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Research Article

Effects of Fertilizer Supply Ways on the Nitrogen use Efficiency and Yields Performance in Maize

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Abstract: This research aimed to find out the best fertilizer type and fertilization methods in local summer maize production. We analyzed the effects of three fertilizer supply ways on photosynthetic characteristics, nitrogen use efficiency and grain yield in summer maize. The results showed that the LAI, SPAD and nitrogen use efficiency of CRF (Controlled release fertilizer was applied as the basal application without top-dressing) were higher than CK (Compound fertilizer was applied as the basal application with urea as top-dressing). The grain yield of CRF was lower than CK and CF (Compound fertilizer was applied as the basal application without top-dressing). Treatment CK needed extra labor cost of topdressing and its process was complicated than CF and CRF. Treatment CF and CRF could simplified the cultivation of the summer maize. Compared with CF, the grain yield of CRF was more stable and the safety factor is higher. Therefore, the controlled release fertilizer had high safety factor and more stable grain yield. And it could improve photosynthetic characteristics and nitrogen use efficiency and effectively simplified the cultivation of the summer maize. The controlled release fertilizer was the best fertilizer type and fertilization methods in local summer maize production.

Keywords: Controlled release fertilizer, grain yield, nitrogen use efficiency, single fertilization, summer maize

INTRODUCTION

Summer maize is one of the most important grain crops in China and nitrogen is a most important factor affecting the grain yield of maize. However, the unreasonable use of nitrogen fertilizer has led to the nitrogen loss and the environment pollution (Díez *et al*., 1994; Liu *et al*., 2010). In recent years, more research on the mechanism and application methods of slow-released nitrogen fertilizer in maize production have been done. It has been found that controlled release fertilizer could significantly improve the grain yield of summer maize (Zhao *et al*., 2013; Wang *et al*., 2010; Zhao *et al*., 2008; Wang, 2013) and it could improve photosynthetic characteristics of summer maize than compound fertilizer (Zhao *et al*., 2013). It could improve the nitrogen use efficiency and decrease the risk of nitrate pollution (Wang *et al*., 2010; Wang, 2013; Zhang *et al*., 2012). As the controlled release fertilizer could effectively simplify the fertilizer application work during the whole maize growing season (Wang *et al*., 2010; Zhao *et al*., 2008), it has been more and more used in the farmer field. The aim of this research was to further investigate the effect of controlled release fertilizer on photosynthetic characteristics and nitrogen accumulation, especially on grain yield in summer maize in local summer maize production.

MATERIALS AND METHODS

Experiment materials: The field experiment was conducted in 2013 and 2014 in vertisol soil (Anonymous, 1998) at the Research Farm of Qingdao Agricultural University, Jiaozhou Experiment Station (36°15’52’’N, 120°01’41’’E), Qingdao, China. The soil at the experimental site was fluvo-acqui soil with a pH of 6.88; the organic matter concentration was 6.75 g/kg, the available nitrogen (N) was 84.00 mg/kg, the available phosphorus (P) was 69.25 mg/kg and the available potassium (K) was 86.82 mg/kg.

Experiment design: This experiment set of two fertilizer application level (Medium and High) and each fertilizer level had two fertilizer types in 2013 and three fertilizer types in 2014 (Table 1). All the fertilizers were supplied by Kingenta Ecological Engineering Group Co., Ltd. There were three replicates for each treatment. Each plots was 334 m^2. The plant density was 82500 plants/hm^2. Maize was sown on June 26, 2013 and June 17, 2014 and harvested on October 9, 2013 and October 8, 2014, The maize cultivar was

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Table 1: The treatments in this experiment

Year	Treatments codes	Fertilizer level	Treatments detail
2013	CK	M	Compound fertilizer (N-P_2O_5-K_2O: 18-12-10) was applied with 525 kg/hm^2 as the basal application with urea (46%) 235 kg/hm^2 as top-dressing
	CF	M	Compound fertilizer (N-P_2O_5-K_2O: 26-6-8) was applied with 750 kg/hm^2 as the basal application without top-dressing
	CRF	M	Controlled release fertilizer (N-P_2O_5-K_2O: 27-7-7) was applied with 750 kg/hm^2 as the basal application without top-dressing
	CRF	H	Controlled release fertilizer (N–P_2O_5–K_2O: 27-7-7) was applied with 900 kg/hm^2 as the basal application without top-dressing
2014	CK	M	Compound fertilizer (N-P_2O_5-K_2O: 25-4-6) was applied with 488 kg/hm^2 as the basal application with urea (46%) 131 kg/hm^2 as top-dressing
	CF	M	Compound fertilizer (N-P_2O_5-K_2O: 26-6-8) was applied with 675 kg/hm^2 as the basal application without top-dressing
	CRF	M	Controlled release fertilizer (N-P_2O_5-K_2O: 27-7-7) was applied with 675 kg/hm^2 as the basal application without top-dressing
	CK	H	Compound fertilizer (N-P_2O_5-K_2O: 25-4-6) was applied with 637 kg/hm^2 as the basal application with urea (46%) 180 kg/hm^2 as top-dressing
	CF	H	Compound fertilizer (N-P_2O_5-K_2O: 26-6-8) was applied with 900 kg/hm^2 as the basal application without top-dressing
	CRF	H	Controlled release fertilizer (N-P_2O_5-K_2O: 27-7-7) was applied with 900 kg/hm^2 as the basal application without top-dressing

CF: Compound Fertilizer CRF: Controlled Release Fertilizer

'Zhengdan' 958, which is popular in the local area. During the growing seasons of summer maize, a light irrigation was given on July 6 in 2013 and July 27, 2014 after planting and no additional irrigation was supplied for either year.

Measurement items and methods: The Leaf Area Index (LAI) and SPAD (SPAD-502, Japan) were measured at silking stage, dough stage and maturity stage. The harvested plants were partitioned into individual organs and all plant material was firstly dried at 105°C for half an hour and then dried at 75°C for 72 h. The dried plant samples were weighted and ground in a stainless steel mill and passed through a 0.25-mm sieve before analyzing the total nitrogen content. Grain yield and yield components were measured at maturity, the plants in the middle two zones of each plot were sampled to measure the total biomass and grain yield. Twenty ears were selected to determine the components of yield, such as number of kernel rows per ear, number of kernels per row and 100-kernel weight.

Statistical analysis: The data were analyzed using standard analysis of variance (ANOVA) (SAS Institute, 1996).

RESULTS AND ANALYSIS

Effects of different treatments on Leaf Area Index (LAI) after silking: At medium fertilizer supply in 2013, the LAI at each stage of treatment CRF was higher than CK and CF (Table 2). And the LAI of CRF increased with the increase of fertilizer supply. In 2014, there was no significant difference on the LAI between silking stage and dough stage. At maturity stage, the LAI of CRF was higher than CK and CF in two fertilizer supplies. And the LAI of CK, CF and CRF increased with the increase of fertilizer supplies at all growing stage.

Effects of different treatments on the SPAD of ear leaf after silking: In 2013, there was significant difference on the SPAD of ear leaf at silking and dough stage, there was no significant difference at maturity stage (Table 3). The SPAD of CRF was higher than those of both CK and CF with medium fertilizer supply. And the SPAD of CRF increased with the increase of fertilizer supply. In 2014, the SPAD of CRF was higher than that of CK with both two fertilizer supply. With the increase of the fertilizer supply, the SPAD of all treatments were increased.

Effects of different treatments on the nitrogen accumulation and the nitrogen use efficiency at maturity stage: In 2013, the nitrogen accumulation in the shoot and grain of CRF were both higher than those of CK and CF with medium fertilizer supply and the N accumulation in shoot and grain of CRF decreased with the increase of the fertilizer supply. The nitrogen use efficiency of CRF was lower, compared with CK and CF with medium fertilizer supply and the nitrogen use efficiency of CRF increased with the increase of the fertilizer supply.

In 2014, the nitrogen accumulation in shoot and grain of CRF were lower than CK and CF with two fertilizer supply levels. With the increase of the fertilizer supply, the nitrogen accumulation in shoot and in the grain of all treatments increased. The nitrogen use efficiency of CRF was higher than CK and CF at two fertilizer supply. With the increase of the fertilizer supply, the nitrogen use efficiency of all treatments decreased (Table 4).

Effects of different treatments on the grain yield and dry matter at maturity stage: In 2013, the yield of different treatments with medium fertilizer supply were in the sequence: CRF>CK>CF; the dry matter of different treatments with medium fertilizer supply were in the sequence: CF>CRF>CK. The yield and dry

Table 2: The Leaf Area Index (LAI) at different growing stage

			The Leaf Area Index (LAI)		
Time	Treatments	Fertilizer level	Silking stage	Dough stage	Maturity stage
2013	CK	M	5.53a	4.14a	2.24a
	CF	M	5.23a	3.87a	2.42a
	CRF	M	5.68a	4.45a	2.48a
	CRF	H	5.89a	4.49a	2.52a
2014	CK	M	5.31a	5.56a	2.49c
	CF	M	5.73a	5.93a	3.96ab
	CRF	M	5.43a	5.69a	3.09bc
	CK	H	5.78a	6.39a	4.34a
	CF	H	5.38a	6.41a	4.01ab
	CRF	H	5.91a	5.80a	4.26a

The different letters represents significant at p = 0.05. The same as below

Table 3: The SPAD at different growing stages

			SPAD value		
Time	Treatments	Fertilizer level	Silking stage	Dough stage	Maturity stage
2013	CK	M	49.83b	46.69b	33.78a
	CF	M	49.43b	48.34b	35.16a
	CRF	M	51.91a	48.56b	37.66a
	CRF	H	51.96a	53.53a	37.86a
2014	CK	M	50.23ab	49.02b	38.89c
	CF	M	50.23ab	53.09ab	46.89ab
	CRF	M	47.99b	52.20ab	44.18bc
	CK	H	49.90ab	53.00ab	50.91a
	CF	H	53.00ab	55.44a	48.09ab
	CRF	H	53.29a	54.39a	49.68ab

Table 4: The difference in nitrogen accumulation and the nitrogen use efficiency

			Nitrogen accumulation (g/plant)		Nitrogen use efficiency
Time	Treatments	Fertilizer level	Aboveground total N	Grain	(kg/kg)
2013	CK	M	2.78ab	1.49b	69.56a
	CF	M	2.63b	1.75b	64.56a
	CRF	M	3.74a	2.69a	56.15a
	CRF	H	3.58ab	2.53a	58.76a
2014	CK	M	2.73ab	1.46cd	59.27a
	CF	M	2.71ab	1.66bc	59.65a
	CRF	M	2.08 b	1.25d	59.52a
	CK	H	2.98 a	1.84ab	57.97a
	CF	H	3.26 a	2.02a	58.66a
	CRF	H	2.88 a	1.78ab	58.38a

Table 5: Effects of different treatments on yield and dry matter (kg/hm^2)

Time	Treatments	Fertilizer level	Grain yield	Dry matter
2013	CK	M	10019.30a	15869a
	CF	M	9352.300a	16272a
	CRF	M	10787.30a	16033a
	CRF	H	10300.90a	15058a
2014	CK	M	12206.30ab	20736b
	CF	M	12830.90a	26267a
	CRF	M	10790.90b	20135b
	CK	H	13249.60a	22245ab
	CF	H	12781.50a	23351ab
	CRF	H	12058.80ab	22974ab

Table 6: The cost details of different treatments (RMB hm^{-2})

Time	Treatments	Seeding	Seed	Pesticide	The cost of top-dressing	The cost of field management
2013	CK	600	450	480	450	340
	CF	600	450	480	——	340
	CRF	600	450	480	——	340
2014	CK	600	450	652	450	850
	CF	600	450	652	——	850
	CRF	600	450	652	——	850

Table 7: The economic benefit of different treatments (RMB hm^{-2})

			Cost				
Time	Treatments	Fertilizer level	Fertilizer	Other cost	Total	Output value	Benefit
2013	CK	M	2098	2320	4418	25048	20630
	CF	M	2175	1870	4045	23381	19336
	CRF	M	3300	1870	5170	26968	21798
	CRF	H	3960	1870	5830	25752	19922
2014	CK	M	2018	3002	5020	30516	25496
	CF	M	2430	2552	4982	32077	27095
	CRF	M	3038	2552	5590	26977	21387
	CK	H	2653	3002	5655	33124	27469
	CF	H	3240	2552	5792	31954	26162
	CRF	H	4050	2552	6602	30147	23545

In 2013, the price of compound fertilizer (N-P_2O_5-K_2O: 18-12-10) was 3.1 RMB/kg, the price of urea (46%) was 2 RMB/kg, the price of compound fertilizer (N-P_2O_5-K_2O: 26-6-8) was 2.9 RMB/kg, the controlled release fertilizer (N-P_2O_5-K_2O: 27-7-7) was 4.4 RMB/kg; In 2014, The price of compound fertilizer (N-P_2O_5-K_2O: 25-4-6) and compound fertilizer (N-P_2O_5-K_2O: 26-6-8) was 3.6 RMB/kg, the controlled release fertilizer (N-P_2O_5-K_2O: 27-7-7) was 4.5 RMB/kg. The other costs in Table 7 were the sum of Table 6. The price of summer maize was 2.5 RMB/kg

matter of CRF decreased with the increase of fertilizer supply. In 2014, the yield of different treatments at medium fertilizer supply was in the sequence: CF>CK>CRF, the yield of different treatments with high fertilizer supply was in the sequence: CK>CF>CRF; the dry matter of different treatments at medium fertilizer supply was in the sequence: CF>CK>CRF, the yield of different treatments at high fertilizer supply was in the sequence: CF>CRF>CK (Table 5).

Effects of different treatments on the cost and economic benefit: Contrast with CF and CRF, The CK fertilizer management needed some extra labor cost (Table 6). In 2013, the economic benefit of CRF at medium fertilizer supply was higher than those of CK and CF (Table 7). In 2014, the economic benefit of different treatments at medium fertilizer supply was in the sequence: CF>CK>CRF; the economic benefit of different treatments at high fertilizer supply was in the sequence: CK>CF>CRF.

DISCUSSION AND CONCLUSION

The results showed that different fertilizer supply ways had great influence on nitrogen use efficiency, grain yield and photosynthetic characteristics. We found that both LAI and SPAD of CK were lower than those of CF and CRF. The grain yield of CRF was higher than CK and CF in 2013, which was consistent with the report by Zhao *et al*. (2008, 2013). There was no much rainfall before silking stage in 2014, which prevented fertilizer shortage and nitrogen leaching, therefore the yield of CF at medium fertilizer supply in 2014 was higher than those of CK and CRF, this is consistent with the report by Yang *et al*. (2009). We found that the grain yield of CK was higher than those of CF and CRF with high fertilizer supply in 2014.

It was reported that surplus rainfall could cause the nitrogen loss in single fertilization supply way in summer maize (Cai *et al*., 2012; Gao *et al*., 2007). We found that the nitrogen use efficiency of CRF was lower than those of CK and CF in 2013, while was higher that the latter two treatments in 2014. It might be relate to the different weather between two years.

The Controlled Release Fertilizer (CRF) could effectively simplify the field management work of the summer maize (Wang *et al*., 2010; Zhao *et al*., 2008). Compared with CF and CRF, the fertilizer supply way CK needed some extra labor and time for the topdressing. Compared with CRF, the grain yield with CF fertilizer supply way was less stable.

On the whole, compare with the Ck and CF fertilizer supply way, CRF could effectively simplify field management work and stabilize the yield in maize., therefore, it could be recommend in this local area and medium fertilization supply would be suggested.

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