Characterizing the Response of Rainfed Rapeseed to Fertilizer Application

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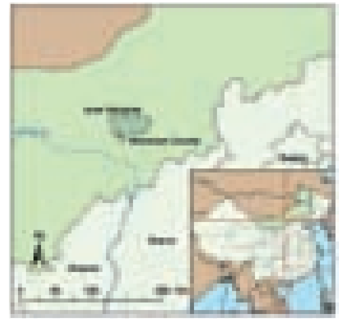

Field experiments on the response of rainfed rapeseed to N, P, and K fertilizer application showed significant yield increases due to their balanced use. Recovery efficiencies averaged 31% for N, 12% for P, and 35% for K. Each 100 kg of rapeseed removed 5.5 kg N, 1.7 kg P_2O_5, and 4.5 kg K_2O, respectively.

Rapeseed is one of the most important oil crops in China. In 2006, the rapeseed area planted was 6.9 million hectares (M ha) supporting a production of 12.7 M tonnes (t), or 41% of China's total oil production. The Inner Mongolia Autonomous Region (IMAR) has 210,000 ha planted annually and its production in 2006 was 250,000 t (China Agriculture Statistical Report, 2006). The average yield of rapeseed is about 1.2 t/ha, with the range of 0.7 to 3.0 t/ha. This crop is often planted in low fertility soils with little fertilizer input (15 to 30 kg/ha of diammonium phosphate). Given this modest level of management, there is great potential to increase rapeseed yields by utilizing the well understood principles of balanced fertilization. This research was aimed at characterizing crop nutrient demand and fertilizer use efficiency under a production system with higher yield potential.

Field experiments were carried out from 2002 to 2005 in Dongtucheng Town, Wuchuan County, IMAR. The IMAR has a temperate continental climate. Spring is warm and windy; summer is short and hot with many rainy days; autumn usually sees early frost and plummeting temperature into winter. The region has 80 to 150 frost-free days depending on location. The IMAR has a sharp annual rainfall gradient, from 600 mm in the east to less than 100 mm in the west. Most of the rainfall occurs from May to September, coinciding with high temperatures (Yu et al., 2004). During the 4 years of study, the site had growing season precipitation ranging between 162 to 317 mm and accumulated growing degree units (GDUs) between 1,888 to 2,137 (**Table 1**). Selected soil properties (0 to 20 cm depth) are shown in **Table 2**.

Table 1. Precipitation and growing degree unit (GDU) accumulation in the growing seasons from 2002 to 2005.

	Precipitation, mm				Accumulative GDU, °C			
	2002	2003	2004	2005	2002	2003	2004	2005
May	30	54	68	33	379	405	339	376
June	62	42	43	24	538	460	505	579
July	20	100	84	46	608	564	569	630
August	50	121	104	108	574	518	475	552
Total	162	317	299	211	2,099	1,947	1,888	2,137

Research in Inner Mongolia quantified rapeseed response to N, P, and K fertilizer under a more intensive production system.

The series of experiments compared four treatments including an NPK 'optimum' (OPT), and treatments excluding N (OPT-N), P (OPT-P), and K (OPT-K). Plots were arranged in a randomized complete block design with three replicates. Rates within the OPT were recommended based on soil analysis (Hunter and Portch, 2002) and a realisitic yield target of 2 to 2.5 t/ha (**Table 3**). Fertilizer sources were urea, triple superphosphate, and potassium chloride. All fertilizers were band applied before sowing in the spring at a 15 cm depth. The rapeseed variety was Dahuang, a mustard-type (*Brassica juncea Czern. et Coss*), and a major variety planted in IMAR. This variety has multiple branches and a prolonged flowering period and can be harvested 100 days after seeding. Seed and straw samples were collected at harvest from 2002 to 2005 and total N, P, and K contents were analyzed and total nutrient accumulation was determined.

Table 3. Nutrients applied in rapeseed experiments, kg/ha.

	2002	2003	2004	2005
N	64	0	45	45
P_2O_5	45	58	30	30
K_2O	45	56	30	30

Despite large year-to-year variations in yield, balanced use of NPK application was

Table 2. Soil properties at experimental sites

Year	pH	OM %	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
			mg/L										
2002	8.3	0.9	9.1	13.2	75.8	3,256	175	9.1	1.0	2.0	11.4	9.1	0.7
2003	8.4	1.1	10.3	14.8	94.0	3,186	194	1.6	1.8	3.5	22.0	12.4	1.7
2004	8.4	1.0	58.0	13.5	46.9	3,008	159	2.0	3.4	1.1	6.4	6.6	0.6
2005	8.4	1.2	34.2	11.2	54.8	3,218	193	8.7	2.8	1.8	16.2	4.4	1.0

Note: Soil was analyzed using ASI method in China-Canada Cooperative Lab in Beijing

Abbreviations and notes for this article: N = nitrogen; P = phosphorus; K = potassium; AE = agronomic efficiency; RE = recovery efficiency.

most consistent at producing highest yields compared to the three nutrient omission treatments (**Table 4**). The main limiting factor in rapeseed production was N, followed by P, and then K. Yields under the OPT were 13 to 26% (mean = 18%) higher than the OPT-N treatment, 4 to 18% (mean = 13%) higher than the OPT-P treatment, and 3 to 16% (mean = 7%) higher than the OPT-K treatment.

There was a significant difference in rapeseed yield between years (**Table 4**). In 2002, there was sufficient rain over the year with more rain in June improving crop growth, and good drying conditions in July promoting flower pollination. Rapeseed grew well in 2003 under conditions of good rainfall. The lower yield of rapeseed in 2005 was attributed to scarce rainfall and high temperatures, especially in June when rapeseed was in its rapid growth phase.

Nutrient use efficiency can be expressed in many ways including partial factor productivity (PFP), agronomic efficiency (AE), and crop recovery efficiency (RE) (Fixen, 2007). This paper makes use of the latter two terms to assess the impact of balanced NPK application where AE refers to the crop yield increase per unit nutrient applied, and RE refers to the increase in plant nutrient uptake per unit nutrient added. Measurements of AE for applied N, P, and K resulted in large year-to-year variability which is likely linked to the over-riding climatic conditions in that particular year. Mean AE values were 5.4 kg/kg N, 5.8 kg/kg P_2O_5, and 3.2 kg/kg K_2O (**Table 5**). The respective ranges were 3.7 to 8.0 kg/kg N, 1.9 to 9.0 kg/kg P_2O_5, and 1.4 to 6.8 kg/kg K_2O. Plant nutrient uptake was much more consistent over years. Under the OPT treatment, each 100 kg rapeseed required 5.2 to 6.1 kg N (mean = 5.5), 0.8 to 2.8 kg P_2O_5 (mean = 1.7), and 4.1 to 5.1 kg K_2O (mean = 4.5). Nutrients taken up by plants are not only derived from applied fertilizer, but also from the soil native nutrient pool. The mean RE values were 33% for N, 13% for P, and 53% for K (**Table 5**). The respective RE ranges were 27 to 38% for N, 9 to 18% for P, and 40 to 60% for K.

Table 4. Effect of fertilizer application on rapeseed.

		Year				
		2002	2003	2004	2005	Mean[a]
Yield, t/ha	OPT	2.13a	2.59a	1.75a	1.48a	1.99a
	OPT-N	1.85b	2.29b	1.39b	1.24b	1.69c
	OPT-P	1.83b	2.48b	1.48ab	1.32b	1.78c
	OPT-K	2.07ab	2.51b	1.66ab	1.27b	1.88b
	Mean[b]	1.97b	2.47a	1.57c	1.33d	

[a] Different letters in the same column indicate significant difference between treatment at $p<0.05$.
[b] Different letters in the row indicate significant yearly difference at $p<0.05$.

Table 5. Nutrient use efficiency of N, P_2O_5, and K_2O.

		Year				
		2002	2003	2004	2005	Mean
Agronomic efficiency[a], kg/kg	N	4.4	3.7	8.0	5.3	5.4
	P_2O_5	6.8	1.9	9.0	5.4	5.8
	K_2O	1.5	1.4	2.9	6.8	3.2
Nutrient uptake/100kg seed[b]	N	5.5	5.3	5.2	6.1	5.5
	P_2O_5	1.6	1.6	0.8	2.8	1.7
	K_2O	4.6	4.1	4.1	5.1	4.5
Recovery efficiency[c], %	N	38	27	33	34	33
	P_2O_5	11	9	14	18	13
	K_2O	59	40	60	53	53

[a] Agronomic efficiency (kg/kg) = (yield of OPT - yield of omitted nutrient treatment)/amount of nutrient applied)
[b] Nutrient uptake (kg/100 kg) = total of nutrient uptake (seed + straw)/seed yield x 100
[c] Recovery efficiency (%) = (nutrient uptake of OPT - nutrient uptake of omitted nutrient treatment)/amount of nutrient applied x 100

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Summary

Results place a significant importance on balanced NPK management for optimal rainfed rapeseed production in IMAR. The importance of managing adequate nutrient supplies throughout the growing season is especially critical. Year-to-year climatic variability greatly influenced yield and nutrient use efficiency at the site. Although accumulative GDUs were reasonably consistent, precipitation throughout the entire year was constantly less than 400 mm and was much less during the growing season. Soil moisture limitations may be one reason why nutrient use efficiency values were relatively low. There will be great potential to increase rapeseed yield and nutrient use efficiency if current water limitations were removed by supplementing with irrigation in the future. BC

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