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RESEARCH ARTICLE

Relationship between population competitive intensity and yield in maize cultivars

ZHAI Li-chao[1, 2*], **XIE Rui-zhi**[1*], **LI Shao-kun**[1], **FAN Pan-pan**[1]

[1] *Institute of Crop Sciences, Chinese Academy of Agricultural Sciences/Key Laboratory of Crop Physiology and Ecology, Ministry of Agriculture, Beijing 100081, P.R.China*

[2] *Center for Agricultural Resources Research, Institute of Genetics and Development Biology, Chinese Academy of Sciences, Shijiazhuang 050021, P.R.China*

Abstract

Competition is a common phenomenon in agriculture production. Research on the relationship between competitive ability and crop yield is extensive, but the results have been inconsistent. Few studies have focused on the relationship between population competitive intensity and yield of maize (*Zea mays* L.) cultivars. The main objective of this study was to determine if a consistent relationship exists between maize yield and competitive ability. A two-year field experiment was conducted, employing a de Wit replacement series design. When two maize cultivars were grown in a mixture, yield was reduced for the modern cultivar and increased for the older cultivar. In each replacement series, per plant level yield of each cultivar, and population level yield of the mixture, decreased with increasing proportion of the older cultivar. Competitive ratio (CR) reflected differences in competitive ability of the three maize cultivars. In each replacement series, population competition pressure (PCP) increased with increasing proportion of the older cultivar, indicating that the older cultivar was a strong competitor. Biomass yield, grain yield, harvest index, thousand-kernel weight, and kernel number per plant, were negatively correlated with PCP. Our results demonstrated that inter-cultivar competition affects maize productivity, and increasing PCP will decrease translocation of assimilates to grain and, ultimately, reduce yield. Therefore, there is a negative correlation between population competitive intensity and yield performance in maize, breeders should develop a communal ideotype that would not perform well in competition in future.

Keywords: maize, competition, competitive ability, population competitive pressure, yield

1. Introduction

Competition is a common phenomenon in nature. It is also an important factor in agriculture production. The effects of competition are widespread, and easily observed in crop mixtures. Competition is also known to affect recruitment, growth and reproduction of crop plants (Keddy 2012).

Numerous studies have focused on the relationship between competitive ability and crop grain yield, but the results have been inconsistent. Some studies have demonstrated

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Correspondence LI Shao-kun, Tel/Fax: +86-10-82108891, E-mail: lishaokun@caas.cn
[*] These authors contributed equally to this study.

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an inconsistent relationship between the yield of a cultivar in a mixture and its yield in monoculture (Christian *et al*. 1941; Sahai 1955). Dong *et al*. (2007) and Du *et al*. (2011) also found that the competitive ability of wheat (*Triticum aestivum* L.) cultivars is not necessarily correlated with its grain yield. However, Worthington and Reberg-Horton (2013) suggested that competitive cereal crops should be bred for weed suppression. Crop cultivars with strong weed competitiveness and high yield potential could be compatible (Garrity *et al*. 1992; Ni *et al*. 2000; Fischer *et al*. 2001; Gibson *et al*. 2003; Zhao *et al*. 2006). These results suggest that crop cultivars with strong competitive ability could also produce high yield under a weedy conditions.

In general, crops with higher competitive ability perform better in response to weed suppression (Jordan 1993). There is, however, a growing body of evidence indicating that crop yield is negatively correlated with its competitive ability (Fasoula 1990; Reynold *et al*. 1994; Lemerle *et al*. 2001; Murphy *et al*. 2008; Reid *et al*. 2009; Song *et al*. 2009; Fang *et al*. 2011). Snaydon (1984) and Zhang *et al*. (1999) reported a negative correlation between competitive ability and productive performance of wheat cultivars. Lemerle (2001) found that increased wheat competitive ability might be associated with decreased crop yield, and a study of 63 spring wheat cultivars showed that increased grain yield caused slight reductions in weed suppression over the past 150 years (Murphy *et al*. 2008). Vandeleur and Gill (2004) found that modern semi-dwarf wheat cultivars have low tolerance to weed competition and suffer greater yield losses from weed competition than older and lower yield potential cultivars. These studies above suggested that modern wheat cultivars with high yield potential are weak competitors. They reported a negative relationship between competitive ability and crop yield. In order to achieve a high yield, Donald (1968) agrued that plants in the crop community will compete with each other to a minimum degree, and suggested that a successful crop ideotype will be a weak competitor, relative to its mass.

Crop production is a process of population, the research on the relationship between competitive ability and yield should also be conducted at the populaiton level. However, all previous people measured the competitive ability of crop cultivars at individual level in inter-cultivar competition, but not at population level. Since the competitive ability of crop cultivars is measured according to competitive indices that are based on crop biomass yield or grain yield, our hypothesis is that competition may change the allocation of photosynthate, and a higher population competitive intensity would reduce crop yield. The main objectives of this study were to (1) identify the mixing effects of maize cultivars, and (2) to determine whether there is a relationship between population competitive intensity and yield, if so, how to elucidate that relationship.

2. Materials and method

2.1. Experiment site

Field experiments were conducted in two consecutive years: 7 May to 30 September, 2013 (Year 1) and 25 April to 30 September, 2014 (Year 2) at the Gongzhuling Experimental Station of the Chinese Academy of Agricultural Sciences (43°11´–44°9´N, 124°02´–125°18´E), which is located in a humid, continental monsoon climate in Gongzhuling County of Jilin Province, China. Spring maize is usually grown from late April to late September, under rainfed conditions and with ridge planting. The mean annual air temperature at the experimental station is 5.6°C, average annual precipitation is 594.8 mm, and the annual frost-free period is approximately 144 d. The soil type is chernozem, with 26.3 g kg^{-1} organic matter, 1.5 g kg^{-1} total N, 124.90 mg kg^{-1} available N, 28.52 mg kg^{-1} available P, and 184.47 mg kg^{-1} available K in the upper soil profile. The rainfall during the maize growing period was 553.9 mm in 2013 and 438.1 mm in 2014. The accumulated temperatures (≥10°C) were 3 188.5 in 2013 and 3 056.4 in 2014.

2.2. Plant materials

Three maize cultivars, released in different eras in China, were used for this study. Zhongdan 2 (ZD2) is a relative old maize cultivar very widely grown in northern China in the 1970s. Yedan 13 (YD13) was grown widely in China in the 1990s. Zhongdan 909 (ZD909), a modern maize cultivar released recently, is currently widely grown in China. All three cultivars were the most popular cultivars in their respective periods. The three maize cultivars differed in plant traits (Table 1), and were easily distinguished when grown in a mixture.

2.3. Experimental design

The experimental design was a de Wit replacement series design (de Wit 1960), which consists of a set of pure and mixed populations in which the combined density of the components is held constant. The proportion of each component ranges from 0 to 1. In this study, all cultivar pairs (YD13:ZD909, ZD2:ZD909, ZD2:YD13) were combined in the ratios of 0:6, 1:5, 2:4, 3:3, 4:2, 5:1, and 6:0, respectively. The 2:4, 3:3 and 4:2 treatments were grown at 1:2, 1:1 and 2:1 ratios, respectively. Seeds were sown manually at a plant density of 6.7 plants m^{-2} and row spacing was 65 cm, with a blank row between plots (Fig. 1). Plots were 6 m×7 m and there were three replicates. Manual sowing occurred on 7 May 2013 and 25 April 2014, at a rate of two seeds per hill, and plots were thinned to one plant per hill at the