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RESEARCH ARTICLE

Soil Applied Boron Improved Productivity and Oil Yield of Canola Cultivars

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ABSTRACT

Canola (*Brassica napus* L.) is one of the most important oilseed crop. Although micronutrients are required in minute quantity, but their deficiency affects fundamental physiological and biochemical processes leading to reduced crop yield. In this study, field experiments were conducted to identify the optimum level of boron (B) to get maximum growth, seed and oil yield of canola. Experimental treatments comprised of four canola cultivars *viz.*, Faisal Canola, Pakola, PARC Canola hybrid and Rainbow and three levels of B (0, 1, 2 kg ha^{-1}). Results showed that Pakola produced the taller plants (24-30% taller than other cultivars), and higher number of branches per plant (18-24%), seed per pod (47-51%), thousand seed weight (8-9%), biological yield (4-5%), seed yield (10-11%) and oil yield (10-13%) as compared to other tested cultivars. With the increase of B levels (0 to 2 kg ha^{-1}) increase of plant height (19-24%), number of branches (33-51%), seed per pods (30-39%), thousand seed weight (8-11%), biological yield (11-12%), seed yield (25-27%) and oil yield (30-32%) increased ($P \leq 0.05$) than control treatment during succeeding years. In conclusion, Pakola performed better in growth, seed and oil yield than the other three cultivars; whereas, 2 kg ha^{-1} of B was found as the best level for higher canola yield under rainfed condition.

INTRODUCTION

Pakistan is facing deficiency of edible oils and its demand is increasing with rapid increase in population. The present per capita consumption of edible oil in Pakistan is 15.34 kg. During 2015-16, 14% edible oil requirement in Pakistan was fulfilled by local production, while remaining 86% imported by spending 284.55 billion rupees. Canola belongs to family *Brassicaceae*. It has become one of the most important oilseed crop throughout the world (Miri, 2007). In Pakistan, total area under canola cultivation during 2016-17 was 13.4 thousand hectare, yielding 15 thousand tonnes of seed and 6 thousand tonnes of oil (GOP, 2017).

There are many yield limiting factor that reduce the growth and development of oilseed crops. Non-availability of high yield genotypes and late planting of canola are important factors that affect the yield and quality of canola (Salmasi et al., 2006). Balanced fertilization with NPK is beneficial in all the oilseed crops both under rainfed and irrigated conditions. The micronutrients, also termed as trace element such as boron, copper, iron, manganese, molybdenum and zinc are essential for plant growth and development (Imtiaz et al., 2010). Deficiency of micronutrients has drastically reduced the yield of agronomic crops (Malakouti, 2007). Micronutrient deficiency reduced the crop growth and development that ultimately decreased yield and thus crop become more susceptible to diseases and pests attacks (Alloway, 2003).

Boron (B) is a one the most important micronutrients required for normal growth and development of cereal crops especially wheat and rice (Ahmed et al., 2012) and have a wider use for agronomic and horticultural crops (Devi et al., 2012). It is an essential element for the growth of cultivated plants species and B deficiency exerts significant negative impacts on the yield of these species (Rashid et al., 2002). Deficiency of B reduces the plant growth and seed yield (Stangoulis et al., 2001) due to floral abortion (Naser and Islam, 2001). The B application is more important for economic yield of oilseed crops due to its role in pollen tube formation. It also plays an important role the in transportation of sugars, plasma membrane integrity by binding membrane compounds and also trigger the activities of some enzymes related to membrane function or structure or participating phenolics metabolism (Goldbach et al., 2002). During the peak vegetative flowering, pod formation and seed development stages, balanced and optimum supply of B is necessary for maximum seed yield of canola (Yang et al., 2009; Malhi et al., 2003). In Pakistan, 82% irrigated area is B deficit (Niaz et al., 2007) and 50% of Pothwar region and 73% of Chakwal district are B deficient (Rashid et al., 2007).

A very limited work is present regarding the optimization of B level for canola crop especially under rainfed conditions. Keeping in view the importance of canola as an oilseed crop and B as an important micronutrient, the present study was conducted to identify the optimum B level to improve the growth, seed and oil yield of canola cultivars in the region.

MATERIALS AND METHODS

Experimental conditions

Field experiments were conducted at Koont Research Farm, Pir Mehr Ali Shah Arid Agriculture University (PMAS-AAU), Rawalpindi, Pakistan (72° 55' 0 East Longitude and 32° 6' 48 North latitude. The altitude of study area is 189 m and average rainfall is 519 mm annually. The study was conducted during Rabi season in two consecutive years, i.e. 2013-14 and 2014-15. Composite soil samples (0-15 cm and 15-30 cm depth) were taken to determine the physicochemical characteristics and B status of the experimental site (Table 1). Meteorological data of the experimental site was recorded during the course of study from the weather station at Koont Research Farm, PMAS-AAU (Table 2).

Treatments variables

Four canola cultivars *viz.*, Faisal Canola, Pakola, PARC Canola hybrid and Rainbow with three B levels i.e. 0, 1 and 2 kg ha^{-1} were used in the current study. The treatments were arranged in a randomized complete block design split plot with four replications. The cultivars were placed in the main plot and B levels in the sub plots. The area of sub plots was 2.7×5 m^2.

Crop husbandry

The crop was sown on October 15, 2013 and October 17, 2014 with single row hand drill having seeding depth of 3-4 cm at the seed rate of 5 kg ha^{-1}. There were six rows in each sub plot, row to row (R×R) distance was kept 45 cm and plant to plant distance was maintained at 10 cm after thinning. Replications were separated from each other by 2 meter distance. Recommended doses of fertilizer (90 kg N and 60 kg P ha^{-1}) were applied during seedbed preparation. Phosphorus was applied in the form of di-ammonium phosphate (DAP) and nitrogen in the form of urea and DAP. The B was applied in the form of borax (H_2BO_3) as basal application. The crop was harvested on April 20, 2014 and April 25, 2015 during 1st and 2nd years, respectively.

Table 1: Soil physicochemical characteristics of the experimental site

	2013-14		2014-15	
Parameter	Soil depth (cm)		Soil depth (cm)	
	0-15	15-30	0-15	15-30
Soil texture	Loam	Loam	Loam	Loam
B (mg kg^{-1})	0.35	0.38	0.36	0.39
pH	7.34	7.2	7.14	7.2
EC (dS m^{-1})	0.85	0.89	0.90	0.95
Organic matter (g kg^{-1})	6.8	3.8	6.7	3.7
Total N (g kg^{-1})	0.34	3.19	0.31	0.19
Extractable P (mg kg^{-1})	6.6	5.3	6.7	5.2
Extractable K (mg kg^{-1})	120	110	120	120

Data collection

Ten plants were randomly selected from each plot to record the agronomic traits viz. plant height, number of pods per plant, number of seed per pod, thousand seed weight, primary and secondary branches per plant. An area of 1 m^2 from each plot was harvested to determine biological and seed yield. Seed oil content was measured by solvent extraction method using n-hexane (Elluche et al., 2007). Oil yield of canola cultivars was measured by following formula (Raja et al., 2007).

Oil yield (kg ha^{-1}) = Oil contents of seed (%) × Grain yield (kg ha^{-1}) / 100

Table 2: Mean rainfall, temperature and relative humidity during crop growth period (2013-14 and 2014-15)

		Months					
Climatic values	Years	October	November	December	January	February	March
Temperature (^{0}C)	2013-14	20.15	15.30	11.50	10.43	12.44	15.22
	2014-15	21.85	17.28	12.61	11.64	14.46	17.34
Rainfall (mm)	2013-14	1.05	1.15	0.00	1.78	6.45	10.75
	2014-15	1.66	1.77	0.00	2.45	7.14	11.81
Relative humidity (%)	2013-14	55.8	56.4	58.5	56.9	54.8	53.2
	2014-15	57.3	57.8	59.4	58.9	56.5	54.1

Statistical analysis

Collected data were analyzed by using the Fisher's analysis of variance (ANOVA) techniques and treatments' means were compared using least significance difference (LSD) test at 5% probability level (Steel et al., 1997). Year effect was significant for most of studied parameters thus data has been presented separately for both years. The data were statistically analyzed by using STATISTIX 8.1.

RESULTS

Morphological parameters

The ANOVA indicated that plant height and number of primary branches per plant were significantly different among various canola cultivars; results being non-significant for number of secondary branches per plant during both experimental years. Boron application also significantly affected the plant height and number of primary and secondary branches per plant during both year of experimentation. However, the interaction (V×B) was only significant for number of secondary branches per plant during second year; results being non-significant for plant height and number of primary branches during both year and secondary branches per plant during first year of experimentation (Table 3).

The tallest plants were produced by cultivar "Pakola" which was statistically similar with cultivar "PARC canola hybrid", while the smallest plants were produced by cultivar 'Faisal canola' during both years. The tallest plants were observed under 2 kg ha^{-1} B, while plants grown under no B had the lowest plant height (Table 4). The highest number of primary branches was recorded for cultivar 'Pakola' and the lowest were recorded for cultivar 'Faisal canola' during both years of experimentation. The highest number of primary and secondary branches per plant was recorded with B application at 2 kg ha^{-1} during both years and that was statistically similar with B application at 1 kg ha^{-1}; plants grown under no B had the lowest number of primary and secondary branches during second year (Table 4). The interaction (V×B) showed that the highest number of secondary branches per plant was recorded in cultivar 'Pakola' with B application at 2 kg ha^{-1} during first year (Table 4).

Yield Parameters

The ANOVA indicated that pods per plant, seeds per pod and 1000-seed weight were significantly different among various canola cultivars during both experimental years. Boron application also significantly affected the pods per plant, seeds per pod and 1000-seed weight during both year of experimentation. However, the interaction (V×B) was only significant for seeds per pod during both years and pods per plant during first year; results being non-significant for pod per plant during second year and 1000-seed weight during both years (Table 3).

The highest pods per plant were produced by cultivar "Pakola" and cultivar "PARC canola hybrid", while the smallest plants were produced by cultivar 'Faisal canola' and cultivar 'Rainbow' during both years. The highest pods per plant were observed under 2 kg ha^{-1} B, while plants grown under no B produced the lowest pods per plant (Table 4). The highest seeds per pod were recorded for cultivar 'Pakola' for both years, the lowest for the cultivar 'Faisal canola' during second year and for the cultivars 'Faisal canola' and 'Rainbow' during the first year of experimentation. The highest 1000-seed weight was recorded for cultivar 'Pakola' for both years. The highest number of seeds per pod and 1000-seed weight was recorded with B application at 2 kg ha^{-1} during both years; plants grown under no B had the lowest seeds per pod and 1000-seed weight (Table 4). The interaction (V×B) showed that the highest pods per plant during first year and seeds per pod during both years were recorded in cultivar 'Pakola' with B application at 2 kg ha^{-1} during first year (Table 4).

Biological/seed and oil yield

The ANOVA indicated that biological yield, seed yield and oil yield were significantly different among various canola cultivars during both experimental years. Boron application also significantly affected the biological

Table 3: Analysis of variance (ANOVA) on yield components and oil yield of canola varieties at different boron levels

Source	df	Mean square																	
		PH		PB		SB		Pod per plant		Seed per pod		TSW		SY		BY		OY	
		2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Block	3	88.39	120.13	0.79	0.68	1.74 s	0.95	63.39	245.23	1.89 ns	2.66	0.13	0.16 **	9012.13	13285.5	143965.13	166160.35	4769	3609
Varieties (V)	3	1836.09 **	1409.84 **	1.86 **	1.45 *	2.09 ns	1.26 ns	4105.01 **	3075.39 **	171.11 **	191.28 **	0.27 **	0.20 **	57151.24 **	52502.61 **	97648.63 **	137187.97 **	21638 **	16507 **
Boron level (B)	2	2079.11 **	1577.11 **	13.50 **	8.48 **	50.95 **	18.88 **	34174.18 **	28832.42 **	152.16 **	110.88 **	0.63 **	0.40 **	644400.65 **	591405.44 **	1312145.9 **	1460320.6 **	195531 **	186457 **
V × B	6	53.23 ns	45.32 ns	0.39 ns	0.30 ns	2.09 *	0.85 ns	1919.49 **	1065.21 ns	2.79 *	0.828 *	0.02 ns	0.02 ns	4154.86 ns	4083.29 ns	15836.50 ns	2842.84 ns	1543 ns	475 ns
Error	33	40.46	42.05	0.32	0.45	0.70	0.64	434.91	541.30	0.89	0.54	0.01	0.02	3045.41	3314.60	20335.73	14150.17	2222	1387
CV (%)		6.0	5.7	12.6	13.3	16.9	13.6	13.2	14.2	5.1	3.7	3.3	3.8	3.4	3.5	2.6	2.2	6.1	4.8

PH, plant height; PB, primary branches; SB, secondary branches; TSW, thousand seed weight; SY, seed yield; BY, biological yield; OY, oil yield; ns=non–significant; *significant at P≤0.05; **Highly significant at P≤0.01.

yield, seed yield and oil yield during both year of experimentation. However, the interaction (V×B) was non-significant for biological yield, seed yield and oil yield during both years (Table 3).

The highest biological yield was produced by cultivar "Pakola" during both years and that was statistically similar with cultivar 'Faisal canola' and cultivar 'PARC canola hybrid'. The seed yield was the highest in cultivar 'Pakola' and lowest in cultivar 'Rainbow' during both years of experimentation. The oil yield was the highest in cultivar 'Pakola' during both years. During first year, the cultivar 'Rainbow' produced the lowest oil yield; the oil yield was the lowest and statistically similar in cultivar 'Faisal canola', 'PARC canola hybrid' and the cultivar 'Rainbow' during the second year (Table 5). The highest biological yield, seed yield and oil yield were recorded with B application at 2 kg ha^{-1} during both years; plants grown under no B had the lowest biological yield, seed yield and oil yield (Table 5).

DISCUSSION

This study indicated that B as a micronutrient plays an important role in the growth and yield of oilseed crop. In the present experiment, the maximum plant height was produced in cultivar 'Pakola' with B application at 2 kg ha^{-1}. The present results are in line with findings of Naser and Islam (2001) who reported maximum plant height of canola cultivars as a result of B application at 1.5 kg B ha^{-1}. In another study, Jasmin et al. (2015) also reported that the highest plant height was obtained where B was applied at 2 kg ha^{-1}. This improvement in plant height due to B application might be attributed to the role of B in cell division and expansion in oilseed crops. At higher B level (2 kg ha^{-1}), the cultivar 'Pakola' produced the maximum number of primary branches which supports the findings of Jasmin et al. (2015) who reported that maximum number of primary branches of canola were recorded when B was applied at the rate of 2 kg ha^{-1}. In another study, Naser and Islam (2001) reported the maximum number of secondary branches per plant of canola cultivars in response to 1.5 kg B ha^{-1}.

In current study, maximum numbers of pods per plant were recorded in cultivar 'Pakola' at higher B level (2 kg ha^{-1}). The current results are in line with the findings of Halder et al. (2007) who reported the maximum number of siliqua per plant of mustard in response to 2 kg B ha^{-1}. The present results also showed that maximum number of seeds per pod was recorded in cultivar 'Pakola' with B application at 2 kg ha^{-1}. The similar findings were also reported by Hossain et al. (2012) as they documented that mustard cultivars produced the maximum seeds per pod in response to B application at 1 kg ha^{-1}. At higher B level, the greater 1000-seed weight (4.16 and 4.21 g) was recorded in cultivar 'Pakola' at B application of 2 kg ha^{-1}. These results are in line with the findings of Naser and Islam (2001) who revealed that maximum 1000-seed weight was obtained in mustard with 1.5 kg B ha^{-1}.

The maximum seed yield was obtained in cultivar 'Pakola' at B application of 2 kg ha^{-1}. This highest seed yield was attributed to the more numbers of pods per pod, seeds per pod and 1000-seed weight. The better performance of yield related attributes in canola in this study is due to role of B in pollen fertility which improves the grain formation in field crops. The present findings are in accordance with the work of Nadian et al. (2010) who recorded the maximum seed yield of canola with 2.5 kg B ha^{-1}. Similarly, Halder *et al.* (2007) recorded maximum seed yield where B was applied at 2.0 kg ha^{-1}. The maximum biological yield was obtained at highest B level (2 kg ha^{-1}) in cultivar 'Pakola' which was attributed to the more plant height and number of primary and secondary branches which improved the biomass and eventually the biological yield. The maximum oil yield was also recorded in cultivar 'Pakola' at B application of 2 kg ha^{-1}. The present results are similar by the findings of Nadian et al. (2010) who revealed that the maximum oil yield (1383.0) was obtained when B was applied at the rate of 2.5 kg ha^{-1}.

Table 4: Effect of variety and boron application on yield of canola during 2013-14 and 2014-15

Treatments	Plant height (cm)		Primary branches per plant		Secondary branches per plant		Pod per plant		Seed per pod		1000-seed weight (g)	
Varieties (V)	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Faisal canola	89.9^{c}	98.8^{c}	4.05^{b}	4.67^{b}	5.03^{ab}	5.99^{a}	148.2^{b}	153.1^{b}	15.3^{c}	16.9^{c}	3.81^{b}	3.90^{b}
Pakola	116.8^{a}	122.2^{a}	5.02^{a}	5.52^{a}	5.3^{a}	6.27^{a}	176.8^{a}	175.9^{a}	22.8^{a}	24.4^{a}	4.16^{a}	4.21^{a}
PARC canola hybrid	115^{a}	121.3^{a}	4.52^{ab}	5.06^{ab}	5.06^{ab}	5.97^{a}	169.6^{a}	177.8^{a}	20.7^{b}	22.1^{b}	3.91^{b}	3.98^{b}
Rainbow	105.5^{b}	113.1^{b}	4.54^{ab}	5.07^{ab}	4.4^{b}	5.49^{a}	137.1^{b}	146.2^{b}	15.5^{c}	16.2^{d}	3.88^{b}	3.94^{b}
LSD ($P \leq 0.05$)	5.28	5.38	0.47	0.56	0.69	0.66	17.32	19.32	0.78	0.61	0.10	0.12
Boron Level (kg ha^{-1})												
0	95.5^{c}	104.6^{c}	3.53^{c}	4.27^{b}	3.1^{c}	4.71^{b}	110.3^{c}	120.9^{c}	15.58^{c}	17.35^{c}	3.75^{c}	3.84^{c}
1	106.5^{b}	112.5^{b}	4.73^{b}	5.26^{a}	5.0^{b}	6.26^{a}	161.2^{b}	163.1^{b}	18.51^{b}	19.76^{b}	3.92^{b}	4.01^{b}
2	118.3^{a}	124.4^{a}	5.34^{a}	5.69^{a}	6.8^{a}	6.81^{a}	202.6^{a}	205.8^{a}	21.75^{a}	22.61^{a}	4.15^{a}	4.16^{a}
LSD($P \leq 0.05$)	4.57	4.66	0.41	0.48	0.60	0.57	15.01	16.73	0.68	0.53	0.09	0.10

Different letters indicate statistically significant-difference among the values in each column and individual factors.

Table 5: Effect of variety and boron application on yield component and oil yield of canola during 2013-14 and 2014-15

Treatments	Seed yield (kg ha^{-1})		Biological yield (kg ha^{-1})		Oil yield (kg ha^{-1})	
Varieties (V)	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Faisal canola	1623.3^{b}	1636.8^{b}	5448.6^{ab}	5475.1^{b}	746.4^{bc}	754.5^{b}
Pakola	1725.1^{a}	1736.4^{a}	5589^{a}	5666.2^{a}	827.2^{a}	832.7^{a}
PARC canola hybrid	1639.8^{b}	1661.2^{b}	5448.5^{ab}	5497.2^{b}	775.6^{b}	779.6^{b}
Rainbow	1557.4^{c}	1576.6^{c}	5372.8^{b}	5417.3^{b}	730.6^{c}	753.5^{b}
LSD (P≤0.05)	45.83	47.81	118.44	98.80	39.2	30.9
Boron Level (kg ha^{-1})						
0	1460.7^{c}	1483.2^{c}	5189.2^{c}	5226.6^{c}	673.5^{c}	692.7^{c}
1	1593.3^{b}	1613.6^{b}	5444.1^{b}	5486.2^{b}	745.7^{b}	746.8^{b}
2	1855.2^{a}	1861.6^{a}	5760.8^{a}	5828.9^{a}	890.6^{a}	900.8^{a}
LSD (P≤0.05)	39.69	41.41	102.57	85.56	33.9	26.8

Different letters indicate statistically significant-difference among the values in each column and individual factors.

Conclusions

From overall results, it was concluded that the cultivar 'Pakola' resulted in higher productivity and yield among all studied varieties by applying different level of B. Results also showed that yield of canola varieties was increased by increasing the B level and the 2 kg B ha^{-1} was found optimum, to which the canola crop gave the better response under rainfed condition. This optimum dose of B can be recommended for canola growing farmers of the rainfed area. However, the higher doses of B must be evaluated in future studies for more improvement in canola yield keeping in mind the economics of B application.

Authors' contributions

All authors contributed equally in this manuscript.

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