Title
Comparison of biological and chemical phosphorus fertilizers on rapeseed yield in Iran

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Introduction

The role of phosphorus (P) for plant growth has been intensively investigated (Antoun *et al*, 1996, Rodriguez and Feraga 1999, Madani 2006) as an important plant nutrient P regulates many physiological processes which affect yield components. Rather than adding to this vast body of knowledge the aims of this study were to compare the effects of phosphorus solublizing bacteria applied as biological fertilizers and ammonium phosphate as a mineral fertilizer on growth, seed yield and physiological properties of rapeseed (*Brassica napus* L.).

Materials and Methods

An experiment was carried out on the experimental farm of Arak Islamic Azad University, Iran (Table 1) in the 2006/07 growing season to study the response of rapeseed to phosphorus solublizing bacteria and mineral P fertilizers (ammonium phosphate at 50% P_2O_5). The factorial experiment arranged as randomized complete block design (RCBD) with 3 replications comprised 12 treatments consisting of three rates of mineral P and four different application modes of P solubilizing bacteria (*Pantoea agglomeranes* strain p5 and *Microbacterium laevaniformans* strain p13 those are as commercial product Barvar 2). Phosphorus was applied as ammonium phosphate (AP) at AP0 = control, AP1 = 125 kg AP ha^{-1}, AP2 = 250 kg ha^{-1}). For PSB, treatments comprised PSB0 = control, PSB1 = application of $100*10^8$ CFU PSB per 100 g biofertilizer applied at sowing only, PSB2 = application of $100*10^8$ CFU PSB per 100 g biofertilizer topdressed in early spring, PSB3 = use of $100*10^8$ CFU PSB per 100 g biofertilizer applied at sowing and in early spring.
Rapeseed cv. Okapi was sown on 5 September 2006 at a distance of 5 cm within and 30 cm between rows. Each plot consisted of eight rows of 8 m length and 2.4 m width leading to a plot area of 19.2 m^2. Irrigation, weed and pest control followed typical practices at the experimental location.

Table 1: Physical and chemical analysis of the experimental soil on the experimental Farm of Arak Islamic Azad University, Iran.

Physical properties	0-30 depth
Soil texture	Sandy loam
Clay (%)	12
Silt (%)	36
Fine send (%)	52
Chemical analysis	
Available (K) (mg kg^{-1})	434
Available (P) (mg kg^{-1})	11.4
Total nitrogen (mg kg^{-1})	6.2
$CaCO_3$ (%)	28
Organic matter (%)	0.61
EC (dS m^{-1} at 25°C)	0.6
pH	8.0

Measurements of plant height (cm) and shoot dry matter were taken in representative samples (5 plants) which were collected randomly from every experimental plot. At harvest the number of pods per plant, the oil content in grains and grain yield were calculated based on a harvested area of 4 m^2. Total P in the vegetative and reproductive plant parts were determined according to Troug and Mayer (1939). All data were subjected to analysis variance using

Mstat-c whereby treatment means were compared using Duncan’s multiple range test at $P < 0.05$.

Results and Discussions

Effects of ammonium phosphate fertilizer application

No effect of P application on plant height, biomass yield and oil content in grains was observed (Table 2). However, P application caused a significant increase in the number of pods per plants, in grain yield and in the P concentrations of vegetative plant parts and seeds. Compared to the unfertilized control grain yields were 34% higher in AP1 and 44% higher in AP2 (Table 2). The application of the 250 kg AP ha^{-1} increased the P concentration in vegetative shoot parts from 1.9 to 2.2 mg kg^{-1} and in grains from 5.1 to 6.1 mg kg^{-1}. In contrast AP application did not affect grain oil concentrations, biomass yield and plant height.

Table 2: Effect of different sources and rates of phosphorus fertilizer on rapeseed grown on the experimental farm of Arak Islamic Azad University, Iran.

Phosphorus treatments		Plant height	Biomass yield	Pods per plant	Oil content	Grain yield	P content vegetative plant part	P concentration in reproductive plant parts	Seed P concentration
		(cm)	(t ha^{-1})	(No)	(%)	(t ha^{-1})	(g kg^{-1})	(g kg^{-1})	(g kg^{-1})
Ammonium phosphate (AP kg ha^{-1})	AP0: 0	91.108	9.387	61.582	48.927	3.433c	1.9c	5.3c	5.1c
	AP1: 125	85.900	8.958	76.875	49.071	5.156b	2.2b	5.5ab	6.1b
	AP2: 250	87.608	10.597	98.497	49.047	6.112a	2.9a	5.7a	6.9a
Mean									
Phosphorus solubilizing bacteria (PSB 10^8 CFU per /100g biophosphate ha^{-1})	PSB0	77.700c	7.451b	62.287c	48.356b	3.018d	2.1c	5.1c	5.3c
	PSB1	85.222b	10.000ab	82.382bc	49.036ab	4.992c	2.6b	5.8b	6.3b
	PSB2	92.567a	9.739ab	95.482b	49.157ab	7.028b	3.2a	6.3ab	6.8a
	PSB3	97.333a	11.400a	115.787a	49.511a	9.897a	3.3a	6.9a	6.8a
Mean									
AP x PSB interaction	AP0 PSB0	83.000	7.153	55.077	48.080	2.597	2.1e	5.2e	5.4d
	AP0 PSB1	85.433	10.120	84.428	49.067	5.153	2.3d	5.5d	6.1c
	AP0 PSB2	97.233	9.610	102.558	49.230	7.210	2.5c	6.2bc	6.6ab
	AP0 PSB3	98.767	10.663	124.265	49.330	10.773	2.2d	6.8b	6.6ab
	AP1 PSB0	73.667	7.803	51.920	48.200	2.830	2.5c	5.5d	6.0c
	AP1 PSB1	84.800	9.520	70.740	49.477	4.703	3.1b	5.8c	6.5bc
	AP1 PSB2	89.900	8.333	92.077	49.070	7.323	3.3ab	6.3bc	6.6ab
	AP1 PSB3	95.233	10.177	92.763	49.537	9.767	3.5a	6.9b	6.6ab
	AP2 PSB0	76.433	7.397	79.865	48.787	3.627	2.3d	7.0b	6.2c
	AP2 PSB1	85.433	10.360	91.979	48.563	5.120	0.28bc	7.3ab	6.6ab
	AP2 PSB2	90.567	11.273	91.812	49.170	6.550	3.1b	7.8a	6.9a
	AP2 PSB3	98.000	13.360	130.333	49.667	9.150	3.6a	7.8a	6.8a
Mean		—— F-probability ——							
Mean square probability	Ammonium phosphate (AP)	ns	ns	0.03	ns	.02	0.014	0..33	0.1
	Phosphorus solubilizing bacteria(PSB)	0.005	0.006	.004	0.002	.002	0.036	0.02	0.02
	AP x PSB interaction	ns	ns	ns	ns	ns	0.005	0.01	0.01
CV%		9.9	19.5	20.3	1.7	13.6	2.0	3.1	3.6

Means with different letters are significantly different at P (<0.05). AP = ammonium phosphate AP0= Control, AP1= 125kg ha^{-1}), AP2= 250kg ha^{-1}) PSB= Phosphorus solubilizing bacteria, PSB0 =control, PSB1= at sowing time only, PSB2 = in early spring, PSB3 = dual fertilization at sowing and in early spring.

Effects of P solubilizing bacteria

The application of P solubilizing bacteria (PSB) led to increases in plant height, total dry matter, pod number per plant, grain oil concentration, grain yield, P concentration in vegetative plant parts and in grains (Table 2). The highest rapeseed yield was obtained with the addition of AP application and dual application of PSB.

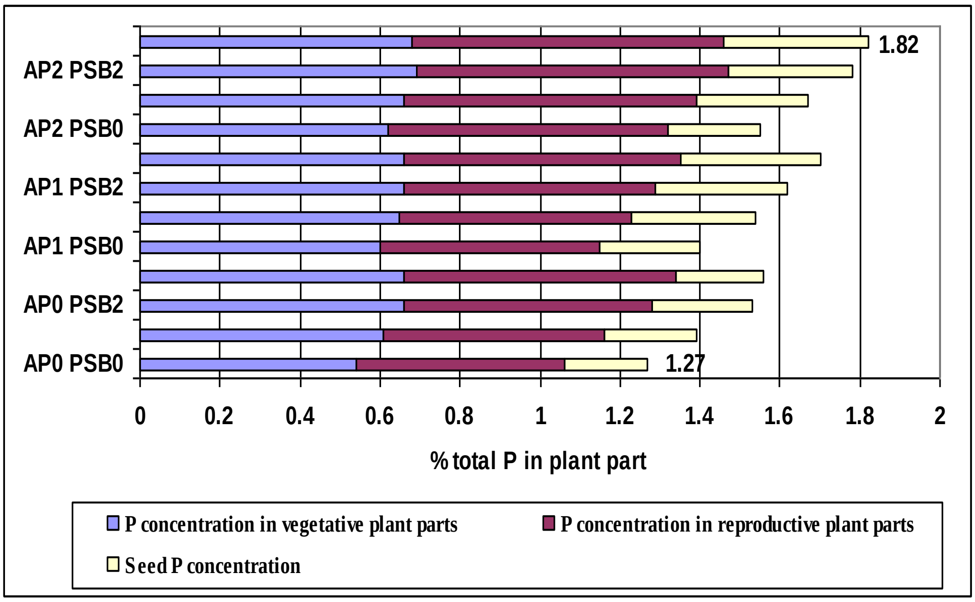

Figure 1: Phosphorus (P) uptake by rapeseed in vegetative parts, reproductive parts (siliques) and grains of rapeseed .AP0= Control, AP1= ammonium phosphate applied at 125 kg ha^{-1}), AP2 = ammonium phosphate applied at 250 kg ha^{-1}), PSB0 = control, PSB1= use of 100*10^{8} CFU PSB per 100 g biofertilizer applied at sowing, PSB2 = use of 100*10^{8} CFU PSB per 100 g biofertilizer topdressed in early spring, PSB3 = use of 100*10^{8} CFU PSB per 100 g biofertilizer applied at sowing and in early spring.

The combination of AP application and PSB shows maximum P absorptions ranging from 1.27 to 1.82 mg kg^{-1} at whole plants respectively (Figure 1). It was concluded that the application of mineral P fertilizer associated with PSB strongly enhanced P uptake from the soil. This supports earlier research by Gupta *et al*. (1999) and Ghoname and Shafeek *et al*. (2004).

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