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Effects of Baby Corn Density on the Crop and Weed Performance under Different Maize-Soybean Intercropping Systems

Thieu Thi Phong Thu, Tran Thi Thiem, Nguyen Thi Loan & Pham Van An

Faculty of Agronomy, Vietnam National University of Agriculture, Hanoi 131000, Vietnam

Abstract

This study was conducted to examine the effects of baby corn density on the crop and weed performance under two different maize-soybean intercropping systems. Treatments included four baby corn densities (D1= 138,888 plants ha^{-1}, D2 = 111,111 plants ha^{-1}, D3 = 92,592 plants ha^{-1}, and D4 = 79,365 plants ha^{-1}), and three intercropping methods (P0 = a sole cropping of baby corn, P1 = 1 row of soybean + 1 row of baby corn (density of soybean, 10 plant m^{-2}), and P2 = 2 rows of soybean + 1 row of baby corn (density of soybean, 20 plants m^{-2}). Physiological characteristics and yield were measured for the baby corn and soybean. The weed species, weed frequency, and the growth of the weeds were recorded at the final harvesting time of the baby corn. The results showed that the yield of soybean and the growth of the weeds were statistically different under the different maize-soybean intercropping systems. Increasing the baby corn density increased the leaf area index, dry matter accumulation, and cob yield, but did not have a clear effect on the soybean yield under both intercropping methods. In addition, the P2 intercropping method produced significantly higher soybean yield and gave better results of weed growth reduction in comparison with the P1 intercropping method. In the P2 intercropping method, baby corn should be grown at a density of 111,111 plants ha^{-1} to optimize the population productivity and achieve reasonable weed control for the sustainability of agriculture.

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Correspondence to
ttpthu@vnua.edu.vn

ORCID

Thieu Thi Phong Thu
https://orcid.org/0000-0003-0762-0301

Tran Thi Thiem
https://orcid.org/0000-0002-3730-1523

Nguyen Thi Loan
https://orcid.org/0000-0002-7194-8996

Keywords

Baby corn density, baby corn yield, maize-soybean intercropping, weed control

Introduction

With the increasing number of health concerns, people around the world, nowadays, are looking for quality and safe agricultural products. Baby corn (*Zea may* L.) refers to a healthy and safe vegetable. It is also free from the residual effects of pesticides as it is harvested within a week of tassel emergence and the young cob is wrapped up tightly within the husk and well protected from pests (Dar *et al.*, 2017). Baby corn is the immature corn and the entirely edible cobs are normally harvested just before fertilization when they are 2-3cm long at the silk emergence stage. It is becoming prominent worldwide as a high-value crop due to its high nutritive values with 13% potassium, 14% B6 riboflavin, 17% vitamin C, and 11% fiber per four ounces (Fakir & Islam, 2008), delicious taste, and very large demand by foreign tourists.

In recent decades, weed control methods have become one of the top major problems in the vegetable cropping system. Weeds, as undesirable plants, interfere with production, and can reduce yield and product quality (Dar *et al.*, 2017). In one study, about 43% of the crop yield was lost when weeds were uncontrolled (Lemessa & Wakjira, 2014). In parallel with this, the reduction of synthetic herbicides in agriculture production has been considered in many countries because humans perceive the negative aspects of chemical overuse in weed control such as the problems of food safety, environmental pollution, undesirable effects on living organisms, and the appearance of herbicide-resistance (Al Samarai *et al.,* 2018). Therefore, non-chemical methods to control weeds have been studied in corn, including management of cover plants and increased corn planting densities (Tavella *et al*., 2014)

Living cover crops suppress weeds during their growing phases and act as living mulch by competing for resource availability (light, nutrients, and water). They create a canopy for a greater number of crop plants in a unit area (Kumar *et al*., 2017) and through physical, biotic, and allelopathy – based inhibition of weed germination interactions (Radicetti, 2012; Lemessa & Wakjira, 2014). The use of legumes, which are able to fix nitrogen, as a living cover crop in an intercropping system leads to increased soil available nitrogen and thus alters the crop – weed relationship towards being more beneficial for the crop and improving the competitiveness of the crop over the weeds (Lemessa & Wakjira, 2014). Kumar *et al*. (2017) recorded more effectiveness in weed suppression presented in a lower weed density and a lower dry weight in the intercropping system of maize and *Lathyrus*. These results are in line with the studies of Haque *et al.* (2016) and Iqbal *et al.* (2019) who used maize – soybean intercropping systems. It has also been shown that cereal – legume intercropping systems maintain and improve soil fertility through nitrogen acquisition, and improve the field microclimate with favorable temperatures, light intensity, and relative humidity leading to increases in the photosynthetic rate of leaves and improvements in plant growth and crop yield (Iqbal *et al.*, 2019).

Higher plant populations enable corn to combat weeds more effectively by expediting canopy closure and light interception (Williams *et al.*, 2014), which dramatically increase corn yield (El – Sobky & El – Naggar, 2016). Nguyen Viet Long *et al.* (2009) also recorded a statistically higher leaf area index (LAI), and higher total and marketable yield of baby corn at a plant density of 167,000 plants ha^{-1} than in other densities (114,000, 133,000, or 143,000 plants ha^{-1}). Marin & Weiner (2014) and Youngerman *et al.* (2018) reported that increased crop density results in increased weed suppression resulting in low weed biomass. However, excessive populations can have a negative impact on corn grain yield. In the study of Ghosh *et al.* (2017), baby corn yield reached the highest value at the density of 100,000 plants ha^{-1} and slightly decreased at the density of 120,000 plants ha^{-1}. Williams *et al.* (2014) indicated that reduced corn yield under high plant populations is due to decreases in the number of leaves per plant and leaf area leading to less radiation interception per plant and consequently less synthesized assimilates for corn.

Effective non-chemical weed management strategies in corn require farmers to practice a range of weed control techniques contemporarily. Coupling optimum corn planting density and corn – legume intercropping could lead to more effective weed management in baby corn. This research was conducted to compare weed control, corn and soybean growth, and yield affected by different planting densities on different maize - soybean intercropping systems.

Materials and Methods

The culture of host plants

The baby corn cultivar was LVN23. The baby corn seed was produced by the Vietnam National Maize Research Institute. The soybean cultivar was DT84, which was provided by the Department of Genetics and Plant Breeding, Faculty of Agronomy, Vietnam National University of Agriculture.

Experimental design, treatments, and cultivation practices

This study was conducted in a research field at Vietnam National University of Agriculture (VNUA), Hanoi, Vietnam in the 2020 spring season.

The experimental design was a randomized complete block design with three replications. The treatments included four maize densities (D1: 138,888 plants ha^{-1} (equally, 12cm x 60cm), D2: 111,111 plants ha^{-1} (equally, 15cm x 60cm), D3: 92,592 plants ha^{-1} (equally, 18cm x 60cm), and D4: 79,365 plants ha^{-1} (equally, 21cm x 60cm)) and two intercropping methods (P1: 1 row of soybean + 1 row of baby corn (density of soybean, 10 plant m^{-2}), and P2: 2 rows of soybean + 1 row of baby corn (density of soybean, 20 plants m^{-2})) and P0, a sole cropping of baby corn (**Figure 1**).

The germinated baby corn seed was sown on a plastic bag with a substrate of soil, sand, and chicken compost for 2 weeks. Once the baby corn reached the 2-3 leaf baby corn stage, the seedlings and soybean seeds were sown in the field on the same day according to the treatments and experiment design. The applied doses of fertilizer were 120 kg N, 100 kg P_2O_5, and 100 kg K_2O ha^{-1}. The total amount of phosphorous and 20% nitrogen fertilizer were applied basally. The amounts of nitrogen and potassium were split into two applications: at the 3-4 leaf growth stage (40% N, 50% K_2O), and at the 7-9 leaf growth stage (40% N, 50% K_2O).

Parameters and measurements

For the baby corn, the physiological characteristics of leaf area index (LAI) (m^2 of leaf/m^2 of land), chlorophyll content via SPAD index, dry matter accumulation (g m^{-2} of land), number of cobs ha^{-1}, fresh weight of cobs (g $plant^{-1}$), fresh weight of de-husked cobs (g $plant^{-1}$), green biomass (tons ha^{-1}), and yield (tons ha^{-1}) were collected. LAI and dry matter were measured from three individual plants for each replication at the 7-9 leaf stage and harvesting stages. Leaf area index (LAI) was calculated as the leaf area divided by the ground area, where leaf area was calculated by the length x the maximum width

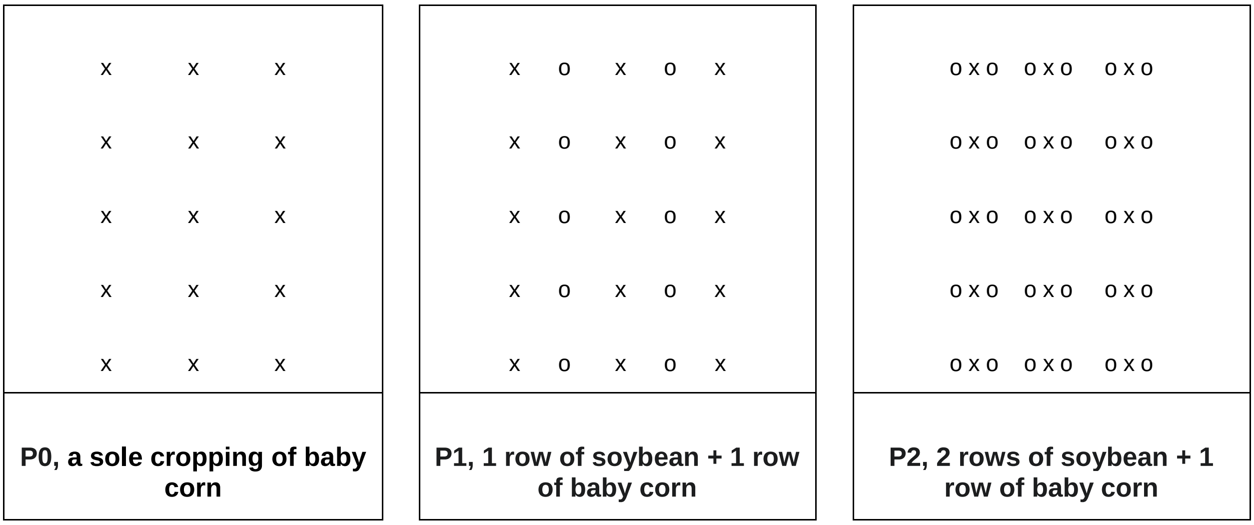


Figure 1. Different methods of maize (x) and soybean (o) intercropping

x 0.75 x total number of leaves (Nguyen Van Loc & Nguyen Van Minh, 2019).

Regarding the soybeans, LAI, dry matter accumulation, number of pods per plant, grains per plant, 100-grain weight, and yield were investigated. The yield of the soybeans was the fresh weight of the pods at the beginning of the maturity stage.

Concerning the weeds, the weed species, weed frequency, and growth of the weeds (g of fresh and dry weight for $1m^2$ of land) were recorded at the final harvesting time of the baby corn. The measurements of the weeds were determined by using three quadrat ($0.25m^2$) frames which were randomly placed in each experimental plot. The weeds within each quadrat were collected to determine the fresh and dry weights. The dry matter weights of the baby corn, soybean, and weeds were determined after drying the samples in an oven at 80^oC for 48h. The weed frequency was calculated according to the formula: Frequency (%) = (Number of surveyed locations where a species occurred/Number of total surveyed locations) x 100. The weed frequency was divided into four levels: <10% (+); 10- 30% (++); 30-50% (+++), and > 50% (++++) (Nguyen Hong Son & Nguyen Thi Tan, 1999).

Statistical analysis

The data were subjected to ANOVA for the planting density, intercropping method, interaction of planting density and intercropping method, and replication, using IRRISTAT 5.0. The treatment mean differences were analyzed using least significant difference (LSD) at the 5% significance level.

Results and Discussion

Effect of baby corn densities and maize-soybean intercropping methods on the physiological traits of LVN23 baby corn and DT82 soybean

Effect of baby corn density and maize-soybean intercropping method on the SPAD values of LVN23 baby corn

The results showed that the SPAD indexes increased through the growth stages (**Table 1**). The highest SPAD values were reached at the harvest period. Plant density did not affect the SPAD indexes, but the intercropping methods affected the SPAD indexes at the 7-9 leaf and flowering stages. The P1 intercropping method increased the SPAD indexes in comparison with the P0 and P2 methods at the flowering stage. The interaction effects of baby corn density and maize-soybean intercropping method on SPAD were significant at the 7-9 leaf and flowering stages at the 5% probability level. The P1D4 treatment showed the value of the SPAD index (42.0) being significantly higher than the P2D3 treatment (37.0). However, in the harvest period, no statistically significant differences were observed among the treatments.

Effect of baby corn density and maize-soybean intercropping method on LAI

It can be seen that the density of the baby corn significantly affected the LAI, the higher the density, the higher the leaf area (**Table 2**). The highest LAI was observed at the harvest stages of both baby corn and soybean. Prasad & Brooks (2005) found an increase in maize plant density to significantly affect the LAI in maize-soybean intercropping. Nguyen Viet Long *et al.* (2009) also recorded statistically higher LAI, and higher total and marketable yield of baby corn when the density of corn increased. Regarding soybean, the baby corn density did not have a significant effect on soybean LAI at both the flowering and harvest stages. The interaction effects of the baby corn density and maize-soybean intercropping method on the LAI were significant in both baby corn and soybean at both the flowering and harvest stages. Concerning baby corn's LAI, the density of D1 gave the highest LAI, followed by D2, D3, and D4 at the flowering and harvest periods in all the intercropping methods. However, for soybeans, in the P2 intercropping method, D2 yielded the highest LAI at both the flowering and harvest stages. The lowest LAIs were found in D1 at the flowering stage and D3 at the harvest stage.

The advantages of intercropping are the creation of a high coverage density and large

Table 1. SPAD values affected by the baby corn density and maize-soybean intercropping method

Treatments		Growth stage of baby corn		
		7-9 leaf stage	Flowering	Harvest
Density (D)	D1	34.9[a]	38.9[a]	43.1[a]
	D2	36.2[a]	39.7[a]	42.6[a]
	D3	36.1[a]	38.7[a]	42.4[a]
	D4	36.2[a]	39.6[a]	43.2[a]
Intercropping method (P)	P0	36.9[a]	38.9[ab]	43.1[a]
	P1	35.9[ab]	40.6[a]	43.2[a]
	P2	34.8[b]	38.2[b]	42.2[a]
P0	D1	36.8[a]	40.4[ab]	43.6[a]
	D2	37.8[a]	39.4[ab]	44.3[a]
	D3	36.2[a]	38.7[ab]	42.4[a]
	D4	36.8[a]	37.1[b]	42.1[a]
P1	D1	35.5[ab]	38.9[ab]	44.2[a]
	D2	36.5[a]	40.9[ab]	41.6[a]
	D3	35.7[ab]	40.5[ab]	42.8[a]
	D4	36.8[a]	42.0[a]	44.3[a]
P2	D1	32.4[b]	37.3[b]	41.5[a]
	D2	34.3[ab]	38.8[ab]	41.9[a]
	D3	35.7[ab]	37.0[b]	42.0[a]
	D4	36.8[a]	39.8[ab]	43.2[a]
$LSD_{0.05\%}$ (D)		2.1	2.3	1.7
$LSD_{0.05\%}$ (P)		1.8	2.0	1.5
$LSD_{0.05\%}$ (DxP)		3.7	4.0	3.0
CV(%)		5.7	6.1	4.2

Note: Means followed by the same letter in each column for the single factors (density or intercropping method) or the interaction of baby corn density and maize-soybean intercropping method are not significantly different in the LSD tests

biomass. The system has been shown not only to be more efficient than sole cropping (Remison, 1978) but also improve the overall ecology (Adelana, 1984). In agreement with these ideals, the P2 intercropping method and increased maize density resulted in a higher coverage density due to the higher LAI. This can increase the competitiveness of resources between the crop and weeds, thereby increasing weed control and resulting in the highest control efficiency of the treatments, finally increasing overall productivity. The P2D2 treatment produced the highest coverage density with the general LAI (the sum of the LAI values of corn and soybean) of 11.6 at the harvest stage. A combined leaf canopy might make better special use of light (Waddington & Edward, 1989).

Effect of baby corn density and maize-soybean intercropping method on dry matter

It is clear to see that there was a significant difference in the dry matter of baby corn among the treatments. The increased density increased the dry matter accumulation of baby corn. In addition, the intercropping method did not significantly change the maize dry matter accumulation but had a significant effect on the soybean dry matter accumulation. The P2 intercropping treatment resulted in two times the dry matter of soybean compared with the P1 method. The interaction effect of the density and

Table 2. Effects of baby corn density and maize-soybean intercropping method on the LAI of LVN23 baby corn and DT84 soybean

Unit: m^2 of leaves m^{-2} of land

Treatments		LVN23 baby corn		DT84 soybean	
		Growth stage of baby corn			
		Flowering	Harvest	Flowering	Harvest
Density (D)	D1	4.10^{a}	4.96^{a}	2.12^{a}	5.48^{a}
	D2	3.27^{b}	4.00^{b}	2.09^{a}	5.60^{a}
	D3	2.68^{c}	3.31^{c}	2.06^{a}	5.45^{a}
	D4	2.36^{d}	2.77^{d}	1.91^{a}	5.13^{a}
Intercropping method (P)	P0	3.05^{b}	3.75^{a}		
	P1	3.16^{a}	3.79^{a}	1.47^{b}	3.73^{b}
	P2	3.10^{ab}	3.74^{a}	2.62^{a}	6.60^{a}
P0	D1	4.02^{b}	5.03^{a}		
	D2	3.30^{c}	4.00^{b}		
	D3	2.59^{d}	3.28^{cd}		
	D4	2.29^{f}	2.70^{e}		
P1	D1	4.26^{a}	4.94^{a}	1.95^{c}	4.43^{d}
	D2	3.23^{c}	4.00^{b}	1.09^{e}	3.60^{de}
	D3	2.78^{d}	3.45^{c}	1.49^{d}	3.23^{e}
	D4	2.39^{e}	2.77^{e}	1.36^{de}	3.65^{de}
P2	D1	4.04^{b}	4.90^{a}	2.29^{bc}	6.52^{b}
	D2	3.28^{c}	4.01^{b}	3.08^{a}	7.59^{a}
	D3	2.67^{d}	3.21^{d}	2.63^{b}	5.68^{c}
	D4	2.39^{e}	2.83^{e}	2.47^{b}	6.61^{b}
$LSD_{0.05\%}$(D)		0.12	0.13	0.26	0.59
$LSD_{0.05\%}$(P)		0.10	0.11	0.18	0.42
$LSD_{0.05\%}$(DxP)		0.21	0.23	0.37	0.84
CV(%)		4.0	3.7	10.5	9.3

Note: Means followed by the same letter in each column for the single factors (density or intercropping method) or the interaction of baby corn density and maize-soybean intercropping method are not significantly different in the LSD tests.

the intercropping method also caused statistically significant differences in maize dry matter accumulation among the treatments. At the D1 (138,888 plant ha^{-1}) and D2 (111,111 plant ha^{-1}) maize densities, the P2 intercropping method created a higher volume of maize dry matter. Moreover, when comparing the two intercropping methods, P2 gave a higher soybean dry matter than P1 at the density of D2 (1.73 times higher in P2 compared with P1), followed by D1, D3, and D4 (**Table 3** and **Figure 2**).

Total dry matter values of maize and soybean at the harvest stage were higher in the P2 intercropping method compared with P1, where D1 gave the highest total dry matter (772 g m^{-2}), followed by D2 (671.3 g m^{-2}), D3 (642.8 g m^{-2}), and D4 (596.5 g m^{-2}). This result is consistent with the highest results of the total LAI of maize and soybeans calculated in P2D2. It has been reported that intercropping systems are known to make more efficient use of growth factors as they capture and make better use of radiant energy (Matusso *et al.*, 2014), available water,

Table 3. Effects of baby corn density and maize-soybean intercropping method on the dry matter of LVN23 baby corn and DT84 soybean

Unit: g m^{-2} of land

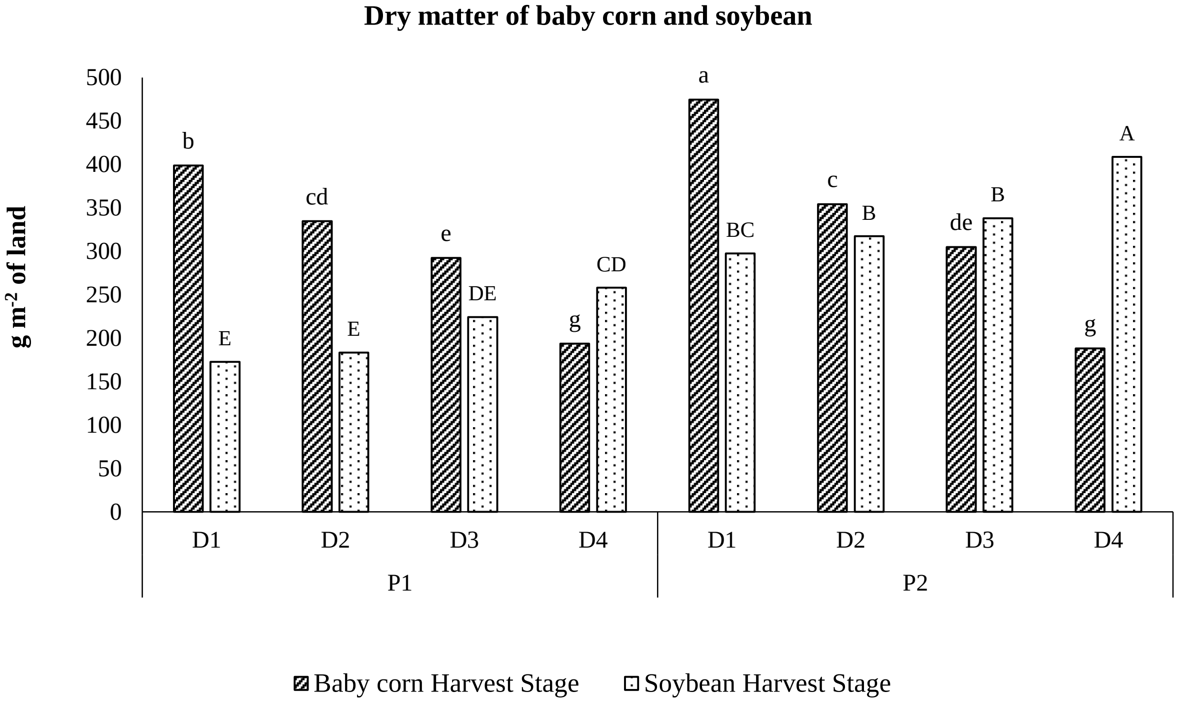
Treatments		LVN23 baby corn		DT84 soybean	
		Growth stage of baby corn			
		Flowering	Harvest*	Flowering	Harvest
Density (D)	D1	528.9^{a}	440.0^{a}	89.50^{c}	235.1^{c}
	D2	407.0^{b}	364.8^{b}	86.35^{c}	250.4^{bc}
	D3	334.5^{c}	282.9^{c}	108.1^{b}	281.1^{b}
	D4	209.7^{d}	205.0^{d}	130.1^{a}	333.2^{a}
Intercropping method (P)	P0	374.1^{a}	334.5^{a}		
	P1	371.4^{a}	304.7^{b}	79.37^{b}	209.6^{b}
	P2	364.6^{a}	330.4^{a}	127.6^{a}	340.3^{a}
P0	D1	545.4^{a}	446.8^{a}		
	D2	372.8^{de}	405.7^{b}		
	D3	338.3^{f}	251.9^{f}		
	D4	240.1^{h}	233.4^{f}		
P1	D1	543.6^{a}	398.7^{b}	77.00^{d}	172.6^{e}
	D2	393.4^{d}	334.5^{cd}	62.50^{d}	183.5^{e}
	D3	357.0^{ef}	292.1^{e}	78.32^{d}	224.2^{de}
	D4	191.7^{i}	193.6^{g}	99.68^{c}	257.9^{cd}
P2	D1	497.8^{b}	474.5^{a}	102.0^{c}	297.5^{bc}
	D2	454.7^{c}	354.1^{c}	110.2^{c}	317.2^{b}
	D3	308.3^{g}	304.8^{de}	137.9^{b}	338.0^{b}
	D4	197.7^{i}	188.1^{g}	160.6^{a}	408.4^{a}
$LSD_{0.05\%}$(D)		14.8	20.6	15.1	38.0
$LSD_{0.05\%}$(P)		12.8	17.9	10.6	26.8
$LSD_{0.05\%}$(DxP)		25.7	35.8	21.3	53.7
CV(%)		4.1	6.5	5.7	11.2

*Note: Means followed by the same letter in each column for the single factors (density or intercropping method) or the interaction of baby corn density and maize-soybean intercropping method are not significantly different in the LSD tests. * Dry matter of maize at harvest stage did not include cob weight.*

and nutrients (Sullivan, 1998). Thus, suitable intercropping combined with reasonable density can promote efficient resource usage.

Effect of baby corn density and maize-soybean intercropping method on yield components and yield

Baby corn is the main crop in the maize-soybean intercropping system. The results showed that increasing the baby corn density significantly increased the number of cobs, cob yield, de-husked cob yield, and green biomass (**Table 4** and **Figure 3**). The intercropping method did not have a statistically significant effect on baby corn yield. The results in many reports indicated that the yield of maize declined as a result of varying spacing in intercropping systems with cowpea. This further agrees with the report of Gangwar & Sharma (1994) who observed that there was a decrease in the yield of maize due to intercropping with legumes, i.e. cowpea and cluster bean. Interestingly, in our experiment, the yield of baby corn did not decrease when intercropped. This is possibly because the baby corn is harvested at the silking stage, which is earlier than when maize is harvested. These results have achieved the purpose of the soybean-maize intercropping



Note: Means followed by the same letter in each bar for baby corn (lowercase letter) or soybean (uppercase letter) are not significantly different in the LSD tests.

Figure 2. Interaction effects of baby corn density and maize-soybean intercropping method on dry matter of LVN23 baby corn and DT84 soybean at the harvest stage

system of maximizing the maize–legume association in order to reach a full yield of the maize plus the selected legume yield (Chui & Richards, 1984). The interaction between the baby corn density and intercropping method also caused a statistically significant effect on the baby corn yield and green biomass. The highest yields and green biomass were found in treatments of P1D1, P2D1, P1D2, and P2D2. The baby corn densities did not affect soybean yield, while the intercropping methods did have a significant affect. The P2 intercropping method produced a higher soybean yield than the P1 method. Moreover, there was no significant difference in baby corn yield between the P1 and P2 intercropping methods (**Table 5**). Therefore, increasing the number of soybean rows in the intercropping increased soybean yield while ensuring corn yield. Research work also revealed that the spacing for higher cereals can be altered to a certain degree without reducing their yields while providing a more promising environment for the intercropped legume (Chui & Richards, 1984). For the P2 intercropping method, soybean fresh yield was the highest at the D2 density, followed by D1, D4, and D3. The interaction effect between the baby corn densities and intercropping methods also caused a statistically significant effect on the soybean green biomass. The highest green biomass was found in the treatment P2D2, followed by P2D1, P2D4, and P2D3.

An important measurement in grassland resources is the yield of forage, which is defined as the volume of dry matter obtainable to livestock (Shi *et al.*, 2013). Maize-legume intercropping could considerably increase forage quantity and quality, lessening conditions for protein supplements (Soleymani & Shahrajabian, 2012). In this study, regarding the total biomass of the intercropping system (the sum of the green biomass of baby corn and soybean), and the interaction between corn density and the intercropping method resulted in a remarkable amount of green matter. Intercropping maize with soybean by the P2 method combined with the D2 corn density created the highest total green biomass yield. Keating & Carberry (1993) reported a better use of solar radiation by intercropping soybeans and maize. In addition, intercropping enhanced the efficient use of strong light by maize and weak light by groundnuts which subsequently led to a yield advantage (Jiao *et al.*, 2008).

Effect of baby corn density and maize-soybean intercropping method on weeds

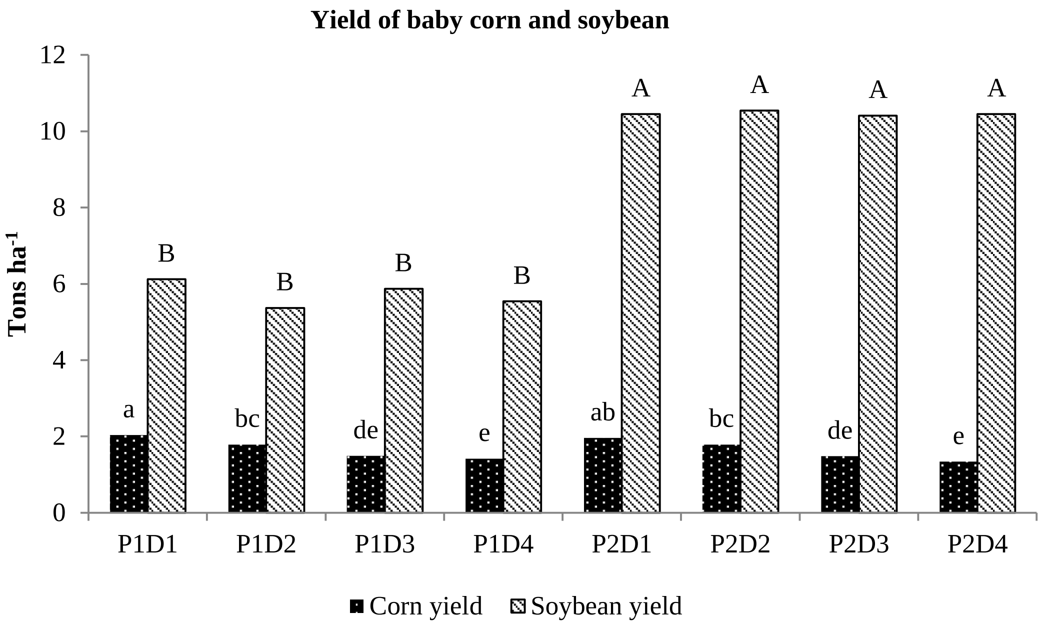
The component and frequency of weeds

Regarding the weeds component, *Eleusine indica* (L.) Gaertn. (cỏ Mần trầu) was observed in all the treatments and found in the highest frequencies (from 30 to 50%), followed by *Echinochloa crus-galli* (L.) Beauv (cỏ Lồng vực cạn), *Cyperus rotundus* (L.) (cỏ Gấu) *Leptochloa chinensis* (L.) Nees (cỏ Đuôi phụng), *Eclipta*

Table 4. Effects of baby corn density and maize-soybean intercropping method on the yield components and yield of LVN23 baby corn

Treatments		Fresh weight of cobs (g plant^{-1})	Fresh weight of de-husked cobs (g plant^{-1})	Number of cobs (1000 cobs ha^{-1})	Cob yield (tons ha^{-1})	De-husked cob yield (tons ha^{-1})	Green biomass (tons ha^{-1})
Density (D)	D1	114.8^{a}	27.54^{a}	425.9^{a}	9.74^{a}	1.96^{a}	23.77^{a}
	D2	116.0^{a}	27.84^{a}	343.2^{b}	8.47^{b}	1.78^{b}	18.23^{b}
	D3	115.2^{a}	27.64^{a}	281.8^{c}	6.65^{c}	1.51^{c}	16.74^{b}
	D4	117.4^{a}	28.16^{a}	250.4^{d}	5.90^{d}	1.39^{d}	14.34^{c}
Intercropping method (P)	P0	115.0^{ab}	27.59^{ab}	324.4^{a}	7.71^{a}	1.65^{a}	18.45^{a}
	P1	113.2^{b}	27.17^{b}	324.3^{a}	7.81^{a}	1.69^{a}	17.35^{a}
	P2	119.3^{a}	28.63^{a}	327.3^{a}	7.55^{a}	1.64^{a}	19.01^{a}
P0	D1	118.1^{ab}	28.34^{ab}	435.1^{a}	9.00^{bc}	1.90^{bc}	24.85^{a}
	D2	116.9^{ab}	28.06^{ab}	340.7^{cd}	8.63^{d}	1.76^{cd}	18.98^{bc}
	D3	113.1^{b}	27.14^{b}	283.9^{e}	7.54^{e}	1.56^{e}	16.11^{cde}
	D4	125.6^{a}	26.81^{b}	238.0^{g}	5.76^{f}	1.40^{f}	13.84^{e}
P1	D1	112.0^{b}	26.89^{b}	425.9^{ab}	10.53^{a}	2.04^{a}	20.53^{b}
	D2	113.2^{b}	27.16^{b}	333.3^{d}	8.00d^{e}	1.79^{cd}	17.35^{bcde}
	D3	112.9^{b}	27.10^{b}	283.9^{e}	6.56^{f}	1.49^{ef}	17.32^{bcde}
	D4	114.8^{b}	27.54^{b}	253.9^{fg}	6.15^{f}	1.42^{fg}	14.19^{e}
P2	D1	114.1^{b}	27.39^{b}	416.6^{b}	9.69^{ab}	1.96^{ab}	25.92^{a}
	D2	118.0^{ab}	28.31^{ab}	355.5^{c}	8.78^{cd}	1.79^{cd}	18.35^{bcd}
	D3	119.6^{ab}	28.69^{ab}	277.7^{e}	5.97^{f}	1.48^{ef}	16.80^{cde}
	D4	125.6^{a}	30.14^{a}	259.2^{f}	5.79^{f}	1.34^{g}	14.98^{de}
$LSD_{0.05\%}$ (D)		5.4	1.3	10.3	0.54	0.06	2.14
$LSD_{0.05\%}$ (P)		4.7	1.1	8.9	0.46	0.05	1.85
$LSD_{0.05\%}$ (DxP)		9.4	2.2	17.8	0.94	0.11	3.71
CV% (DxP)		4.8	4.8	3.2	7.2	4.0	12.0

Note: Means followed by the same letter in each column for the single factors (density or intercropping method) or the interaction of baby corn density and maize-soybean intercropping method are not significantly different in the LSD tests.



Note: Means followed by the same letter in each bar for the baby corn (lowercase letter) or soybean (uppercase letter) are not significantly different in the LSD tests.

Figure 3. Interaction effects of baby corn density and maize-soybean intercropping method on the yield of LVN23 baby corn and DT84 soybean

Table 5. Effects of baby corn density and maize-soybean intercropping method on the yield components and yield of DT82 soybean

Treatments		Number of pods per plant	Number of grains per plant	100-grain weight (g)	Cob yield (tons ha^{-1})	Green Biomass (tons ha^{-1})
Density (D)	D1	107.2^{a}	302.0^{a}	21.96	8.29^{a}	15.99^{a}
	D2	105.7^{a}	298.3^{a}	22.00	7.95^{a}	15.69^{a}
	D3	103.2^{a}	288.9^{a}	21.45	8.14^{a}	13.09^{b}
	D4	107.6^{a}	305.3^{a}	21.95	8.00^{a}	13.66^{b}
Intercropping method (P)	P1	105.3^{a}	296.6^{a}	21.73	5.72^{b}	10.59^{b}
	P2	106.7^{a}	300.6^{a}	21.92	10.46^{a}	18.62^{a}
P1	D1	102.6^{abc}	282.6^{bc}	21.96	6.12^{b}	13.34^{d}
	D2	99.7^{bc}	280.2^{bc}	21.93	5.37^{c}	9.94^{e}
	D3	110.0^{ab}	312.5^{ab}	21.50	5.87^{bc}	9.47^{e}
	D4	109.1^{ab}	310.3^{ab}	21.53	5.54^{c}	9.61^{e}
P2	D1	112.8^{a}	320.4^{a}	21.96	10.45^{a}	18.63^{b}
	D2	111.7^{a}	316.4^{a}	21.96	10.54^{a}	21.43^{a}
	D3	96.4^{c}	265.4^{c}	21.40	10.41^{a}	16.40^{c}
	D4	106.1^{abc}	300.2^{ab}	22.36	10.45^{a}	17.72^{bc}
$LSD_{0.05\%}$ (D)		7.8	23.8	1.62	0.36	1.00
$LSD_{0.05\%}$ (P)		5.5	16.8	0.85	0.26	0.71
$LSD_{0.05\%}$ (DxP)		11.1	33.7	2.79	0.52	1.42
CV% (DxP)		6.0	6.5	4.4	3.7	5.6

Note: Means followed by the same letter in each column for the single factors (density or intercropping method) or the interaction of baby corn density and maize-soybean intercropping method are not significantly different in the LSD tests.

Table 6. Effects of baby corn density and maize-soybean intercropping method on the component and frequency of weeds

Vietnamese name		Lồng vực cạn	Mần trầu	Đuôi phụng	Cỏ cháo	Cỏ mực	Cải Ấn	Cỏ gấu
Scientific name		*Echinochloa colona* (L.) Link	*Eleusine indica* (L.) Gaertn.	*Leptochloa chinensis* (L.) Nees	*Cyperus difformis* (L.)	*Eclipta prostrata* (L.) L.	*Rorippa indica* (L.) Hiern.	*Cyperus rotundus* (L.)
Treatments	P0D1	++	++	++	+	+	+	++
	P0D2	++	+++	++	++	+	++	++
	P0D3	++	+++	++	++	+	++	++
	P0D4	++	+++	++	++	+	++	++
	P1D1	+	+	+	+	+	+	+
	P1D2	+	++	+	+	+	+	+
	P1D3	+	++	+	+	+	+	+
	P1D4	++	++	+	++	+	++	+
	P2D1	+	+	+	+	-	-	-
	P2D2	+	++	+	+	-	+	+
	P2D3	+	++	+	+	-	+	+
	P2D4	+	++	+	+	+	+	+

Note: The weed frequency is divided into four levels: <10% (+); 10- 30% (++); 30-50% (+++), and > 50% (++++).

alba Hassk. (Cải Ấn), and *Cyperus difformis* (L.). (cỏ Cháo) (**Table 6**). In general, the treatment with a higher baby corn density gave better results of weed reduction than the treatment with a lower planting density. Though Goosegrass (*Eleusine indica)* was the dominant weed species, it was strongly suppressed by baby corn density and maize-soybean intercropping. Both of the intercropping methods increased the weed-limiting effects. However, the P2 intercropping method was more successful because some types of weeds were almost absent from this intercropping treatment.

The growth of weeds

Both the effects of the single factors as well as the interaction between the densities and the intercropping methods on the growth of the weeds were statistically significant. Increasing the baby corn density clearly decreased the fresh and dry weight of the weeds. Particularly, the fresh weights of the weeds at D1 and D2 (94.48 and 94.45 g m^{-2}, respectively) were significantly lower than that at D4 and D3 (136.10 and 148.60 g m^{-2}, respectively) (**Table 7**). Differences in the dry weight of the weeds were also similarly observed. In addition, both intercropping methods increased the weed-limiting effects. However, the treatment with the P2 intercropping method gave better results in terms of weed growth reduction in comparison with the P1 intercropping method. Remarkably, the P2 intercropping method and the increased maize density resulted in a high coverage density due to the high LAI. This can be a reason for the higher competitiveness for resources with the weeds, thereby increasing weed control. On the other hand, the results of the interaction effects between baby corn density and intercropping methods showed that within the P2 intercropping method, the baby corn densities of D1 and D2 depressed weed growth at the same level.

Putting the results together, it can be suggested that a combination of controlling the baby corn density suitably with an intercropping method is necessary to increase plant growth, limit the population of weeds, and increase the population yield. The P2D2 treatment should be chosen for the cultivation of baby corn to achieve a balance between high productivity and sustainability.

Table 7. Effects of baby corn density and maize-soybean intercropping method on the growth of weeds

Treatments		Fresh weight (g m^{-2})	Dry weight (g m^{-2})
Density (D)	D1	94.48^{c}	16.19^{b}
	D2	94.25^{c}	16.07^{b}
	D3	148.6^{a}	23.79^{a}
	D4	136.1^{b}	23.69^{a}
Intercropping method (P)	P0	211.0^{a}	37.03^{a}
	P1	71.6^{b}	11.42^{b}
	P2	62.0^{b}	11.36^{b}
P0	D1	168.0^{c}	27.70^{c}
	D2	147.7^{c}	23.93^{c}
	D3	255.9^{b}	43.82^{b}
	D4	312.4^{a}	52.67^{a}
P1	D1	63.0^{fg}	10.51^{de}
	D2	71.2^{ef}	12.37^{de}
	D3	101.8^{d}	13.29^{de}
	D4	50.42^{fg}	9.50^{de}
P2	D1	52.35^{fg}	10.38^{de}
	D2	63.79_{fg}	11.92^{de}
	D3	88.22^{de}	14.25^{d}
	D4	45.70^{g}	8.89^{e}
LSD (D)		12.2	2.82
LSD (P)		10.7	2.44
LSD (DxP)		21.5	4.89
CV% (DxP)		10.7	14.5

Note: Means followed by the same letter in each column for the single factors (density or intercropping method) or the interaction of baby corn density and maize-soybean intercropping method are not significantly different in the LSD tests.

Conclusions

This study optimized the suitable combination of baby corn density and soybean intercropping for the higher performance of their yield as well as the suppression of weeds. The results showed that the effects of baby corn density on the yields of baby corn, soybean, and weeds were statistically significant under the different maize-soybean intercropping systems. The higher baby corn density increased the leaf area index, dry matter accumulation, and cob yield, but, did not affect soybean yield under both intercropping methods. In addition, the P2 intercropping method (2 rows of soybean + 1 row of baby corn) produced significantly higher soybean yield compared with the P1 method (1 row of soybean + 1 row of baby corn). However, baby corn yield was the same in both the P1 and P2 intercropping methods. Regarding weed growth, the treatments with the P2 intercropping method significantly reduced weed growth compared with the P1 intercropping method. For the P2 intercropping method, the D1 (138,888 plants ha^{-1}) and D2 (111,111 plants ha^{-1}) baby corn densities depressed weed growth at the same level. Therefore, it can be concluded that the intercropping system of two soybean rows on either side of one baby corn row (P2), along with growing baby corn at a density of 111,111 plant ha^{-1} (D2) can optimize the population productivity and achieve reasonable weed control for sustainability agriculture.

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