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Effect of phosphorus and potassium fertilization on drought tolerance of broad bean (*Vicia faba L.*)

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ABSTRACT

Two greenhouse experiments were carried out during 2019/2020 and 2020/2021 seasons at the Experimental Farm of the Agronomy Department, Faculty of Agriculture, Al-Azhar University, Nasr City, Cairo, Egypt. These experiments aimed to investigate the effect of nine phosphorus (P) and potassium (K) fertilizer rates, i.e., F_1(unfertilized-control), F_2(100 kg P), F_3(200 kg K), F_4(50 kg K), F_5(100 kg P + 50 kg K), F_6(200 kg P + 50 kg K), F_7(100 kg K), F_8(100 kg P + 100 kg K) and F_9(200 kg P + 100 kg K) on broad bean plants grown at two irrigation regimes, i.e. Ir_1 (well-irrigation treatment) and Ir_2(drought stress).

The obtained results could be summarized as follows:

Drought stress treatment significantly decreased plant height, leaf area/ plant, net assimilation rate, number of flowers produced per plant and pod setting as compared with the well irrigation treatment in both seasons. Drought stress treatment significantly decreased number of pods, weight of pods and seed yield per plant as compared with the well-watered treatment in both seasons. Phosphorus and potassium fertilization increased all studied traits as compared with control (unfertilized treatment) in both seasons. There was a significant interaction between phosphorus and potassium fertilization treatments and irrigation regimes. However, the highest seed yield /plant was obtained under the application of F_4 (50 kg K), F_3 (200 kg P) and well irrigation treatment in first season and second season, respectively. Phosphorus and potassium fertilization increased the drought tolerance of broad bean.

KEYWORDS: Broad bean, Fertilization, Drought stress, Flowering.

1. INTRODUCTION

Broad bean (*Vicia faba L.*) is a major grain legume crop in all countries of the world. Therefore, its dry seeds are one of the excellent and cheep sources of protein for poor people in developing countries as well as its green pods are used as vegetables.

In addition, broad bean is one of the biofactory of nitrogen by fixing the atmospheric nitrogen through symbiotic relationship with nitrogen fixing bacteria (*Rhizobium*). Thus it increase soil fertility, whereas it can add about 130-160 kg N/ ha annually (Hoffman et al. 2007).

Broad bean is the most important grain legume in Egypt. It constitutes one of the main dishes on the breakfast and dinner tables. In 2020, broad bean production in Egypt was 190.000 ton, while its consumption is 460.000 ton. Thus, there is a great gab between the production and the consumption. Therefore, it is necessary to increase its production to decrease this gab (Central Agency for Public Mobilization and Statistics (CAP MAS) (2020)

However, increasing broad bean production in Egypt can be achieved by increasing its cultivated area. This can be done by cultivating it in newly reclaimed soils, but most of these soils lie under desert conditions and face many problems , mainly water shortage for irrigation and drought.

Drought is one of the main abiotic stresses which cause crop yield losses. It was found that broad bean is sensitive to drought than some other grain legumes (Mc Donald and Paulsen , 1997 and Amede et al. 2003), whereas water deficit cause 40% reduction in seed yield (Wu and Wang , 2000).Therefore, improving broad bean yield under drought stresses is a major goal of crop physiologists and breeders.

Improving broad bean drought tolerance can be attained by application of some agriculture treatments such as fertilization. In this respect Oukaltouma et al. (2021) reported that phosphorus contributes for extension of root system and alleviate drought stress of the plants. It was also found that potassium fertilization increased root growth, plant osmotic adjustment and total dry mass for plants living under drought conditions and also improve water uptake as well as water conservation (Kurdali et al, 2002).

Therefore, this investigation was carried out to study the effect of phosphorus and potassium fertilization on drought tolerance of broad bean plants.

2. MATERIALS AND METHODS

Two greenhouse experiments were carried out during 2019/2020 and 2020/2021 growing seasons at the Experimental Farm of the Agronomy Department, Faculty of Agriculture, Al–Azhar University, Nasr City, Cairo, Egypt. These experiments aimed to investigate the effect of phosphorus and potassium fertilization on growth, flowering and seed yield of broad bean grown under different soil moisture contents.

2.1. Experimental treatments

2.1.1. Irrigation Regimes

Two irrigation regimes were applied as follows:

Ir_1- Irrigation at 80% of field capacity (well-irrigated).

Ir_2- Irrigation at 40% of field capacity (drought stress).

The irrigation regimes were imposed after 15 days from sowing date and maintained during plant growth periods.

2.1.2. Phosphorus (P) and potassium (K) fertilization rates

Phosphorus and potassium fertilizers were added in the forms of calcium super phosphate (15.5% P_2O_5) and potassium sulfate (48% K_2O), respectively. The applied P and K fertilizers were added into two doses. The first dose was added with sowing irrigation and the second one was added after 35 days from the first dose.

1- F1 (control - without adding P and K fertilizer)
2-F2 (applying 100 kg P/fed).
3-F3 (applying 200 kg P / fed).
4-F4 (applying 50 kg K / fed)
5- F_5 (applying 100 kg P + 50 kg K /fed)
7-F_7 (applying 100 kg K /fed)
8- F_8 (applying 100 kg P + 100 kg K / fed)
9- F_9 (applying 200 kg P + 100 kg K /fed).

2.2. Experimental design

Plants were grown in cement basins (50 cm width and 40 cm deep) and has a drainage outlet at the bottom of the basins. The basins filled with 100 Kg of air dried and homogenous sandy soil in both seasons.

Eleven seeds of broad bean variety Giza 843 (indeterminate growth habit variety) were sown at each basin in 2019/2020 and 2020/2021 seasons. The seed were obtained from Agriculture Research Centre, Giza. The seeds were inoculated with the specific Rhizobium strain (*Rhizobium legumonesirum*) just before sowing. All basins were fertilized with 2 g Urea as a starter nitrogen fertilizer before sowing. The seedlings were thinned to six plants per basin after 35 days from sowing.

Split plot design in three replications was applied, whereas the irrigation regimes occupied the main plots and the phosphorus and potassium treatments were allocated in the sub-plot. The chemical analysis of the experimental soil in 2019/2020 and 2020/2021 seasons are presented in Table (1). The average air temperature data of the experimental site during 2019/2020 and 2020/2021 seasons are presented in Table (2).

Table 1. Chemical analysis of the experimental soil in 2019/2020 and 2020/2021 seasons.

Season	EC_e(mmhos/cm at 20C^o)	HCo_3 (ppm)	Ca^{++} (ppm)	Na^+ (ppm)	K^+ (ppm)	N (ppm)	P (ppm)
2019/2020	2.44	1.00	7.50	10.95	0.42	88.00	4.98
2020/2021	2.32	2.5	7.50	9.1	0.65	193.00	9.12

Table 2. Average air temperature data (C^o) of the experimental site during 2019/2020 and 2020/2021 seasons.

Month	1st season				2nd season			
	Week				Week			
	1	2	3	4	1	2	3	4
November	23.31	24.31	19.76	19.32	22.41	21.04	19.27	18.15
December	17.84	16.88	15.55	15.75	17.61	18.61	17.16	15.94
January	13.37	13.74	14.46	13.60	17.31	16.87	12.19	13.62
February	15.25	14.91	16.14	16.02	17.32	17.34	11.03	14.46
March	17.86	18.56	16.76	20.63	14.46	17.54	18.99	13.75
April	21.05	19.74	22.73	23.04	18.01	16.64	24.55	23.27

2.3. Data recorded

2.3.1. Vegetative growth characters

Two plants were taken randomly from each treatment after 30 and 51 days from sowing date and the following date were recorded:

1- Plant height (cm).
2- Leaf area/ plant (cm^2).
3- Number of branches/ plant.
4- Net assimilation rate (NAR).

Net assimilation rate (NAR) expresses the gain of assimilate, mostly photosynthetic, per unit of leaf area and time. It was calculated according to the following formula (Watson. 1958):

$$NAR = \frac{W_2 - W_1}{LA_2 - LA_1} \times \frac{Log_e LA_2 - Log_e LA_1}{T_2 - T_1} \quad (g/ cm^2/ day)$$

Whereas:
W_2 = The weight at end period.
W_1 = The weight at start period.
LA_2 = Leaf area at end period.
LA_1= Leaf area at start period.
T_2 = Number of days at end period.
T_1 = Number of days at start period.
Log_e= Nabarian log =2.303× Log_{10}.

2.3.2. Flowering and pod setting traits

After 35 days from sowing date (before flowering appearance) two plants were chosen and identified and the following data were recorded daily:

1-Total number of flowers/plant
2- Pod setting percent/plant.

2.3.3. Seed yield and its components

At harvest time the plants per basin were harvested and the following traits were recorded.

1-Number of pods / plants.
2- Pods weight / plant (g).
3- Seed yield / plant (g).

3. RESULTS AND DISCUSSION

3.1. Vegetative growth characters

3.1.1. Plant height (cm)

Data recorded in Table 3 show that the different irrigation regimes significantly affected plant height of broad bean plants in both growing seasons. However, Ir_1 irrigation regime (80% of FC) gave the highest average plant height values as compared with those of Ir_2 irrigation regime (40% of FC) in both growing seasons. For example, this irrigation treatment (Ir_1) gave 46.28 % and 26.70 % increase in plant height over those of Ir_2 treatment in 2019/2020 and 2020/2021seasons, respectively.

However, the reduction in plant height of broad bean plants grown under water stress conditions might be attributed to that soil moisture stress decrease the availability and uptake of the water and nutrient by the roots resulting in decreasing water content of plant tissues and this lead to a reduction in cell division and cell enlargement of the apical meristems and this in tun lead to reduction in stem elongation as compared with those of plants grown under favorable soil moisture. These results are in agreement with those of Fayed, et. al. (2021).

Data presented in Table 3 show that phosphorus and potassium fertilization insignificantly affected the plant height of broad bean irrespective of irrigation treatments. These results might be attributed to that phosphorus and potassium increase root growth and penetration in the soil more than stem elongation. These results are in agreement with those of sangakkara et al (1996).

The results recorded in Table 3 indicate that there is insignificant effect between phosphorus and potassium fertilization as well as irrigation regimes on broad bean plant height in both seasons.

3.1.2. Leaf area per plant (cm2)

Table 3 show that leaf area per plant was significantly decreased as affected by irrigation regimes. In 2019/2020 season, Ir_2 irrigation regime (drought stress) decreased leaf area per plant by 47.54 % compared with those of Ir_1 irrigation regime (well irrigation) at 51 days after sowing. Results obtained in 2020/2021 season followed similar trend. The reduction in leaf area per plant under drought stress might be attributed to that drought stress decrease the number of leaves produced per plant and decrease the size of the leaves. These results are in agreement with those of Alghamdi et al. (2015).

Data recorded in Table 3 show that phosphorus and potassium fertilization significantly increased leaf area per plant in both seasons. However, the highest leaf area per plant was obtained at F_3 and F_5 as compared with the control (without fertilization) in 2019/2020 and 2020/2021 seasons, respectively.

In 2019/2020 season, F_3 treatment gave 121.61% increase in leaf area per plant over those of the control. In 2020/2021 season, $F_5$and F_9 gave 36.39 % and 36.36 % increase in leaf area per plant over those of the control, respectively. These results are in agreement with those of Duleimi and Fahdawi (2015).

Table 3 show that the interaction effect between irrigation regimes and fertilization treatments are significant. However, the highest leaf area / plant was obtained at Ir_1 and F_3 and F_5 treatments in 1^{st} and 2^{nd} seasons, respectively. The obtained results show also that under.

Table 3. Effect of phosphorus and potassium fertilization on plant height (cm), leaf area(cm^2)/ plant and number of branches/plant of broad bean plants at 51 days after sowing date grown under different irrigation regimes in 2019/ 2020 and 2020/2021 seasons.

Irrigation regimes	Fertilization treatments (kg/fed)	2019/2020 season			2020/2021 season		
		Plant height	Leaf area	No. of branches	Plant height	Leaf area	No. of branches
Ir_1	F_1	46.33	448.2	2.67	48.67	865.5	3.00
	F_2	49.33	1010.6	2.67	51.67	887.0	2.67
	F_3	47.00	1081.0	4.00	55.00	1014.0	3.67
	F_4	44.67	949.2	2.67	55.00	875.5	3.33
	F_5	47.00	729.0	3.00	53.33	1151.0	2.67
	F_6	46.67	694.9	2.33	54.67	673.8	3.33
	F_7	48.00	847.4	3.00	55.00	1028.9	2.33
	F_8	49.00	725.0	2.67	55.00	854.3	3.00
	F_9	46.67	912.6	2.67	57.33	1143.2	3.67
Mean		47.19	822.0	2.85	53.96	943.7	3.07
Ir_2	F_1	25.00	264.4	1.33	41.33	382.4	2.33
	F_2	33.67	465.6	2.00	41.67	471.5	3.33
	F_3	34.67	498.1	2.67	43.67	461.0	2.33
	F_4	33.33	394.3	2.00	41.67	552.1	2.67
	F_5	31.67	605.1	2.67	43.67	551.1	2.33
	F_6	34.00	443.7	1.67	42.00	445.9	2.67
	F_7	33.33	416.9	2.00	44.00	554.3	2.33
	F_8	32.67	403.2	1.33	39.67	642.5	2.67
	F_9	32.00	389.8	2.00	45.67	558.6	2.67
Mean		32.26	431.2	1.96	42.59	513.3	2.59
0verall mean for fertilization treatments	F_1	35.67	356.3	2.00	45.00	624.0	2.67
	F_2	41.50	738.1	2.33	46.67	679.3	3.00
	F_3	40.83	789.6	3.33	49.33	737.5	3.00
	F_4	39.00	671.8	2.33	48.33	713.8	3.00
	F_5	39.33	667.0	2.83	48.50	851.1	2.50
	F_6	40.33	569.3	2.00	48.33	559.8	3.00
	F_7	40.67	632.1	2.50	49.50	791.6	2.33
	F_8	40.83	564.1	2.00	47.33	748.4	2.83
	F_9	39.33	651.2	2.33	51.50	850.9	3.17
L.S.D at 5% level for:							
Irrigation regimes (Ir)		*	*	*	*	*	*
Fertilization (F)		N.S.	91.62	N.S.	N.S.	109.41	N.S.
Interaction (Ir x F)		N.S.	129.57	N.S.	N.S.	154.73	N.S.

water stress Ir_2 treatment all fertilization rates increased leaf area/ plant over those of the control (unfertilized) at the same drought stress treatment (Ir_2). These indicate that phosphorus and potassium fertilization can reduce the deleterious effect of drought on leaf area per plant, resulting in increasing drought tolerance of broad bean.

3.1.3. Number of branches per plant

Results presented in Table 3 indicate that the different irrigation regimes significantly affected number of branches per plant of broad bean plants in both seasons. However, In 2019/2020 season Ir_1 irrigation regime gave 45.41% increase in number of branches per plant over those of Ir_2 irrigation regimes (drought stress). Results in 2020/2021 season followed similar trend. These results are agreement with those of Fayed, et. al. (2021).

Data recorded in Table 3 show that the number of branches/ plants was significantly decreased under soil drought stress treatment (Ir_2) as compared with Ir_1 treatment in both seasons.

The reduction in the number of branches/ plant under drought stress (Ir_2) treatment might be attributed to that the reduction in soil water decrease the availability of soil water which in turn decrease the availability of water and the uptake nutrients, leading to decrease in photosynthetic rate and inhibit the initiation and growth of the axillary buds which form branches. These results are in agreement with those of De Costa et al. (1997).

Results presented in Table 3 indicate that phosphorus and potassium fertilization rates insignificantly affected the number of branches/ plant at 51 DAS in both seasons.

Table 3 show that the interaction effect between irrigation regimes and phosphorus and potassium fertilization treatments on number of branches/ plant was insignificant at all growth periods in both seasons.

3.1.4. Net assimilation rate (NAR) g/cm2/day

Results presented in Table 4 show the effect of phosphorus and potassium fertilization as well as different irrigation regimes on net assimilation rate (NAR) during the period 30-51 days after sowing date in 2019/2020 and 2020/2021 seasons.

Table 4 indicate that Ir_2 irrigation regime (drought stress) significantly decreased NAR compared to those of Ir_1 irrigation regime (well irrigation) in both seasons at 30-51 DAS. This irrigation treatment (Ir_2) decreased NAR by 65.15 % and 57.45 % as compared with those of Ir_1 treatment in the first and second seasons, respectively.

The reduction in NAR under drought stress treatment might be attributed to that drought stress cause a reduction in water and nutrients uptake by the roots resulting in decreasing photosynthetic rate. These results are in agreement with those of Abid et al (2017). The obtained results show that all phosphorus and potassium fertilizer rates increased NAR as compared with the unfertilized treatment (control) in both 2019/2020 and 2020/2021 seasons. However, F_3 and F_9 treatments gave the highest NAR as compared with all other treatments in 2019/2020 and 2020/2021 seasons, respectively. These treatments i.e. F_3 and F_9 gave 110.00 % and 61.54 % increase in NAR over those of control in 2019/2020 and 2020/2021 seasons, respectively. These results are in agreement with those of Hashemabadi (2013).

Table 4. Effect of phosphorus and potassium fertilization on net assimilation rate-NAR (g/cm^2/day) at 30-51 days after sowing date of broad bean plants grown under different irrigation regimes in 2019/ 2020 and 2020/2021 seasons.

Fertilization treatments (kg/fed)	2019/2020 season			2020/2021 season		
	Irrigation regimes		Mean	Irrigation regimes		Mean
	Ir_1	Ir_2		Ir_1	Ir_2	
F_1	0.47	0.14	0.30	0.76	0.28	0.52
F_2	0.70	0.19	0.45	0.95	0.49	0.72
F_3	0.92	0.33	0.63	0.95	0.24	0.59
F_4	0.57	0.23	0.40	1.04	0.55	0.79
F_5	0.71	0.21	0.46	0.97	0.40	0.68
F_6	0.46	0.29	0.37	0.83	0.41	0.62
F_7	0.53	0.25	0.39	0.89	0.37	0.63
F_8	0.81	0.23	0.52	0.85	0.42	0.63
F_9	0.80	0.22	0.51	1.20	0.47	0.84
Mean	0.66	0.23		0.94	0.40	
L.S.D at 5% level for:						
Irrigation regimes (Ir)			*			*
Fertilization (F)			0.08			0.13
Interaction (Ir x F)			0.11			N.S.

Data recorded in Table 4 indicate that the interaction effect among phosphorus and potassium fertilization and irrigation regimes was significant in both seasons. The highest NAR value were obtained at Ir_1 irrigation regime with F_3 and F_9 fertilization treatments in 2019/2020 and 2020/2021 seasons, respectively.

The obtained results show also that under Ir_2 irrigation regime (drought stress) all phosphorus and potassium fertilizer rates increased NAR as compared with those of unfertilized treatment at the same irrigation regime (drought stress). These results indicate that phosphorus and potassium fertilization decrease the deleterious effect on NAR. These results are in agreement with those of Ashraf et al. (2010).

3.2. Flowering and pod sitting

3.2.1. Flowering

Data presented in Table 5 illustrate that different irrigation regimes significantly affected the total number of flowers produced per plant in both seasons. Ir_1 irrigation treatment (well irrigation) increased the total number of flowers per plant by 98.60 % and 322.09 % over those of the Ir_2 treatment (drought stress) in 2019/2020 and 2020/2021 seasons, respectively. The reduction in the total number of flowers per plant under Ir_2 treatment (drought stress) might be attributed to that soil water deficit decrease the plant height as shown in Table 3 resulting in a reduction in the number of reproductive nodes along the stem as well as retarding flowers initiation at axillary meristems.These results are in agreement with those of Zabawi and Dennet (2010).

Data recorded in Table 5 show that phosphorus and potassium fertilization treatment significantly increased the total number of flowers produced per plant during the reproductive period in 2019/2020 season as compared with the control treatment (without fertilization) with the exception F_3, F_4 and F_9. The results show that F_5 treatment gave the highest number of flowers (275.63) as compared with all other treatments. F_5 gave 18.04 % increase in the total number of flowers per plant over those of F_1 treatment (unfertilized) in 2019/2020. In 2020/2021 season F_9 gave the highest number of flowers per plant as compared with all other treatments. These results are in confirmed with those of Younise (2002).

Results recorded in Table 5 show that the total number of flowers produced per plant was significantly affected by the interaction between phosphorus and potassium fertilization and irrigation regimes in both seasons. The highest number of flowers/ plants was recorded under F_2 and F_9 treatments and Ir_1 irrigation treatment in 2019/2020 and 2020/2021seasons, respectively.

Table 5. Effect of phosphorus and potassium fertilization on the total number of flowers produced per plant and pod setting percentage in broad bean plants grown under different irrigation regimes in 2019/2020 and 2020/2021 seasons.

Irrigation regimes	Fertilization treatments (kg/fed)	2019/2020 season		2020/2021 season	
		Total no. of flowers/plant	Pod setting (%)	Total no. of flowers/plant	Pod setting (%)
	F_1	329.00	11.99%	244.00	8.50%
	F_2	362.50	12.55%	192.50	9.40%
	F_3	310.75	14.83%	208.00	7.94%
	F_4	333.00	16.67%	198.25	20.56%
Ir_1	**F_5**	354.75	12.56%	169.25	7.55%
	F_6	284.00	9.83%	189.00	16.92%
	F_7	308.25	15.39%	202.75	7.48%
	F_8	341.50	14.10%	227.75	7.82%
	F_9	318.50	17.75%	244.75	7.72%
Mean		326.92	13.96%	208.47	10.43%
	F_1	138.00	7.42%	56.75	9.27%
	F_2	142.00	6.33%	46.00	10.87%
	F_3	154.50	7.94%	62.25	8.08%
	F_4	114.50	8.22%	18.50	20.27%
Ir_2	**F_5**	196.50	6.36%	36.25	17.09%
	F_6	195.25	4.76%	65.75	6.85%
	F_7	238.50	4.20%	60.50	6.16%
	F_8	156.75	6.84%	39.00	10.71%
	F_9	145.50	9.00%	59.50	7.57%
Mean		164.61	6.79%	49.39	10.76%
	F_1	233.50	9.71%	150.38	8.89%
	F_2	252.25	9.44%	119.25	10.14%
	F_3	232.63	11.39%	135.13	8.01%
0verall mean	**F_4**	223.75	12.45%	108.38	20.42%
for fertilization	**F_5**	275.63	9.46%	102.75	12.32%
treatments	**F_6**	239.63	7.30%	127.38	11.89%
	F_7	273.38	9.79%	131.63	6.82%
	F_8	249.13	10.47%	133.38	9.27%
	F_9	232.00	13.38%	152.13	7.64%
L.S.D at 5% level for:					
Irrigation regimes (Ir)		*	*	*	N.S.
Fertilization (F)		30.01	3%	17.61	5%
Interaction (Ir x F)		42.44	N.S.	24.90	N.S.

The obtained results show also that under the water stress Ir_2 treatment, all fertilization treatments increased the total number of flowers per plant as compared with the unfertilized treatment (control) at the same drought stress treatment (Ir_2) in 2019/2020 season. In the second season F_6 increased the total number of flowers per plant as compared with the unfertilized treatment (control) at the same drought stress treatment (Ir_2).These results indicate that phosphorus and potassium fertilization can reduce the injurious effect of drought on the number of flowers produced per plant. These results are in harmony with those of Wahab and Abd-Alla (1995).

3.2.2. Pod setting

The results indicate that irrigation regimes significantly affected pod setting. In 2019/2020 season, Ir_1 irrigation regimes (well irrigation) caused 13.96 % pod setting compared to 6.79 % for plants grown under Ir_2 (drought stress). Data in 2020/2021 followed similar trend but the differences among the irrigation regimes did not reach level of significant.

The reduction in pod setting under Ir_2 treatment (drought stress) might be attributed to that water stress cause cessation of young pods to grow and abscise despite successful the pollination and fertilization as well as the internal competition for assimilates within the plant particularly between young pods and the vegetative growth. These results are in agreement with these of **Younise (2002).**

Data presented in Table 5 show that phosphorus and potassium fertilization treatments significantly affected pod setting percentage in both seasons. However, In 2019/2020 season, F_9 treatment (200 kg P + 100 kg K) and F_4 (50 kg K) gave the highest pod setting (13.38 % and 12.45 %) respectively.

In 2020/2021, F_4 gave the highest pod setting (20.42%) as compared with all other treatments. These results are in agreement with those of Younise (2002).

Table 5 show that there is an insignificant effect among irrigation regimes and phosphorus and potassium fertilization on pod setting in both seasons. However, in 2019/2020 season, Table 5 show florally that under Ir_2 irrigation (drought stress), F_9 and F_4 gave the highest pod setting i.e. 9.00 % and 8.22 %, respectively as compared with all other fertilization treatments as well as the control treatment (without adding fertilization under the same irrigation regime (Ir_2 – drought stress). In 2020, under drought stress irrigation treatment (Ir_2), F_4 fertilization treatment gave the highest pod setting (20.27 %) as compared with all other treatments under the same irrigation regime (Ir_2). These results are in agreement with those of Oukaltouma et al. (2021) who reported that potassium and phosphorus apply mitigated the adverse effects of water deficit on broad bean.

3.3. Seed yield and its components

3.3.1. Number of pods per plant

Data recorded in Table 6 indicate that irrigation regimes significantly affected the number of pods per plant, However Ir_1 irrigation regime (well-irrigated plants) gave 249.11 % and 324.63 % increase in number of pods/plant over those of the plants grown under Ir_2 treatment (water-stressed plants) in 2019/2020 and 2020/2021 seasons, respectively Ammar et al. (2015) found similar results. However, the reduction in the number of pods/ plant under drought conditions might be attributed to that the drought decrease the number of flowers produced/ plant (Table 5) and decreased pod setting (Table 5) resulting in decreasing number of pods/plant. These results are in agreement with those of Migdadi et al. (2016).

Results presented in Table 6 show that all phosphorus and potassium fertilization treatments increased the number of pods/ plant as compared with the control (without adding phosphorus and potassium) in 2019/2020 season.

Results presented in Table 6 indicate that the interaction between phosphorus and potassium fertilization as well as irrigation regimes had a significant effect on the number of pods/ plant in both seasons. However, in 2019/2020 season F_9 (application of 200 kg P + 100 kg K) and Ir_1(irrigation at 80% of FC) gave the highest number of pods/ plant (37.33) as compared with all other treatments. In 2020/2021 season, F_4 (application of 50 kg K and Ir_1 gave the highest number of pods per plant as compared with all other treatments.

In 2019/2020 season, Table 6 show that under drought stress (Ir_2) all phosphorus and potassium fertilization rates increased the number of pods / plant over those of the control (without adding fertilization, grown under the same drought stress treatment (Ir_2). Results in 2020/2021 season followed similar trend with some exceptions. For example, in 2019/2020 season, under Ir_2 (drought stress, the application of 200 kg P + 100 kg K (F_9) gave 106.69 % increase in the number of pods / plant over those of the control (unfertilized plants) under the same drought treatment (Ir_2). These results are confirmed with those of El-Gizawy, et. al. (2009).

3.3.2. Weight of mature pods/ plant

The obtained results in Table 6 show that Ir_2 irrigation regime (soil water stress) significantly decreased the weight of mature pods /plant by 67.19% and 77.45 % compared to those of Ir_1

Table 6. Effect of phosphorus and potassium fertilization on number and weight of mature pods / plant as well as seed yield / plant (g) of broad bean plants grown under different irrigation regimes in 2019/ 2020 and 2020/2021 seasons.

Irrigation regimes	Fertilization treatments (kg/fed)	2019/2020 season			2020/2021 season		
		No.of pods/ plant	Weight of pods/ plant	Seed yield / plant	No.of pods/ plant	Weight of pods/ plant	Seed yield / plant
	F_1	27.33	54.33	41.66	15.67	28.99	20.93
	F_2	29.83	64.96	46.96	15.33	37.62	28.49
	F_3	23.67	49.28	37.53	12.50	42.68	33.56
	F_4	29.50	74.88	58.11	21.83	31.94	23.48
Ir_1	F_5	34.08	82.48	56.86	10.00	22.57	16.48
	F_6	24.83	49.50	35.49	10.83	26.76	20.22
	F_7	33.44	72.67	51.09	13.17	26.93	19.70
	F_8	26.08	39.01	31.35	13.67	40.55	30.87
	F_9	37.33	75.47	57.28	15.83	32.50	23.87
Mean		29.57	62.51	46.26	14.31	32.28	24.18
	F_1	5.08	17.54	11.97	3.17	7.35	5.86
	F_2	7.17	21.26	15.56	4.33	9.26	7.36
	F_3	10.00	24.59	18.39	4.00	8.78	6.98
	F_4	10.83	15.90	11.29	3.33	6.88	5.04
Ir_2	F_5	10.00	21.15	15.75	3.00	6.12	4.60
	F_6	6.08	14.67	10.54	2.67	9.00	6.96
	F_7	8.08	21.22	15.34	3.17	7.38	5.80
	F_8	8.50	23.88	17.83	3.50	5.21	3.99
	F_9	10.50	24.39	17.34	3.17	5.52	4.23
Mean		8.47	20.51	14.89	3.37	7.28	5.65
	F_1	16.21	35.93	26.81	9.42	18.17	13.40
	F_2	18.50	43.11	31.26	9.83	23.44	17.93
	F_3	16.83	36.94	27.96	8.25	25.73	20.27
0verall mean for fertilization treatments	F_4	20.17	45.39	34.70	12.58	19.41	14.26
	F_5	22.04	51.82	36.31	6.50	14.34	10.54
	F_6	15.46	32.09	23.02	6.75	17.88	13.59
	F_7	20.76	46.95	33.22	8.17	17.15	12.75
	F_8	17.29	31.44	24.59	8.58	22.88	17.43
	F_9	23.92	49.93	37.31	9.50	19.01	14.05
L.S.D at 5% level for:							
Irrigation regimes (Ir)		*	*	*	*	*	*
Fertilization (F)		3.81	4.70	4.36	1.91	2.22	1.84
Interaction (Ir x F)		5.39	6.65	6.16	2.72	3.14	2.60

irrigation treatment (well- irrigated) in 2019/2020 and 2020/2021seasons, respectively.

The significant reduction in the number of pods/ plant under drought stress irrigation treatment (Ir_2) compared to Ir_1 treatment (well- irrigated) might be attributed to that the drought stress decrease number of pod setting / plant as show in Table 5. These results are in agreement with those of Mwanamwenge et al. (1999).

Data recorded in Table 6 show that the weight of pods / plant was significantly affected by the application of phosphorus and potassium fertilizer rates irrespective of irrigation regimes in both seasons. Tables 6 show that F_5 (the application of 100 kg P + 50 kg K) and F_3 (the application of 200 kg P) gave the highest weight of the mature pods/plant in 2019/2020 and 2020/2021 seasons, respectively. These results are in agreement with those of Hashemabadi, (2013).

Data recorded in Table 6 show that the interaction effect between phosphorus and potassium fertilizer rates as well as irrigation regimes significantly affected weight of pods /plant in both seasons. However, the highest weight of pods /plant (82.48 g) and (42.68 g) was obtained at Ir_1 and F_5 and F_3 treatments, in 2019/2020 and 2020/2021seasons, respectively.

The obtained results (Table 6) indicate that broad bean plants grown under Ir_2 irrigation treatment and F_3 in 2019/2020 season gave 40.19 % increase in the weight of pods /plant over these of the control (unfertilized) at the same irrigation regime (Ir_2

treatment). Results in 2020/2021 followed similar trend.

3.3.3. Seed yield per plant

Results presented in Table 6 show that Ir_2 irrigation regime (drought stress- 40% of field capacity) significantly decreased yield per plant in 2019/2020 and 2020/2021 seasons as compared with those of well irrigated treatment (Ir_1) (80% of field capacity treatment).

The results indicate that broad bean plants grown under Ir_1 irrigation treatment gave 210.68 % and 327.96 % increase in seed yield per plant over those of plants grown under Ir_2- irrigation treatment in 2019/2020 and 2020/2021seasons, respectively.

The reduction in seed yield per plant due to soil drought (Ir_2), might be attributed to its reducing effect on the number and weight of pods per plant at harvest time (Table 6). These results are in agreement with those of Wu and Wang (2000).

Table 6 show that the reduction in seed yield per plant due to drought stress in the second season was higher than those in the first season. This variation might be attributed to the climatic conditions, mainly air temperature. Table 2 show the average temperature during the growing seasons. Generally, in second season the air temperature was higher than those in the first season. These results are in agreement with those of McDonald and Paulsen (1997).

Data presented in Table 6 show that regardless of irrigation treatments the different phosphorus and potassium fertilization treatments significantly affected seed yield per plant in both seasons. However, the results indicate that all phosphorus and potassium rates increased seed yield per plant as compared with the control (without phosphorus and potassium application) in both seasons, with some exceptions. These results are in agreement with those of Kurdali and Al-Shamma'a (2010).

Table 6 show that the highest seed yield per plant (37.31g) was obtained under F_9 treatment as compared with all other treatments in the first season. In the second season F_3 treatment gave the highest seed yield value (20.27g) as compared with all other treatments.

Table 6 indicate that the interaction effect of Ir and F treatments was significant in both seasons. In the first season, the highest seed yield per plant (58.11g) was obtained under Ir_1 and F_4 treatments, while in the second season, Ir_1 with F_3 gave the highest value (33.56 g).

Results presented in Table 6 indicate also that at Ir_2 irrigation regime (soil drought stress), the application of P and K fertilization increased the seed yield per plant over those of the control (without addition P and K) at the same irrigation regime i.e.Ir_2. In the first season, at Ir_2 (drought stress), F_3 (P_{200}) treatment increased seed yield per plant by 53.63 % over those of the control (without addition P and K fertilization) at the same irrigation regime Ir_2 (drought stress). Results in 2020/2021 followed similar trend. These results indicate that phosphorus and potassium fertilization increased the drought tolerance of broad bean plants. These results are in agreement with those of Oukaltouma et al. (2021).

However, our results indicate that:

Broad bean is sensitive crop to drought, therefore sufficient water apply must be provided not less than 70% of field capacity during vegetative and reproductive grow stages to obtain high seed yield.

The application phosphorus and potassium fertilizer alleviate the injurious effects of drought on broad bean plants.

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الملخص العربي

تأثير التسميد الفوسفاتى والبوتاسى على تحمل نباتات الفول البلدي للجفاف

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أجريت تجربتان في صوبة قسم المحاصيل – كلية الزراعة – جامعة الأزهر – مدينة نصر – القاهرة، لدراسة تأثير معدلات السماد الفوسفاتى (سوبر فوسفات الكالسيوم ١٥.٥% فو٢أ٥) والبوتاسى (كبريتات البوتاسيوم ٤٨% بو٢أ) على تحمل نباتات الفول البلدى للجفاف.

المعاملات

أ- معاملات السماد الفوسفاتى والبوتاسى

١- بدون إضافة سماد (للمقارنة) ٢- إضافة ١٠٠ كجم سوبر فوسفات الكالسيوم

٣- إضافة ٢٠٠ كجم سوبر فوسفات الكالسيوم ٤- إضافة ٥٠ كجم كبريتات بوتاسيوم

٥- إضافة ١٠٠كجم سوبر فوسفات الكالسيوم + ٥٠ كجم كبريتات بوتاسيوم

٦- إضافة ٢٠٠كجم سوبر فوسفات الكالسيوم + ٥٠ كجم كبريتات بوتاسيوم

٧-إضافة ١٠٠ كجم كبريتات بوتاسيوم

٨- إضافة ١٠٠كجم سوبر فوسفات الكالسيوم + ١٠٠ كجم كبريتات بوتاسيوم

٩- إضافة ٢٠٠كجم سوبر فوسفات الكالسيوم+ ١٠٠ كجم كبريتات بوتاسيوم

ب- معاملات الرى

١- الرى عند ٨٠% من السعة الحقلية (رطوبة أرضية مثلى لنمو النبات)

٢- الرى عند ٤٠% من السعة الحقلية (تعريض النباتات للإجهاد الرطوبى –جفاف)

وتتلخص أهم النتائج المتحصل عليها فيما يلى:

١- أدت معاملة الجفاف (٤٠% من السعة الحقلية) إلى نقص معنوي في طول النبات ومساحة السطح الورقي وعدد الأفرع المتكونة على النبات بالمقارنة بالنباتات التي تروى عند ٨٠% من السعة الحقلية (رطوبة أرضية مثلى) في موسمي النمو.

٢- لقد أدت معاملة الرى عند ٤٠% من السعة الحقلية إلى نقص معنوى في عدد الأزهار ونقص نسبة عقد القرون بالمقارنة بالنباتات التي تروى عند ٨٠%من السعة الحقلية في موسمى النمو.

٣- لقد أدت معاملة الجفاف (الري عند ٤٠% من السعة الحقلية) إلى نقص عدد ووزن القرون/ نبات ومحصول النبات من البذور معنويا بالمقارنة بمثيلتها التي تروى عند ٨٠% من السعة الحقلية في موسمى ٢٠١٩/٢٠٢٠و٢٠٢٠/٢٠٢١م.

٤- لقد أدى التسميد الفوسفاتى والبوتاسى إلى زيادة طول النبات ومساحة السطح الورقى وصافى معدل التمثيل الضوئى وعدد الأزهار التي تكونت على النبات ونسبة عقد القرون وعدد ووزن القرون / نبات ومحصول البذور/ نبات بالمقارنة بالنباتات التي لم يتم تسميدها في موسمى الزراعة.

لقد كان هناك تفاعل معنوى بين معاملات التسميد الفوسفاتى والبوتاسى على كل الصفات المدروسة، عدا عدد الأفرع المتكونة على النبات ولقد أدى التسميد الفوسفاتى والبوتاسى إلى زيادة تحمل نباتات الفول البلدى للجفاف.