Response of Nitrogen, Phosphorus and Potassium Fertilization on Productivity and Quality of Winter Rapeseed in Central China

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Abstract

Winter rapeseed (Brassica napus L.) is a dominant oilseed crop and has become an alternate crop both for edible oil production and energy agriculture. This study was conducted to find out the response of nitrogen (N), phosphorus (P) and potassium (K) fertilizer combinations on yield, oil and protein contents in oilseed rape crop. Four fertilizer treatments of N, P and K fertilizers (NPK, NP, NK, and PK) were applied according to the local recommendations at three different sites in Hubei province, during the year 2012-2013. Rapeseed yield was significantly increased by 61-72% under NPK fertilization as compared to PK across study sites. Yield responses to fertilization were ranked as NPK>NP>NK>PK, illustrating that N was the most limiting nutrient in rapeseed productivity following P and K. Oil and protein yields were significantly affected to applied N, P, and K fertilizers. Among all combinations, NPK combination performed best. Oil and protein contents along with other fatty acids (palmitic acid, stearic acid, oleic acid, linoleic acid and linolenic acid) were not influenced significantly by the application of P and K fertilizer. By increasing the amounts of N fertilizer application, oil contents of rapeseed reduced and protein contents increased consistently. These results suggest that NPK combination is more productive as compared to the other combinations. © 2016 Friends Science Publishers

Keywords: Winter rapeseed; NPK; Yield; Protein yield; Oil content

Introduction

Oilseed rape (Brassica napus L.) is an essential agricultural crop generally grown for oil and biofuel generation. Rapeseed oil is ordinarily utilized in human diets on account of its great nutritional quality with a high proportion of unsaturated fatty acids and fair-minded fatty-acid composition (Rehman et al., 2013; Wang et al., 2014). After extraction, remaining rapeseed meal can be used as an organic fertilizer to the cropland or as a source of animal feed (Gao et al., 2010). The nutritional nature of these products is of prime significance, because of their immediate and circuitous effects on human health. Additionally, rapeseed oil is developing consideration as an imperative option for bioenergy asset, because of the deficiency and unpredictability of the worldwide petroleum supply (Högy et al., 2010). The rapeseed is broadly planted on 34.3 million ha around the globe, with almost 22% of the planting ranges situated in China (FAO, 2013).

Among numerous other parameters, the nutritional values of the crop are thought to be most imperative element. N, P, and K are considered to be critical being the crucial part of harvest yield and nutritious values of the oilseed rape yield. Nitrogen is the most important macro-element required for seed oil (Colenne et al., 1998) and it is suggested that oilseed rape has a higher basic N demand for biomass development than wheat. The suitable quantity of N fertilizer is requisite for optimal economic yield and oil generation (Mason and Brennan, 1998). Smith et al. (1988) reported that high amount of N fertilizer reduced the oil contents but enhanced the protein contents in canola and found a negative co-relation between oil concentration and protein contents.

Phosphorus (P) is an imperative nutrition for plant development as concerned with photosynthesis, cellular energy transfer, and respiration. Regardless of the way that canola demands more phosphorus than grain crops for perfect yields, it might need minor levels of P fertilizers, as it is extraordinarily suitable for utilizing both applied and soil P...
(Bailey and Grant, 1990; Irshad et al., 2016). Higher P applications assume a significant role in achieving the yield and quality contents of the crop. P fertilizations additionally improved the seed and oil yield when applied up to 60 kg P ha\(^{-1}\) (Reddy et al., 1997; Tamak et al., 1997). Besides N and P, potassium fertilization has been accounted for to impact the efficiency of seed yield and its oil concentrations (Ghosh et al., 1995). K is obligatory in enough amounts for common plant development and advancement. Kandil (1984) documented that use of K alongside N and P fertilizers enhanced the seed yield of rapeseed. The study objectives were to (i) evaluate the effectiveness of N, P, and K fertilization on yield, oil and protein contents of winter rapeseed and (ii) explore the responses of rapeseed quality to N, P, and K application on five major fatty acids.

Materials and Methods

Description of Experimental Sites

Field experiments were conducted during the year of 2012–2013 on winter rapeseed (Brassica napus L.) at three study sites, Honghu (HH), Shayang (SY) and Jingzhou (JZ) of the Hubei province of China (Fig. 1). The climate is of subtropical type in the study region, with a mean temperature ranging from 4.7 to 23.6°C at HH, 3.9 to 23.4°C at SY and 4.1 to 23.2°C at JZ site while rainfall varies from 19.2 to 217.8 mm at HH, 17.0 to 240.2 mm at SY and 8.7 to 244.6 mm at JZ site (Fig. 2). During the cropping season, the temperature was mostly low (4°C or lower) with little precipitation (<120 mm) from January to February. Location of experimental sites and soil properties of the plow layer (0–20 cm) before the start of the on-farm experiments are given in Table 1.

Experimental Design and Operation

The experiment was laid out in a randomized complete block design with four treatments and three replicates consisting of: PK=chemical phosphorus and potassium fertilization with no nitrogen; (2) NK= chemical N and K fertilization with no phosphorus; (3) NP = chemical N and P fertilization with no potassium; (4) NPK= chemical N, P and K fertilization. The plot size for each replicate was 20 m\(^2\) (3 m \(\times\) 6.7 m). This bigger plot size allowed the convenient drainage during the oilseed rape growing season. All fertilization treatments received N 180 kg ha\(^{-1}\) as urea (N 46.4%) and applied in three splits i.e., 60% was applied just before sowing, 20% in over-wintering stage and 20% at the initiation of stem elongation. The whole P fertilizer at the rate of 60 kg ha\(^{-1}\) as calcium superphosphate (P 5.2%) was applied at sowing. The K fertilizer was applied at 90 kg ha\(^{-1}\) as potassium chloride (K 52.3%), 70% of which was applied before sowing of oilseed rape and 30% at the top dressing stage. Borax fertilizer (15 kg ha\(^{-1}\)) was added 100% as a basal application in all plots to meet the nutrients requirement for normal growth of oilseed rape.

![Fig. 1: Map of three experimental sites in central China](image)

The experimental fields at the three sites were well prepared, plowed and leveled by the rotary plow and basal fertilizers were incorporated during final plowing. The straw residues were removed before the construction of experimental plots and local cultivar, Hua youza 9 was used for investigation, because it is widely cultivated in the experimental regions with a high yield performance and extensive adaptability. The nursery was raised near the experimental sites on fertile seed bed and transplanted to the fields after 30 days. Previous crops were different at each site following rapeseed.

All other field operations such as planting density, herbicide appliance, irrigation, and disease and pest control were managed by following a local methodology. No major attack of weeds, disease, and pest or the weather was recorded during the growth season of nursery and fields. Planting densities were kept uniform as 112, 500 plants ha\(^{-1}\) for oilseed rape at each site. The previous crop was rice before growing of oilseed rape. The seeding, transplanting and harvesting time of oilseed rape cultivars at each site are shown in Table 2.

Sampling and Measurement

Soil and plants sampling and measurement were performed using the similar protocols at each study site. When each experimental site was established, soil samples were taken at depths 0–20 cm from 20 random points. A subsample of fresh soil was used for the measurement of inorganic N according to Rowell, 1994. The residual soil was air-dried and put through a 2 mm sieve for the measurements of pH (1:2.5 soil/water ratio), organic C (dichromate oxidation method), total N (Kjeldahl acid-digestion method). Olsen-P by spectrophotometer, NH\(_4\)OAc-K by flame photometer, and soil type was determined by hydrometer method. Before harvesting, 10 oilseed rape plants were collected from each plot and separated into two parts: seed and straw (including stem and pod wall). A subsample of seed was used to measure quality traits by using a Near-Infrared Seed Analysis System (NYDL-3000; Oil Crops Research
Table 1: Locations and soil properties (0–20 cm) of three experimental sites in central China

<table>
<thead>
<tr>
<th>Site</th>
<th>Coordinate</th>
<th>Soil texture</th>
<th>pH</th>
<th>Organic C (g kg⁻¹)</th>
<th>Total N</th>
<th>Olsen-P (mg kg⁻¹)</th>
<th>NH₄OAc-K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Honghu</td>
<td>30°01’N, 113°32’E</td>
<td>Silty clay loam</td>
<td>7.47</td>
<td>24.2</td>
<td>1.93</td>
<td>6.9</td>
<td>96.1</td>
</tr>
<tr>
<td>Shayang</td>
<td>31°00’N, 112°24’E</td>
<td>Silt loam</td>
<td>5.88</td>
<td>21.1</td>
<td>1.59</td>
<td>18.9</td>
<td>86.5</td>
</tr>
<tr>
<td>Jingzhou</td>
<td>30°20’N, 112°13’E</td>
<td>Silt loam</td>
<td>6.31</td>
<td>26.6</td>
<td>1.97</td>
<td>7.9</td>
<td>98.0</td>
</tr>
</tbody>
</table>

Table 2: Timing of each operation for oilseed rape at three study sites in central China

<table>
<thead>
<tr>
<th>Operation</th>
<th>Experimental sites</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Honghu</td>
</tr>
<tr>
<td>Transplanting</td>
<td>13 May 2013</td>
</tr>
</tbody>
</table>

Table 3: Effects of N, P and K fertilization on oil, protein and fatty acid (FA) concentrations (%) of oilseed rape in 2012-2013

<table>
<thead>
<tr>
<th>Site</th>
<th>Treatment</th>
<th>Oil</th>
<th>Protein</th>
<th>Oleic acid</th>
<th>Linoleic acid</th>
<th>Linolenic acid</th>
<th>Stearic acid</th>
<th>Palmitic acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Honghu</td>
<td>PK</td>
<td>48.88a</td>
<td>17.71b</td>
<td>63.90a</td>
<td>16.97a</td>
<td>9.48a</td>
<td>1.68a</td>
<td>3.89a</td>
</tr>
<tr>
<td></td>
<td>NK</td>
<td>42.10c</td>
<td>24.07a</td>
<td>79.07a</td>
<td>10.66b</td>
<td>6.89a</td>
<td>2.16a</td>
<td>4.02a</td>
</tr>
<tr>
<td></td>
<td>NP</td>
<td>45.22b</td>
<td>22.55a</td>
<td>59.96a</td>
<td>17.06a</td>
<td>9.16a</td>
<td>2.00a</td>
<td>3.76a</td>
</tr>
<tr>
<td></td>
<td>NPK</td>
<td>44.37bc</td>
<td>22.23a</td>
<td>71.34a</td>
<td>16.63a</td>
<td>8.03a</td>
<td>2.13a</td>
<td>4.12a</td>
</tr>
<tr>
<td></td>
<td>Analysis of variance</td>
<td>**</td>
<td>*</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Shayang</td>
<td>PK</td>
<td>48.01a</td>
<td>17.84b</td>
<td>69.38a</td>
<td>17.10a</td>
<td>8.70a</td>
<td>2.13a</td>
<td>3.92a</td>
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<tr>
<td></td>
<td>NK</td>
<td>43.70b</td>
<td>23.93a</td>
<td>71.74a</td>
<td>18.18a</td>
<td>10.54a</td>
<td>1.67a</td>
<td>3.39a</td>
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<tr>
<td></td>
<td>NP</td>
<td>47.55a</td>
<td>23.10a</td>
<td>78.31a</td>
<td>15.59a</td>
<td>7.77a</td>
<td>2.49a</td>
<td>4.25a</td>
</tr>
<tr>
<td></td>
<td>NPK</td>
<td>42.83b</td>
<td>22.12a</td>
<td>69.76a</td>
<td>16.85a</td>
<td>10.60a</td>
<td>2.38a</td>
<td>4.12a</td>
</tr>
<tr>
<td></td>
<td>Analysis of variance</td>
<td>*</td>
<td>*</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Jingzhou</td>
<td>PK</td>
<td>48.66a</td>
<td>18.56b</td>
<td>65.66a</td>
<td>15.98a</td>
<td>8.49a</td>
<td>1.75a</td>
<td>4.18a</td>
</tr>
<tr>
<td></td>
<td>NK</td>
<td>43.81c</td>
<td>24.36a</td>
<td>70.81a</td>
<td>16.86a</td>
<td>8.29a</td>
<td>2.05a</td>
<td>4.13a</td>
</tr>
<tr>
<td></td>
<td>NP</td>
<td>45.22bc</td>
<td>22.64a</td>
<td>67.53a</td>
<td>15.94a</td>
<td>8.35a</td>
<td>1.73a</td>
<td>4.11a</td>
</tr>
<tr>
<td></td>
<td>NPK</td>
<td>45.96b</td>
<td>22.12a</td>
<td>74.30a</td>
<td>16.75a</td>
<td>7.51a</td>
<td>2.04a</td>
<td>4.15a</td>
</tr>
<tr>
<td></td>
<td>Analysis of variance</td>
<td>**</td>
<td>*</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

Mean values within a column for each season followed by different letters are significantly different at P < 0.05 according to LSD
*Indicates significance at P<0.05; ** Indicates significance at P<0.01

Institute, Chinese Academy of Agricultural Sciences, Wuhan, China, including oil, protein, and other fatty acids (palmitic acid, stearic acid, oleic acid, linoleic acid and linolenic acid). At maturity stage, rapeseed was harvested from each plot to measure its yield.

Calculations and Data Analysis

Oil and protein yields were measured by multiplying seed yields with oil and protein contents respectively. Analysis of variance (ANOVA) was conducted on data to evaluate treatment means. The differences among the treatments were calculated according to least significance difference test (LSD) at 0.05 probability level by using the SPSS 17.0 version. Figures were prepared using the MS Excel 2007 and Origin Pro 8.5 software program.

Results

Yield of Rapeseed in Response to NPK Fertilization

A significant effect of different fertilization treatments on rapeseed yield was observed at each study site (Fig. 3). Depending on different fertilization treatments, the rapeseed yield varied from 793 to 2060 kg ha⁻¹, 639 to 2268 kg ha⁻¹ and 727 to 2600 kg ha⁻¹ at HH, SY and JZ sites respectively. Among sites, the highest rapeseed yield was observed at JZ site followed by SY and HH. Compared to PK fertilization, NPK and NP treatments significantly increased the rapeseed yield at each site, while NK fertilization found significant only at SY site. The highest rapeseed yield was observed under NPK application followed by NP and NK, while the lowest yield was observed under PK fertilization at each site. The results indicated that fertilization under NPK for rapeseed productivity was found to be statistically better compared to the other fertilizer treatments and increased the total yield across all study sites by 61–72% compared to PK treatment where no N was applied.

Oil and Protein Yield Responses to NPK Fertilization

The oil yields showed a significant response to different fertilizer treatments at all three sites (Fig. 4). Among sites,
the highest oil yield was observed at JZ followed by SY and HH. Oil yield ranged between 354 to 1195 kg ha\(^{-1}\) at JZ site, 307 to 972 kg ha\(^{-1}\) at SY and 388 to 914 kg ha\(^{-1}\) at HH. Significantly, maximum oil yield was observed under NPK treatment followed by NP and NK, while minimum oil yield was observed in PK treatment having similar trend at all three sites. NPK and NP treatments were statistically at par with each other at HH and JZ site while at SY site; NPK was significantly higher than NP. Consequently, the response of protein yield to applications of N, P, and K indicated comparative patterns as oil yield response to applied N, P, and K (Fig. 5). Across all the sites, an increase in protein yield was ranged from 114 to 574 kg ha\(^{-1}\) depending on different fertilization treatments. The significantly maximum protein yield was obtained by the application of NPK followed by NP and NK, while lowest was observed when PK was applied.

**Rapeseed Quality Responses to NPK Fertilization**

Seed quality parameters like palmitic acid, stearic acid, oleic acid, linoleic acid and linolenic acid were not significantly affected by different fertilization treatments across all experimental sites (Table 3). Application of P and K fertilizer showed no significant effect on protein contents of rapeseed at each site but regarding oil concentrations, P and K applications found significant only at JZ and SY sites respectively (Table 3). In contrast, regardless of the P and K applied, application of fertilizer N consistently reduced oil contents (Fig. 6) and enhanced protein contents in rapeseed (Fig. 7) at each site. Consequently, N fertilizer always found significant to concentrations of oil and protein in rapeseed.

**Discussion**

**Seed and Nutritional Yields**

We found that application of different fertilization treatments significantly affected the rapeseed yield. Compared with PK fertilization, the yield of rapeseed was increased at each site by NPK, NP, and NK, indicating the importance of N to improve crop productivity (Fig. 3). At each site, the results of this study showed that oil and protein yields of rapeseed were significantly affected by fertilization treatments. As the oil and protein yields were closely associated with seed yield so the yield was higher in plots receiving N compared to the no-N plots (Fig. 4; 5). Ozor (2003), Barlög and Grzebisz (2004a, b), Rathke \textit{et al.} (2005) and Juan \textit{et al.} (2009) documented that N fertilization improved seed yield, dry matter production, N uptake and demonstrated the importance of N fertilizer in oilseed rape production and in other crops (Sheoran \textit{et al.}, 2016). Furthermore, the highest yields were obtained in plots receiving P. According to Malhi \textit{et al.} (2007), there ought to be an adequate provision of nutrients at early development stages since canola plant uptakes a large portion of its phosphorus during the early development phase, both from soil and applied fertilizer for receiving higher yields. Elevated levels of P significantly increased the P concentration in plants (Idris \textit{et al.}, 1989) and increased canola productivity (Ibrahim, 1989; Kar \textit{et al.}, 1989). K also plays a significant role for oil and protein yield of rapeseed. The K and N interaction were observed significant for seed productivity and oil yield (Brennan and Bolland, 2007). Among treatments, NPK fertilization was best in producing the highest seed yield and oil and protein yield of rapeseed compared with all other treatments. This was due to the balanced supply of all important nutrients to
plants. Other treatments such as NP, NK, and PK were lacking a supply of at least one major nutrient i.e., either N, P or K thus may induce that specific nutrient deficiency stress and retard overall growth of rapeseed with a concomitant reduction in yields. The variation in the seed and nutritional yields at different sites was might be due to the different weather conditions and the differences in indigenous nutrients supply capacity of soil. These differences were also observed in the yield of rice cultivars grown in seven different rice regions of China (Chen et al., 2011; Wang et al., 2012). Further, this discrepancy could also be partly explained by the different previous crops at each site affecting the indigenous nutrients supply capacity of soil (Ren Tao et al., 2015). Oil application did not alter the oil and protein concentrations of rapeseed except at JZ, but a seed oil concentration was decreased. This might be due to the different previous crops affecting the indigenous nutrients supply capacity of soil at study sites (Chen et al., 2011; Ren Tao et al., 2015). Oil contents remain unchanged under applied P fertilizer (Lickfett et al., 1999) and seed protein contents increased at high P supply at 80 kg ha\(^{-1}\) (Tomar et al., 1996). Delivering higher amounts of N consistently decreased the oil contents (Fig. 6) and increased the protein contents (Fig. 7). The results are in agreement with Brennan and Bolland (2007) and Rathke et al. (2005). The conceivable purpose behind the diminishment in seed oil content with expanding N may be because of the way that N is the significant constituent of protein so it advances the seed protein contents, thus, there may be lessening in the level of oil contents since it has an inverse relationship with protein (Öztürk, 2010).

**Rapeseed Quality**

In our study, non-significant improvements were observed in palmitic acid, stearic acid, oleic acid, linoleic acid and linolenic acid under applied N, P and K fertilizers (Table 3). Oil and protein contents were not responded to applied K fertilizer, supporting the results of previous studies (Brennan and Bolland, 2007) except that at SY site, the oil concentrations decreased by K fertilizer application in rapeseed might be due to different soil fertility status and weather conditions (Chen et al., 2011; Wang et al., 2012). P application did not alter the oil and protein concentrations of rapeseed except at JZ, but a seed oil concentration was decreased. This might be due to the different previous crops affecting the indigenous nutrients supply capacity of soil at study sites (Chen et al., 2011; Ren Tao et al., 2015). Oil contents remain unchanged under applied P fertilizer (Lickfett et al., 1999) and seed protein contents increased at high P supply at 80 kg ha\(^{-1}\) (Tomar et al., 1996). Delivering higher amounts of N consistently decreased the oil contents (Fig. 6) and increased the protein contents (Fig. 7). The results are in agreement with Brennan and Bolland (2007) and Rathke et al. (2005). The conceivable purpose behind the diminishment in seed oil content with expanding N may be because of the way that N is the significant constituent of protein so it advances the seed protein contents, thus, there may be lessening in the level of oil contents since it has an inverse relationship with protein (Öztürk, 2010).
Conclusion

This multi locational study showed that seed and nutritional yields responded significantly to applied N, P, and K fertilizers. Other fatty acids of rapeseed palmitic acid, stearic acid, oleic acid, linoleic acid and linolenic acid) were not affected by N, P and K applications. Oil and protein contents did not respond significantly to N and K fertilizer application, but N fertilizer applications consistently increased the contents of oil and increased the protein contents. This shows that N is the major constituent of protein so it promotes the seed protein contents, and thus, there might be a reduction in the percentage of oil content due to the inverse relationship of oil content with protein. Combined application of NPK increased seed, oil and protein yields. So we recommend combined application of NPK for better rapeseed quality and productivity. These results could be valuable to the researchers seeking to increase the rapeseed quality and also for farmers for oilseed rape productivity in China and throughout the world.

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References


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