sep, 2015
3	1852-1, Yuktong-ri, Angang-eup, Gyeongju-si, Gyeongbuk (P3)	05 June, 2015	30 Sep, 2015
4	1360-1, Yuktong-ri, Angang-eup, Gyeongju-si, Gyeongbuk (P4)	05 June, 2015	30 Sep, 2015
5	1862-4, Yuktong-ri, Angang-eup, Gyeongju-si, Gyeongbuk (P5)	05 June, 2015	30 Sep, 2015
6	446-2, Gapsan-ri, Angang-eup, Gyeongju-si, Gyeongbuk (P6)	15 June, 2015	07 Oct, 2015
7	443, Gapsan-ri, Angang-eup, Gyeongju-si, Gyeongbuk (P7)	15 June, 2015	07 Oct, 2015
8	1158-1, Nodang-ri, Angang-eup, Gyeongju-si, Gyeongbuk (P8)	15 June, 2015	07 Oct, 2015
9	1169-2, Nodang-ri, Angang-eup, Gyeongju-si, Gyeongbuk (P9)	15 June, 2015	08 Oct, 2015
10	1169-1, Nodang-ri, Angang-eup, Gyeongju-si, Gyeongbuk (P10)	15 June, 2015	08 Oct, 2015
11	96-5, Seonjeong-ri, Samseong-myeon, Eumseong-gun, Chungbuk (P11)	04 June, 2015	08 Oct, 2015
12	75-3, Seonjeong-ri, Samseong-myeon, Eumseong-gun, Chungbuk (P12)	04 June, 2015	08 Oct, 2015
13	1040-106, Gonae-ri, Yeonmu-eup, Nonsan-si, Chungnam (P13)	18 June, 2015	14 Sep, 2015
14	808-3, Hwajeong-ri, Yeonmu-eup, Nonsan-si, Chungnam (P14)	18 June, 2015	14 Sep, 2015
15	43-6, Anseong, Gyeonggi-do, Dongyang (P15)	28 May, 2015	15 Aug, 2015
16	Nojingil216, Jangan-myeon, Hwaseong-si, Gyeonggi (P16)	29 May, 2015	16 Aug, 2015
17	2673, ilburi, Sannae-myeon, Gyeongju-si, Gyeongbuk (P17)	28 May, 2015	16 Aug, 2015

4. Parameters studied

Comparative effect of corn as monocrop and corn-soybean mixed cropping pattern was determined in terms of following parameters of growth and forage yield.

1) Height of corn stalk & ear and soybean plant (cm)
2) Quantity of corn stalks, ears and soybean (No.)
3) Dry matter (%)
4) Dry matter yield (ton/ha)
5) Total digestible nutrients yield (ton/ha)

5. Data collection

Height of corn stalk, corn ear & soybean was recorded on the day of harvesting in centimeters. The corn height was measured from ground to the top of plant, whereas height of corn ear was taken from ground to the bud of ear evolved. Similarly, soybean height was measured from ground to the top of plant. Five plants were taken randomly from each replicate for measuring data regarding height. Number of stalk, ear & soybean was recorded by counting every plant in the replicate on harvesting date. However, fresh yield data was taken by cutting central 2 lines out of 4 lines through weighing into kilogram. The Kg fresh yield out of 7 m^2 area (5 x 1.4 m) was then converted into tons per hectare. Similarly, 2 samples from each replicate were taken for dry matter yield, initially weighed, dried in oven at 70° C for 72 hours & then again weighed after drying. The Kg dry matter yield was also converted into tons per hectare. Finally, total digestible nutrient of corn was calculated through following equation (Holland et al., 1990),

$$\text{Total digestible nutrient} = \{(\text{DM yield of corn stalk} \times 0.582) + (\text{DM yield of ear} \times 0.85)\}$$

6. Statistical analysis

Data were analyzed using SAS 9.1.3 software and treatment mean comparison was made through *T*-test.

Ⅲ. RESULTS

Effect of cropping strategies on growth of forage plants

Height of corn stalks and ears between both treatments were found similar (P>0.05) as shown by Fig. 1. However, soybean

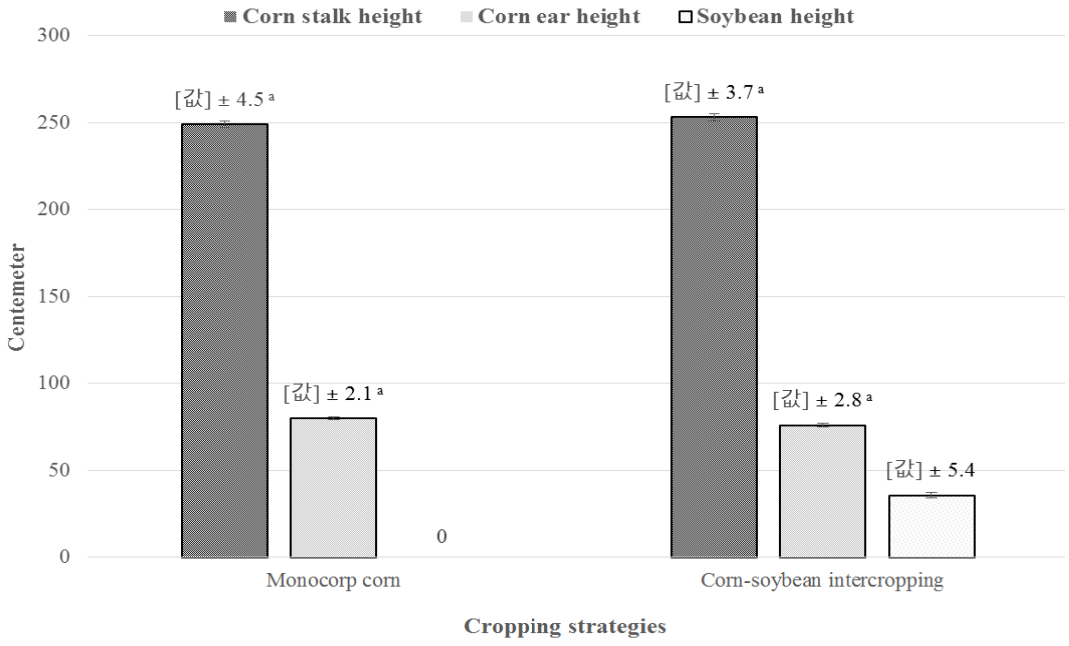

Figure 1. Effect of cropping strategies on corn stalk height, ear height and soybean height (Mean ± SE)

[a] Similar bars with values at top having same superscript are not different (P>0.05)

SE. Standard error

height was found 35.8 ± 5.4 cm in mixed cropping field. Similarly, quantity in terms of corn stalks number and lodged corn stalks was also not different (P>0.05) between two treatments. Anyhow, corn ear number was found higher (P<0.05) in corn-soybean mixed cropping than that of control treatment having monocrop corn as elucidated in Table 3.

Effect of cropping strategies on forage yield

Dry matter yield (DM) in both components of corn plant: corn stalk and corn ear was higher (P<0.05) in mixed cropping field than that of only corn crop as shown in Table 4. In addition to that DM of soybean 0.18 ± 0.03 tons/ha was also yielded in intercropped forage and then consequently, total DM yield of mixed cropped forage remained higher (P<0.05) than that of control treatment. It was noted that dry matter yield was increased 12.2% and 22.8% in corn stalks and corn ears, respectively. In addition to that, computed land equivalent ratio for component of biculture corn was 1.17 and biculture mixed forage 1.19 as compared to that of monocrop corn.

Table 2. Average monthly temperature (°C) and total rain fall (mm) in research areas.

Months	Gyeongbuk		Gyeonggi		Chung-nam		Chung-buk	
	Temp	Rain Fall	Temp	Rain Fall	Temp	Rain Fall	Temp	Rain Fall
May, 2015	12.1	48.5	18	27	18.5	39.0	17.5	33.5
Jun, 2015	18.9	75.6	24	94	23	97	23	75
Jul, 2015	21.1	84.4	28	275	28	120	27	210
Aug, 2015	23.7	94.8	23	74	24	31	21	81
Sept, 2015	25.5	101.9	20	20	21	15	18	32
Oct, 2015	19.9	79.7	14.3	55.5	14.1	79.5	12.1	57.5

Temp: Ambient temperature
mm: Millimeter

Table 3. Effect of different cropping strategies on growth parameters of forage (*Mean ± SE*)

Parameters	Treatment-1 (Control)	Treatment-2
	Monocrop Corn	Corn-soybean Intercropping
Corn stalks (No./ha)	35078 ± 1020 [a]	37142 ± 811 [a]
Corn ears (No./ha)	32380 ± 1005 [b]	35793 ± 930 [a]
Corn stalks lodged (No./ha)	4047 ± 783 [a]	4840 ± 865 [a]
Soybean plants (No./ha)	-	19681 ± 3085

[a.b.] Variables having varying superscript in the same row are different (P<0.05)
SE. Standard error

Table 4. Effect of different cropping strategies on forage and its DM & TDN value (*Mean ± SE*)

Parameters	Treatment-1 (Control)	Treatment-2	Land Equivalent Ratio
	Monocrop Corn	Corn-soybean Intercropping	
Corn stalk DM yield (%)	24.83 ± 0.83 [a]	22.94 ± 0.50 [a]	-
Corn ear DM yield (%)	53.00 ± 1.59 [a]	56.58 ± 1.15 [a]	-
Soybean DM yield (%)	-	18.03 ± 2.82	-
Corn stalk DM yield (ton/ha)	4.57 ± 0.23 [b]	5.20 ± 0.27 [a]	1.12
Corn ear DM yield (ton/ha)	4.32 ± 0.37 [b]	5.30 ± 0.37 [a]	1.22
Soybean DM yield (ton /ha)	-	0.18 ± 0.03	-
Total dry matter yield (ton /ha)	8.97 ± 0.42 [b]	10.68 ± 0.52 [a]	1.19
Total digestible nutrients (ton/ha)	6.57 ± 0.28 [b]	7.66 ± 0.35 [a]	1.16

[a.b.] Variables having varying superscript in the same row are different (P<0.05)
SE. Standard error

Effect of cropping strategies on total digestible nutrients (TDN) value of forage for livestock

In terms of total digestible nutrients for livestock was also improved and remained higher ($P<0.05$) in corn-soybean mixed forage than that of corn monocrop as mentioned in Table 4. It was also observed that corn-soybean intercropping strategy improved 16.5% TDN value of forage.

Ⅳ. DISCUSSION

Comparative effect of cropping pattern (Monocrop corn *vs*. corn-soybean intercropping) on forage growth in this study depicts that intercropping strategy not only can maintain height of corn plants without any effect but also enhance 10.3% quantity of corn ears as compared to that of traditional cultivation of monocrop corn. No significant effect on corn plant's height (Amini et al., 2013) due to intercropping and substantial increase in component of corn ear number was also endorsed previously (Verdelli et al., 2012). This improvement might be attributed to factor of corn & soybean association in which soybean might enhance nitrogen use efficiency for corn under mixed cropping pattern (El-Shamy et al., 2015).

In case of forage yield, significantly higher dry matter yield in corn soybean mixed forage was in accordance to findings of previous studies that yield components were markedly higher in corn-soybean intercropping as compared to those of monocrop sole corn (El-Shamy et al., 2015; He et al., 2012; Oswald et al., 2002; Yuanyuan et al., 2016). Additional yield in present study was also affirmed by Latatie et al. (2013) that intercropping had augmented corn yield by more than 12.5% and Maddonni et al. (2006) ascertained this increase up to 13 to 16%. Moreover, yield advantage of mixed cropping in this study was also evidenced by having land equivalent ratios (LER) over than 1.0 value which would be indicator of efficient utilization of available land resources. In comparison to monocropping strategy, LER 1.17 for component of biculture corn and 1.19 for biculture mixed forage depicted that farmers facing scarcity of land resources would require 17 to 19% less land to produce the same dry matter yield through adopting intercropping technique. Other workers (Amjadian et al., 2013; Hayder et al., 2003; Tsujimoto et al., 2015; Waktola et al., 2014; Zhang et al., 2015) had also substantiated higher land productivity in case of corn-soybean intercropping.

In response to implementing intercropping as innovative forage production technique at farmer level, greater yield in corn fodder components might be attributed to compounding effect of corn soybean biculture in which soybean as leguminous plant may provide advantage to cereal crop corn through nitrogen excretion (Eaglesham et al., 1981) and nodule decomposition (Bonetti, 1991). Consequently, the fixed nitrogen by legume can be utilized by cereals (Shen and Chu, 2004) like corn for their better growth & more dry matter yield. The other reason might be efficient absorption of resources; light, water & nutrients and then conversion into crop biomass by the intercropping culture (Tsubo et al., 2001).

In connection to intercropping, the total digestible nutrients (TDN) value for livestock by increasing might be attributed to increased level of DM yield in determining factors of TDN; corn stalks and corn ears. Forage nutritive value improved through corn-soybean mixed planting was also reported by Seo et al. (2014) while observing increased contents of crude protein & crude fat and decreased ADF & NDF in bi-culture forage than corn as monocrop. As decreased NDF & ADF contents in the intercrop forage, it would increase value of fodder for animals in terms of high dry matter intake and TDN yield. Consequently, intercropping corn with legume enhanced the forage quality (Javanmard et al., 2015).

Ⅴ. CONCLUSION

It was concluded that corn-soybean intercropping could be suitable than corn monocrop, because of having adverse effect on soybean component. Soybean can improves soil fertility through nitrogen fixation by leguminous, so intercropping can reduce production cost. Corn-soybean intercropping would be an innovative forage production technique that growth of mixed crops under limited land resources.

Ⅵ. ACKNDOLEDGEMENTS

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