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Asian Journal of Plant Science and Research, 2017, 7(3):1-10

ISSN : 2249-7412
CODEN (USA): AJPSKY

The Competitive Ability of Intercropped Soybean in Two Row Ratios of Maize-Soybean Relay Strip Intercropping

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ABSTRACT

Row ratios directly affect inter-specific competition and crop yield in intercropping system. The objective of this research was to determine the inter-specific competition ability of intercropped soybean between intercrops in different row ratios planting patterns. A two-year field experiment was conducted from 2012 to 2013 in maize-soybean relay strip intercropping systems with two row ratios (1M:1S row ratio with the distance between maize and soybean was 50cm; 2M:2S row ratio with the distance between maize and soybean was 60cm, respectively). We found that, competitive ratio, partial relative crowding and aggressivity values of intercropped soybean were increased with the increasing of the maize and soybean row distance (from 50 cm to 60cm). Furthermore, the highest values of yield, land equivalent ratio (LER), system productivity index, actual yield loss, monetary advantage index and intercropping advantage were also obtained in 2M:2S row ratio. The partial relative crowding value of maize was increased with the increasing of the maize/soybean row ratios, however, the competitive ratio and aggressivity values of maize had a decline trend. These results showed that, the maize/soybean with row ratio of 2M:2S increased the distance between maize and soybean, led to the decline of inter-specific competition and thus enhance of competitive ability of intercropped soybean. Therefore, the maize/soybean with row ratio of 2M:2S intercropping planting pattern had a high yield of intercropped soybean and economic advantage. We could have a conclusion that intercropping advantage could be achieved by changing the row ratios configuration to coordinate the inter-specific competition between maize and soybean.

Keywords: Relay strip intercropping pattern, Row ratio, Inter-specific competition, Distance between maize and soybean

INTRODUCTION

Intercropping of cereals with legumes is one of the most practical multi-cropping techniques have been employed for centuries around the world many years ago [1-3], thus, this planting pattern was defined as traditional intercropping. The main advantage of intercropping is the more efficient utilization of the available resources and increasing productivity compared with each sole crop of the mixture [4,5], furthermore, intercropping agro-ecosystem could reduce incidence of weeds, insect pest, and diseases [6]. However, in these cropping systems, the more narrow row distance of the mixed crops caused the competition between components of the mixture that might reduce yield and affect quality of forage produced by mixtures (such as maize and soybean) compared with monoculture crops [7]. Therefore, appropriate planting patterns were important to regulate the interspecies competition.

In china, half of the total grain yield was produced with multiple cropping. Particularly, maize-soybean relay strip intercropping systems is one of major planting patterns in the southwestern regions [8,9]. In maize-soybean relay strip intercropping systems, maize was usually sown using narrow-wide row planting pattern, whereas soybean was planted in wide rows [10]. Compared with traditional intercropping planting pattern, narrow-wide planting pattern changed the light environment because of the increasing row distance between the maize and soybean [11], furthermore, the increasing row distance between maize and soybean caused a result that the effect of maize shading on soybean was weaken [12,13]. Therefore, optimum spatial ratio had a significantly interspecies competition and yield efficiency in maize-soybean relay strip intercropping systems.

Some researchers had analyzed the effect of plant spacing and row spacing on yield in intercropping [14], Borghi et al. found that higher grain yield of maize was observed with narrow spacing than with wide row spacing in maize and palisade grass intercropping [15]. Previous studies had focused on the effect of row configuration (e.g. four rows barley alternated with four rows of pea or two rows barley alternated with two rows of pea) on the yield of a certain crop in intercropping [16]. Thus, intercrop yield was influenced by inter/intra-specific competition [17]. However, few studies addressed the impact of varied distance between the maize and soybean rows ratio on the interspecies competition of each crop and mixed yield in maize-soybean relay strip intercropping.

The objectives of the work reported in this paper were to: (1) measure the grain yield of intercrops and sole crops with two row ratios configuration (2M:2S row ratio and 1M:1S row ratio, respectively) in maize-soybean relay strip intercropping systems; (2) explore the relationship between the competition indices and yield in different planting patterns (3) determine the optimum planting pattern in maize-soybean relay strip intercropping.

MATERIALS AND METHODS

Experiment site

The field experiments were conducted at the farms of the Ya'an (29°59′N, 103°00′E) and Lezhi (30°18′N, 105°01′E) county in Sichuan Province, China from 2012 to 2013. Experimental weather data during the growth season in two locations was shown in Table 1. Experimental soil indicators were presented in Table 2.

Experiment design

Four cropping patterns were designed using a randomized block design with three replications. The experiment management was described in Figure 1. The intercropping systems were designed based on maize-soybean relay strip intercropping (Figure 1A) and traditional intercropping (Figure 1B). In maize-soybean relay strip intercropping system, the row ratio of maize to soybean was 2M:2S (2M:2S), the maize planting pattern was adopted: "160+40" wide – narrow row planting (i.e., wide row of 160 cm and narrow row of 40 cm), soybean was planted in the wide rows before the reproductive stage of maize. In traditional intercropping, the row ratio of maize and soybean was 1M:1S (1M:1S). The row distance between maize and soybean was 50 cm (one maize row was alternated by one soybean row). Both of monocultured maize (Figure 1C) and monocultured soybean (Figure 1D) were used as control and planted at the same density as the relay intercrop plots, the row distance of monocultured maize and soybean was 100 cm and 50 cm, respectively. The maize cultivar was Chuandan 418 and Denghai 605 in 2012 and 2013, respectively; the soybean cultivar was Nandou1. Maize was sown on 8 April, 2012 and 10 April, 2013 and soybean was sown on 10 June, 2012 and 12 June, 2013. Maize was harvested on 2 August, 2012 and 4 August, 2013. Soybean was harvested on 28 October, 2012 and 1 November, 2013. The plant densities of maize and soybean were 5 and 10 plants·m^{-2} in both sole crop and intercrops, respectively.

Table 1: Climatologically data in the two study locations

Location	Elevation (m)	Temperature (°C)	Rainfall (mm)	Sunshine (h)	Frost-free season (day)
Ya'an	500-1000	16.2	1250-1750	1005	300
Lezhi	297-596.3	16.7	955	1330	275

Table 2: Nutrients and characteristics of soil before the controlled experiment conducted

Soil parameters	Ya'an	Le zhi
Soil surface texture	Clay loam	Clay loam
pH	6.6	6.76
Organic carbon (g kg^{-1})	29.8	11.1
Available N (mg kg^{-1})	317	165
Available P (mg kg^{-1})	42.2	4.87
Available K (mg kg^{-1})	382	391

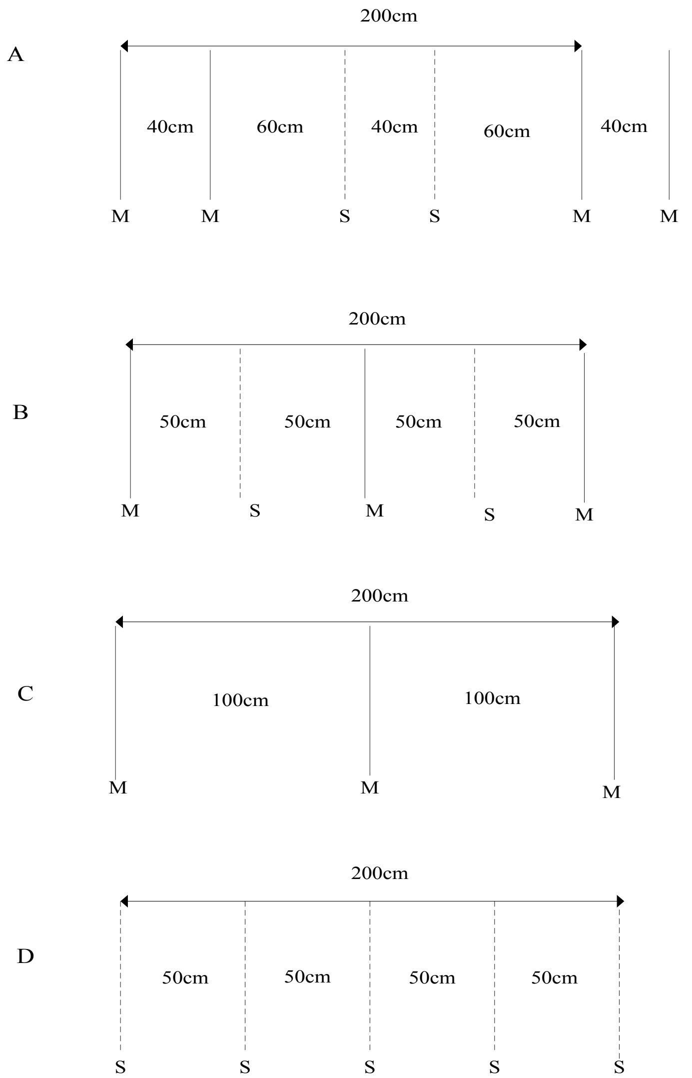

Figure 1: Layout of the row ratios for the maize-soybean relay strip intercropping systems. The maize and soybean had different row distance. A represents maize-soybean relay strip intercropping, B represents maize-soybean traditional intercropping, C represents maize monoculture. D represents soybean monoculture, respectively, while M and S denote the maize and soybean rows, respectively

Competition indices and monetary advantages

Grain yield and system productivity index

Crops in 2 m × 5 m quadrat of each plot were harvested after physiological maturity. Grain yield of each plot was individually sampled and weighted. Maize and soybean grains were naturally dried until water content was lower than 15%, before the determination of the grain yields.

System productivity index (SPI) was calculated as [18]:

$$SPI = \left(\frac{SA}{LB} \times Lb \right) + Sa \qquad (1)$$

Where SPI means System productivity index, SA and LB are the yield of maize and soybean in sole cropping, Sa and Lb are the yield of maize and soybean in intercropping.

Land equivalent ratio

Land equivalent ratio (LER) was estimated as the sum of the yield of the component crops in the intercrop relative to their sole reference crops [19]. Land equivalent ratio (LER) was calculated as follows [20]:

$$LER = \left(LER_{maize} + LER_{soybean}\right) = \left\{\left(\frac{Y_{im}}{Y_{sm}}\right) + \left(\frac{Y_{is}}{Y_{ss}}\right)\right\} \quad (2)$$

LER_{maize} and $LER_{soybean}$ were the partial LER of maize and soybean, respectively. Where Y_{sm} and Y_{im} were grain yield of sole and intercropped maize (mg ha^{-1}), respectively and Y_{ss} and Y_{is} were grain yield of sole and intercropped soybean (mg ha^{-1}), respectively.

Competitive ratio

The competitive ratio (CR) is an index which gives a more desirable competitive ability for the crops [21]. CR gives a better measurement of competitive ability of the crops and also is more advantageous. The CR is calculated according to the following formula:

$$CR_m = \left(\frac{LER_{maize}}{LER_{soybean}}\right)\left(\frac{Z_{is}}{Z_{im}}\right) \quad (3)$$

$$CR_s = \left(\frac{LER_{soybean}}{LER_{maize}}\right)\left(\frac{Z_{im}}{Z_{is}}\right) \quad (4)$$

If CR_m<1, there is a positive benefit and the crop can be grown in association; if CR_m>1, there is negative benefit. The reverse is true for CRs. Z_{im} was the sown proportion of maize and Z_{is} was the sown proportion of soybean in intercropping.

Aggressivity

Aggressivity (A) measures the interspecies competition in intercropping by relating the yield changes of the two component crops [22]. This index is derived from the equation:

$$A_m = \left(\frac{Y_{im}}{Y_m Z_{im}}\right) - \left(\frac{Y_{is}}{Y_s Z_{is}}\right) \quad (5)$$

$$A_s = \left(\frac{Y_{is}}{Y_s Z_{is}}\right) - \left(\frac{Y_{im}}{Y_m Z_{im}}\right) \quad (6)$$

if A_m=0, both crops are equally competitive; if A_{ms} is positive, the maize is dominant; if A_s is positive, the soybean is the dominated species.

Relative crowding coefficient

The relative crowding coefficient (K), a measure of the aggressiveness of one species towards another was calculated following [23,24] as follows:

Crowding coefficient of maize $K_m = \frac{Y_{im} \times Z_{is}}{(Y_m - Y_{im}) \times Z_{im}}$ (7)

Crowding coefficient of soybean $K_s = \frac{Y_{is} \times Z_{im}}{(Y_s - Y_{is}) \times Z_{is}}$ (8)

where Y_m and Y_s were yield of sole maize and sole soybean, respectively, Y_{im} and Y_{is} were yield of intercropped maize and intercropped soybean, respectively.

Actual yield loss

The partial actual yield losses, AYL_{maize} or $AYL_{soybean}$ represent the relative decrease of yield per sowing proportion in intercropping of maize and soybean compared to corresponding yields in sole crops [25]. The AYL is calculated according as follows:

$$AYL = AYL_{maize} + AYL_{soybean} \quad (9)$$

$$AYL_{maize} = \left\{ \left[\left(\frac{Y_{im}/Z_{im}}{Y_m/Z_{mm}} \right) \right] - 1 \right\} \quad (10)$$

$$AYL_{soybean} = \left\{ \left[\frac{Y_{is}/Z_{is}}{Y_s/Z_{ss}} \right] - 1 \right\} \quad (11)$$

Positive AYL indicates an intercropping advantage; negative AYL indicates disadvantage in intercropping system.

Economic indices

The monetary advantage index (MAI) was calculated since none of the above competition indices provides any information on the economic advantage of the intercropping system. The calculation of MAI was as follows:

$$MAI = \frac{(\text{value of combined intercrops}) \times (\text{LER-1})}{\text{LER}} \quad (12)$$

MAI value indicates the profit of the cropping system and IA contributing in the intercropping advantage of system [26]. Additionally, intercropping advantage (IA) was calculated as:

$$IA_{maize} = AYL_{maize} \times P_{maize} \quad (13)$$

$$IA_{soybean} = AYL_{soybean} \times P_{soybean} \quad (14)$$

where P_{maize} is the commercial value of maize (the current price is €153.27 per Mg) and $P_{soybean}$ is the commercial value of soybean (the current price is €378.35 per Mg).

Statistical analysis

Data were analyzed by one-way ANOVA of SPSS (version 15, Chicago, IL, USA). The ANOVA was performed by using a randomized block design with 9 treatments replicated three times. Treatment mean differences were separated and tested by post hoc comparisons using Student-Newman-Kuels (SNK) test significant difference (LSD) at P=0.05 significance level. Because the analysis of variance indicated no treatment × experimental time interaction, the values were reported as means of the two growing seasons.

RESULTS

Grain yield and system productivity index (SPI)

The grain yields of both maize and soybean were higher in sole crops than the intercrop in two locations (Table 3). In intercropping, the highest grain yield of maize was obtained in 1M:1S row ratio, but no significant difference compared with 2M:2S row ratio. The highest grain yield of soybean was 1.685 and 1.645 mg ha^{-1} occurred in 2M: 2S row ratio at Ya'an and Lezhi, respectively. Compared with sole crop, the mean reduction in grain yield of soybean was 19.7% in 2M:2S row ratio, and 59.81% in 1M:1S row ratio. The value of SPI in 2M:2S row ratio was higher by 22.23% and 18.04% than 1M:1S at Ya'an and Lezhi during two growing seasons, respectively.

Land equivalent ratio (LER) and relative crowding coefficient (K)

The values of LER and K in different row ratios were presented in Table 4. The partial LER values of maize (LER_{maize}) were higher than 0.5 in 2M:2S and 1M:1S row ratio. LER_{maize} was no significant difference in 2M:2S and 1M:1S row ratio. The partial LER value of soybean ($LER_{soybean}$) was more than 0.5 in 2M:2S row ratio, and less than 0.5 in 1M:1S row ratio. The LER values were more than 1.0 in 2M:2S and 1M:1S row ratio. The maximum LER value was 1.85 and 1.52 occurred in 2M:2S row ratio at Ya'an and Lezhi, respectively. The partial K values of maize (K_{maize}) were greater than 1.0 in all row ratios. While the partial K value of soybean ($K_{soybean}$) was less than 1.0 in 1M:1S row ratio and more than 1.0 in 2 M:2S row ratio.

Table 3: Maize yield, soybean yield and System productivity index (SPI) for different treatments during two growing seasons. Different letters in the same line column indicated significant differences between treatments for maize and soybean at α=0.05

Year	Location	Treatment	Yield (mg ha^{-1})		SPI
			Maize	Soybean	
2012	Ya'an	2M:2S	7.959a	1.677b	14.60a
		1M:1S	7.911a	0.981c	11.80b
		Sole maize	7.990a	—	—
		Sole soybean	—	2.018a	—
	Lezhi	2M:2S	6.326a	1.628b	11.23a
		1M:1S	6.363a	0.963c	9.26b
		Sole maize	6.399a	—	—
		Sole soybean	—	2.125a	—
2013	Ya'an	2M:2S	6.851a	1.638a	14.27a
		1M:1S	7.203a	1.019b	11.82b
		Sole maize	7.631a	—	—
		Sole soybean	—	1.684a	—
	Lezhi	2M:2S	9.336a	1.475b	15.34a
		1M:1S	9.657a	0.886c	13.25b
		Sole maize	10.046a	—	—
		Sole soybean	—	2.480a	—

Table 4: The Land equivalent ratio (LER) and Relative crowding coefficient (K) of the maize and soybean based on different row ratios planting patterns. Different letters in the same line column indicated significant differences between treatments for maize and soybean at α=0.05. Subscript m represent maize, subscript s represent soybean

Year	Location	Treatment	LER_m	LER_s	LER	K_m	K_s	K
2012	Ya'an	2M:2S	1.00a	0.83a	1.83a	256.74	4.92	1262.63
		1M:1M	0.99a	0.49b	1.48b	100.14	0.95	94.73
	Lezhi	2M:2S	0.99a	0.77a	1.75a	86.66	3.28	283.86
		1M:1M	0.99a	0.45b	1.45b	176.75	0.83	146.48
2013	Ya'an	2M:2S	0.90a	0.97a	1.87a	8.78	35.61	312.76
		1M:1M	0.94a	0.61b	1.55b	16.83	1.53	25.79
	Lezhi	2M:2S	0.93a	0.59a	1.52a	13.15	1.47	19.3
		1M:1M	0.96a	0.36b	1.32b	24.83	0.56	13.8

Table 5: The aggressivity (A), competitive ratio (CR), and actual yield loss (AYL) of the maize and soybean based on different row ratios planting patterns. Subscript m represent maize, subscript s represent soybean

Year	Location	Treatment	A		CR		AYL		
			A_m	A_s	CR_m	CR_s	AYL_m	AYL_s	AYL
2012	Ya'an	2M:2S	0.33	-0.33	1.20	0.83	0.99	0.66	1.65
		1M:1M	1.01	-1.01	2.04	0.49	0.98	-0.03	0.95
	Lezhi	2M:2S	0.44	-0.44	1.29	0.77	0.98	0.53	1.51
		1M:1M	1.08	-1.08	2.19	0.46	0.99	-0.09	0.90
2013	Ya'an	2M:2S	0.15	-0.15	0.92	1.08	0.80	0.95	1.74
		1M:1M	0.68	-0.68	1.56	0.64	0.89	0.21	1.10
	Lezhi	2M:2S	0.67	-0.67	1.56	0.64	0.86	0.19	1.05
		1M:1M	1.21	-1.21	2.69	0.37	0.92	-0.29	0.64

Aggressivity (A), competitive ratio (CR) and actual yield loss (AYL)

The values of A, CR and AYL in different row ratios were presented in Table 5. The values of A_{maize} were positive in 2M: 2S and 1M:1S row ratio. We found that the intercropped maize had a greater CR_{maize} compared with intercropped soybean

Table 6: The IA and MAI of the maize and soybean based on different row ratios planting patterns. Subscript m represent maize, subscript s represent soybean

Year	Location	Treatment	IA			MAI
			IA_m	IA_s	IA	
2012	Ya'an	2M:2S	152.08	250.48	402.56	1854.37
		1M:1M	150.24	-10.5	139.74	1583.68
	Lezhi	2M:2S	39.76	118.39	158.15	1585.54
		1M:1M	40.89	-84.52	-43.63	1339.61
2013	Ya'an	2M:2S	121.94	357.68	479.62	1669.79
		1M:1M	136.08	79.53	215.61	1489.54
	Lezhi	2M:2S	131.61	71.7	203.31	1988.99
		1M:1M	141.4	-108.01	33.39	1815.35

in 2M:2S and 1M:1S row ratio. The values of CR_{maize} were greater than 1.0 in 2M:2S and 1M:1S row ratio, however, the values of $CR_{soybean}$ were less than 1.0 and the maximum value of $CR_{soybean}$ was 0.96 and 0.71 occurred in 2M:2S row ratio at Ya'an and Lezhi during the two growing seasons, respectively. Furthermore, the values of AYL_{maize} were positive in 2M:2S and 1M:1S row ratio, the maximum values of $AYL_{soybean}$ and AYL_{maize} were obtained in 2M:2S row ratio.

Monetary advantage index (MAI) and intercropping advantage (IA)

The values of MAI and IA in different row ratios were shown in Table 6. The value of MAI in 2M:2S row ratio was higher than that in 1M:1S, the maximum value of MAI was 1762.08 and 1787.27 occurred in 2M:2S row ratio at Ya'an and Lezhi, respectively. The values of IA_{maize} were always positive, showing that maize had an advantage in intercropping. The value of $IA_{soybean}$ in 1M:1S row ratio was negative, however, in 2M:2S row ratio had an opposite result. The values of $IA_{soybean}$ and IA were higher in 2M:2S row ratio than that in 1M:1S. The maximum value of $IA_{soybean}$ and IA_{maize} were 199.56 and 310.91 at Ya'an and Lezhi during the two growing seasons.

DISCUSSION

Yield, land equivalent ratio (LER) and system productivity index (SPI)

Grain yield for both maize and soybean in relay strip intercropping were higher than that in sole cropping (Table 3). Previous studies had reported that cereal/legume intercropping system could achieved an enhanced biomass and yield over corresponding sole cropping [27,28]. However, the performance of cereal and legume intercropping was influenced by planting patterns [29,30]. In our research, the grain yield of maize was no significant difference in 2M:2S and 1M:1S row ratios. The grain yield of intercropped maize could be improved which resulted from positive effects of the border row of intercropped maize in 2M:2S, however, the border effect was offset during to intra-competition in narrow row of maize. Therefore, the maize grain yield was not influenced by row ratios of maize and soybean. However, the grain yields of intercropped soybean in 2M:2S is higher than that in 1M:1S row ratio. This indicated that the interspecific competition in 2M:2S was weaker than that in 1M:1S row ratio, which led to the improving grain yield of intercropped soybean. During two growing seasons, the values of LER were above 1 in 2M:2S and 1M:1S row ratios, which suggested a yield advantage and substantially higher land-use efficiency compared with maize or soybean monoculture [31]. Furthermore, the maximum LER was obtained in 2M:2S row ratio. The maximum LER was caused by the higher photosynthetic active radiation intensity and border effect with the increasing row distance between maize and soybean. This result implied that 2M:2S row ratio planting pattern achieved a higher yield advantage than 1M: 1S row ratio during to the increasing yield of intercropped soybean. Similarly, the maximum value of SPI was obtained in 2M:2S row ratio. This result implied a relatively stable productivity. Recently, some studies also demonstrated that intercropping of maize with soybean had a potential for increasing biomass yields [32,33], our findings were consistent with those results.

Competition indices

The yield of an intercropping system was positively associated with the competitiveness of the components crops [34]. Plant ecologists defined interspecific competition as an interaction between two species that could reduce the fitness of one or both of them [35]. The interspecific interactions intensity occurred at the interface of the border row of each species strip between two intercropped species [36] and the interspecific competitiveness played an important role in determining the species yields in intercropping system [37]. In generally, the dominant species or superior competitor with a stronger competitiveness resulted in a greater capacity to acquire resources and occupy the superior ecological niche [38]. The productivity of the dominant species directly influenced the apparent performance of the intercropping communities [39,40]. Therefore, the behavior of interspecific competition was an important factor for the structural stability of the intercropping agro-ecosystem.

In our study, the CR value of intercropped soybean was lower than maize and the CR value of intercropped maize in 2M:2S row ratio was lower than that in 1M:1S row ratio because of the narrow row spacing of maize, this result was consistent with the West's and Wahla's results [41,42]. The CR value of intercropped soybean in 2M:2S row ratio was higher than that in 1M:1S row ratio because of the increasing row distance between maize and soybean. Meanwhile, the K_{maize} was increased with the maize rows increasing (from one row to two rows) which affected by the intraspecific competition, however, the value of K_{maize} was not affected by interspecific competition as a dominate crop. The same trend was also observed in $K_{soybean}$ which increased with the increasing row distance between maize and soybean (the row ratio from 1M:1S to 2M:2S). This finding indicated that the interspecific competition was reduced with the increasing row distance between maize and soybean and the competitive ability of intercropped soybean was improved. The maximum value of K was observed in 2M:2S row ratio, which indicated a yield advantage as the row distance between maize and soybean from 50 cm (1M:1S) to 60 cm (2M:2S). This research found that the result of A was consistent with the result of CR. The value of A_{maize} in 2M:2S row ratio was lower than that in 1M:1S row ratio, the value of $A_{soybean}$ in 2M:2S row ratio was higher than that in 1M:1S row ratio. As the row ratio from 1M:1S to 2M:2S, the row distance between maize and soybean increased, and the row distance of maize reduced. The results suggested that competitive ability of maize decreased and soybean increased.

A similar trend was also observed in AYL. The value of AYL_{maize} had no significant difference in 2M:2S and 1M:1S row ratios, because the border effect of maize in 2M:2S row ratio offset the yield loss which caused by intraspecific competition. Oppositely, the value of $AYL_{soybean}$ was positive in 2M:2S row ratio, which has shown a yield advantage of intercropped soybean with the increasing row distance between maize and soybean. The values of MAI were positive in 2M:2S and 1M:1S row ratios, which shown a yield and economic advantages in maize-soybean relay strip intercropping systems. The value of MAI was increased as the row ratio increased from 1M:1S to 2M:2S. The maximum MAI was obtained in 2M:2S row ratio during two growing seasons that was 1774.67. The value of IA was also an indicator of the economic feasibility of intercropping systems. In this research, the maximum IA_{total} was 310.9, appeared at 2M:2S row ratio during two growing seasons. The maximum values of MAI and IA were observed in 2M: 2S row ratio indicated that this intercropping system had a highest economic advantage compared with 1M:1S. These results were also in agreement with the results of LER and the other competition indices. Similarly, Ghosh found that a significant economic benefit expressed when the LER was higher, in this condition; the higher value of MAI was also obtained [26].

CONCLUSION

Different row ratios planting patterns significantly affected the grain yield of intercrops in the maize-soybean relay strip intercropping system. With increasing row ratios, the grain yield of intercropped maize was no significant difference. The yield of intercropped soybean increased with increasing row ratio from 1M:1S to 2M:2S.

The values of CR, A and K clearly indicated that the row ratios of maize and soybean influenced the competitive ability of intercrops. When the row ratio of maize and soybean changed from 1M:1S to 2M:2S (the row distance between maize and soybean from 50 cm to 60 cm), the photosynthetic active radiation intensity of the soybean canopy improved and interspecific competition reduced that resulted in the $CR_{soybean}$, $K_{soybean}$ and $A_{soybean}$ values of intercropped soybean increased. With increasing the row ratio of maize and soybean, the intra-specific competition which caused by the narrow row distance of maize led to the values of CR_{maize} and A_{maize} decreased, the value of K_{maize} increased.

In all row ratios planting patterns, the 2M:2S row ratio was the most profitable and had the highest yield advantage based on LER and economic benefits. Therefore, the highest yield of the 2M:2S row ratio in maize-soybean relay strip intercropping system can be attributed to the improved utilization of growth resources by the intercrop coordinates.

AKNOWLEDGEMENT

This investigation was funded by the National Key Research and Development Program of China (grant numbers 2016YFD0300209, 2016YFD0300602), the National Natural Science Foundation (grant number 31571615), and Program on Industrial Technology System of National Soybean (grant number CARS-04-PS19).

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