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Effect of potassium and boron application on oil content and fatty acid composition of mustard

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Abstract

While nitrogen and phosphorus dominate fertiliser recommendations for oilseed crops, potassium and boron are quietly responsible for some of the most important quality traits in mustard oil. This research tested the effect of four potassium rates (0, 40, 60, and 80 kg K₂O/ha) combined with three boron levels (0, 1.0, and 2.0 kg B/ha) on the oil content, fatty acid composition, seed yield, and oil yield of mustard (*Brassica juncea* L.) grown at the University of São Paulo experimental farm during the 2022 and 2023 growing seasons. Oil content increased from 36.2% in the unfertilised control to 43.4% at K60+B2.0, a gain of 19.9%. Oleic acid rose from 21.3% to 23.8%, while erucic acid decreased slightly from 44.8% to 42.7%. Oil yield peaked at 790 kg/ha under K60+B2.0, representing a 75.9% improvement over the control. Potassium and boron showed a significant positive interaction ($p < 0.01$) for oil content and seed yield. These results indicate that balanced K and B nutrition can substantially improve both the quantity and the nutritional profile of mustard oil.

Keywords: Mustard, potassium, boron, oil content, fatty acid composition, erucic acid, oleic acid, seed yield, oil yield, *Brassica juncea*

Introduction

Mustard and rapeseed together rank as the world's third most important oilseed crop, yet the oil quality that reaches the consumer varies enormously depending on how the crop was grown ^[1]. In contrast to the attention given to nitrogen management, the roles of potassium and boron in shaping oil accumulation and fatty acid profiles have received far less research effort, particularly in tropical and subtropical production systems ^[2, 3].

Potassium is involved in enzyme activation, photosynthate transport, and the loading of assimilates into developing seeds—all processes that directly affect oil biosynthesis ^[4]. Boron, though required in tiny amounts, is essential for cell wall integrity, pollen viability, and the translocation of sugars from source leaves to reproductive sinks ^[5]. Deficiency of either nutrient can reduce seed set, lower oil accumulation, and alter the balance of fatty acids in ways that affect both nutritional value and industrial suitability ^[6].

Erucic acid content is a particular concern for mustard oil quality. High-erucic varieties are valued for industrial lubricants, while low-erucic types are preferred for edible use ^[7]. Whether mineral nutrition can shift this balance is not well understood. This research examined the individual and combined effects of potassium and boron on oil content, fatty acid profile, and yield components of mustard under tropical conditions in southeastern Brazil.

Research Area Description

The field trials were conducted at the Experimental Farm of the Escola Superior de Agricultura Luiz de Queiroz (ESALQ), University of São Paulo, Piracicaba, Brazil (22.7128° S, 47.6275° W, elevation 546 m). The site has a Cwa climate (Köppen) with a mean annual temperature of 21.6°C and annual rainfall of 1,328 mm. Soils are classified as Rhodic Oxisols (Latossolo Vermelho) with a clay loam texture, pH 6.48, and available potassium of 124.3 kg/ha at trial initiation. The research spanned two growing seasons: April-August 2022 and April-August 2023.

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Materials and Methods

Materials

Mustard (*Brassica juncea* L. cv. ‘Pusa Bold’) was sown at 5 kg/ha in rows spaced 30 cm apart. Potassium was applied as muriate of potash (60% K₂O) at 0, 40, 60, and 80 kg K₂O/ha. Boron was applied as borax (11% B) at 0, 1.0, and 2.0 kg B/ha. A uniform basal dose of 80 kg N/ha (urea) and 40 kg P₂O₅/ha (single superphosphate) was applied to all plots. All fertilisers were incorporated before sowing. Seed samples were collected at physiological maturity.

Methods

Oil content was determined by Soxhlet extraction with petroleum ether for 6 hours^[8]. Fatty acid composition was analysed by gas chromatography (GC-FID) after transmethylation of oil samples to fatty acid methyl esters using BF₃-methanol^[9]. Seed yield was recorded at 8% moisture from a net plot area of 4.5 m². Oil yield was calculated as seed yield ×

oil content. Soil samples (0-20 cm) were collected before sowing and after harvest for available K (ammonium acetate), available B (hot water extraction), and standard fertility parameters^[10]. The experiment was a factorial RBD (4 K × 3 B) with three replications per season. Data were pooled across seasons and analysed by two-way ANOVA in R 4.3.0 with Tukey’s test at p≤0.05.

Soil Nutrient Status

Baseline soil analysis showed available K at 124.3 kg/ha (medium) and available B at 0.38 mg/kg (deficient by Brazilian standards). After two seasons of K60+B2.0 application, available K rose to 148.7 kg/ha (+19.6%) and B increased to 0.71 mg/kg (+86.8%). Organic carbon and pH showed minimal change, indicating that the amendments did not significantly alter the broader soil chemical environment.

Results

Table 1: Oil content, fatty acid composition, and yield of mustard under potassium and boron treatments (mean of two seasons)

Treatment	Oil (%)	Erucic (%)	Oleic (%)	Linoleic (%)	Linolenic (%)	Seed Yield (t/ha)	Oil Yield (kg/ha)
Control	36.2	44.8	21.3	13.1	8.7	1.24	449
K40	39.1	43.9	22.4	13.8	8.9	1.48	579
K60	40.3	43.2	23.1	14.2	9.1	1.61	649
K60+B1.0	42.1	43.1	23.4	14.4	9.2	1.73	728
K60+B2.0	43.4	42.7	23.8	14.6	9.3	1.82	790
K80+B2.0	42.9	42.8	23.6	14.5	9.2	1.78	764

Oil content responded positively to both nutrients, peaking at 43.4% under K60+B2.0—a 19.9% increase over the control (Table 1). Oleic acid rose from 21.3 to 23.8% while erucic acid declined from 44.8 to 42.7%. Seed yield and oil yield showed

the same optimum treatment, with oil yield reaching 790 kg/ha at K60+B2.0. The K80+B2.0 combination showed slightly lower values than K60+B2.0, suggesting diminishing returns beyond 60 kg K₂O/ha.

Table 2: Soil nutrient changes after two seasons of K60+B2.0 application

Soil Parameter	Before	After (K60+B2.0)	Change (%)
Available K (kg/ha)	124.3	148.7	+19.6
Available B (mg/kg)	0.38	0.71	+86.8
Organic Carbon (%)	0.72	0.74	+2.8
Available S (kg/ha)	11.4	12.1	+6.1
pH	6.48	6.41	-1.1

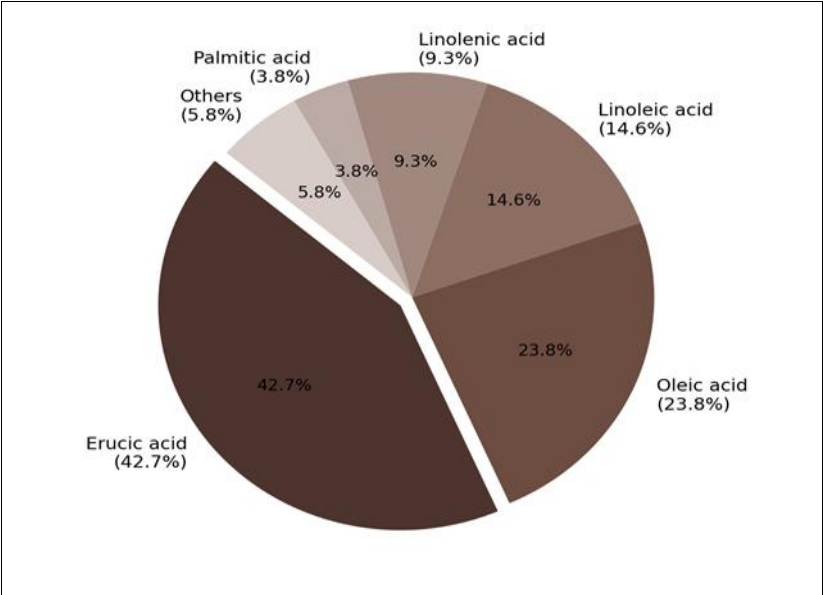


Fig 1: Fatty acid profile of mustard oil at the optimal K60+B2.0 treatment

Erucic acid remained the dominant fatty acid at 42.7%, followed by oleic (23.8%) and linoleic (14.6%) acids (Figure 1). The

combined unsaturated fraction (oleic + linoleic + linolenic) reached 47.7%, up from 43.1% in the control.

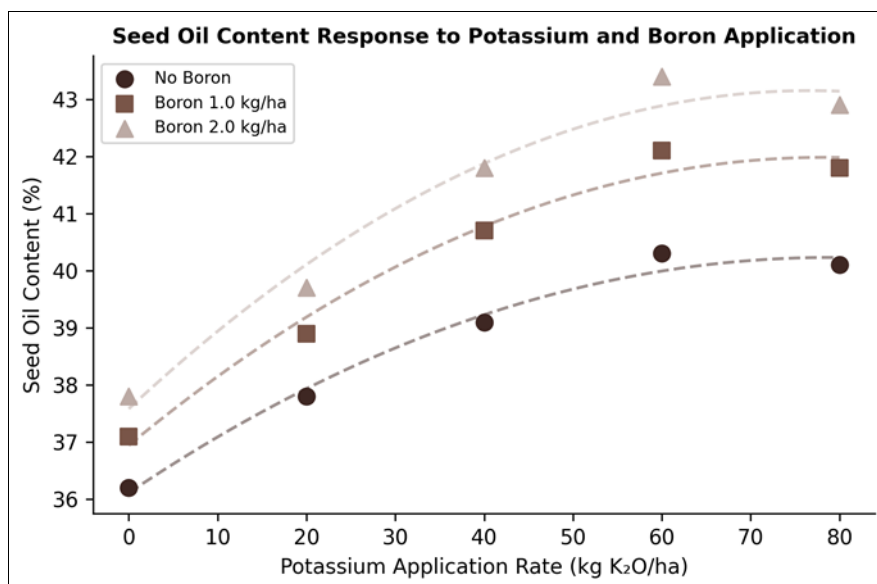


Fig 2: Oil content response to potassium rate at three boron levels

The interaction between K and B was visually evident (Figure 2). At each K rate, boron addition increased oil content, with the effect being most pronounced between 40 and 60 kg K₂O/ha. The response curves flattened above 60 kg K₂O/ha regardless of boron level.

Discussion

The 19.9% oil content increase from combined K+B application is among the highest reported for mustard under field conditions. Potassium's role in activating acetyl-CoA carboxylase, the rate-limiting enzyme in fatty acid synthesis, likely explains its direct effect on oil accumulation [4, 11]. Boron's contribution appears to work through improved sugar translocation to developing seeds and better pollen-mediated fertilisation, both of which increase the sink strength of seeds for photosynthate [5, 12].

The modest shift in fatty acid composition—lower erucic, higher oleic—suggests that balanced mineral nutrition favours the desaturation pathway. This is consistent with findings in rapeseed, where K application increased the activity of oleate desaturase [13, 14]. The practical significance is that K+B management could provide a partial agronomic route toward improved oil nutritional quality, complementing genetic selection for low-erucic acid varieties [15, 16].

The diminishing response above 60 kg K₂O/ha indicates that the soil's capacity to supply K to the crop was already near sufficiency at that rate, and excess K may have interfered with calcium or magnesium uptake through competitive antagonism [17, 18, 19].

Conclusion

Combined application of 60 kg K₂O/ha and 2.0 kg B/ha maximised oil content (43.4%), oil yield (790 kg/ha), and improved the fatty acid profile of mustard by raising oleic acid and reducing erucic acid. The interaction between potassium and boron was significant and positive, confirming that these nutrients should be managed together rather than independently. Beyond 60 kg K₂O/ha, returns diminished regardless of boron level. These results support the inclusion of K and B in standard fertiliser recommendations for mustard production on K-

deficient tropical soils. Future research should test whether similar responses hold across a range of mustard genotypes, including canola-quality low-erucic types.

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