Effects of Potassium Fertilization on Agronomic Characters and Resistance to Chocolate Spot and Rust Diseases in faba bean

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ABSTRACT

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The use of potassium (K^+) fertilization in faba bean to improve the agronomic characters and the resistance to foliar diseases was studied. A field experiment was conducted during two consecutive seasons (2007/08 and 2008/09) to determine the effect of potassium fertilizer on foliar diseases (rust and chocolate spot) in faba bean cv. Giza 402, susceptible to both diseases. Grain yield and its related characters were also considered. Potassium fertilization treatments included soil application, foliar application, and soil + foliar applications. The results showed that the potassium soil + foliar applications of fertilizer with increasing the quantity of K^+ until level 3 (171.36 + 3.4 Kg K_2O/ha) increased significantly the values of the majority of the plant characters and the resistance towards the desired direction. This result could be beneficial for faba bean growers looking for improving their grain yield through the agronomic characters and increasing the resistance of the crop to foliar diseases.

Keywords: Chocolate spot, faba bean, potassium, resistance, rust, yield

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Faba bean (*Vicia faba*) is one of the earliest domesticated legumes which represents a very important source of proteins for the human diet in Egypt and/or for animal feed in several countries. The surfaces and grain yields vary from year to year and from location to another. One of the drawbacks affecting this crop is yield and quality instabilities attributed to various biotic and abiotic stresses (1, 31, 45). Among biotic stresses, foliar diseases i.e. rust due to *Uromyces viciae-fabae* and chocolate spot caused by *Botrytis fabae* are the destructive limiting factors for faba bean production in Northern parts of Egypt (3, 10, 25, 26, 31). The subsequent loss was estimated to be more than 55% for susceptible cultivars (25) and in other cases, losses were found to score approximately 100%, especially when favorable conditions prevail (49).

The faba bean crop, and especially the cultivar Giza 402 used in this study, suffers from *B. fabae* and *U. viciae-fabae* infections as reviewed by many researchers (3, 10, 25, 26, 31). These foliar pathogens cause damages on leaves and hence reduce yield. Therefore,

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searching efficient means for controlling the foliar diseases is so urgent for improving faba bean yield and its components. Selection of resistant cultivars to foliar diseases is the appropriate mean to increase the yield of the crop. There are a wide range of models used to improve understanding of plant disease resistance. These include models for specific components of the disease cycle, spatial analysis of pathogen and disease distributions. Our approaches consist in the use of chemical fertilizers, particularly potassium sulphate in different application modes and forms (Soil, Foliar and Soil + Foliar Applications) to check and compare their roles for improving the agronomic characters and enhancing disease resistance. Despite the importance of this subject, few researches have addressed the effect of potassium deficiency in faba bean. Hence, the possible use of K^+ via solution as a spray directly to the foliage for reducing disease was therefore investigated. Potassium (in K_2O) was chosen because it is the main form of potassium fertilizer used on crops throughout the world (13). Although, it is a primarily soil-applied, but it can be sprayed as a solution in water on the foliage for more rapid uptake (27), and is used in some commercial foliar fertilizers. Fixen (29) found reductions of leaf diseases when potassium sulphate or ammonium chloride have been applied to crops in liquid form, with the intended target the soil, as fertilizers for supplying the nutrients potassium or nitrogen. In this connection, field experiments have shown that symptoms of glume blotch on wheat (34), brown rust on barley (33), leaf blotch and powdery mildew on wheat (21) can all be reduced by foliar sprays of potassium. Potassium is one of the essential elements for all living organisms. In plants, it is an important cation, comprising almost 6% of a plant's dry weight and involved in different physiological pathways (24). Potassium is the main osmotic solute in plants and its accumulation in the cell favors water uptake, thus generating the cell turgor pressure required for growth (36), in addition it helps stomatal opening (28). Moreover, it is involved in activating a wide range of enzyme systems regulating photosynthesis, water use efficiency and movement, nitrogen uptake and protein building (38). Also, potassium application can improve the water content in the faba bean leaves, which leads to more tolerance of plants to drought stress (46).

The mechanism of the effect of potassium on pathogen fungi both in vitro and in vivo was studied. Plasmolysis was observed when spores were suspended in K^+ as solution (Cook, unpublished). So, it was hypothesized that potassium controls the pathogen *Erysiphe graminis* by a reduction in spore germination through an osmotic mechanism. Therefore, this paper dealing with the rationale behind this approach, gives practical and/or applied example for choosing potassium rate as screening criteria for foliar diseases of the crop. Also, some agronomic traits were considered to be parallel and consistent with resistance to both diseases. Therefore, the objective of the present work was to identify, the potassium fertilization dose that could be used for controlling rust (*U. viciae fabae*) and chocolate spot (*B. fabae*) as a foliar diseases under field conditions. Also, it illustrates a useful picture for the relationship between yield and its related characters under potassium applications. The relationship between grain yield and all studied characters were also confirmed here through correlation and regression coefficients as well.

MATERIALS AND METHODS

Field trials were carried out during seasons 2007/08 and 2008/09 at the Experimental Farm of the Faculty of Agriculture, Suez Canal University, Ismailia, Egypt. The experimental soil was classified as a sandy textured (94.5% sand, 2.5% silt and 3.0% clay) with pH of 7.8. The potassium content was estimated as a total to be 0.5-1.5% in surface soil (15-18 cm), while the available part is 0.2%. The rate of potassium available was 11.65 and 11.90 ppm during the two seasons of 2007/08 and 2008/09, respectively.

Giza 402 was used as a susceptible cultivar to rust and to chocolate spot as reviewed earlier by several investigators (3, 10, 25, 26, 31). The cultivar was selected by Food Legumes Research Department, Agriculture Research Centre, Giza, Egypt. The potassium application treatments used in this work are presented in Table 1.

Table 1. Potassium application treatments and levels used in the trials

Treatment / Level	Potassium Soil Appl. (PSA)	Potassium Foliar Appl. (PFA)	Potassium Soil + Foliar Appl. (PSFA)
L0 (Control)	0	0	0
L1	57.12 Kg K_2O/ha	1.14 Kg K_2O/ha	57.12 + 1.14 Kg K_2O/ha
L2	114.24 Kg K_2O/ha	2.28 Kg K_2O/ha	114.24 + 2.28 Kg K_2O/ha
L3	171.36 Kg K_2O/ha	3.40 Kg K_2O/ha	171.36 + 3.4 kg K_2O/ha

Every experiment included 12 treatments as shown in Table 1. The experimental field was designed in split-plot design with three replicates (4 m long four-row field plots, spacing between rows = 45 cm and spacing between plants in the same row = 20 cm). The main plot contains potassium fertilizer treatments (PSA, PFA and PSFA), while the sub-plots contain the levels of potassium fertilizer (L0, L1, L2 and L3). Field plots with no potassium application were used as control (level L0). The soil and foliar potassium application was added for four equal doses at 20, 40, 60 and 80 days after sowing. All recommended agronomic practices were carried out regularly as faba bean plants needed.

The faba bean plants were checked weekly for any rust and chocolate spot diseases as specific disease symptoms due to *U. viciae-fabae* and *B. fabae*, respectively. Disease severity was assessed by determining the percentage of leaf area affected by *U. viciae-fabae* and *B. fabae* using a visual key (17). Leaf chlorophyll content was determined at the flowering stage using chlorophyll meter (24) which estimates SPAD value [SPAD 502, Soil-Plant Analysis Development (SPAD) section, Minolta Camera Co. Osaka, Japan].

The total shedding percentage in the plant stem was recorded as the following equation: Total shedding percentage = (total number of flowers – total number of mature pods) × 100/ total number of flowers.

Beside the above mentioned traits, some other traits such as days of 50% flowering, plant height (cm), number of branches/plant, number of pods/plant, 100-grain weight (g) and single plant yield (g/plant) were also considered. Data recorded, on the studied traits, were statistically analyzed using CoStat V. 6.311 (CoHort software, Berkeley, CA94701). Potassium levels (L), application treatment (A) means, and their interaction (L × A) for all studied traits including average of both diseases incidence were compared using least significant difference, LSD (44).

Probability levels lower than 0.05 were held to be significant. The relations between grain yield (g/plant) and all the studied traits were analyzed by linear regression coefficients.

RESULTS

Grain yield and its related characters. Data of the different treatments according the level of potassium and its mode of application for the different studied traits on faba bean cv. Giza 402 for seasons 2007/08 and 2008/09 and for both seasons are presented in Tables 2 and 3. Days to 50% flowering, increased with increasing of potassium (K_2O) from L0 (control) or L1 to L2 (114.24, 2.28 or 114.24 + 2.28 Kg K_2O/ha) or L3 (171.36, 3.40 or 171.36 + 3.4 Kg K_2O/ha), through both seasons and their combination (Table 2). Also, the potassium soil and foliar applications (PSFA) were the best modes for decreasing the days to 50% flowering (earliness).

In regards to the characters *i.e.* plant height (cm), number of branches/plant, leaf chlorophyll content (SPAD value), number of pods/plant, 100-grain weight (g), and grain yield (g/plant) had the same behavior under the different levels of potassium and also application of potassium sulphate mode in both seasons (2007/08 and 2008/09) and also in combination as presented in Tables 2 and 3. The potassium soil + foliar application (PSFA), as a fertilizer mode of application, was the best and suitable one among all for increasing plant height, branches number, leaf chlorophyll content (SPAD value), pods number/plant, 100-grain weight (g) and grain yield (g/plant) as shown in Tables 2 and 3.

In respect of shedding rate character, it was observed that the percentage of shedding was decreased significantly with increasing of the potassium quantity, starting from L0 (control) or L1 (57.12, 1.14 and 57.12 + 1.14 Kg K_2O/ha) to L2 (114.24, 2.28 or 114.24 + 2.28 Kg K_2O/ha) or L3 (171.36, 3.40 or 171.36 + 3.4 Kg K_2O/ha). Also, adding the potassium fertilization in forma of soil + foliar application (PSFA) was more effective in decreasing the percentage of shedding on faba bean cultivar (Giza 402) as compared to the other modes of potassium application (Table 3).

The interaction effects between levels (L) and application (A) modes of potassium on grain yield and its related characters were highly significant in most cases. Data in Tables 2 and 3 revealed that the application of the L3 level by potassium soil + foliar application (PSFA) followed by either L2 by potassium soil application (PSA) or L1 by potassium foliar application (PFA) were the best combinations with the exception of percentage of shedding.

Rust and chocolate spot incidences. Data of rust and chocolate spot incidences are presented in Table 4. It can be noticed that adding potassium fertilization in forma of soil + foliar application (PSFA) gave the best results for controlling the infection of both diseases. The lowest values of disease incidences were 33.2, 31.2 and 33.1% with rust and 34.8, 32.4 and 33.6% with chocolate spot in seasons 2007/08, 2008/09 and in average of both seasons, respectively (Table 4). On the other hand, K_2O application at different concentrations showed decreasing in disease incidences with increasing of potassium fertilization doses.

Table 2. Effect of soil and/or foliar potassium sulphate fertilizers and their levels on days to 50% flowering, maturity days, plant height and number of branches/plant traits in faba bean (Giza 402) through seasons 2007/08, 2008/09 and their combination (L0 to L3: see Materials and Methods)

Treatment	2007/08				2008/09				Combination (2007/08 and 2008/09)			
Level	Soil appl.	Foliar appl.	Soil & foliar appl.	Mean	Soil appl.	Foliar appl.	Soil & foliar appl.	Mean	Soil appl.	Foliar appl.	Soil & foliar appl.	Mean
Days to 50% flowering												
L0	43.14	44.80	42.67	43.54 c	43.11	43.15	41.93	42.73 c	43.13	43.98	42.30	43.14 c
L1	49.29	49.33	42.79	47.14 b	48.01	52.27	46.60	48.96 b	48.65	50.80	44.70	48.05 b
L2	51.64	52.44	52.64	52.24 a	50.78	52.47	53.40	52.17 a	51.21	52.46	53.02	52.21 a
L3	50.33	53.68	51.43	51.18 a	52.00	54.51	53.57	53.36 a	51.75	52.42	52.50	52.27 a
Mean	48.60 b	50.06 a	47.38 c		48.48 b	50.60 a	48.88 b		48.54 b	51.36 a	48.13 b	
LSD	**Level (L)** 1.47	**Appl (A)** 1.74	**L*A** 2.69		**Level (L)** 1.13	**Appl (A)** 1.76	**L*A** 2.02		**Level (L)** 1.03	**Appl (A)** 1.19	**L*A** 1.79	
Plant height (cm)												
L0	64.67	62.37	63.90	63.65 d	65.41	65.24	64.90	65.18 c	65.04	63.81	64.40	64.42 d
L1	65.00	68.01	70.10	67.70 c	65.68	65.61	62.58	64.62 c	65.34	66.81	66.34	66.16 c
L2	70.44	70.54	74.17	71.72 b	71.41	75.33	75.58	74.11 b	70.93	72.94	73.61	72.92 b
L3	74.47	78.21	77.47	76.72 a	78.35	78.89	87.63	81.62 a	76.41	78.55	82.55	79.17 a
Mean	68.65 c	69.78 b	71.41 a		70.21 a	71.26 a	72.67 a		69.43 c	70.52 b	72.04 a	
LSD	**Level (L)** 1.99	**Appl (A)** 1.12	**L*A** 3.47		**Level (L)** 1.49	**Appl (A)** 1.39	**L*A** 2.59		**Level (L)** 1.20	**Appl (A)** 0.89	**L*A** 2.08	
Number of branches/plant												
L0	2.96	2.90	2.97	2.94 d	3.04	2.96	2.94	2.98 c	3.00	2.93	2.96	2.96 b
L1	4.29	3.86	3.45	3.87 c	4.02	3.85	4.35	4.07 b	4.16	3.90	3.90	3.97 ab
L2	3.56	4.08	4.30	3.98 b	3.73	4.60	4.67	4.33 a	3.65	4.34	4.49	4.16 a
L3	4.03	4.13	4.86	4.34 a	4.32	4.71	4.59	4.54 a	4.18	4.42	4.73	4.44 a
Mean	3.71 b	3.74 b	3.90 a		3.78 c	4.03 b	4.14 a		3.75 b	3.89 b	4.02 a	
LSD	**Level (L)** 0.10	**Appl (A)** 0.15	**L*A** 0.24		**Level (L)** 0.24	**Appl (A)** 0.10	**L*A** 0.42		**Level (L)** 1.36	**Appl (A)** 0.09	**L*A** 2.02	
Leaf chlorophyll content (SPAD value)												
L0	34.33	35.67	34.75	34.92 d	36.53	37.33	35.00	36.29 c	35.43	36.50	34.88	35.61 d
L1	39.00	41.67	42.33	41.00 c	38.67	39.00	43.67	40.45 b	38.84	40.34	43.00	40.73 c
L2	41.00	43.67	46.67	43.78 b	37.00	41.00	43.67	40.56 b	39.00	42.34	45.17	42.17 b
L3	45.33	46.33	49.33	46.99 a	44.33	46.00	48.60	46.31 a	44.83	46.17	48.97	46.65 a
Mean	39.92 c	41.84 b	43.27 a		39.13 b	40.83 a	42.73 b		39.53 c	41.34 b	43.00 a	
LSD	**Level (L)** 1.09	**Appl (A)** 1.11	**L*A** 1.91		**Level (L)** 1.43	**Appl (A)** 1.94	**L*A** 2.49		**Level (L)** 0.87	**Appl (A)** 0.93	**L*A** 1.51	

Table 3. Effect of soil and/or foliar potassium sulphate fertilizers and their levels on number of pods/plant, pod length, shedding rate and 100-grain weight traits in faba bean (Giza 402) through seasons 2007/08, 2008/09 and their combination (L0 to L3: see Materials and Methods)

Treatment Level	2007/08				2008/09				Combination (2007/08 and 2008/09)			
	Soil appl.	Foliar appl.	Soil & foliar appl.	Mean	Soil appl.	Foliar appl.	Soil & foliar appl.	Mean	Soil appl.	Foliar appl.	Soil & foliar appl.	Mean
Number of pods/plant												
L0	10.43	11.97	12.45	11.62 d	10.69	11.51	11.67	11.29 d	10.56	11.74	12.06	11.46 d
L1	12.62	11.41	12.26	12.10 c	12.60	13.07	13.28	12.98 c	12.61	12.24	12.77	12.54 c
L2	12.29	13.49	14.26	13.35 b	13.44	14.66	15.40	14.50 b	12.87	14.08	14.05	13.93 b
L3	14.69	15.39	15.85	15.31 a	13.90	15.96	15.91	15.26 a	14.30	15.68	15.88	15.29 a
Mean	12.50 c	13.07 b	13.71 a		12.66 c	13.80 b	14.07 a		12.58 c	13.44 b	13.89 a	
	Level (L)	**Appl (A)**	**L*A**		**Level (L)**	**Appl (A)**	**L*A**		**Level (L)**	**Appl (A)**	**L*A**	
LSD	0.40	0.62	0.70		0.44	0.42	0. 76		0.29	0.37	0.50	
Shedding rate (%)												
L0	55.60	56.67	55.10	55.79 a	54.00	54.97	55.90	54.96 a	54.80	55.82	55.50	55.38 a
L1	54.45	53.53	49.16	52.38 b	57.98	54.45	50.14	54.19 a	56.22	53.99	49.65	53.29 b
L2	52.06	51.17	47.07	50.10 c	50.84	47.23	48.20	48.76 b	51.45	49.20	47.64	49.43 c
L3	50.80	48.05	46.97	48.61 d	50.97	49.30	47.78	49.35 b	50.89	48.68	47.38	48.98 c
Mean	53.23 a	52.36a	49.58 b		53.45 a	51.49 b	50.51 b		53.34 a	51.93 c	50.05 b	
	Level (L)	**Appl (A)**	**L*A**		**Level (L)**	**Appl (A)**	**L*A**		**Level (L)**	**Appl (A)**	**L*A**	
LSD	1.36	1.49	2.70		1.96	1.86	3.41		1.21	0.99	2.10	
100-grain weight (g)												
L0	64.73	64.85	64.86	61.48 d	65.70	68.62	66.80	62.46 d	65.22	66.74	65.83	61.97 d
L1	65.11	66.30	67.51	65.31 c	65.54	66.90	67.32	66.59 c	65.33	66.60	67.42	65.95
L2	70.25	74.32	76.45	73.01 b	72.57	71.60	76.31	73.49 b	71.41	72.96	76.38	73.25 b
L3	76.06	78.83	84.01	80.30 a	78.31	78.42	83.40	80.04 a	77.19	78.63	83.71	80.17 a
Mean	69.04 c	71.08 b	73.21 a		70.53 b	71.38 b	73.28 a		69.79 c	71.23 b	73.25 a	
	Level (L)	**Appl (A)**	**L*A**		**Level (L)**	**Appl (A)**	**L*A**		**Level (L)**	**Appl (A)**	**L*A**	
LSD	0.62	1.37	2.93		1.32	1.22	2.29		0.92	0.57	1.59	
Grain yield (g/plant)												
L0	40.49	41.17	42.01	41.31 d	44.33	45.31	44.81	44.81 d	42.41	43.24	43.41	43.06 d
L1	43.59	46.14	47.81	44.85 c	49.24	50.99	52.17	50.80 c	46.42	48.57	49.99	47.83 c
L2	45.85	50.99	52.28	49.37 b	48.61	52.58	54.94	52.04 b	47.23	51.79	53.61	50.21 b
L3	50.55	55.55	57.51	54.54 a	54.61	56.37	57.54	56.17 a	52.58	55.96	57.53	55.36 a
Mean	45.12 c	47.22 b	48.90 a		49.20 b	51.31 a	52.35 a		47.16 c	49.27 b	50.63 a	
	Level (L)	**Appl (A)**	**L*A**		**Level (L)**	**Appl (A)**	**L*A**		**Level (L)**	**Appl (A)**	**L*A**	
LSD	1.09	1.11	1.91		1.43	1.94	2.49		0.87	0.93	1.51	

Table 4. Effect of soil and/or foliar potassium sulphate fertilizers and their levels on rust and chocolate spot disease incidence in faba bean (Giza 402) through seasons 2007/08, 2008/09 and their combination (L0 to L3: see Materials and Methods)

Treatment	2007/08				2008/09				Combination (2007/08 and 2008/09)			
Level	Soil appl.	Foliar appl.	Soil & foliar appl.	Mean	Soil appl.	Foliar appl.	Soil & foliar appl.	Mean	Soil appl.	Foliar appl.	Soil & foliar appl.	Mean
Rust disease incidence (%)												
L0	48.33	49.30	47.03	48.22 a	47.07	48.67	47.01	47.58	47.70	48.99	47.02	47.90 a
L1	47.67	42.27	32.33	40.76 b	44.00	38.33	37.33	39.89	45.84	40.30	34.83	40.32 b
L2	43.33	33.00	29.13	35.15 c	40.67	29.10	26.33	32.03	42.00	31.05	27.73	33.59 c
L3	36.48	31.67	24.17	30.77 d	33.00	25.33	21.67	26.67	34.74	28.50	22.92	28.72 d
Mean	43.99 a	39.06 b	33.17 c		41.44 a	35.61 b	31.17 c		42.57 a	37.21 b	33.13 c	
LSD	**Level (L)** 4.24	**Appl (A)** 5.26	**L*A** 7.41		**Level (L)** 4.29	**Appl (A)** 5.14	**L*A** 10.06		**Level (L)** 3.47	**Appl (A)** 3.88	**L*A** 6.01	
Chocolate spot disease incidence (%)												
L0	47.67	47.67	46.13	47.16 a	45.67	48.33	44.80	46.27 a	46.67	48.00	45.47	46.72 a
L1	42.10	40.60	39.00	40.57 b	40.67	39.63	33.67	37.99 b	41.39	40.12	36.34	39.28 b
L2	37.67	33.00	31.67	34.11 c	35.00	31.67	28.63	31.77 c	36.34	32.36	30.15	32.94 c
L3	33.03	25.33	22.33	26.90 d	30.00	24.98	22.33	25.76 d	31.52	25.16	22.33	26.33 d
Mean	40.12 a	36.65 b	34.78 b		37.83 a	36.15 ab	32.36 b		38.98 a	36.41b	33.57 b	
LSD	**Level (L)** 5.99	**Appl (A)** 5.39	**L*A** 7.38		**Level (L)** 5.58	**Appl (A)** 4.98	**L*A** 6.61		**Level (L)** 3.95	**Appl (A)** 3.05	**L*A** 6.85	

Table 5. Correlation coefficients between different characters of faba bean cultivar (Giza 402) through seasons 2007/08, 2008/09 and their combination

Trait	Year	Days to 50% flowering	Plant height (cm)	Number of branc-hes/plant	Leaf chlo. content (SPAD value)	Number of pods /plant	Shedding rate (%)	100-grain weight (g)	Grain yield (g/plant)	Rust disease incidence	Chocolate spot disease incidence
Days to 50% flowering	2007/08	------	0.794**	0.754**	0.769**	0.818**	- 0.118	0.838**	0.846**	- 0.704**	- 0.729**
	2008/09	------	0.698**	0.794**	0.820**	0.836**	-0.121	0.835**	0.869**	-0.759**	-0.774**
	Comb.	------	0.740**	0.745**	0.794**	0.825**	-0.110	0.834**	0.858**	-0.734**	-0.753**
Plant height (cm)	2007/08		------	0.795**	0.708**	0.762**	0.186	0.848**	0.796**	-0.497**	-0.514**
	2008/09		------	0.751**	0.667**	0.671**	0.221	0.801**	0.747**	-0.643**	-0.717**
	Comb.		------	0.719**	0.685**	0.715**	0.198	0.823**	0.769**	-0.576**	-0.620**
Number of branc-hes/plant	2007/08			------	0.824**	0.856**	- 0.036	0.746**	0.903**	-0.542 **	-0.523**
	2008/09			------	0.883**	0.895**	0.012	0.899**	0.872**	-0.532**	-0.502**
	Comb.			------	0.814**	0.827**	-0.46	0.787**	0.843**	-0.767**	-0.684**
Leaf chlo. content (SPAD value)	2007/08				------	0.882**	- 0.206	0.808**	0.932**	-0.744**	-0.709**
	2008/09				------	0.859**	0.258	0.832**	0.942**	-0.914**	-0.827**
	Comb.				------	0.867**	- 0.237*	0.815**	0.932**	-0.831**	-0.767**
Number of pods /plant	2007/08					------	- 0.004	0.805**	0.864**	-0.706**	-0.688**
	2008/09					------	- 0.212	0.845**	0.863**	-0.833**	-0.810**
	Comb.					------	-0.97	0.825**	0.862**	-0.767**	-0.749**
Shedding rate (%)	2007/08						------	0.054	-0.221	0.382	0.276
	2008/09						------	0.059	- 0.181	0.151	0.019
	Comb.						------	0.063	0.188	0.224	0.138
100-grain weight (g)	2007/08							------	0.818**	-0.531**	-0.542**
	2008/09							------	0.820**	-0.782**	-0.760**
	Comb.							------	0.819**	-0.669**	-0.654**
Grain yield (g/plant)	2007/08								------	-0.677**	-0.653**
	2008/09								------	-0.845*	-0.811**
	Comb.								------	-0.771**	-0.737**
Rust disease	2007/08									------	0.917**
	2008/09									------	0.895**
	Comb.									------	0.894**

*, ** Denotes significant at 5% and 1% level of probability, respectively.

Interactions between the level and the application mode of potassium related to rust and chocolate spot disease incidences were significant (Table 4). It appeared that the best control of rust and chocolate spot was obtained with L2 as foliar application.

Correlation and linear regressions of the studied characters. An overall study of the simple correlation coefficients among pairs of all studied characters in seasons 2007/08, 2008/09 and their combination was estimated and presented in Table 5. The results indicated that the degree of association, which was highly significant between the agronomic character pairs, could be accompanied by high yielding ability under such conditions. The associations between character pairs were highly significant with positive values in most characters cases, except some of them (Table 5).

With respect to grain yield (g/plant), days to 50% flowering, plant height, number of branches/plant, leaf chlorophyll content (SPAD value), number of pods/plant and 100-grain weight as agronomic traits, revealed a positive significant correlations among themselves through the both seasons (2007/08 and 2008/09) and their respective combination (Table 5). On the other hand, all these characters were not correlated with shedding rate. However, regarding to the foliar disease (rust and chocolate spot) incidences, the correlations between grain yield (g/plant) and incidences of both diseases were negative and highly significant (Table 5).

Leaf chlorophyll content presented negative and highly significant coefficients with rust and chocolate spot disease incidences for seasons 2007/08 and 2008/09 and with combined season data (Table 5). On the other hand, the correlations between shedding rate and both disease incidences were not significant.

The coefficient of determination (R^2) with a significant value may indicate useful criteria for improving the characters than those with insignificant values. A linear regression equation based on the relationship between grain yield (g/plant) and the related agronomic traits, and with foliar disease incidences under potassium fertilizer application levels are presented in Figs. 1-7 and Figs. 8 and 9, respectively. On the basis of the linear equation, coefficients of determination for the relationship between grain yield and its related agronomic characters *i.e.* days of 50% flowering, plant height, number of branches/plant, leaf chlorophyll content, number of pods/plant, shedding rate and 100-grain weight (Figs. 1-7) were ranged from 0.528 (number of pods/plant) to 0.968 (leaf chlorophyll content). The highest values of determination coefficients (R^2) scored were 0.968 (leaf chlorophyll content), followed by 0.798 (days of 50% flowering) and 0.796 (shedding rate). High coefficients of determination of grain yield with rust ($R^2 = 0.925$) and with chocolate spot ($R^2 = 0.941$) were recorded (Figs. 8 and 9).

DISCUSSION

There are major constraints in obtaining high yield and good faba bean grain quality under intensive production systems. Growers and researchers have thinking in new series of approaches based on treatment application to decrease the harmful effects of any constraints of faba bean. Recently, several research programs aiming to reduce the impact of diseases on yield by increasing their resistance have been deve1oped. One of these programs is the use of appropriate agricultural practices, including fertilizers via potassium, which could be used to minimize the harmful effects of fungal pathogens and to increase the grain production.

Days to 50% flowering trended to increase with adding potassium from level zero L0 (control) to level L3 (171.36, 3.40 or 171.36 + 3.4 Kg K_2O/ha) and also with the potassium application in foliar form (PFA). The potassium has a positive effect when sprayed as a solution in water on the foliage for more rapid uptake (27), and its accumulation in the cell favors water uptake, thus generating the cell turgor required for growth (23, 36) and stomata opening (28).

The plant height (cm), number of branches/plant, leaf chlorophyll content (SPAD value), number of pods/plant, 100-grain weight (g) and grain yield (g/plant) were increased significantly with types of potassium application PSA, PFA, and PSFA through L0 to L3. It means that plants with an adequate potassium supply have better-hydrated tissues than those with potassium deficiency. Similar finding was reported earlier (37). This finding mentioned above due to the potassium, an important macronutrient, and has a major action in higher plants. Indeed, this element is essential for enzyme activation, protein synthesis and photosynthesis, and it mediates osmoregulation during cell expansion. These results were in harmony with those obtained by other researchers (8, 11).

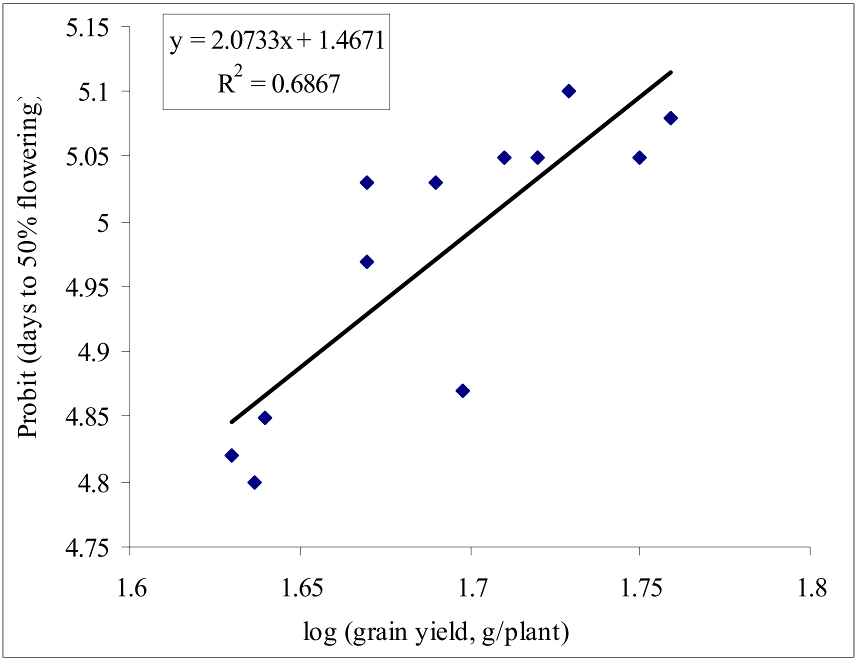

Fig. 1. Regression coefficient between grain yield (g/plant) and days to 50% flowering in combined seasons (2007/08 and 2008/09).

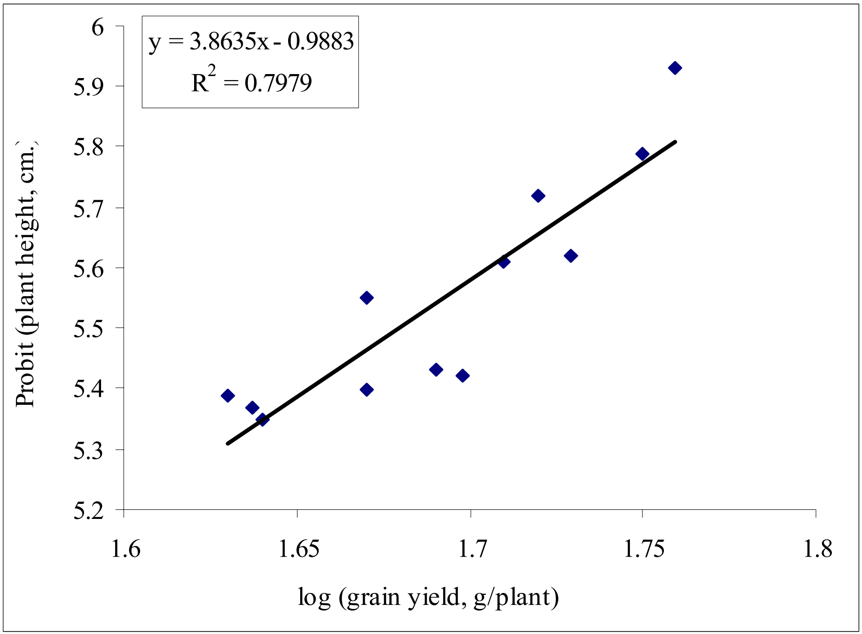

Fig. 2. Regression coefficient between grain yield (g/plant) and plant height (cm) in combined seasons (2007/08 and 2008/09).

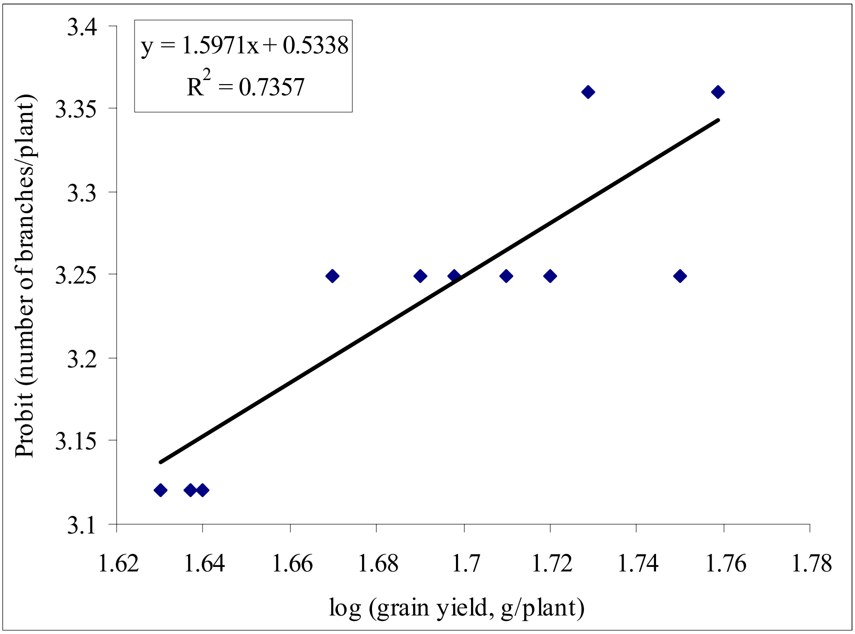

Fig. 3. Regression coefficient between grain yield (g/plant) and number of branches/plant in combined seasons (2007/08 and 2008/09).

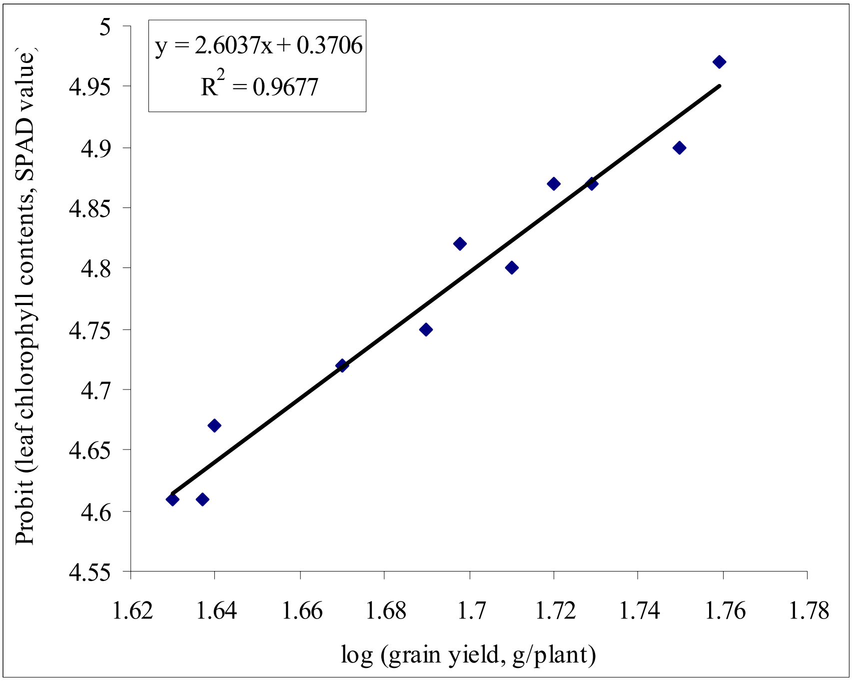

Fig. 4. Regression coefficient between grain yield (g/plant) and leaf chlorophyll content (SPAD value) in combined seasons (2007/08 and 2008/09).

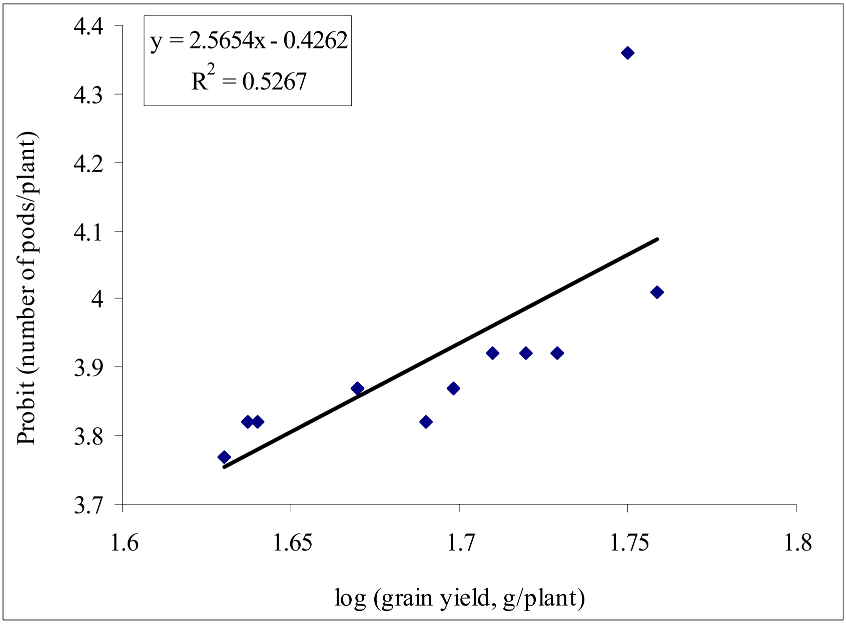

Fig. 5. Regression coefficient between grain yield (g/plant) and number of pods/plant in combined seasons (2007/08 and 2008/09).

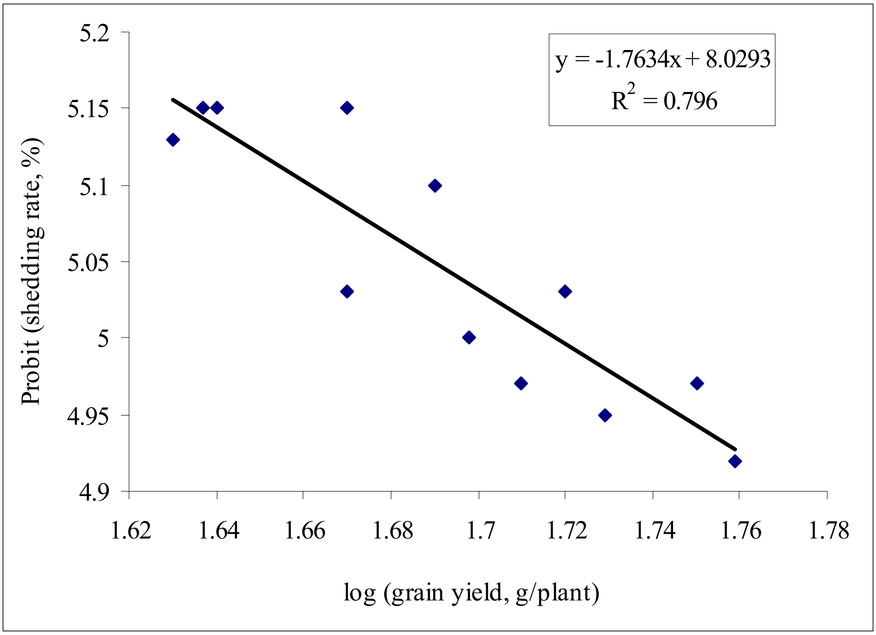

Fig. 6. Regression coefficient between grain yield (g/plant) and shedding rate (%) in combined seasons (2007/08 and 2008/09).

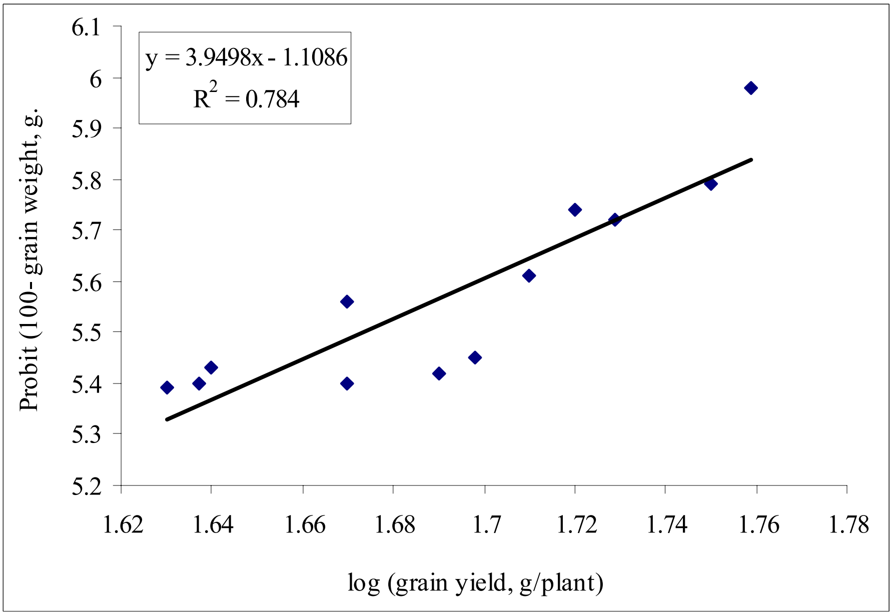

Fig. 7. Regression coefficient between grain yield (g/plant) and 100-grain weight in combined seasons (2007/08 and 2008/09).

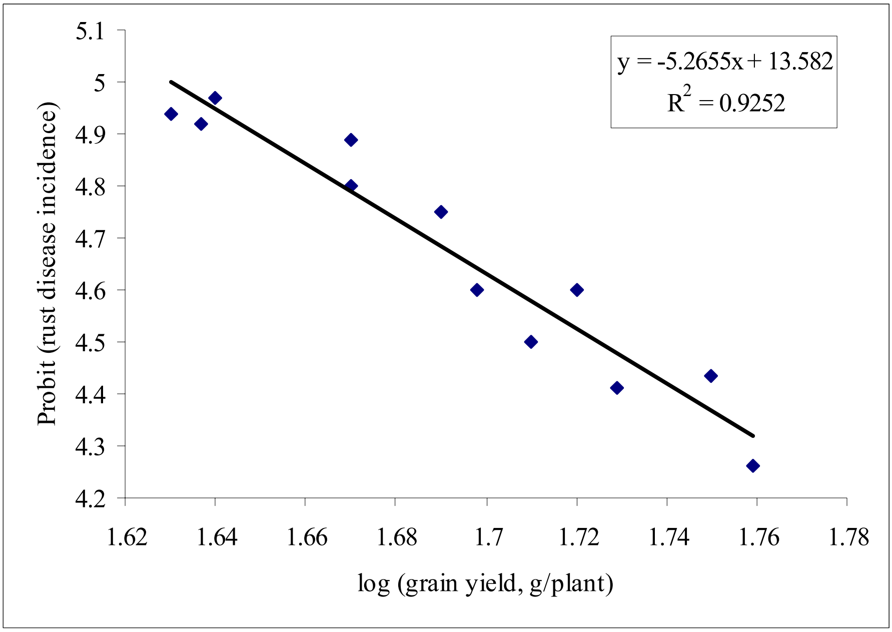

Fig. 8. Regression coefficient between grain yield (g/plant) and rust disease infection in combined seasons (2007/08 and 2008/09).

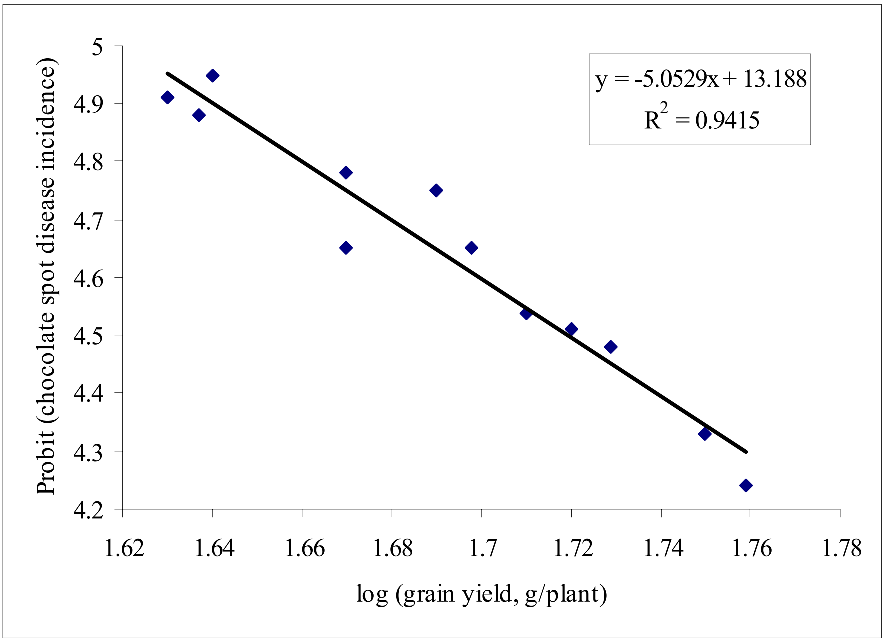

Fig. 9. Regression coefficient between grain yield (g/plant) and chocolate spot disease infection in combined seasons (2007/08 and 2008/09).

In the same connection, we have to report that the potassium soil + foliar applications (PSFA) as a fertilizer type was the best and suitable one among all for increasing plant height, branches number, leaf chlorophyll content (SPAD value), pods number/plant, 100-grain weight (g) and grain yield (g/plant). This is due to potassium sulphate as a potassium fertilizer that may alleviate the negative effects of stress in faba bean (2), consequently it was more effective in growing these characters in order to promote vigorously faba bean crop. Potassium is the main osmotic solute in plants (48) and of course, its accumulation in the cell generates cell turgor required for growth (23, 36). K_2O is so urgent and essential for enzymes and plastids activation in the leaves, protein synthesis and photosynthesis and stomatal movements, then can be rate-limiting for improving the chlorophyll production in the leaf and, consequently, increasing the grain yield and their absolute weight. This finding was in the same line of those reported earlier (11, 12, 19, 22, 35, 41).

In respect of shedding rate character, adding the potassium fertilizer in forma of soil + foliar application (PSFA) was more effective in decreasing the percentage of shedding rate on faba bean cv. Giza 402 in comparison with the other forms of potassium application (Table 3). These findings could be true because K_2O is so urgent and essential for plant growth, since the growth parameters are under the influence of potassium application. In this respect, Oosterhuis (39) mentioned that K_2O is not a constituent of any known component, but it is implicated in over 60 enzymatic reactions involving many processes in the plant such as photosynthesis, respiration, carbohydrate metabolism, translocation and protein synthesis.

The highly significant interaction effects between levels (L) and application (A) modes of potassium on grain yield and its related characters detected in most cases (Tables 2 and 3) may be due to potassium fertilization achieving enzyme activation inside the cell plant reducing the flower drop and pod abortion in faba bean plants. These results are in agreement with those reported by Shabala (42).

Fungal diseases are the major constraints of faba bean crop, therefore potassium application could be a good approach for reducing the negative effects of pathogens such as *U. viciae-fabae* causing rust and *B. fabae* causing chocolate spot. Low values of rust incidences (33.2 in 2008, 31.2 in 2009 and 33.1% for both) and chocolate spot incidences (34.8 in 2008, 32.4 in 2009 and 33.6% for both) confirm the negative effect of soil + foliar application of potassium on both diseases (Table 4). These results were in agreement with those obtained by other researchers (34, 47).

On the other hand, K_2O application at different concentrations and/or levels showed decreasing in both disease incidences with increasing of potassium fertilization doses. In this connection, Barber *et al.* (14) found that chlorophyll content in leaves of cotton plants decreased under K deficiency, leading to highly marked reduction of leaf photosynthesis close to 95%. However, plants that have an optimum level of potassium in leaves will be more efficient in photosynthesis and become more resistant and tolerant to adverse conditions.

For supporting the above finding, potassium chloride may cause this reduction in disease severity caused by *U. viciae-fabae* or *B. fabae* by various modes of action. Potassium is involved in many processes within plants, including photosynthesis, respiration and osmotic pressure regulation (43). Potassium is rapidly taken up by the plant. Alexander (5) recommended foliar application of potassium chloride from the beginning of stem extension. With this regard, Griffith and Wagner (30) speculated that plants exhibited thicker cuticles and more turgid cells when plant tissue was high in potassium content. Such physiological properties may lead to greater resistance against pathogens. In the same way, reductions in disease severity have been observed in other crops when small amounts of potassium or phosphate have been applied (39, 40).

The results in Table 5, which indicate that the degree of association between traits was highly significant for agronomic character pairs, could be accompanied by high yielding ability under such conditions. Therefore, it could be concluded that selection of faba bean plants under potassium fertilizer application should be based on the above characters studied to improve grain yield of faba bean (Giza 402). These results are in agreement with those reported earlier (4, 6, 7). Indeed, the highest correlation coefficients were obtained between grain yield (g/plant) and each of the following traits: days to 50% flowering, plant height, number of branches/plant, leaf chlorophyll content (SPAD value), number of pods/plant and 100-grain weight through the seasons 2007/08 and 2008/09, and their combined data (Table 5). Therefore, it can be concluded that selection of faba bean plants under potassium fertilizer application should be based on the above characters for the improvement of grain yield of Giza 402. These results are in accordance with earlier studies (4, 41). On the other hand, the studied characters, which were correlated negatively with shedding rate and did not reach the significant level (Table 5), supported the selection for decreasing the shedding rate under application of potassium fertilization. However, the negative and significant correlations observed between grain yield (g/plant) and each of both diseases (rust or chocolate spot) confirm their negative impact on grain yield of faba bean. In this connection, Kairon and Singh (32) reported strong relationship between these characters.

Leaf chlorophyll content (SPAD value) trait had negative and highly significant correlation with each of rust and chocolate spot diseases in both seasons, while the correlation between shedding rate and both diseases did not pass the significance level in all cases (Table 5). These obtained results confirmed that low level of disease severity to rust and chocolate spot diseases is associated with high leaf chlorophyll content, while there were no effects for the percentage of shedding rate on levels of the foliar diseases incidence. These findings are more or less in agreement with the results signaled by Ashraf and Zafar (9).

The coefficient of determination (Figs. 1-7) with a significant value may indicate useful criteria for improving the characters than those with insignificant values. The highest value of coefficient of determination (R^2), which scored 0.968 (leaf chlorophyll content), followed by 0.798 (days of 50% flowering) and 0.796 (shedding rate), indicated that these parameters played an important role for improving grain yield of faba bean.

The results obtained in respect of the coefficient of determination (R^2) of rust disease and chocolate spot disease infections with grain yield (Figs. 8 and 9) confirmed that the breeding program for improving grain yield in faba bean should take in consideration resistance to rust and chocolate spot diseases. These results were in harmony with those of some previous studies (16, 17, 18).

In conclusion, this study demonstrates that the potassium is an important element for agronomic characters improvement and for enhancing the resistance to rust and to chocolate spot diseases. The results showed that the potassium soil + foliar application (PSFA) at level 3 (171.36 + 3.4 Kg K_2O/ha) followed by potassium as foliar application (PFA) at level 3 (3.40 Kg K_2O/ha), increased significantly the majority of studied characters towards the desired direction and that of plant breeders and growers wishes (increase the agronomic characters and/or increase resistance to foliar diseases). Further researches are needed to clarify the mechanisms of potassium element (K^+) for improving the resistance to foliar diseases and grain yield and its related characters on faba bean.

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RESUME

El-Bramawy M.A.S.A. et Shaban W.I. 2010. Effets de la fertilisation au potassium sur les caractères agronomiques et la résistance aux taches brunes et à la rouille chez la fève. Tunisian Journal of Plant Protection 5: 131-150.

L'utilisation de la fertilisation au potassium (K^+) de la fève pour l'amélioration des caractères agronomiques et de la résistance aux maladies foliaires a été étudiée. Une expérience au champ a été conduite pendant deux campagnes consécutives (2007/08 et 2008/09) pour déterminer l'effet du potassium fertilisant sur les maladies foliaires (rouille et taches brunes) de la fève, cv. Giza 402 sensible aux deux maladies. Le rendement en grains et ses composantes ont aussi été étudiés. Les traitements au potassium fertilisant comprenaient l'application foliaire, l'application au sol et les applications au sol + sur feuilles. Les résultats ont montré que les traitements au sol + sur feuilles, par le potassium fertilisant, avec des quantités croissantes de K^+ jusqu'au niveau 3 (171,36 + 3,4 Kg K_2O/ha) augmentaient significativement les valeurs de la majorité des caractères et de la résistance de la plante vers la direction souhaitée. Ce résultat peut-être bénéfique aux cultivateurs de la fève qui cherchent à améliorer leur rendement en grains à travers les caractères agronomiques et à augmenter la résistance de la culture aux maladies foliaires.

Mots clés: Fève, potassium, rendement, résistance, rouille, taches brunes

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ملخص

البرماوى، محمد عبد الحميد سيد أحمد ووليد إبراهيم شعبان. تأثيرات التسميد بالبوتاسيوم في الصفات المحصولية ومقاومة أمراض التبقع الشوكولاتي/البني والصدأ عند الفول.
Tunisian Journal of Plant Protection 5: 131-150.

تمت دراسة استخدام التسميد البوتاسي في تحسين الصفات المحصولية والمقاومة للأمراض التي تصيب المجموع الورقي عند الفول. أجريت تجربة حقلية خلال موسمين متتاليين (2008/2007 و 2009/2008) لتحديد مدى تأثير السماد البوتاسي

في الأمراض التي تصيب المجموع الورقي (الصدأ والتبقع الشوكولاتي) على الفول (صنف جيزة 402 القابل للإصابة بالمرضين المذكورين). كما تم الاهتمام بالإنتاج الحبي للفول وبعض الصفات المرتبطة به. اشتملت معاملات البوتاسيوم في التجربة على ثلاث طرق تمثلت في تسميد أرضي وتسميد ورقي وتسميد ورقي وأرضي. أظهرت النتائج أن زيادة معدلات التسميد بالبوتاسيوم في صورتها المخلوطة الأرضية والورقية إلى المستوى الثالث (171.36 + 3.4 كغK_2O/هك) ترفع معنويا مستويات معظم الصفات المحصولية والمقاومة في الاتجاه المرغوب. يمكن أن تكون هذه النتائج مفيدة لمنتجي الفول العاملين على تحسين إنتاجهم الحبي من خلال الصفات المحصولية والزيادة في مقاومة هذه الزراعة للأمراض الورقية.

كلمات مفتاحيه: إنتاجية، بوتاسيوم، تبقع بني، صدأ، فول، مقاومة

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