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Characteristics of Nutrient Accumulation and Efficiency in Maize under Different Agronomic Managements

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ABSTRACT

A four-year field experiment was conducted to understand the characters of nutrient accumulation and distribution in maize under different yield levels, so as to provide scientific guidance for effective utilization of mineral fertilizers, and eventually for high yield of spring maize. The grain yield, nutrient (nitrogen, phosphorous, potassium) accumulation and uptake efficiency were evaluated under different agronomic managements and nitrogen application treatments. The data showed that the two-year average grain yield under high Yield Management (HY) was significantly increased by 35.3% as compared with Traditional Farming management (FP). Interestingly, the increased range of grain yield may be associated with harvest ear numbers, indicating that high planting density could lead to high maize production. Moreover, the total amounts of nitrogen, phosphorous and potassium in maize significantly increased and the ratio of accumulation after flowering was also improved under HY management. Our results suggested that the high grain yield and nutrient use efficiency would ultimately be achieved through integrating and optimizing high yield cultivation techniques, which not only improve biomass and harvest index, but also promote the growth and nutrient accumulation of maize.

Keywords: Cultivation pattern, N level, Nutrition, Spring maize.

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INTRODUCTION

Maize is one of the most important crops in China. In 2010, the yield increase of maize contributed over 50% to the total crop yield increase in China. Nevertheless, with continued rapid growth of population and decreasing arable land, to increase crop yield per unit area is still in urgent need to meet the challenges of feeding such a large population. It is forecasted that the average annual yield increase should be 2% per unit area to guarantee China's food security in 2030 (Wang, 2005). Fertilizers, particularly N fertilizers, have played a key role in increasing maize production. Therefore, farmers are inclined to overuse fertilizers to achieve high yield (Guo *et al*., 2010). However, blindly applying large amounts of fertilizers could not only cause serious waste of resources, but also bring in environmental problems. The results based on 1,333 fields in China's main crop production area showed that the utilization rate of N, phosphates, and potash fertilizers of major crops including maize, rice, and wheat were all less than 30, 15, and 35%, respectively (Zhang *et al*., 2008). Such low utilization rate of fertilizers

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could not only result in the increase of agricultural cost, but also easily cause a series of bad environmental responses in rivers and lakes (Lv *et al*., 1998), air (Mosier and Zhu, 2000) and underground water (Zhang *et al*., 1996).

How to further improve crop yield and fertilizer efficiency is of great essential for agricultural production at present. Xue *et al.* (2010; 2011) analyzed the characteristics of the formation of rice yield and N fertilizer utilization rate under different agronomic management modes, and established the agronomic technical system which coordinated rice high yield with efficient utilization of nutrients. There are related reports about the researches directed for different agronomic practices and N fertilizer application methods for maize (Bender *et al.,* 2013; Tokatlidis and Koutroubas, 2004) and summer maize (Wang *et al*., 2011; Yang *et al*., 2010), as well as the wheat-maize rotation system (Zhang *et al*., 2011). In northeast spring maize zone of China, most researches were either focused on the super high yield cultivation technology for spring maize (Wang *et al*., 2004 and Chen *et al*., 2012), or focused on field nutrient management technology (Cai *et al*. 2012; Liu *et al*. 2011; Jin *et al.,* 2012). Currently, there are few reports about simultaneously improving maize yield and nutrient utilization rate through the integration and optimization of cultivation technologies. The cultivation technical mode yield with 12.7-13.5 ton.ha^{-1} is established in this research based on the growth law and local planting habit of spring maize in the middle region of northeast China (Ren *et al*. 2008; 2011). The present experiment was conducted to systematically evaluate the characters of nutrient accumulation and distribution in sprig maize under different yield levels in the middle part of northeast region based on monitoring yield of spring maize and nitrogen, phosphorus, and potassium absorption amount under different cultivation methods and N fertilizer application levels, so as to provide scientific basis for high yield of spring maize and high efficiency of nutrients uptake.

MATERIALS AND METHODS

Experimental Site

The experiment was started in 2006 on the experimental field of Jilin Academy of Agricultural Sciences, Gongzhuling City, Jilin Province (43° 29′ 55″ N, 124° 48′ 43″ E). The experimental field was in the maize continuous cultivation zone. The soil in the field was black soil and the 0-20 cm arable layer mainly contained 2.1% of organic matters, 111.8 mg kg^{-1} available nitrogen, 31.5 mg kg^{-1} readily available phosphorus, 185.9 mg kg^{-1} available potassium and pH value of 6.0. The precipitations during the growth period of maize in the years 2007-2010 were 310.3, 541.6, 319.4, and 628.2 mm, respectively.

Experimental Design

There were six nitrogen fertilizer rate treatments in the experiment. Among them, N0, N1, and N2 were adopted by the traditional farming management, N3, N4, and N5 were adopted by the high yield management (Table 1). There were four replicates in each treatment with the same plots since 2006 to 2010. The plots were 12.0 m long, with six rows spaced 0.7 m apart. The statistical design layout was randomized blocks with plat size area of 50 m^2. The maize hybrids sown were ZhengDan958 (ZD958) in 2007 and 2008, and XianYu335 (XY335) in 2009 and 2010. Sowing and harvesting dates were April 26th and September 28th (2007), April 27th and September 30th (2008), May 1st and September 28th (2009) and April 29th and September 27th (2010), respectively. The related details were as follows:

Traditional Farming Management (FP)

Target yield was 9-10 t ha^{-1}; local farmers' planting method; cleaning stubble

Table 1. Application rate and time of nitrogen fertilizer in different nitrogen treatments under two managements (kg ha^{-1}).

Management method [a]	N treatment	$N:P_2O_5:K_2O$				
		Before planting	Seeding	V6	VT	Total amount
FP	N0	0:100:90	0:0:0	0:0:0	0:0:0	0:100:90
	N1	60:100:90	0:0:0	120:0:0	0:0:0	180:100:90
	N2	50:100:90	0:0:0	100:0:0	50:0:0	200:100:90
HY	N3	0:100:90	0:0:0	0:0:0	0:0:0	0:100:90
	N4	110:67:72	20:33:18	110:0:0	80:0:0	320:100:90
	N5	150:67:72	20:33:18	130:0:0	100:0:0	400:100:90

[a] Under the HY management, the organic fertilizer, 8 t ha^{-1}, was applied as basal fertilizer with Mg, S, Mn, Zn, B, etc. and microelements, of which organic matter, total N, total P, and total K was 386.6, 16.6, 5.9, and 20.6 g kg^{-1}, respectively.

after harvest; without organic fertilizer; and the planting density was 50,000 plants ha^{-1}. The phosphate and potassium fertilizers were applied before planting as one time basal application.

High Yield Management (HY): Target yield was 13-14 t ha^{-1}; the subsoil tillage was performed with a subsoiling chisel plow in combination with inter tillage in mid-to-late June (V6 stage) with 30 cm depth. Maize stubble remaining in field; organic fertilizer (8 t ha^{-1}) was applied before planting with organic matter 386.6 g kg^{-1}, total N 16.6 g kg^{-1}, total P 5.9 g kg^{-1}, and total K 20.6 g kg^{-1}; the planting density was 70,000 plants ha^{-1}. Also, 67% of phosphate fertilizer and 80% of potassium fertilizer were applied before planting as basal fertilizers; 33% of phosphate fertilizer and 20% of potassium fertilizer were applied at planting as seed fertilizers. Besides, Mg, S, Mn, Zn, B, etc. were also applied before planting as basal application, with 40 kg Mg ha^{-1}, 15 kg Zn ha^{-1}, 8 kg Mn ha^{-1}, and 8 kg B ha^{-1}, respectively.

The amount of phosphate (P_2O_5) and potassium (K_2O) fertilizers were 100 and 90 kg ha^{-1} in both of the two kinds of cultivation methods. N fertilizer source was urea (46% N); phosphate fertilizer was applied as superphosphate (containing 12% P_2O_5), which was applied only to N0 and N3 treatments, and diammonium phosphate (N-P_2O_5-K_2O:18-46-0), which was applied to N1, N2, N4, and N5 treatments. Potassium fertilizer was applied as potassium chloride (contains 60% K_2O). Other management practices were the same as general fields including weeding, thinning, etc.

Measurement Methods of Different Parameters

The soil samples of 0-20 cm arable layers were collected before maize planting, and then standard methods were adopted to measure the nutrient in the soil. Three representative plants were selected in each plot during the five growth stages including six leaves with collars visible stage (V6), twelve leaves with collars visible stage (V12), silking stage (R1), filling stage (R3), and physiological maturity stage (R6). The leaves, stems (sheaths), grains, and ear axis of the plants were separated, dried and smashed to be used for measuring the concentrations of N, P and K. Among them, total nitrogen was determined by Kjeldahl method, total phosphorus was determined by Mo-Sb anti-spetrophotography method, and total potassium was determined by Flame photometer method (Bao, 2000). The grain yield was determined by harvesting the two central rows at mature stage, and calculated based on moisture content of 14%. Partial Factor Productivity was calculated as follows: *PFP (kg kg^{-1}) = Grain yield/N, P, K fertilizer rate.*

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Data Analysis

One-way analysis of variance in SAS 8.0 was used for data analysis. The means of treatments between the measured traits were compared using least significant difference at a significant level of 0.05. Microsoft Excel 2007 was adopted to process the data and make the drawings.

RESULTS

Grain Yield and Its Components

Compared with FP management treatment, the grain yields were remarkably increased under HY management (supplementary Tables 1 and 2). The grain yields under HY management were 16.3, 23.6, 35.2, and 35.3% higher than those of FP management in years 2007-2010, respectively. There were significant difference between nitrogen and without nitrogen for grain yield (p<0.05). Under FP management, there were no obvious differences on the yield between N1 and N2 treatments in the two years. Under HY management, the yields under N4 treatment in 2009 and 2010 were 4.4 and 13.4% higher than N5 treatment, respectively.

The yield differences between the two managements were mainly from harvested ear numbers. The harvested ear numbers under HY management in 2009 and 2010 were 41.5 and 67.9% higher than FP management, respectively. The variation range of the numbers of harvested plants and ears between nitrogen treatments under the same management was only between 0.7-4.6%. Under FP management, the numbers of ears in the treatment with nitrogen were 22.0 and 16.9% higher than in the treatment without nitrogen in two years; while the thousand-grain weights were 6.7 and 6.5% higher than the treatment without nitrogen. Under HY management, the numbers of ears in the treatment with nitrogen were 33.3 and 20.4% higher than the treatment without nitrogen in 2009 and 2010, respectively; while the thousand-grain weights were 0.9 and 6.4% higher than the treatment without nitrogen.

Growth Characteristics of Maize

The total above-ground weight of maize was small from the seeding stage to

Table 2. Grain yield and its components of maize in different nitrogen treatments under two managements. [a]

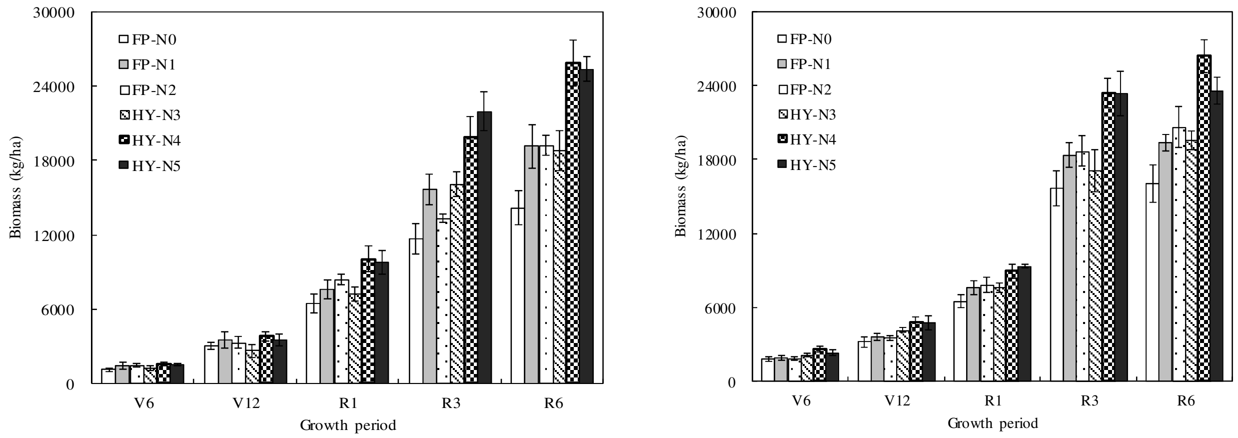
Year	Management method	N treatment	Grain yield (kg ha^{-1})	Plant number	Ear number	Kernel number	1000 kernel weight (g)
2009	FP	N0	6609 c	50279 b	45761 b	387.9 b	383.5 a
		N1	9530 b	50633 b	50093 b	478.3 a	398.9 a
		N2	9528 b	50426 b	48640 b	468.1 a	419.1 a
	HY	N3	9388 b	71691 a	67647 a	357.0 b	388.7 a
		N4	12931 a	72794 a	68658 a	476.0 a	395.7 a
		N5	12385 a	71875 a	68199 a	475.7 a	381.7 a
2010	FP	N0	8003 c	45285 b	45037 b	476.5 b	390.6 a
		N1	9477 b	44030 b	45257 b	550.7 a	414.3 a
		N2	10719 b	44751 b	45898 b	563.2 a	417.9 a
	HY	N3	10314 b	71150 a	74290 a	454.1 b	317.4 c
		N4	14790 a	72289 a	78313 a	553.0 a	342.4 b
		N5	13042 a	72475 a	76026 a	540.6 a	332.9 b

[a] Different letters mean significant differences among a whole column in six nitrogen treatments each year at 5% level.

elongation stage, only making up 6.1-19.7% of the R6 stage (Figure 1). The growth differences were very obvious after silking stage in the two managements. The average dry matter accumulation under HY management was 28.8% higher than under FP management. Under FP management, the biomass differences between nitrogen treatments mainly occurred after silking, but there were no obvious differences between N1 and N2 treatments. Under HY management, the biomass differences between nitrogen treatments were large even at V12 stage, and the biomass amount in N4 treatment was 2.0 and 12.1% higher than N5 treatment in 2009 and 2010, respectively, however, no significant differences were observed between the treatments.

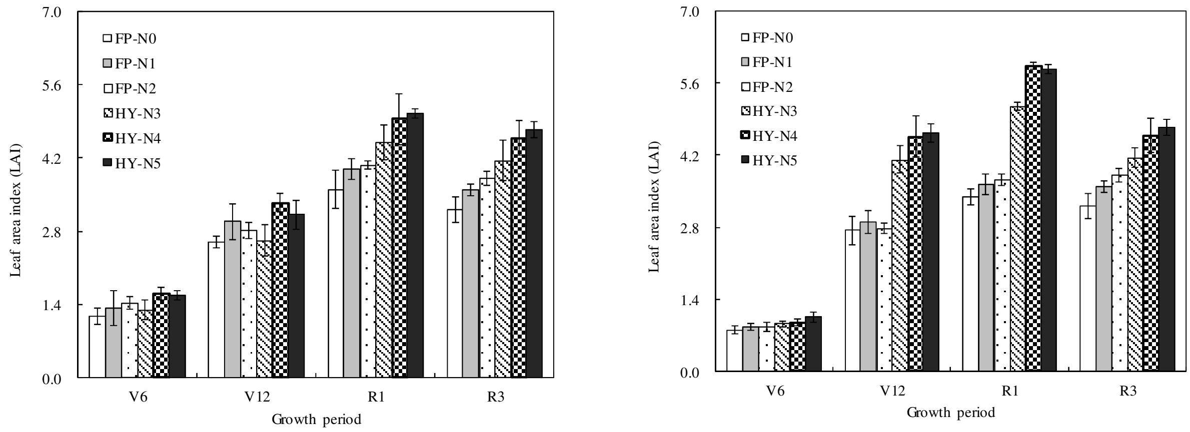
Dynamics of Characteristics of Leaf Area Index (LAI)

The LAI changed in unimodal curve during the growth progress under different treatments (Figure 2). It reached the highest value at R1 stage. LAI under HY management was significantly higher than under FP management, which was largely caused by the difference of planting density



(a) (b)

Figure 1. Dynamics of biomass in different management treatments [(A) 2009, (B) 2010].



(a) (b)

Figure 2. Dynamics of Leaf Area Index (LAI) in different management treatments [(A) 2009, (B) 2010].

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of the two cultivation methods. Under FP management, the differences between nitrogen treatments were mainly detected after silking; while there were no obvious differences between N1 and N2 treatments. However, the differences between nitrogen treatments were large even after V12 stage under HY management.

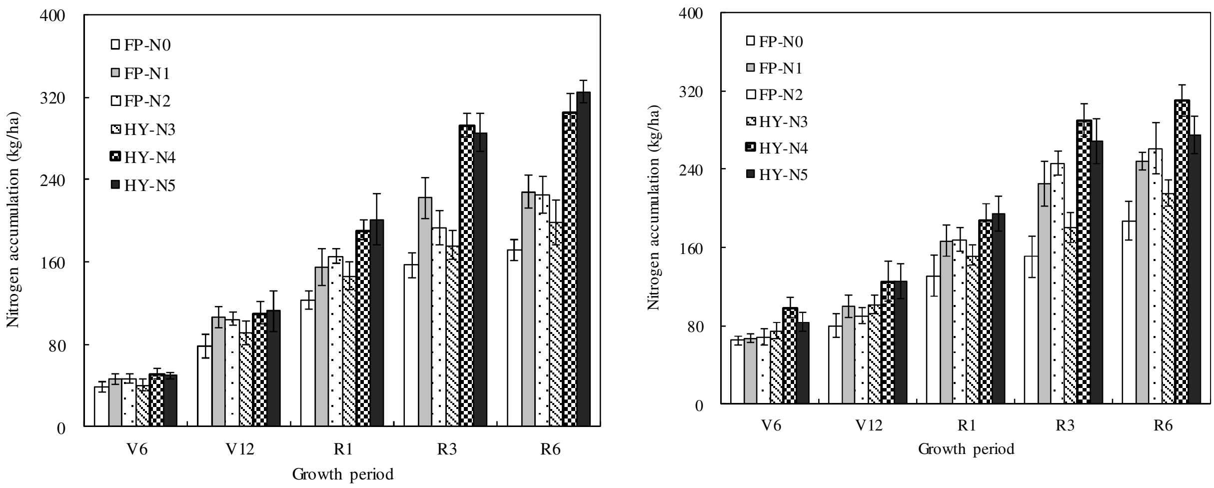
Characteristics of Nutrient Accumulation

Nitrogen Accumulation Characteristics

The accumulation of nitrogen and biomass basically followed the same trend during the plant growth process, however, the nitrogen uptake of maize had distinguished differences during the entire growth period under different managements. It was more apparent in 2010 than 2009 (Figure 3). The average total amount of nitrogen accumulation under HY management was 23.0% higher than under FP management. Under FP management, the total amount of nitrogen uptake between nitrogen treatments showed obvious differences since V6 stage period, except for the V6 stage, in 2010. The plant nitrogen uptake amount between nitrogen treatments started to show significant differences since V12 stage under HY management. And the plant nitrogen accumulation in N4 treatment was obviously higher than that in N5 treatment after R3 stage, in 2010.

Phosphorus Accumulation Characteristics

The plant's phosphorus accumulation characteristics were similar to nitrogen and biomass accumulations during the growth of the maize (Figure 4). The average phosphorus accumulation amount under HY management was 18.6% higher than under FP, in 2009 and 2010. The total amount of maize phosphorus absorption between nitrogen treatments started to show differences after silking under FP management. Nitrogen application obviously promoted the plant's absorption of phosphorus. The phosphorus accumulation amounts in the two nitrogen application treatments were 27.5-55.9% higher than in N0 treatment; while there were no obvious differences between N1 and N2 treatments.



(a) (b)

Figure 3. Dynamics of N accumulation in different management treatments [(a) 2009, (b) 2010].

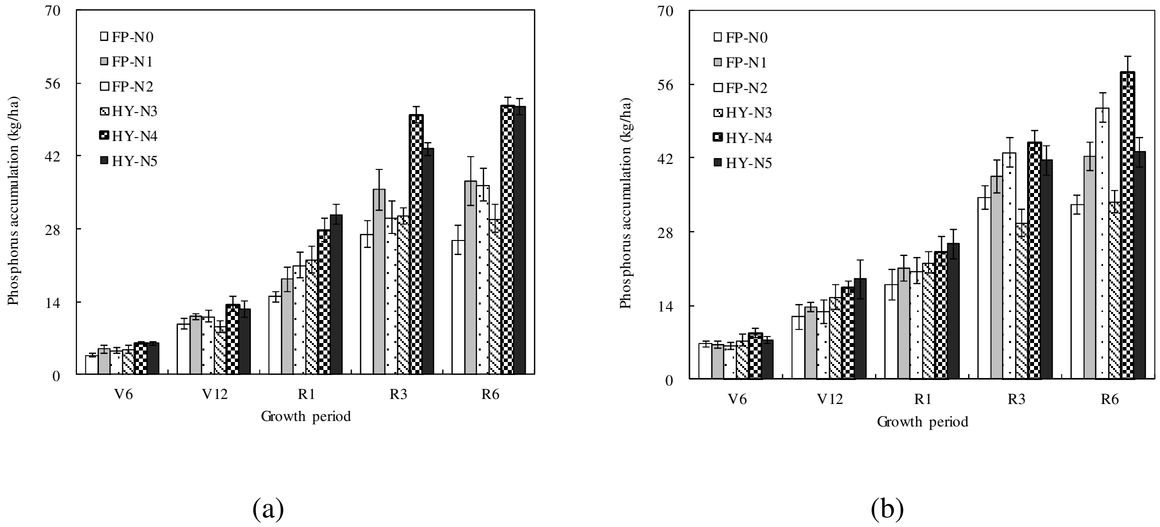


Figure 4. Dynamics of P accumulation in different management treatments [(a) 2009, (b) 2010].

Comparing HY with FP management, the differences of plant's phosphorus absorption amounts between nitrogen treatments were quite similar. However, 45.2-96.9% higher phosphorus accumulation were observed in N3 treatments.

Potassium Accumulation Characteristics

Plant's potassium accumulation, which was different from nitrogen and phosphorus accumulation, was another important parameter of nutrient accumulation. The potassium uptake amounts in different treatments showed unimodal curve changing along the growth progress and the peak value occurred at R3 stage, and then slightly decreased because of the aging and falling of the leaves in the later stages. HY management obviously facilitated plant's absorption of potassium. The potassium accumulations under HY management were 45.8 and 46.1% higher than under FP management in 2009 and 2010, respectively. Under FP management, plant's potassium accumulation was in linear increase with the growth progress, and it slightly increased from R1stage to R3 stage at an average rate of 5.3%. It started to show differences after R1 stage between nitrogen treatments. The amount of potassium accumulation in N1 and N2 treatments increased by 29.3-41.6% compared to the treatment without nitrogen application. The differences between nitrogen treatments under HY management were detected after the V12 stage, and the potassium accumulation amounts between nitrogen treatments increased by 26.4-49.8% compared to the N3 treatment.

Characteristics of Nutrient Accumulation in Grain

In generally, HY management obviously increased the accumulation amounts of N, P, and K nutrients in grain (Table 3). The N, P, K accumulation amounts under HY management were 28.1, 29.3, and 58.9% higher than under FP management in 2009, and 9.7, 2.0, 40.1% higher in 2010. Overall, the total accumulation amounts of N, P, and K nutrients decreased compared to that in 2009 for the reason that the precipitation in 2010 was higher, which promoted the crop's uptake of nutrients. The ratio of grain N, P, and K nutrients content in the gross amount of the plant under FP management was slightly higher than that under HY management with no significant differences.

Table 3. N, P, and K accumulation of grain in different nitrogen treatments under two managements.[a]

Year	Management method	N treatment	NA (kg ha^{-1})	NP (%)	PA (kg ha^{-1})	PP (%)	KA (kg ha^{-1})	KP (%)
2009	FP	N0	103.1 d	60.1 a	19.9 d	77.0 b	15.1 c	15.9 ab
		N1	151.2 b	66.3 a	29.6 c	79.7 b	22.5 b	17.0 a
		N2	147.9 b	65.7 a	28.4 c	77.9 b	22.5 b	18.5 a
	HY	N3	120.6 c	60.8 a	26.5 c	88.4 a	20.0 b	13.1 b
		N4	201.5 a	66.1 a	40.5 a	78.3 b	37.9 a	20.9 a
		N5	193.2 a	59.4 a	33.7 b	65.5 c	37.6 a	21.3 a
2010	FP	N0	116.9 c	62.6 b	29.6 b	89.4 a	16.8 b	16.0 a
		N1	174.1 a	70.3 a	36.7 b	86.9 a	17.3 b	12.3 b
		N2	192.9 a	73.8 a	43.1 a	83.5 a	22.5 b	16.7 a
	HY	N3	145.1 b	67.3 ab	30.1 b	89.4 a	30.4 a	19.2 a
		N4	200.3 a	64.6 b	45.1 a	77.2 a	27.9 a	13.7 b
		N5	185.5 a	67.6 ab	36.4 b	84.5 a	21.0 b	10.9 b

[a] Different letters mean significant differences among a whole column in six nitrogen treatments each year at 5% level. NA: Nitrogen Accumulation; NP: Nitrogen Percentage; PA: Phosphorous Accumulation; PP: Phosphorous Percentage; KA: Potassium Accumulation, KP: Potassium Percentage.

And the ranking of the elements was phosphorus> nitrogen> potassium.

Under the two managements, nitrogen application had obviously increased the accumulation of nitrogen in maize grain, and promoted grain's absorption of phosphorus and potassium. However, it had little effect on the ratio of all elements in grain. There were no obvious differences on N, P, and K accumulations between N1 and N2 treatments during the two years under FP management. Under HY management, the nitrogen accumulation amounts in N4 treatment were 4.3 and 8.0% higher than N5 treatment in 2009 and 2010, respectively; while phosphorus accumulations were 20.2 and 23.9% higher and potassium accumulations were 0.8 and 32.9% higher.

Partial Factor Productivity (PFP) of N, P, and K Fertilizer

Generally, the PFP of nitrogen fertilizer in N1 and N2 treatments under FP management was higher than N4 and N5 treatments under HY management, in 2009 and 2010. The PFP of nitrogen fertilizer in N1 treatment under HY management was the highest among the six N treatments in 2009, and there were no significant differences with that of N1 treatment in 2010 (Table 4). The PFP of phosphorus and potassium fertilizers under HY management were remarkably improved compared to FP management. There were little differences between N1 and N2 treatments for the PFP of N, P, and K fertilizers under FP management in 2009 and 2010. Furthermore, the PFP of N, P, and K in N4 treatment was significantly higher than N5 treatment under HY management in 2010.

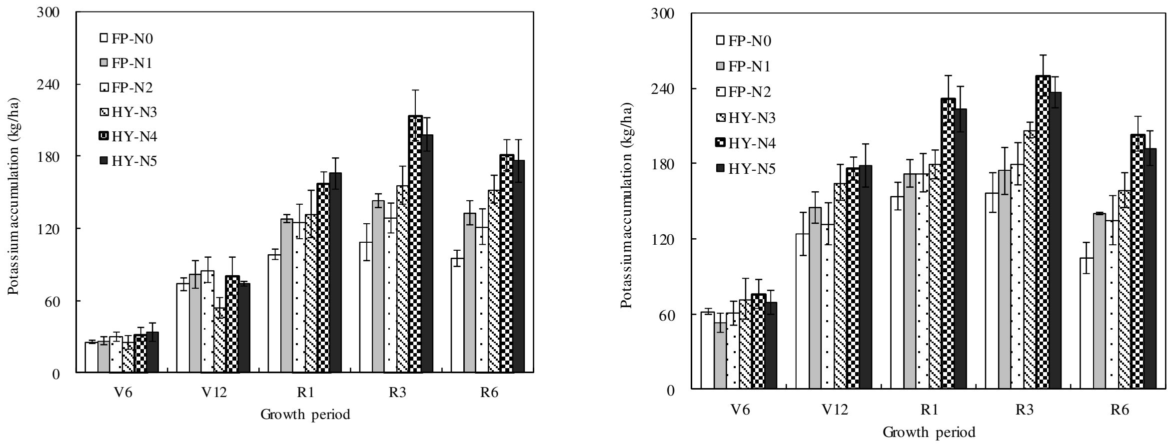
DISCUSSION

Increasing planting density and fertilizer input (especially N fertilizer) are still the main techniques for boosting crop's yield (Xue *et al.,* 2010; Chen *et al*., 2012). In this research, we found that the yield increase could reach as much as 56.1% under HY management compared to FP management. The yield increase is mainly ascribed to the increase of planting density (Duvick, 2005; Liu *et al*., 2010). Under the same agronomic management, the increased input of organic

Table 4. Partial Factor Productivity (PFP) from applied N, P, K fertilizer in different nitrogen treatments under two managements (kg kg^{-1}).[a]

Year	Management method	N treatment	N	P	K
2009	FP	N0	-	66.1 c	73.4 c
		N1	52.9 a	95.3 b	105.9 b
		N2	47.6 a	95.3 b	105.9 b
	HY	N3	-	93.4 b	104.3 b
		N4	40.4 b	129.3 a	143.7 a
		N5	31.0 b	123.8 a	137.6 a
2010	FP	N0	-	80.3 d	88.9 d
		N1	52.6 a	94.8 c	105.3 c
		N2	53.6 a	107.2 c	119.1 c
	HY	N3	-	103.1 c	114.6 c
		N4	46.2 a	147.9 a	164.3 a
		N5	32.6 b	130.4 b	144.9 b

[a] Different letters mean significant differences among a whole column in six nitrogen treatments each year at 5% level. *PFP (kg kg^{-1})= Grain yield/N, P, K fertilizer rate*. Just inorganic fertilizer was calculated for PFP under the HY management.



(a) (b)

Figure 5. Dynamics of K accumulation in different management treatments [(a) 2009, (b) 2010].

fertilizer and N fertilizer fosters the formation of young ear which further advances the grain numbers per ear and the grain weight (Lv *et al*., 2011). Therefore, increasing plant density is the essential key for boosting crop's yield. Meanwhile, crop's high yield and stable yield (Yin, 2000) can be further achieved through rational planting method (Liu *et al.,* 2009), application of organic fertilizer (Ren *et al*., 2008) and proper increase of N fertilizer based on the planting density (Chen *et al*., 2014).

With the development of hybrids and gradual increase of yield, the dry matter accumulation characteristics and nutrients accumulation of crop population have greatly changed (Hu *et al*., 1998a; Wang *et al*., 2005). Generally, the crop's biomass increases with the increase in planting density, but its harvest index decreases (Liu *et al*., 2010). In this research, the biomass under HY management was 28% higher than under FP management; the variation ranges of harvest indexes of the two years were 0.49 on average under FP management and 0.53 on average under HY management. It was a 4 percentage points higher than under FP management, and it did not decrease with the increase in planting density. This proved that crop's growth and development can be regulated through combining with the integration and optimization of various cultivation technologies after properly increasing the planting density (Jin *et al*., 2012). It can increase the harvest index (Hu *et al*., 1998b; Wang *et al*., 2005; Yang *et al*., 2010) while raising the biomass so as to obtain high yield (Xue *et al*., 2011, Song *et al*., 2003 and Li *et al*., 2007). It can improve the nitrogen remobilization efficiency and maintain a higher dry matter accumulation (Chen *et al*., 2014).

Meanwhile, modern maize hybrids with improved agronomic practices may have influenced the accumulation and distribution of nutrient (Bender *et al*., 2013; Tokatlidis and Koutroubas 2004). The plant's N, P, K accumulation amount under HY management were 23.3, 18.6 and 46.0% higher than under FP management, respectively, through monitoring the crop's dynamic change of nutrients absorption and nutrients accumulation characteristics under different managements. The differences of dry matter and nutrient accumulation under the two managements were more significant after flowering. Comparing with FP management, the proportion of N, P, and K absorption after flowering under HY management was improved (Cao *et al*., 2008). The research demonstrated that yield could be further increased by focusing on the input and management of the nutrients after flowering and proper fertilizer application at flowering time in high yield fields (Chen *et al*., 2014; Lv *et al*., 2011).

There was a significant difference in the PFP of N fertilizer between the two managements because of the amount of nitrogen fertilizer application. There was just a slight difference as PFP between two managements. This explained that plant's nutrients absorption and utilization could be promoted through the optimization of management practices (Xue *et al*., 2010). However, the absolute quantity of N-fertilizer loss was increased in HY management. N5 treatment was applied with 80 kg/ha more nitrogen fertilizers than N4 treatment, but the yield in N5 treatment was not increased, and the nitrogen fertilizer efficiency was obviously decreased to 21.1% in 2010. These results showed that nitrogen fertilizer application should have a proper range for different management modes (Cox and Cherney, 2012). Thus, nutrients comprehensive management practices are of great importance not only to control nitrogen fertilizer in a rational range, but to guarantee crop's high yield and high nitrogen fertilizer efficiency (Cai *et al*., 2012; Chen *et al*., 2014).

CONCLUSIONS

High Yield (HY) management significantly increased the grain yield and the total accumulation amount of nutrients in maize such as N, P, and K. The yield increase under HY management mainly benefited from the increase of plants population biomass yield and the improvement of harvest index compared with Traditional Farming (FP) management. According to two years results, the accumulation characteristics of N, P, and K under various treatments were largely consistent. The nutrients accumulation differences between different managements mainly appeared after silking. The two-year positioning results showed that the N, P, K accumulation amounts under HY management were, 23.0, 18.6, and 46.0%, respectively, higher than that under FP management. Compared with FP management, HY management significantly promoted the plant's Partial Factor Productivity (PFP) on phosphorus and potassium, while the PFP differences of nitrogen fertilizer were small between different managements. There are additional potential for further optimization of the application quantity of nitrogen fertilizer under HY management.

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ویژگی های انباشت و کارآیی عناصر غذایی در ذرت در شرایط مختلف مدیریت زراعی

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چکیده

هدف این پژوهش چهار ساله تعیین انباشت و توزیع عناصر غذایی در ذرت با عملکرد های مختلف به منظور ارایه توصیه های علمی برای کاربرد موثر کودهای شیمیایی معدنی و تولید عملکرد بالا در ذرت بهاره بود. به این منظور، عملکرد دانه، انباشت عناصر غذایی(نیتروژن، فسفر، و پتاسیم) و کارآیی جذب آنها در شرایط مختلف مدیریت زراعی تحت تیمارهای متفاوت مصرف نیتروژن ارزیابی شد. داده های آزمایش نشان داد که میانگین عملکرد دو ساله دانه در شرایط مدیریت برای عملکرد بالا(HY) به طور معنی داری تا حد ۳۵٪ بیشتر از زراعت با مدیریت سنتی (FP) بود. جالب این که محدوده افزایش عملکرد دانه با افزایش تعداد بلال برداشت شده همراه بود و چنین نشان می داد که کاشت با تراکم بوته زیاد می تواند به بالا بردن عملکرد ذرت بیانجامد.افزون براین،محتوای کل نیتروژن، فسفر، و پتاسیم در ذرت به طور معنی داری افزایش یافت و نسبت انباشت هم بعد از گلدهی در شرایط HYبهبود یافت. بر اساس نتایج به دست آمده، برای بالا بردن عملکرد و کارآیی مصرف عناصر غذایی می بایست اقدامات مختلف کشت و کار برای دستیابی به عملکرد زیاد به گونه ای با هم ترکیب و بهینه شود که نه تنها بیوماس(زیتوده) و شاخص برداشت را بهبود بخشد بلکه رشد و انباشت عناصر غذایی در ذرت را هم افزایش دهد.

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