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## Evaluation of Competition in Corn (*Zea mays* L.) and Pumpkinseed (*Cucurbita pepo* var. *styriaca*) Intercropping by Reciprocal Yield Model and Some Competitive Indices

\*<sup>1,2</sup>M. Khoramivafa, <sup>2</sup>S. Zehtab Salmasi, <sup>1</sup>A. Dabbagh Mohammadi Nassab,  
<sup>1</sup>A. Javanshir and <sup>1</sup>A. Mohammadi Shuti

<sup>1</sup>Department of Agronomy and Plant Breeding,  
Faculty of Agriculture, Tabriz University, Tabriz, Iran

<sup>2</sup>Razi University, Iran

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**Abstract:** In order to evaluate the intra- and inter specific competition of corn (*Zea mays* L.) and pumpkinseed (*Cucurbita pepo* var. *styriaca*) by reciprocal yield model, two years field experiments were conducted at the research station of faculty of Agriculture, University of Razi, Kermanshah, Iran, in 2003-2004. The experiments laid out as factorial based on randomized complete block design. The interspecific competition of corn on pumpkinseed was greater than that of Pumpkinseed's on corn. Corn Intraspecific competition in second year was greater than that first year; due to delay in planting date. According to relative competitive effects, intraspecific competition affected corn plants less than pumpkinseed plants.

**Key words:** Competition, reciprocal yield model, corn, pumpkinseed, niche differentiation, relative competition

### INTRODUCTION

Yield advantage of crop mixture occur when the component crops are in complementarily with each other, resulting in more effective utilize of environmental resources, such as light, nutrients and water, compared with when grow alone. Understanding the interference between components crops is important in understanding yield advantages associated with intercropping.

In crop association exist three types of competition; include competition between organs of plant known as intraplant competition, competition between plants of one species named as intra-specific competition and interference of different species called as interspecific competition (Park *et al.*, 2002).

Varieties of experimental design and statistical analysis have been used to study of competition in crop mixture, such as replacement and additive series and neighborhood design. These experiments emphasis on three factors, include plant density, spatial arrangement and proportion of plant species (Freckleton and Watkinson, 2001).

The relationship between yield and crop components densities can be described by reciprocal yield model, which is one of the most authentic competition analysis

methods. This model could be evaluate both inter- and intra specific competition of intercropped species (Spitters *et al.*, 1989).

The main objective of this experiment was investigation of the inter-and intra-specific competition of corn and pumpkinseed.

### MATERIAL AND METHODS

Two years field experiment carried out during 2003 and 2004 growing seasons at the Research Station of Faculty of Agriculture, Razi University, Kermanshah, Iran.

Mean annual temperature and precipitation in 2003 and 2004 ranged from 15 to 20°C and 380 to 420 mm, respectively. The soil of field was clay loam with 7.1 pH.

The experimental factors arranged as factorial based on randomized complete block design with three replications. Factors were pumpkinseed (*Cucurbita pepo* var. *styriaca* with 120-150 days growing period), densities at four levels (no pumpkinseed plant or corn sole cropped, one, two and three plants m<sup>-2</sup>) and corn (*Zea mays* L. var. 704, with 150-170 days growing period) plant densities at four levels (no corn plant or pumpkinseed sole cropped, five, six and seven plants m<sup>-2</sup>). Two species intercropped based on additive series. Each plot consists of six rows of

corn and three rows of pumpkinseed, with 4.5 m long. Inter-row spacing was 75 and 150 cm for corn and pumpkinseed, respectively. Intrarow spacing varied as shown in Table 1 to obtain considered densities.

Reciprocal yield models appointed as (Spitter 1983):

$$w_x^{-1} = \beta_{0x} + \beta_{xx}N_x + \beta_{xz}N_z \quad (1)$$

$$w_z^{-1} = \beta_{0z} + \beta_{zx}N_x + \beta_{zz}N_z \quad (2)$$

Where  $w_x$  and  $w_z$  are the mean yield or biomass per plant,  $N_x$  and  $N_z$  are the densities of x and z species, respectively.  $\beta_{0x}$  and  $\beta_{0z}$  yield or biomass of an isolated plant.  $\beta_{xx}$ ,  $\beta_{zz}$  are the intraspecific competition coefficient and  $\beta_{xz}$  and  $\beta_{zx}$  are the interspecific competition coefficient for x and z species, respectively.

The Relative Competitive Ability (RCA), of each species was calculated as (Spitters, 1983):

$$RCA_x = \beta_x/\beta_{xx} \text{ and } RCA_z = \beta_z/\beta_{zz} \quad (3)$$

$RCA_x$  is interpreted as 1 plant of species X and  $\beta_x/\beta_{xx}$  plants of species Z have an equal influence on the average weight per plant of species X.

Niche Differentiation Index (NDI) was been evaluated from the relative competitive abilities of each species as: (Woldeamlak *et al.*, 2001):

$$NDI = (\beta_x/\beta_{xx}) * (\beta_z/\beta_{zz}) \quad (4)$$

This index represents the ratio between intra- and interspecific competition. If NDI was greater than 1, there is niche differentiation indicating that the intraspecific competition exceeds interspecific competition. Therefore, component crops in the intercropping are sharing resources better than sole cropping and indicating that competition for the same resources is less (Woldeamlak *et al.*, 2001).

The Relative Yield (RY) was evaluated as (Woldeamlak *et al.*, 2001).

$$Ry_i = Y_{ij}/Y_{ii} \text{ and } RY_j = Y_{ji}/Y_{jj} \quad (5)$$

Where  $Y_{ii}$  and  $Y_{jj}$  are the yield of species i and j in monocropped and  $Y_{ij}$  and  $Y_{ji}$  are the yield of species i and j in intercropped, respectively.

Table 1: Density, intra-row spacing and plant per plot for corn and pumpkin seed

Species	Density	Plant (m <sup>-2</sup> )	Intrarow spacing	Plants per plot
Corn	Low	5	26	12.5×6
	Medium	6	22	15.0×6
	High	7	19	17.5×6
Pumpkinseed	Low	1	66	5.0×3
	Medium	2	44	10.0×3
	High	3	22	15.0×3

Relative competitive effect (RCE), was appointed as: (Roush *et al.*, 1989)

$$RCE_x = \beta_{xx}/\beta_x \text{ and } RCE_z = \beta_{zz}/\beta_z \quad (6)$$

Relative Crowding Coefficient (RCC) was obtained by: (Roush *et al.*, 1989)

$$RCC_{ij} = (Y_{ij}/Y_{ii})/(Y_{ji}/Y_{jj}) \quad (7)$$

If  $RCC_{ij} > 1$ , species i, is more competitive than species j.

## RESULTS AND DISCUSSION

In both years, interspecific competition coefficient (0.11-0.091) of corn on pumpkinseed, were larger than pumpkinseed's (0.000094-0.0003) on corn.

Consequently, corn was stronger competitor in both years. It may be due to superior corn growth ability and morphological (erect and large leaves) or physiological ( $C_4$  metabolism) attributes.

There is noticeable difference between pumpkinseed interspecific competition coefficient in two years, as it was 0.000094 and 0.0003 in 2003 and 2004, respectively. This difference demonstrates that pumpkinseed had severe competitive effects in second year, due to corn planting date postponement. Because of environmental conditions in second year, corn was planted 10 days later than first year. Corn was fainter competitor for pumpkinseed at second year (0.091 vs. 0.11).

Intraspecific competition coefficients of pumpkinseed were further more than corn's. Therefore, those coefficients were 220 and 128 times higher in first and second year, respectively. Because of pumpkinseed growth habit, like vine stem and span leaves, there was more competition between pumpkinseed plants.

Corn intraspecific coefficient in 2004 was 2.8 times higher than 2003. It can be resulted from later planting date (Norwood, 2001; Darby and Lower, 2002). Therefore, because of increasing of temperature, plants achieve maximum green area, rapidly. It was similar to corn and so intraspecific competition coefficient of corn in 2004 was 1.63 times higher than 2003.

The one plant of corn and 2.65 or 2.2 plants of pumpkinseed, showed equal competitive effects in 2003 and 2004, respectively. It is resulted that corn was stronger competitor than pumpkinseed, especially in 2003. Resource utilization efficiency of corn was 5.3 and 2.3 times more than pumpkinseed in years 2003 and 2004, respectively. It reflected the superior corn yield to pumpkinseed in both years. The component crops in mixture captured more resources and were utilizing

resources probably better than they did as sole crops, which means that the species were not only competing, but also were complementary for some of the resources during the growing season. Weakness of pumpkinseed competitive ability in comparison with corn, possible was due to morphology and form of pumpkinseed growth (such as vine and more leaves overlapping). Similarly, in barley and wheat mixture, RCA was higher for barley than that of wheat and barley intraspecific competition was higher than interspecific because of early maturing of barley (Woldeamlak *et al.*, 2001). In addition, the competitive ability of celery was about three times higher than of leek in intercropping of celery and leek (Baumann *et al.*, 2002).

In both years, NDIs were greater than one (1.325 and 2.2 in 2003 and 2004, respectively), therefore intercropping was more efficient in resources utilizing compared to sole cropping. It may be resulted from differences in morphological and physiological attributes of corn and pumpkinseed. Woldeamlak *et al.* (2001), demonstrated that NDI was greater than one in barley and wheat mixture, due to difference in crops height that it can help

to utilize resources at different times in a better way. Spitters (1983) denoted that species are limited by the same resources and overlapping of their niches, if it was close to one. Therefore, there was more niches overlapping between two species in 2003. Relative competitive ability of corn and pumpkinseed decreased and increased in the year of 2004, respectively. It probably caused by late corn planting date. In this year, while, RCA for pumpkinseed was superior to corn (1.96 vs 1.15), it is resulted that NDI was greater in 2004 compared to 2003. For the weed-free mixture of leek and celery, an NDI of 1.45, indicating a slight complementarity in capture and/or use of light for leek and celery (Baumann *et al.*, 2002).

The three-dimensional diagrams of reciprocal yield models demonstrate the effects of two plants species densities on plant reciprocal yield (Fig. 1 and 2). The rate of competition can be described by sheet slopes. So as more slopes followed by more competition (Pantone and Baker, 1991). On the other hand, sheet slopes show the rate of intraspecific competition, when it is into analogous species orientation and specify interspecific competition, when it is into contrary species orientation.

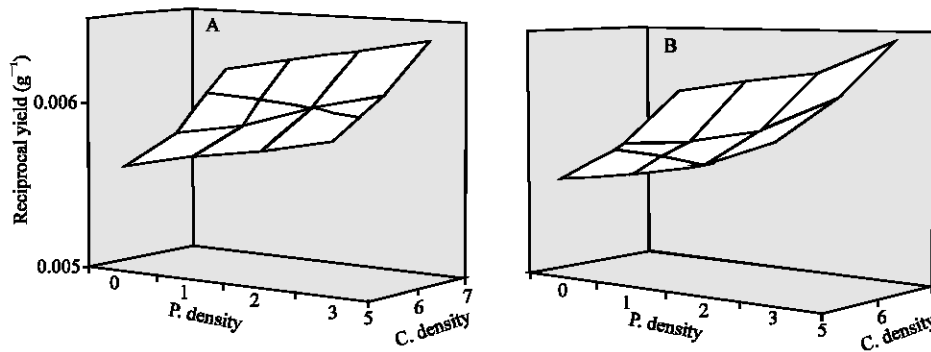


Fig. 1: Corn reciprocal yield related to corn (C) and pumpkinseed (P) densities (plant m<sup>-2</sup>) in 2003 (a) and 2004 (b)

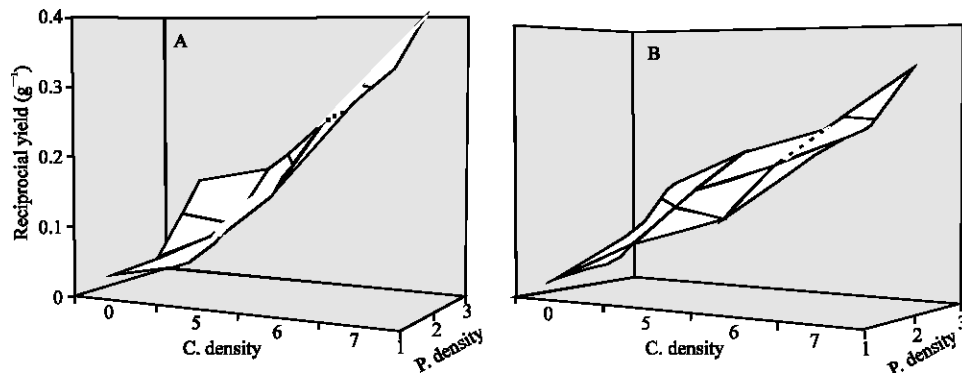


Fig. 2: Pumpkinseed reciprocal yield related to corn and pumpkinseed densities (plant m<sup>-2</sup>) in 2003 (a) and 2004 (b)

Table 2: Intra-and interspecific competition coefficients of corn and pumpkinseed at two years

Year	Crop species	Constants ( $W^{-1}$ )	Intraspecific competition coefficient	Interspecific competition coefficient	RCA <sub>i</sub>	NDI	RCE <sub>i</sub>
2003	Corn	0.005	0.00025	0.000094	2.65	1.325	440
	Pumpkinseed	-0.5756	0.055	0.11	0.5		0.0017
2004	Corn	0.00306	0.0007	0.0003	2.3	2.2	130.87
	Pumpkinseed	-0.4214	0.09	0.09161	0.98		0.0033

Abbreviation: RCE, RCA and i, show relative competitive effect, relative competitive ability and crop species respectively

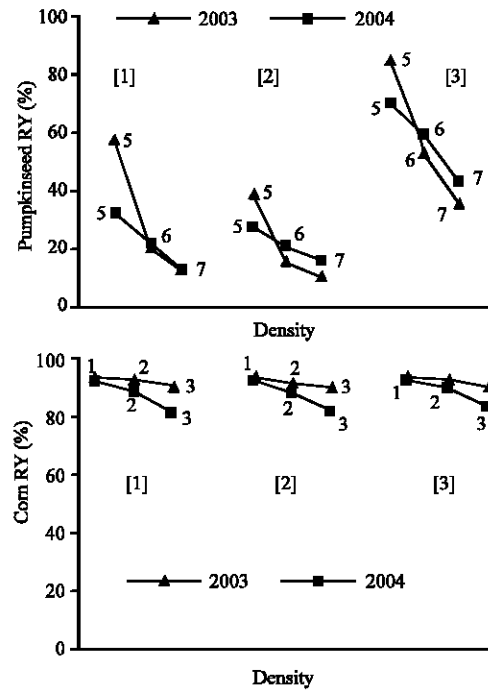


Fig. 3: Corn and pumpkinseed RY against other species density ( $\text{plant m}^{-2}$ ) in 2003 and 2004 (The numbers on lines illustrate corn (up) and pumpkinseed density (down) and in double brackets exemplify pumpkinseed (up) and corn (down) density)

The relative competitive effect of corn and pumpkinseed were 440 and 0.0017 in 2003 and 130.87 and 0.0033 in 2004, respectively (Table 2). Therefore, it is concluded that, corn plants had much more competitive effects on pumpkinseed. On the other hand, pumpkinseed plants showed high competitive effect on same stands and low effects on corn plants. In addition, it was guessed that, pumpkinseed plants had more intraspecific competition in 2004 (0.0017 vs. 0.0033) due to weakness of corn plants in competition with pumpkinseed (Table 2).

The relative yield ( $\text{RY} = \text{Intercropped yield/Sole yield}$ ), of corn declined by increasing pumpkinseed density. Whereas, it was sever in 2004 than 2003 (Fig. 3). There was a little difference for RY of corn between corn densities. When corn density increased the RY of pumpkinseed decreased in both years. The relative yield of pumpkinseed at high density ( $3 \text{ plants m}^{-2}$ ) was greater

Table 3: Relative crowding coefficient of corn and pumpkinseed in different plant densities at two years

		Years			
Density ( $\text{plant m}^{-2}$ )		2003		2004	
Corn	Pumpkin seed	RCC <sub>cp</sub>	RCC <sub>pc</sub>	RCC <sub>cp</sub>	RCC <sub>pc</sub>
5	1	1.68	0.593	2.99	0.334
5	2	2.43	0.409	3.40	0.293
5	3	1.12	0.892	1.22	0.814
6	1	4.50	0.222	4.34	0.229
6	2	5.73	0.174	4.43	0.225
6	3	1.76	0.568	1.44	0.692
7	1	8.17	0.122	7.40	0.134
7	2	8.19	0.121	5.75	0.173
7	3	2.64	0.377	2.02	0.494

than low densities (Fig. 3). Because of strong corn plants in 2003, the RY of pumpkinseed decreased severely, compared to 2004 (Fig. 3).

There was less RY value in pumpkinseed-compared corn in both years. It is imply that, corn had further competitive effects on pumpkinseed, especially at high corn density. However, pumpkinseed plants at higher density well tolerated competition pressure than low densities (Fig. 3).

At intercropping plots, the relative crowding coefficients of corn ( $\text{RCC}_{\text{cp}}$ ) and pumpkinseed ( $\text{RCC}_{\text{pc}}$ ) were greater and lower than one, respectively (Table 3). It is related to high competition ability of corn plants compared to pumpkinseed plants. The greatest mean value (average of two years) of  $\text{RCC}_{\text{cp}}$  (7.79) achieved by high corn density ( $7 \text{ plants m}^{-2}$ ) and low pumpkinseed density ( $1 \text{ plant m}^{-2}$ ). Intercropping of corn and pumpkinseed at combination of 5 and 3 plants per  $\text{m}^{-2}$ , respectively produced lowest mean value of  $\text{RCC}_{\text{cp}}$  (1.17).

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