Effect of Combining Use of Nitrogen, Phosphorus, Potassium and Boron on Yield, Yield components of Rapeseed and Fertilization Use Efficiency

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Abstract

The objective of this study is to determine the effect of the combining use of these elements at different sowing times. Field experiments were conducted at three sowing times (Sept 30th, Oct 14th and Oct 30th) with the same design and cultivar at a field in Nanchang County, Jiangxi, China during the 2009-2010 growing season. The application rates of nitrogen (N), phosphorus (P_2O_5), potassium (K_2O), and boron (borax) were 180, 90, 90 and 16.5 kg/hm^2 respectively. Each experiment had six treatments: NPKB, NPK, NKB, NPB, PKB and check. The results showed that the combining use of NPKB was the best treatment in all the three experiments, the yields for sowing on Sept 30th, Oct 14th and Oct 30th were 1995.9, 2047.4 and 1348.8 kg/hm^2 respectively, while the check yields were only 336.0, 600.2 and 404.0 kg/hm^2 respectively, that is, the checks decreased in yield by more than 70% compared to the balanced fertilization treatment NPKB. Of the four chemical fertilizers, nitrogen fertilization had the most significant effect on yield, and the yield reduction reached more than 50% when P, K and B but N was used. The yields of no P application were reduced by a range from 21.6% to 46.0%, being heaviest influenced at the latest sowing. The treatments without K and the treatment without B decreased in yield ranging 17.4%-39.8% and 8.0%-24.1% respectively, with the least influence for the latest sowing. Fertilizers dominantly affected the agronomic characters like plant height, primary branches, silliques and yield per plant, giving less effect to the 1000-grain weight and grains per sillique. Combining application also improved the apparent use efficiency of fertilizers, which declined evidently with the delay of sowing. N fertilization could enhance the apparent use efficiency of the other nutrients. These results emphasize that balanced fertilization is the effective measure to increase rapeseed productivity and fertilizer use efficiency, and that applying N is the most critical to yield increase, followed by application of P, K and B.

Keywords: Brassica napus; Nitrogen; Phosphorus; Potassium; Boron; fertilization; Yield

1. Introduction

Rapeseed (Brassica napus) is an important oil crop in China where the winter oilseed rape planted in the reach of Yangzts river accounts for approximate 90% of the whole area. Developing rapeseed production is regarded to be an effective strategy of exploring the resources including land, light, temperature, rainfall in seasons of late autumn, winter, spring and early summer, and of improving the market supply of vegetable oil. Chemical fertilizers contribute a lot to the production development of foods including oilseed rape, however, its return and effect on the yield decreases evidently with increase of application amount. Excessive use or abuse of chemical fertilizers not only decreases yield and profit but also adds to ecological environment pollution. Compared to cereal crops, Oilseed rape needs more fertilizer. Consequently, appropriately sufficient and balanced fertilization is especially important to the sustainable production of oilseed rape. Nitrogen (N), phosphorus (P) and potassium (K) are the basic nutrient elements required for plant growth and development. *Brassica napus* is most sensitive to boron (B) deficiency and most responsive to boron application. There have been some research reports about the combining use of these nutrients mentioned above, but little is known about the impact of different sowing dates to the effect and the use efficiency of fertilizers.

2. Materials and methods

2.1. Materials

The cultivar used was Ganyouza 5, a double low hybrid bred by the Institute of Crops, Jiangxi Academy of Agricultural Sciences. Urea, super phosphate, potassium chloride and borax, bought from market, were respectively used as the sources of N, P, K and B.

2.1. Methods

Description of the site

The trials were conducted in the oilseed rape growth season from 2009 to 2010 at Nanchang County, Jiangxi, China. It is often drought in autumn even lasting to winter. It often rains or is cloudy accompanying low temperature in flowering phase in March, which affects the seed-set.

Experimental details

Field experiments were performed at three sowing times (Sept 30th, Oct 14th and Oct 30th) with the same design and cultivar at a field. The preceding crop was rice. Each experiment had six treatments: NPKB, NPK, NKB, NPB, PKB and check (without any fertilization), arranged in a random block design with three repeat. The plot area is 20 m^2. The application rates of N, P (P_2O_5), K (K_2O), and B (borax) were 180, 90, 90 and 16.5 kg/hm^2 respectively. Sixty percent of the N, all of the P, 70% of K and /or 15kg/hm^2 of B was applied in the fertilization ditch according to the amount calculated for each plot before sowing. Twenty percent of the N was supplemented at seedling phase after planting density determined. Twenty percent of the N and 30% of the K were supplemented at bolting phase, and 100g borax dissolved in 25kg of water was fertilized by spraying onto the leaves.

Data collection

Growth and development stages were recorded. After maturity, 10 plants were randomly selected from each plot and plant height, number of primary branch, efficient length of main inflorescence, siliques on main inflorescence, silique per plant, grains per sillique, 1000-grain weight, yield per plant were observed. The 30 plants from the three plots for each treatment were threshed and separated into seed, hull and stem (branch).

Plant nutrient analysis

The seed, hull and stem (branch) were sampled and tested for content of N, P, K and B. Based on the test results, total take-up of nutrients for each treatment was calculated.

Data analysis

Analyses of variance were applied to data of each trial separately. Difference among treatment means was determined using the least significant difference at the probability of 0.05 and 0.01 respectively. All the agronomic characters observed were averaged. Apparent use efficiency (AUE) of N, P, K and/or B fertilizer for each fertilization treatment was calculated according to the following formula:

AUE= (Nutrient $_{fertilized}$-Nutrient $_{check}$)/fertilizer applied

3. Results

3.1 Yield

Yield results listed in the Table 1 demonstrated that it's quite critical to apply sufficient and balanced fertilizers of N, P, K and B in yield increase. The yield mean for all the treatment in the trial of sowing on Sep 30th was 4.5% less than that in the trial of sowing on Oct 14th , while the yield mean of the trial sown on Oct 14th was 42.6% more than that of the trial sown on Oct 30th. Yield trends among the treatments in the three trials are basically consistent. In the trial sown on Sep 30th, yield order among the treatments ranked: NPKB>NKB>NPK>NPB> PKB>check. For the two trials of sowing in October, the yield orders went all the way: NPKB>NPK> NPB>NKB>check. The combining use of NPKB was the best treatment in the three experiments conducted, the yields for sowing on Sept 30th, Oct 14th and Oct 30th were 1995.9, 2047.4 and 1348.8 kg/hm^2 respectively, while the check yields were only 336.0, 600.2 and 404.0 kg/hm^2 respectively, that is, the checks decreased in yield by more than 70% compared to the balanced fertilization treatment NPKB. Accordingly, balanced fertilization played an important role in increasing yield of oilseed rape.

Chemical fertilizers of N, P, K and B didn't play the same role in yield increase. Of the four chemical fertilizers, N fertilization had the most significant effect on yield, and the yield reduction reached more than 50% when P, K and B but N was applied. No P fertilization gave yield losses ranged from 21.6% for the trial sown on Sep 30th to 46.0% for the trial sown on Oct 30th, indicating that the heaviest influence occurred at the latest sowing. The treatment of no K fertilization and the treatment of no B fertilization decreased in yield ranging 17.4%-39.8% and 8.0%-24.1% respectively, and Fertilization of no K and of no B in the case of the latest sowing produced the comparatively less impact to yield.

Table 1 Yield mean for each treatment and the significance test

Trial	Treatment	Yield (kg/hm²)	compared to NPKB (%)	0.05	0.01
30-Sep	Check	336.0	-82.8	d	D
	NPKB	1955.9	0.0	a	A
	NPK	1484.6	-24.1	b	B
	NPB	1441.6	-26.3	b	B
	NKB	1532.6	-21.6	b	B
	PKB	660.1	-66.2	c	C
	Average	1235.1			
14-Oct	Check	600.2	-70.7	e	E
	NPKB	2047.4	0.0	a	A
	NPK	1691.6	-17.4	b	B
	NPB	1233.3	-39.8	c	C
	NKB	1192.2	-41.8	c	C
	PKB	991.5	-51.6	d	D
	Average	1292.7			
30-Oct	Check	404.0	-70.0	d	D
	NPKB	1348.8	0.0	a	A
	NPK	1241.5	-8.0	ab	AB
	NPB	1114.4	-17.4	b	B
	NKB	728.4	-46.0	c	C
	PKB	603.1	-55.3	c	C
	Average	906.7			

3.2 Yield component

Fertilizers dominantly affected the agronomic characters like plant height, primary branches, silliques and yield per plant, giving less effect to the 1000-grain weight and grains per sillique. The agronomic characters observed were listed in Table 2 including plant height, primary branches, available length of main inflorescense, silliques on main inflorescense, silliques per plant, grains per sillique, 1000-grain weight and yield per plant. Among them, the plant height, primary branches, silliques per plant and yield per plant were significantly influenced by fertilization. The silliques per plant for the treatment NPKB in the experiments sown on Sep 30th, Oct 14th and Oct 30th were 312.4, 287.0 and 258.0 respectively, being 227.6, 159.4 and 154.2 more than those for the corresponding checks. The yields per plant for the treatment NPKB in the experiments sown on Sep 30th, Oct 14th and Oct 30th were 14.35, 15.0 and 12.13g respectively, being as 4.8, 3.9 and 2.9 times as those of the corresponding check.

3.3 Apparent use efficiency of fertilizers

The fertilizer use efficiency was closely related to balanced fertilization. The Apparent use efficiency for fertilized treatments of the three experiments was calculated and presented in Table 2. Among the 4 nutrients, the AUE of B was the lowest, followed with P and N, and the AUE of K was the highest. The AUE for the treatment NPKB was the best in each trial. The AUE of N, P, K and B for the treatment NPKB in the trial sown on Sep 30th was 37.19%, 20.98, 73.42 and 7.53% respectively, more than those for the unbalanced treatments.

With the delay of sowing, the AUE of fertilizers declined evidently. The AUE of N for the treatment NPKB in the trial sown on Sep 30th was 37.19%, while in the latest sown trial it was 25.23%, reducing nearly 10 percentage points. The AUE of phosphorous decreased more evidently. It was 20.98% for the NPKB in the first sown trial, but it decreased to be 8.12% for the NPKB in the last sown trial. According to the table 3, N fertilization facilitated the AUE of the other nutrients. No P fertilization caused remarkable reduction in the AUEs of N and K in the latest sown trial.

Table 2 Apparent use efficiency of fertilizers

Trials	Treatments	N (%)	P (%)	K (%)	B (%)
30-Sep	NPKB	37.19	20.98	73.42	7.53
	NPK	31.21	16.32	72.58	
	NPB	30.92	12.39		5.42
	NKB	36.00		66.82	5.84
	PKB		6.40	58.80	3.87
14-Oct	NPKB	30.90	16.21	65.00	5.01
	NPK	28.62	12.52	57.09	
	NPB	20.09	5.39		3.73
	NKB	20.75		45.56	2.81
	PKB		2.74	40.94	2.00
30-Oct	NPKB	25.23	8.12	60.76	3.18
	NPK	23.77	6.30	52.77	
	NPB	22.52	5.67		3.75
	NKB	10.39		18.80	0.73
	PKB		2.43	29.48	1.16

4. Discussion

Previous reports about effects of combining use of fertilizers like N, P, K and B on yield, yield components and fertilizer use efficiency were usually based on the experiments conducted at several sites for several years. Data collected from different environment, soil fertility and sowing time were difficult to determine the effect of a single factor. The field experiments we present here were conducted at three sowing times (Sept 30th, Oct 14th and Oct 30th) with the same design and cultivar on a same field. By doing so, the effects of the sowing time and fertilization on the yield, yield components and apparent use efficiency of fertilizers were investigated. Results about the importance of balanced fertilization agree with most of the previous research work, but the yield effect was different. Without fertilizer input, yield loss exceeded 70%, more than the figures previously reported. Effect of fertilization on yield and fertilizer use efficiency was affected not only by the combining mode of the nutrients involved but also by the sowing time.

5. Conclusion

Effects of combining use of N, P, K and B were investigated through repeated experiments sown at different times. Fertilization played an important role in yield increase, contributing more than 70% of the yield. Combining use of the four nutrients at a suitable proportion increased the yield and fertilizer use efficiency. Among the four elements, N had more influence on yield increase and yield components, producing yield loss by more than 50% without N fertilization. N also improved evidently the apparent use efficiency of other nutrients. Although P had less effect on yield than N, it still caused more than 40% yield loss in the later sowing. No P fertilization brought extraordinary reduction in the apparent use efficiency of N and K in the trial sown on Oct 30th.

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Reference

Omitted