Effect of phosphorus and potassium application on rapeseed yield and nutrients use efficiency

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Abstract

Three field trials were carried out in Hubei Province along the Yangtze River middle area demonstrates how balanced fertilization, focusing on phosphorus (P) and potassium (K), improves rapeseed yield and nutrient use efficiency. Field trial 1 shows that rapeseed (*Brassica napus* L.) yield increased with P application rate up to 135 kg P_2O_5/hm^2. Application of 135 kg P_2O_5/hm^2 produced the highest yield increment of 1,460 kg/hm^2, about 2.2 times higher than the zero P treatment. The amount of N, P, and K absorbed by aboveground biomass in plots treated with 135 kg P_2O_5/hm^2 was 3.0, 4.1, and 2.9 times as much as nutrients absorbed with no P applied. Application of 135 kg P_2O_5/hm^2 resulted in the highest nitrogen (N) recovery efficiency of 52.3% while the zero P treatment only recovered 17.3%. Field trial 2 shows seed yields were significantly affected by K application. Compared with the zero K treatment, plots treated with 150 and 300 kg K_2O/hm^2 produced 17.5 and 31.7% higher yields, respectively. The N utilization efficiency of rapeseed upland part was improved by 1.6% with 75 kg K_2O/hm^2, 7.7% with 150 kg K_2O/hm^2, 6.7% with 225 kg K_2O/hm^2, and 9.0% with 300 kg K_2O/hm^2. A significant yield interaction was observed between P and K application rate from field trial 3. Compared to the check (NB), application of P increased yield by 467 kg/hm^2, while K decreased yield by 41 kg/hm^2, and P plus K increased yield by 1,360 kg/hm^2. Recovery of P for the NPKB treatment was 20% higher than the NPB treatment and K recovery for the NPKB treatment was 76% higher than the NKB treatment.

Key words: Rapeseed (*Brassica napus* L.), Phosphorus (P), Potassium (K), Yield,Nutrients recovery efficiency

Introduction

Fertilizer has very important roles in modern agriculture and fertilization is one of the most important measures for sustained agricultural production (Lin & Li, 1988; Roelck et al., 2004; Jin & Yan, 2005). It is estimated that the contribution of fertilization to improved crop production ranges from 30 to 50% of the total increase in crop yield in the world (Xie et al., 1998; Skeldrick et al., 2003). It is reported that in China about half of the agricultural progress in the past 30 years has come from technical improvements in fertilization (Lin & Li, 1988). However, much is still to be achieved in terms of tapping into the benefits from optimal fertilizer use efficiency (Skeldrick et al., 2003; Jin & Yan, 2005).

Current use efficiency for fertilizers is low in China. According to some research data, the use efficiency of nitrogen (N), phosphorus (P), and potassium (K) are 30 to 35, 10 to 25, and 35 to 50%, respectively (Jin & Yan, 2005). This leads to unsatisfactory economic benefits as well as negative environmental impacts (Cai & Qin, 2006). Unbalanced fertilization is undoubtedly a primary source of nutrient inefficiency (Sheldrick et al., 2003). Application rates for P and K have increased slightly in recent years, but the proportion of P and K consumed is still small compared to the total, primarily comprised of N(Xie et al., 1998; Lu & Chen, 2005).

Hubei Province in south central China is the largest rapeseed producing area in China. Its average yield is China's highest at 1.7 t/hm^2, but this is far lower than average yields in France, Australia, Canada, and the United Kingdom (Diepenbrock, 2000). Provincial average N, P, and K fertilizer application rates for rapeseed were 160 kg N/hm^2, 63 kg P_2O_5/hm^2, and 19.5 kg K_2O/hm^2, respectively(Lu & Chen, 2005). On average, fertilizer application to rapeseed is unbalanced as many researchers have provided evidence that adjustments in rate can improve crop yield and farmers' income (Rathke et al., 2006). This article using three field trials carried out in Hubei Province demonstrates how balanced fertilization, focusing on P and K, improves rapeseed yield and nutrient use efficiency.

Material and Methods

Trial 1: A phosphorus (P) application rate trial was carried out in a double rice/rapeseed rotation in southeast Hubei Province, Qichun County. Soil P content at the site was middle to low at 13.2 mg/kg (Olsen-P). Five rates of P_2O_5 (0, 45, 90, 135, 180 kg/hm^2) were combined with 180 kg N/hm^2, 120 kg K_2O/hm^2, and 15 kg borax (B)/hm^2.

Trial 2: A potassium (K) application rate trial was carried out in Hubei Province, Huanggang County, along the Yangtze River middle area. Soil available K was 91 mg/kg, which is higher than the average level in Hubei Province. Five K_2O treatments (0, 75, 150, 225, 300 kg/hm^2) were combined with 180 kg N/hm^2, 90 kg P_2O_5/hm^2, and 15 kg B/hm^2.

Trial 3: A trial examining the combined effect of P and K application rates was located in Hubei Province, Qichun County. Site characteristics included: soil pH, 4.8; organic matter, 2.78%; 62 mg/kg available N; 9 mg/kg Olsen P; 49 mg/kg available K; 0.2 mg/kg available B. Four treatments included: NB, NPB, NKB, and NPKB, which were respectively applied at 180 kg N/hm^2, 90 kg P_2O_5/hm^2, 120 kg K_2O/hm^2, and 15 kg B/hm^2.

The field trials were conducted during 2003-2005. For all trials each treatment was replicated four times.

At the harvest stage, the aboveground plant with different treatment in plots was separated into seed, pod and stem. All the parts were dried to constant weight and N, P and K content in each part was analyzed routinely. Nutrients uptake amount and recovery efficiency were calculated.

Results and Discussion

The effect of Phosphorus

Table 1 shows that rapeseed yield increased with P application rate up to 135 kg P_2O_5/hm^2. Application of 135 kg P_2O_5/hm^2 produced the highest yield increment of 1,460 kg/hm^2, about 2.2 times higher than the zero P treatment.

Rapeseed uptake of N, P_2O_5, and K_2O also increased to the 135 kg P_2O_5/hm^2 application rate. Compared to the check, the maximum increase in N, P_2O_5, and K_2O absorbed by the seed was by 39.9, 29.3 and 16.0 kg/hm^2, respectively. The amount of N, P_2O_5, and K_2O absorbed by aboveground biomass in plots treated with 135 kg P_2O_5/hm^2 was 3.0, 4.1, and 2.9 times as much as nutrients absorbed with no P applied. Overall, this field experiment is a demonstration of the impact that proper plant nutrient balance can have on maximizing the use of applied nutrients while providing the most optimal yield.

Table 1 Effect of P_2O_5 rates on rapeseed yield and N, P_2O_5 and K_2O uptake

P rate (kg P_2O_5 /hm^2)	Seed yield (kg/hm^2)	N uptake (kg/hm^2)		P_2O_5 uptake (kg/hm^2)		K_2O uptake (kg/hm^2)	
		Seed	Above-ground biomass	Seed	Above-ground biomass	Seed	Above-ground biomass
0	650	18.6	31.1	11.7	15.8	6.2	53.0
45	1500	45.9	64.7	27.8	34.1	15.3	92.0
90	1788	53.3	75.5	33.0	47.4	18.8	109.5
135	2114	58.5	94.2	41.0	64.7	22.2	154.2
180	2000	54.6	82.8	38.4	51.9	21.5	125.7

Low N use efficiency is a particularly important issue for plant nutrient management in China. Using adequate P with other nutrients is a useful measure to improve the recovery and agronomic impact of applied N. Figure 1 provides an example of the effect of adequate P application on N fertilizer recovery. Application of 135 kg P_2O_5/hm^2 resulted in the highest recovery efficiency of 52.3% while the zero P treatment only recovered 17.3%. It is also evident that P application beyond this point only lowered the plant's ability to recover N.

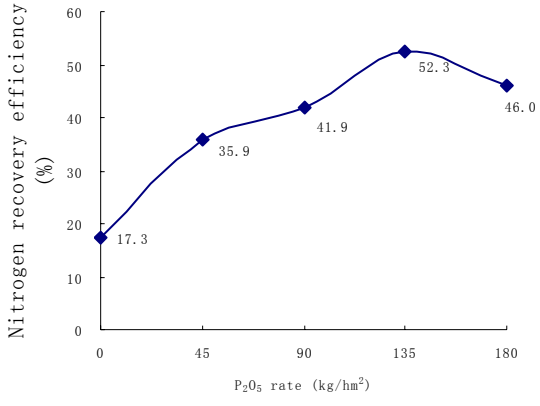

Fig. 1. Influence of P on N recovery efficiency in rapeseed

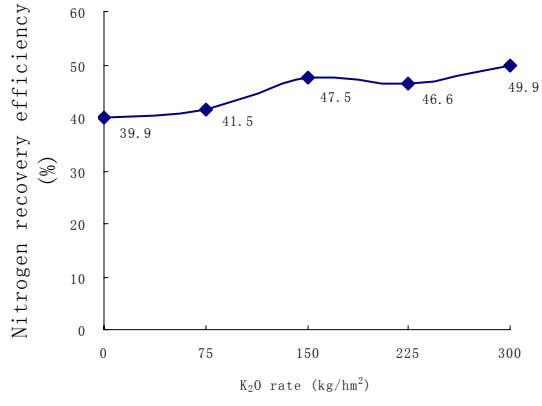

Fig. 2. Influence of K on N recovery efficiency in rapeseed

(N recovery efficiency=N uptake ÷ N application rate × 100%)

The effect of Potassium

Seed yields were significantly affected by K application even though soil available K content was not considered low. For example, compared with the zero K treatment, plots treated with 150 and 300 kg K_2O/hm^2 produced 17.5 and 31.7% higher yields, respectively (Table 2).

By increasing K application rate, uptake of N, P, and K was also increased. Considering the seed N uptake, compared with check, plots treated with 75, 150, 225 and 300 kg K_2O/hm^2 absorbed 3.0, 11.1, 11.9, and 15.6 kg/hm^2 more N, respectively. The N utilization efficiency of rapeseed upland part was improved by 1.6% with 75 kg K_2O/hm^2, 7.7% with 150 kg K_2O/hm^2, 6.7% with 225 kg K_2O/hm^2, and 9.0% with 300 kg K_2O/hm^2 (Figure 2).

Table 2 Effect of K_2O rates on rapeseed yield and N, P_2O_5 and K_2O uptake

K rate (kg K_2O /hm^2)	Seed yield (kg/hm^2)	N uptake (kg/hm^2)		P_2O_5 uptake (kg/hm^2)		K_2O uptake (kg/hm^2)	
		Seed	Above-ground biomass	Seed	Above-ground biomass	Seed	Above-ground biomass
0	1386	47.7	71.9	22.1	64.2	10.7	81.5
75	1433	50.7	74.7	23.4	66.3	10.4	89.6
150	1629	58.8	85.7	27.5	74.3	12.8	111.5
225	1625	59.6	83.9	27.8	69.0	13.4	114.8
300	1826	63.3	88.1	29.3	74.6	14.6	114.8

The effect of P and K combination

Compared to the check (NB), application of P increased yield by 467 kg/hm^2, while K decreased yield by 41 kg/hm^2, and P plus K increased yield by 1,360 kg/hm^2 (Table 3). The complete treatment (NPKB) yielded 5.7 times greater than the NB treatment, 2.2 times greater that the NPB treatment, and 6.7 times greater than the NKB treatment. A significant yield interaction was observed between P and K application rate.

Uptake of N, P, and K showed that both for seed only and for aboveground parts, uptake for plots treated with NPKB was much higher than all other treatments, which indicates that P and K combined to improve fertilizer use efficiency considerably.

Table 3 Effect of P combined with K on rapeseed yield and N, P_2O_5 and K_2O uptake

Treatment	Seed yield (kg/hm^2)	N uptake (kg/hm^2)		P_2O_5 uptake (kg/hm^2)		K_2O uptake (kg/hm^2)	
		Seed	Above-ground biomass	Seed	Above-ground biomass	Seed	Above-ground biomass
NB	290	7.8	12.6	2.7	3.2	2.9	17.1
NPB	756	16.1	24.8	10.8	16.1	7.7	40.5
NKB	248	5.9	9.8	1.4	1.8	2.7	18.5
NPKB	1652	39.6	57.2	28.8	34.1	17.7	109.5

Figure 3 clearly demonstrates the differences in recovery efficiency for the NB, NPB, NKB, and NPKB treatments. Recovery of P for the NPKB treatment was 20% higher than the NPB treatment and K recovery for the NPKB treatment was 76% higher than the NKB treatment. It is evident that unbalanced fertilization lacking either P or K will lead to low yield, wasted investment on crop inputs, labor, and land, as well as increased exposure to the harmful effects of exposing unused soil nutrients to loss into the surrounding environment.

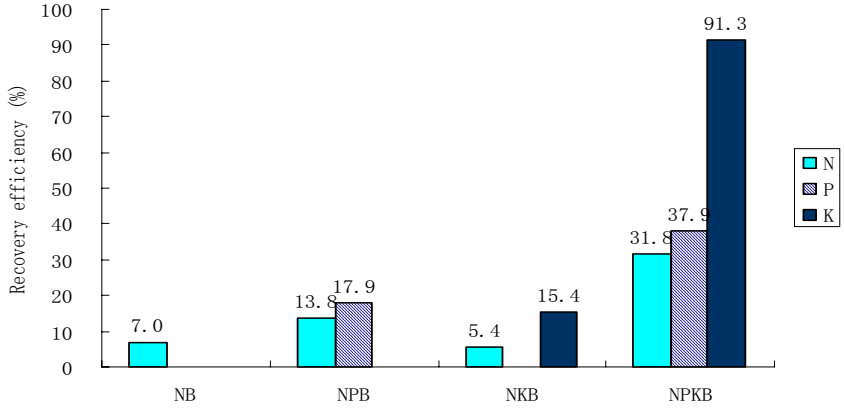

Fig. 3. Influence of P and K on N recovery efficiency in rapeseed

Conclusions

Phosphorus and potassium had great effect on rapeseed yield and nutrient use efficiency in the Yangtze River winter rapeseed cultivated area. Application of 135 kg P_2O_5/hm^2 produced the highest yield increment of 1,460 kg/hm^2, about 2.2 times higher than the zero P treatment. Compared with the zero K treatment, plots treated with 300 kg K_2O/hm^2 produced 31.7% higher yields. Compared to the check (NB), P plus K increased yield by 1,360 kg/hm^2 and a significant yield interaction was observed between P and K application. Both P and K improved N utilization efficiency significantly.

Acknowledgments

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