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Effect of Varying Amounts of Biological Phosphorus on the Morphological Characteristics, Yield and Yield Components of *Brassica napus* L. under End Season Water Deficit

Alireza PIRZAD[1*], Shafie MODARRES MOTLAGH[2]

[1]*Urmia University, Faculty of Agriculture, Department of Agronomy, Urmia, Iran; alirezapirzad@yahoo.com (*corresponding author)*

[2]*Islamic Azad University, Science and Research Branch, Department of Agronomy and Plant Breeding, Tehran, Iran*

Abstract

To evaluate the effect of irrigation (irrigation disruption at beginning of flowering, end of flowering, grain filling and control) and biological phosphorus (0, 50, 100 and 150 g/ha) on the yield of *Brassica napus* L. cv. 'Hyola 401', a split plot experiment was carried out based on randomized complete block design with four replications in 2010. The maximum (4.55 g) and minimum (3.25 g) 1000 seed weight belonged to irrigation disruption at the beginning of flowering with 150 and 50 g/ha of biological phosphorus application, respectively. The highest yield of seed (777.58 kg/ha) was obtained from irrigation disruption at the end of flowering with 50 g/ha biological phosphorus, and the lowest yield of seed (120.87 kg/ha) was obtained from irrigation disruption at the beginning of flowering without biological phosphorus. The maximum number of complete pods (17.38) was observed in 150 g/ha of biological phosphorus application by normal irrigation, and the lowest number of complete pods (5.49) belonged to no phosphorus application with irrigation disruption at the beginning of flowering stage. The highest percent of infertile pods (55.29%) was obtained from no phosphorus application with irrigation disruption at the beginning of flowering. And the lowest infertile pod percent (20.67%) belonged to 150 g/ha biological phosphorus application at normal irrigation.

Keywords: *Brassica napus*, irrigation, phosphorus, morphological characteristics, yield components

Introduction

Canola is one of the most important oil crops in the world (Bybordi, 2010). Oilseed canola plant (*Brassica napus* L.) is an important agricultural crop grown primarily for its edible oil and the meal that remains after oil extraction has value as a source of protein for the livestock feed industry (Jensen *et al*., 1996). Canola container valuable fatty acids and amino acid required by the human body, with 40-49 percent and 35-39 percent protein and oil respectively (Hosseini and Hassibi, 2011).

Plant growth is controlled by several factors, of which water plays a vital role. A small decrease in the availability of water to a growing plant immediately reduces its metabolic and physiological functions (Din *et al*., 2011). Water deficit stress has effect on vegetative and reproductive stages of canola. The effect of water deficit stress was more during reproductive growth than vegetative growth of rapeseed (Ghobadi *et al.,* 2006). Stem length was significantly affected under water stress in potato (Heuer and Nadler, 1995). In soybean, the stem length was decreased under water deficit conditions (Specht *et al.,* 2001). Gan *et al.* (2004) found that canola stressed at earlier growth stages exhibited recovery, whereas stressed during pod development severely reduced most of the yield components.

Phosphorus as one of the major nutrients limiting plant growth, is well known that more than two-third of phosphatic fertilizers are rendered unavailable within a very short period of time after its application due to fixation in soil complex as di-and tri -calcium phosphates (Mandal and Khan, 1972). P-solubilizing micro-organisms (bacteria or fungi) are able to solubilize unavailable soil P and increase the yield of crops (Adesemoye and Kloepper, 2009). De Freitas *et al.* (1997) reported that P-solubilizing *Bacillus* strains significantly increased growth and yield but not P-uptake of canola and to have potential use as inoculants for canola.

The main objective of this research was to study morphological characteristics and yield components of canola under varying end season water deficit (irrigation disruption) and different amounts of biological phosphorus.

Material and methods

To evaluate effects of end season water deficit and biological phosphorus on the yield of *Brassica napus* L. cv. 'Hyola 401', a split plot experiment was carried out based on randomized complete block design with four replications at the research farm of Shahid Beheshti Agriculture College in 2010. The experiment field is located in south

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west of Urmia (latitude 38° 51' N and longitude 41° 44' E and 1313 m above sea level). At first, plowing the land after that leveling of the ground with a disk vertically in order to crushing the hunk was applied. Along with planting the canola seeds got from seed and plant improvement institute of Karaj, was inoculated with pseudomonas and bacillus species of bacteria as biological phosphorus. The experimental units included four rows with 0.30 m interraw and 0.10 m intra-row spacing of 12 m length. Treatments were biological phosphorus (0, 50, 100, 150 g/ha) as main plots and irrigation disruptions (without disruptions, disruptions on grain filling, end of flowering stage, beginning of flowering stage) as sub plots.

At the end of growing season, morphological traits like plant height, stem weight and diameter, leaf weight, number of branches, nods, pods were measured. All traits in harvested plants were measured from 10 samples of each experimental unit and average of each was considered. To measure the 1000 seed weight, 10 samples of each 100 seeds was chosen, weighing and average of seed weight was determined.

Statistical evaluation was performed using MSTATC software (Michigan State University, 1988). The effects of phosphorus amounts (P) and Irrigation disruptions (I) as well as the interactions of these two factors were analyzed with the analysis of variance. The results of statistical analysis are expressed by F-values; asterisks indicate p-values $p \leq 0.05$ and $p \leq 0.01$. The comparison of means carried out with SNK (Student-Neuman Keuls test).

Results

Results of analysis of variance (ANOVA) showed the significant interaction effect between irrigation disruptions and different amounts of biological phosphorus on some of the morphological characteristics like plant height, stem diameter, number of nods, stem weight, and however significant interaction on yield components like number of complete pods, percentage of infertile pods, seed yield ($p \leq 0.01$), the number of incomplete pods and 1000 seed weight ($p \leq 0.05$) (Tab. 1).

Means comparisons indicated that the maximum plant height (68.87 cm) belonged to normal irrigation without phosphorus application as same as plant height of no phosphorus application in irrigation disruptions at the beginning and at the end of flowering stages. The shortest plant (48.14 cm) belonged to irrigation disruption at the beginning of flowering stage with 50 g/ha phosphorus. In control treatment of irrigation, biological phosphorus up to 100 g/ha caused to reduce the plant height. In irrigation disruption at the grain filling stage, increasing phosphorus in all amounts led to reduction of plant height compared to control treatment (0 g/ha) of biological phosphorus. Irrigation disruption at the beginning, and however at the end of flowering stage, produced the same and tallest plant by using 0 and 100 g/ha of phosphorus. While other treatments of phosphorus caused to shorter plants (Tab. 2).

The maximum (0.96 cm) and minimum (0.27 cm) stem diameter obtained from irrigation disruption at the beginning of flowering stage with 50 and 0 g/ha biological phosphorus application, respectively. The stem diameter of all levels of phosphorus treatments in irrigation disruption at the end of flowering stage, grain filling and control treatment (without disruption) were the same with the smallest stem diameter. Biological phosphorus had non-significant effect on stem diameter in irrigation disruptions at the grain filling, end of flowering and control, but in disruption at the beginning of flowering stage, stem diameter significantly decreased by more than 50 g/ha phosphorus (Tab. 2).

The maximum number of nods (14.19) was obtained from 150 g/ha of phosphorus in irrigation disruption at grain filling stage as same as the number of nods of plants treated by 150 g/ha and 50 g/ha phosphorus application at normal irrigation (without disruption). The lowest number of nods (6.75) belonged to 100 g/ha of phosphorus used in irrigation disruption at the end of flowering stage. In normal irrigation and disruption at the grain filling stage, up to 100 g/ha of phosphorus reduced, but more than that (150 g/ha) significantly increased the number of nods. In irrigation disruption at the end of flowering stage, all phosphorus treatments upraised the number of nods compared with 0 g/ha biological phosphorus. But, this increase observed in more than 50 g/ha phosphorus by irrigation disruption at the beginning of flowering (Tab. 2).

The greatest weight of stem (21.58 g/plant) belonged to 50 g/ha biological phosphorus in control treatment of irrigation. The minimum weight of stem (10.43 g/plant) was observed at 0 g/ha of phosphorus by disruption of irrigation at the beginning of flowering. In irrigation disruptions at the grain filling, at the end of flowering and at the beginning of flowering stages stem weights were statistically the same. In all irrigation regimes, biological phosphorus up to 100 g/ha raised the stem weight, but more than that decreased the weight of plant stem. In normal irrigation, phosphorus had enhance the stem weight in small amounts so that 50 g/ha increased the stem weight, but more amounts reduced it (Tab. 2).

The maximum number of complete pods (17.38) was observed in 150 g/ha biological phosphorus at normal irrigation followed by 50 g/ha phosphorus in irrigation disruption at grain filling, and at the end of flowering stage as same as number of complete pods obtained from 0 g/ha of biological phosphorus in irrigation disruption at grain filling. The lowest number of complete pods (5.49) belonged to no phosphorus application in irrigation interrupted at the beginning of flowering stage as same as numbers of 50 g/ha phosphorus in irrigation disruption at the beginning of flowering stage. More than 50 g/ha, phosphorus application caused significant increase in number of complete pods. In irrigation interrupted at grain filling, use of bio-

Tab. 1. Analysis of variance of some morphological traits of *Brassica napus* L. *cv*. 'Hyola 401' under irrigation disruptions and biological phosphorus

Source of variation	df	Plant height	Stem diameter	Number of branches	Number of n branches	Number of nods	Leaf weight	Stem weight	Number of seed in pod	Number of complete pods	Number of incomplete pods	% of infertile pods	Fertile pods height	Number of pods falling	Complete pods weight	Incomplete pods weight	1000 Seed weight	Seed yield
Replication (R)	3	14.30	0.01	0.02**	0.01	0.59	0.24	6.48	0.007	23.18	0.008	140.51	0.62	0.01	0.007	0.0008	0.06	0.02
Phosphorus (A)	3	85.71	0.13**	0.007	0.05**	18.76**	2.32**	20.46**	0.02	3.61**	0.01	48.45	2.33**	0.08**	0.02	0.01**	0.16	0.06
A×R	9	15.82	0.01	0.008	0.01	2.57	0.07	2.03	0.01	29.43	0.008	85.56	0.67	0.01	0.006	0.004	0.24	0.01
Irrigation (B)	3	137.88**	0.06**	0.007	0.009	2.34	8.51**	73.03**	0.03	67.04**	0.02	457.71**	0.77	0.03	0.07**	0.004	0.76**	0.34**
A×B	9	152.57**	0.10**	0.004	0.006	15.09**	0.25	16.47**	0.01	56.90**	0.02*	467.39**	0.90	0.009	0.01	0.003	0.29*	0.14**
Error	36	32.86	0.01	0.004	0.01	3.56	0.13	2.36	0.01	16.35	0.01	104.03	0.46	0.01	0.01	0.002	0.12	0.03
Coefficient of variance (%)		9.71	28.50	8.73	10.92	17.73	9.20	10.16	10.76	33.80	13.73	28.09	13.85	13.95	33.54	33.59	9.63	7.39

*, ** significant at $p\leq 0.05$ and $p\leq 0.01$, respectively; df: degree of freedom

Tab. 2. Means comparison of some morphological characteristics, yield and yield components of *Brassica napus* L. affected by biological phosphorus and irrigation disruption

Irrigation disruption	Biological phosphorus	Plant height (cm)	Stem diameter (cm)	Number of nods	Stem weight (g/plant)	Number of complete pods	Number of incomplete pods	Percent of infertile pods	1000 seed weight (g)	Seed yield (kg/ha)
No disruptions	0	68.9a	0.33b	10.3abc	17.29bc	12.1ab	5.8cde	33.99ab	3.68b	480.7ab
	50	62.3ab	0.34b	9.9abc	21.58a	8.7ab	6.9bcd	45.38ab	3.42b	335.8ab
	100	52.6bc	0.42b	9.6abc	14.25cde	14.6ab	5.3de	26.68b	3.63b	555.7ab
	150	65.2ab	0.48b	12.8ab	18.74b	17.4a	4.5e	20.67b	3.55b	613.2ab
Grain filling	0	62.5ab	0.30b	11.4ab	13.18ef	16.3a	5.3de	25.01b	3.39b	591.4ab
	50	59.2abc	0.36b	8.3bc	16.18cde	16.3a	4.4e	21.75b	3.34b	679.2ab
	100	57.3abc	0.40b	6.8c	16.92bcd	8.8ab	5.5de	39.32ab	3.56b	362.7ab
	150	58.6abc	0.36b	14.2a	15.30cde	9.8ab	8.1abc	44.74ab	3.25b	582.7ab
End of flowering	0	63.7ab	0.27b	11.6ab	13.42def	13.4ab	8.9a	40.44ab	3.80b	526.7ab
	50	57.2abc	0.37b	9.7abc	13.76def	16.0a	6.8bcd	31.57ab	3.85b	777.6a
	100	64.0ab	0.41b	10.0abc	16.30cde	11.9ab	5.0de	32.19ab	3.53b	395.4ab
	150	52.6bc	0.29b	11.2abc	13.21ef	10.6ab	8.8ab	45.56ab	3.68b	425.2ab
Beginning of flowering	0	52.6bc	0.27b	9.6abc	10.43f	5.5b	6.5bcd	55.29a	3.88b	120.9c
	50	48.1c	0.96a	12.7ab	13.42def	7.8ab	4.5e	39.49ab	3.49b	246.0b
	100	65.2ab	0.40b	11.9ab	14.93cde	10.2ab	7.0bcd	44.63ab	3.68b	414.7ab
	150	54.6bc	0.31b	10.2abc	13.10ef	12.0ab	6.3cde	34.14ab	4.55a	480.6ab

The same letters in each column show non significant differences ($p\leq 0.05$)

logical phosphorus more than 50 g/ha, reduced the number of complete pods. In irrigation disruption at the end of flowering stage, giving more than 50 g/ha phosphorus led to less number of complete pods, but in disruption at the beginning of flowering, higher phosphorus upraised the number of complete pods (Tab. 2).

The maximum number of incomplete pods (8.89) belonged to irrigation disruption at the end of flowering stage with no phosphorus followed by 150 g/ha phosphorus in irrigation disruption at the end of flowering. The minimum number of incomplete pods (4.44) was observed in irrigation disruption at grain filling with 50 g/ha phosphorus. This minimum above mentioned numbers of incomplete pods was the same with the pods obtained from 50 g/ha phosphorus in irrigation disruption at the beginning of flowering. More than 50 g/ha phosphorus, the number of incomplete pods significantly was reduced at control treatment of irrigation. In irrigation interrupted at grain filling, higher phosphorus increased incomplete pods. Interrupted irrigation at the end of flowering with use of biological phosphorus up to 100 g/ha decreased the number of incomplete pods. Irrigation disruption at the beginning of flowering, and first giving level of phosphorus, the number of incomplete pods was reduced, and it upraised with 100 g/ha, whereas after that the number of incomplete pods was lessened again (Tab. 2).

The highest percent of infertile pods (55.29%) was obtained from no phosphorus application by irrigation disruption at the beginning of flowering. The minimum percent of infertile pods (20.67%) belonged to 150 g/ha biological phosphorus application at normal irrigation. In normal irrigation (without disruption), giving biological phosphorus more than 50 g/ha caused to lower percentage of infertile pods. In irrigation disruption at the grain filling, increasing phosphorus to more than 50 g/ha, caused to gradual increase of infertile pods. Interrupted irrigation at the end of flowering, inhibited the effecting phosphorus on infertile pods percentage, so all levels were almost the same. In irrigation disruption at the beginning of flowering stage, giving phosphorus in all amounts led to lower percent compared to control treatment of phosphorus (Tab. 2).

Means comparisons indicated that the maximum (4.55 g) and minimum (3.25 g) 1000 seed weight belonged to irrigation disruptions at the beginning of flowering stage with 150 and 50 g/ha biological phosphorus application, respectively. 1000 seed weight of all levels of phosphorus by irrigation disruptions at the end of the flowering stage, seed filling and control treatment are the same to the minimum 1000 seed weight. Biological phosphorus application had no significant effect on 1000 seed weight of irrigation disruption at the grain filling, end of flowering and control treatment of disruption stages (Tab. 2).

Means comparison indicated that the highest seed yield (777.58 kg/ha) belonged to irrigation disruption at the end flowering stage with 50 g/ha phosphorus as same as the seed yield of all levels of phosphorus in irrigation disruptions at the end of the flowering, grain filling and normal irrigation stages. The lowest seed yield (120.87 kg/ha) was obtained from irrigation disruption at the beginning of flowering stage with no phosphorus application. Increasing the biological phosphorus did not significantly affect the seed yield in control treatment and disruption at grain filling. Phosphorus enhanced the seed yield by interrupted irrigation at the end of flowering stage up to 50 g/ha phosphorus, but more than that decreased it. Cut off irrigation at the beginning of flowering stage, increasing phosphorus application led to upraise the seed yield (Tab. 2).

Discussion

Results showed that irrigation disruption has affected the plant height significantly but only the amount of 100 g/ha phosphorus can offset the irrigation disruption (Tab. 2). Tahir *et al.* (2006) experiment showed that plant height increased by the irrigation and about 53% reduction was observed in drought environment. Results were reported by Cheema *et al.* (2001) who observed significantly taller plants in canola when P fertilizer was applied through side drilling.

Our finding indicated that in the amount of 50 g/ha phosphorus, stem diameter increased, with an intense disruption. Less or more than that, gradually did not make significant difference on the stem diameter. Yosefi *et al.* (2011) reported that phosphorus had a significant effect on stem diameter of canola. However, by giving 50 and 100 g/ha number of nods cut off irrigation until grain filling stage decreased the weight of stem, but more than that upraised it. The results of this research revealed that irrigation disruption affected the stem weight at all levels of phosphorus, so 100 g/ha phosphorus partially provided the stem weight. The results showed that increasing the irrigation disruption time (early irrigation cut off) with giving phosphorus, increased the number of complete pods, and although increasing the phosphorus at the beginning of flowering stage reduced this decline. Ahmadi and Bahrani (2009) showed that water stress treatments significantly decreased the number of pods per plant. In irrigation disruption at the end of flowering stage, all levels of phosphorus caused to increase the number of incomplete pods, and after that reduced it. In general, gradual increasing of phosphorus up to 100 g/ha caused to upraise the infertile pods but more than that it was decreased. Except higher 1000 seed weight of 150 g/ha by irrigation cut off at the beginning of flowering stage (early water deficit), irrigation and phosphorus treatments cannot significantly affect the 1000 seed weight. This increasing might due to a minimum numbers of seed productions in this treatment. Hossain *et al.* (1996) and Turk and Tawaha (2002) who found that high P rates significantly increased the seed size which ultimately helped in increasing 1000 seed weight in groundnut. Chimenti *et al.* (2002) and Erdem *et al.* (2006) indicated that grain yield and weight of 1000 grains decreased with increasing drought stress.

Hosseini and Hassibi (2011) showed that water deficit stress in the beginning stage of stem elongation to early flowering showed lowest susceptibility to stress. There was a sharp increase in seed yield by irrigation disruption at the end of flowering and after this stage, especially with 50 g/ha biological phosphorus. For long time water deficit we need to higher densities of phosphate solubilizer bacteria. Rathke *et al.* (2005) reported that the lowest yield is obtained when no fertilizer is applied.

Conclusions

In conclusion, end season water deficit (irrigation disruption) caused to interrupt the growth of canola plants, and however the yield components and morphological characteristics of canola, but biological phosphorus can compensate this reduction.

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