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Influence of phosphorus fertilization levels on productivity of some broad bean cultivars

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Abstract

Field bean is the most needed legume crop in Egypt as a source of protein. In order to increase faba bean production, it was necessary to maximize its productivity by cultivation new cultivars in newly cultivated sandy soil as a way of horizontal expansion. Field experiments were carried out at private field in Toukh El-Aklam Village, El-Sinblawin Center, Dakahlia Governorate, Egypt, during the three un-sequent successive winter growing seasons of 2013/2014, 2014/2015 and 2017/2018 to study the effect of some broad bean cultivars, phosphorus fertilization levels and their interaction on growth, seed yield and its components. The experiment includes four broad bean cultivars i. e. Sakha 1, Giza 3, Giza 843 and Giza 716 and three of phosphorus fertilizer levels i.e. 0, 15, 30 and 45 kg P_2O_5/fed. The results showed that Giza 3 cultivar produced the tallest plants in combined analysis. Giza 716 recorded the highest number of seeds/pod, 100-seed weight and seed yield/fed in combined analysis over seasons. While, Giza 3 resulted in the longest pods of broad bean in combined analysis over seasons. Fertilizing broad bean plants with 45 kg P_2O_5/fed produced the highest values of growth character, seed yield and its components during combined analysis over seasons. It can be concluded that fertilizing broad bean Giza 716 cultivar with kg 45 or 30 P_2O_5/fed could be recommend achieving maximum growth, seed yield and its components under the environmental conditions of Dakahlia Governorate, Egypt.

Keywords: Field bean cultivars, Phosphorus fertilization levels, Growth, Seed yield and its components.

Introduction

Broad bean (*Vicia faba* L.) is one of the oldest crops grown by man and is an important economic crop grown mainly for their seed which is rich in protein (24-32 %, **Li–Juan *et al.*, 1993**). Thus, it is used as a source of protein in human diet particularly in developing countries. Broad bean is a common staple food in the Egyptian diet, eaten by rich and poor alike. Egyptians eat faba beans in various ways: they may be shelled and then dried, bought dried and then cooked. The total cultivated area in 2017 reached about 94403 feddan and the total production exceeded 98132 ton seeds with an average of 6.71 ardab/fed (**FAO, 2019**). It is well known that high productivity of any crop is the final goal of many factors and operations. In addition, the pronounced role of the agronomical processes such as using promising cultivars and phosphorus fertilizer levels has very important effect on growth, seed yield and its components of broad bean crop.

Many workers in Egypt and other countries showed that broad bean cultivars markedly differed in their growth, seed yield and its components. Broad bean genotypes were significantly different in all studied growth, yield and its components characters. Nubaria 1 and E.19 genotypes had the tallest plants, respectively. The highest seed yield per feddan was obtained from Nubaria 1 cultivar, while the medium seeded line L-43130 produced the lowest seed yield per feddan over both seasons. Giza 429 (medium seeded cultivar) followed by Nubaria 1 **(Abd El-Rahman, 2014)**. Sakha 1 cultivar significantly superior other studied cultivars (Sakha 2 and Giza 3 improved) and recorded the highest values of all studied growth, seed yield and its components. While, Sakha 2 cultivar recorded highest percentages of shedding in both seasons **(Abido and Seadh, 2014)**. **Gasim et al. (2015)** reported that inbred lines have considerable variability in yield and yield components. Broad bean cultivars varied highly significantly on plant height, number of pods/plant, 100-seed weight (g), seed yield/plant and seed yield (ardab/feddan). The highest value of plant height was obtained by Giza 843 variety compared with the other varieties. The highest value of number of pods/plant and seed yield was obtained by Giza 843 variety compared with the other varieties. While, the heaviest 100-seed weight (g) and seed yield/plant were achieved by Nubarai 1 variety (**Abou-El-Seba et al., 2016)**. Number of pods/plant, pod length, number of seeds/pod, number of seeds/plant, weight of seeds/plant, weight of 100 seeds, seed yield/plant and seed yield/feddan of Giza 3 and Sakha 4 cultivars had the highest values among the other tested cultivars i.e. Giza 2, Giza 843 and Sakha 1 **(El-Shafey et al., 2016)**. Giza-3 cultivar surpassed Sakha-2 in number of pods and weight of 100 seeds, but Sakha-2 exceed Giza-3 in seed yield and straw yield **(Khattab et al., 2016)**. Syrian cultivar showed more plant weight than Balady and Giza cultivars. Balady cultivar showed highest plant height than the other two cultivars **(Thalji, 2016)**. Broad bean varieties of Libyan landrace, Giza 843, Nubariah 3, Giza 716 and Sakha 1 significantly varied in 100-seed weight, number of pods/plant, number of seeds/plant and seed yield/ha **(Abd AlKader et al., 2017)**. Nubaria-2 achieved the superiority on number of pods/plant and height to first pod. While, Nubaria1 variety presented the first class in number of pods and seeds weight/plant, 100-seed yield, seed and straw yields (**Megawer et al., 2017)**. Field bean seed yield and thousand seed weight has been significantly affected by varieties **(Pluduma-Paunina et al., 2018)**. There was significant difference among the varieties for yield. Higher yield was recorded in Moti, Gora and Wolki varieties, while low yield was recorded from Hachalu and Degaga **(Zebire and Tadesse, 2018)**. Seed yield and its components i.e. number of pods/plant, weight of pods/plant, seed and straw yield/plant, seed and straw yield/feddan, and seed index were significantly differed due to studied broad bean cultivars of Nubaria 2, Sakha 1, Sakha 3, and Sakha 4 **(Abdel-Baky et al., 2019)**.

Phosphorus is one of the major nutrients required for plant growth and reproduction. Phosphorus, like carbon and nitrogen is an essential element in all living systems. It is often referred to phosphorus as the “energizer” since it helps store and transfer energy during photosynthesis. Phosphorus is required for the synthesis of nucleic acid molecules (DNA, RNA). Also, it is a vital component of the biological energy molecule adenosine tri-phosphate (ATP) as hydrophilic phosphate groups, phospholipids and essential components of cell membranes. Phosphorus is often found in fixed chemical forms that cannot immediately be absorbed by plants (**Zhang and Raun, 2006**). Fertilization of broad bean with 46 kg P_2O_5/ha resulted in substantial increase in seed and biological yields over no fertilizer check **(Kubure et al., 2015)**. A significant effect of phosphorus fertilization levels i. e. 0 and 25 kg ha^{-1} on pods number per plant, seeds number per pod, 100-seedweight, pod length and seed yield **Nikfarjam and Aminpanah, 2015)**. Number of pods/plant, biological and seed yield per plant and unit area of broad bean were increased by application of 40 kg phosphorus/ha. The highest 100-seed weight was obtained from 30 kg phosphorus/ha **(Adak and Kibritci, 2016)**. Phosphorus fertilization levels (0, 37 and 74 kg P_2O_5/ha) had significant effect on number of pods/plant, pod length, 100-seed weight and number of seeds per pods and plant **(Abd AlKader *et al.* (2017)**. Application of 26.16 kg P fed^{-1} produced higher seed index and seed yield than that obtained for the control treatment. Moreover, increasing P-fertilization level to 39.34 kg P fed^{-1} resulted in significant increase in straw yield than the levels of 26.16 kg P fed^{-1} **(El-Agrodi et al., 2017)**. **Fouda (2017)** showed that soil application of phosphorus fertilizer significantly increased the average values of yield and its components. The highest values recorded with using 75% from recommended dose P-fertilizers. Broad bean plants receiving 75 kg P_2O_5/ha was significantly superior with 5.33 t/ha seed yield which was 8.33% and 28.74% higher over 50 kg P_2O_5/ha and 25 kg P_2O_5/ha, respectively.

Yield attributing characters also followed the trend of seed yield **(Sarkar et al., 2017)**. The objectives of this study was to determine the effect of some broad bean cultivars, phosphorus fertilization levels and their interaction on growth, seed yield and its components under the environmental conditions of El-Sinblawin Center, Dakahlia Governorate, Egypt.

Materials and Methods

Field experiments were carried out at private field in Toukh El-Aklam Village, El-Sinblawin Center, Dakahlia Governorate, Egypt, during the three un-sequent successive winter growing seasons of 2013/2014, 2014/2015 and 2017/2018 to study the effect of some broad bean cultivars, phosphorus fertilization levels and their interaction on growth, seed yield and its components. The experiment was carried out in split-plot design with three replications. The main-plots were occupied with broad bean cultivars (Sakha 1, Giza 3, Giza 843 and Giza 716). The sub-plots were assigned to phosphorus fertilizer levels (0, 15, 30 and 45 kg P_2O_5/fed. Calcium superphosphate (15.5 % P_2O_5) was added at the aforementioned rates before the first irrigation (21 days from sowing). Each experimental basic unit (sub – plot) included five ridges, each of 60 cm width and 3.5 m long, resulted an area of 10.5 m^2 (1/400 fed). The preceding summer crop was rice (*Oryza sativa* L.) in the three seasons.

Soil samples were taken at random from the experimental field area at a depth of 0-30 cm from soil surface before seed bed preparation during the three growing seasons to measure the physical and chemical soil properties according to **Page (1982)** as shown in Table 1.

Table 1: Mechanical and chemical soil characteristics at the experimental sites during the three growing seasons.

Variables	First season 2013/2014	Second season 2014/2015	Third season 2017/2018
A: Mechanical analysis			
Coarse sand (%)	3.7	3.2	3.1
Fine sand (%)	16.2	14.7	14.5
Silt (%)	31.2	32.8	32.6
Clay (%)	48.9	49.3	49.8
Soil texture class	Clayey	Clayey	Clayey
B: Chemical analysis			
Soil reaction pH	8.05	8.10	7.99
EC (ds/m^2) in soil water extraction (1:5) at 25^0C	1.07	1.13	1.10
$CaCo_3$ (%)	2.76	3.09	2.15
Organic matter (%)	0.81	0.83	0.86
Available N (ppm)	49.70	48.30	51.90
Available P (ppm)	5.37	5.41	5.78
Exchangeable K (ppm)	355	363	359

Broad bean seeds were soaked in water for 24 hours before sowing to raise seed germination and directly sown 3-4 seeds in hills, 20 cm apart on one side of ridges on 25^{th} October in the first and second seasons and 1^{st} November in the third season. After full germination plant densities were adjusted by re-sowing the missing hills or thinning the over plants at 21 days from sowing leaving healthy two plants/hill. Hand hoeing was achieved every 21 days to control weeds (*i.e.* before time of irrigations).

All agricultural practices were implemented according to Ministry of Agriculture and Land Reclamation recommendations.

Studied characters:

1- Plant height (cm). It was measured for each plant of the samples from the soil surface to the top of the plants in the three studied seasons.

At harvest time, ten guarded plants were taken from each sub-plot to estimate

2- Pod length (cm) in 2013/2014 and 2014/2015 seasons.

3- Number of seeds per pod in the three studied seasons.
4- 100 – seed weight (g) in the third studied seasons.
5- Seed yield (ardab/fed). The whole plants in each sub-plot were harvested and left to dry on air, threshed and the seeds (13 % moisture) were weighted (kg).

All obtained data were statistically analyzed according to the technique of analysis of variance (ANOVA) for the split – plot design of season, then the combined analysis was performed between seasons as published by **Gomez and Gomez (1984)** by using means of "MSTAT-C" computer software package. Least significant difference (LSD) method was used to test the differences among treatment means at 5 % level of probability as described **Snedecor and Cochran (1980)**.

Results and Discussion

A- Cultivars performance:

The obtained results showed that the four studied cultivars *i.e.* Sakha 1, Giza 3, Giza 843 and Giza 716 were significantly differed in growth character (plant height), yield and its components (pod length, number of seeds/pod, 100-seed weight and seed yield/fed) during combined analysis over seasons as shown from data presented in Table 1.

Giza 3 cultivar produced the tallest plants in combined analysis. Whereas, Sakha 1 cultivar recorded shortest plants in combined analysis over seasons. Giza 716 recorded the highest number of seeds/pod, 100-seed weight and seed yield/fed in combined analysis over seasons. While, Giza 3 resulted in the longest pods of broad bean in combined analysis over seasons. Sowing Giza 843 cultivar produced the shortest pods and lowest number of seeds/pod, lowest values of 100-seed weight and seed yield/fed in combined analysis over seasons. The superiority of Giza 716 cultivar in seed yield over than Sakha 1, Giza 3 and Giza 843 cultivars might be related to genetic factors which resulted from genetic makeup relations for the varieties. More, the increases in number of seeds/pod and 100-seed weight over than Sakha 1, Giza 3 and Giza 843 cultivars. The obtained results of this study are partially agreement with those noticed and discussed by **Abou-El-Seba *et al.* (2016), El-Shafey *et al.* (2016), Khattab *et al.* (2016), Abd AlKader *et al.* (2017), Megawer *et al.* (2017), Zebire and Tadesse (2018) and Abdel-Baky *et al.* (2019)**.

B- Effect of phosphorus fertilization levels:

The obtained data revealed that phosphorus fertilization levels (0, 15, 30 and 45 kg P_2O_5/fed) significantly affected growth character (plant height), seed yield and its components (pod length, number of seeds/pod, 100-seed weight and seed yield/fed) during combined analysis over seasons as revealed from data presented in Table 1.

It can be stated that all studied characters significantly increased as a result of increasing phosphorus fertilizer levels from 0 to, 15, 30 and 45 kg P_2O_5/fed and the differences between them were obvious during combined analysis over seasons. Application the highest level of phosphorus fertilization (45 kg P_2O_5/fed) produced the highest values of growth character, seed yield and its components during combined analysis over seasons. It means that broad bean plants responded to increasing phosphorus fertilizer level was up to 45 kg P_2O_5/fed. Fertilizing broad bean plants with 30 kg P_2O_5/fed came in the second rank after fertilizing with 45 kg P_2O_5/fed with respect to these characters with lowest difference between them, followed by fertilizing with 15 kg P_2O_5/fed and lastly broad bean plants growing without phosphorus fertilization (control treatment) during combined analysis over seasons.

The increase in seed yield as a result to increasing phosphorus fertilization levels can be easily ascribed to the low soil content of available nitrogen, phosphorus and potassium (Table 1), whereas the phosphorus is considered as one of the major elements for plant nutrition. Where, plants need phosphorus for growth, utilization of sugar and starch, photosynthesis, nucleus formation and cell division. Phosphorus is particularly important to the broad bean seedling during the time it is recovering from transplanting shock. Phosphorus greatly stimulates root development in the young plant, thus increasing its ability to absorb other nutrients from the soil. Energy from photosynthesis and the metabolism of carbohydrates is stored in phosphate compounds such as ATP and ADP for later use in growth and reproduction, consequently, enhancement most growth measurements and yield components that mentioned and demonstrated formerly. These results are agree with those reported by many workers including **Nikfarjam and Aminpanah (2015), Adak and Kibritci (2016), El-Agrodi *et al.* (2017) and Sarkar *et al.* (2017)**.

Table 1: Means of plant height, pod length, number of seeds/pod, 100-seed weight and seed yield/fed as affected by cultivars, phosphorus fertilization levels and their interaction during combined analysis over seasons.

Characters / Treatments	**Plant height (cm)**	**Pod length (cm)**	**Number of seeds/pod**	**100-seed weight (g)**	**Seed yield (ardab/fed)**
Cultivars (C)					
Sakha 1	101.52	11.86	3.964	96.44	10.260
Giza 3	109.05	11.95	3.875	94.80	10.399
Giza 843	107.60	11.44	3.808	94.00	9.700
Giza 716	105.55	11.92	4.025	100.33	11.219
LSD at 5 %	2.56	0.42	0.093	4.20	0.465
Phosphorus fertilization levels (P)					
Without	99.16	10.78	3.694	89.22	9.185
15 kg P_2O_5/fed	104.40	11.62	3.853	94.75	10.183
30 kg P_2O_5/fed	109.54	12.19	4.028	99.44	10.855
45 kg P_2O_5/fed	110.63	12.58	4.097	102.16	11.355
LSD at 5 %	0.93	0.21	0.074	1.41	0.165
Interaction (F. test):					
C × P	NS	*	NS	*	*

C- Effect of interaction:

Regarding the effect of interaction, it could be noticed that pod length, 100-seed weight and seed yield/fed in combined analysis over seasons were significantly influenced by the interaction between broad bean cultivars and phosphorus fertilization levels.

From obtained data graphically illustrated in Fig. 1, it could be stated that the longest pod in combined analysis over seasons was obtained when fertilizing Sakha 1 cultivar with 45 kg P_2O_5/fed. On the contrary, the shortest pod of broad bean was resulted from plants of Sakha 1 cultivar growing without phosphorus fertilization in combined analysis over seasons.

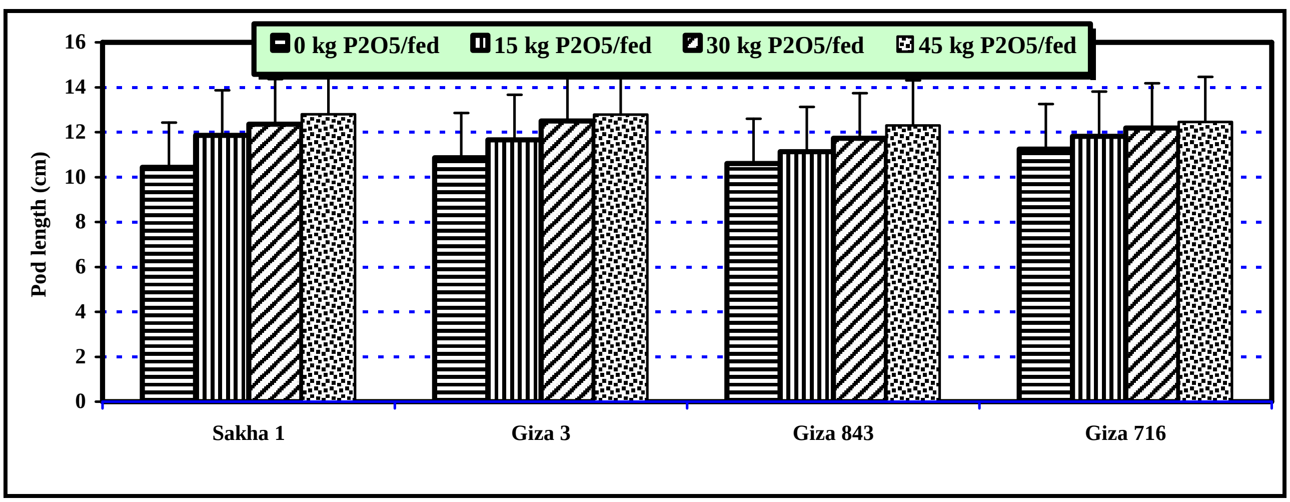

Fig. 1: Means of pod length (cm) as affected by the interaction between cultivars and phosphorus fertilization levels during combined seasons of 2013/2014 and 2014/2015.

The highest value of 100-seed weight was obtained when fertilizing Giza 716 with kg 45 P_2O_5/fed in combined analysis over seasons as graphically illustrated in Fig. 2. On the other hand, the lowest value of 100-seed weight was resulted from sowing Giza 3 cultivar without phosphorus fertilization in combined analysis over seasons.

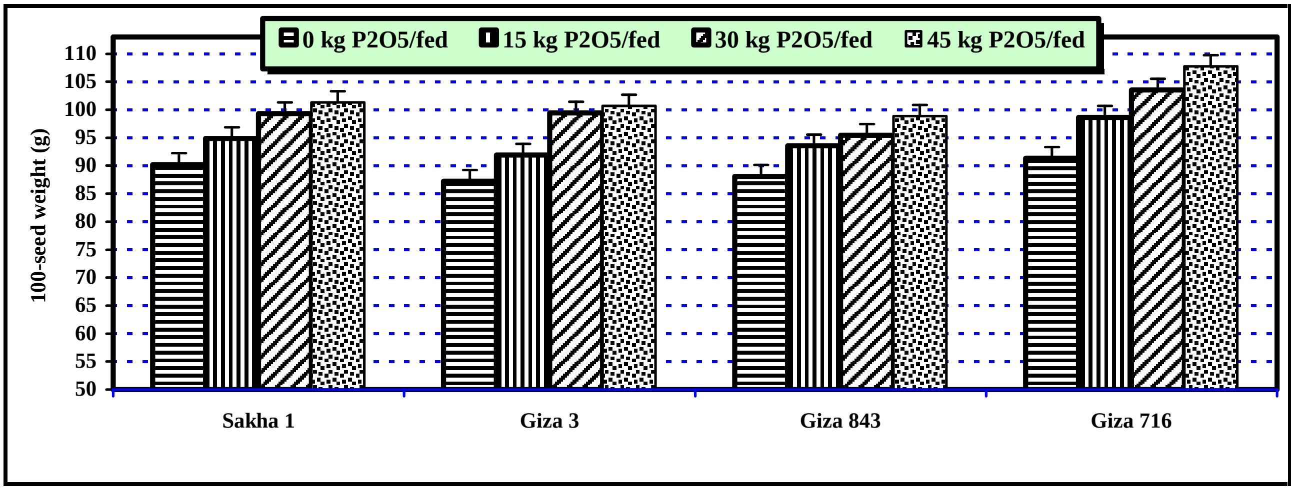

Fig. 2: Means of 100-seed weight (g) as affected by the interaction between cultivars and phosphorus fertilization levels during combined seasons of 2013/2014, 2014/2015 and 2017/2018.

From obtained data graphically illustrated in Fig. 3 which clear that, the highest values seed yield of broad bean were obtained when fertilizing Giza 716 cultivar with kg 45 P_2O_5/fed in combined analysis over seasons. Followed by fertilizing Giza 716 cultivar too with 30 kg P_2O_5/fed in combined analysis over seasons. On the other hand, the lowest values of seed yield of broad bean were resulted from sowing Giza 3 cultivar without phosphorus fertilization in combined analysis over seasons.

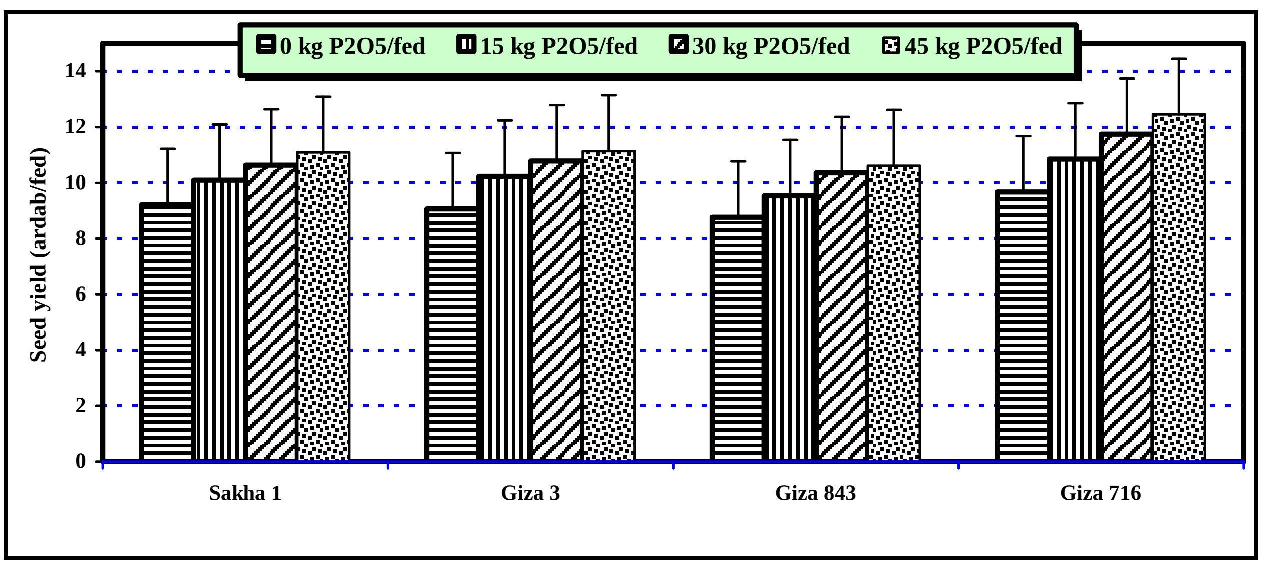

Fig. 3: Means of seed yield (ardab/fed) as affected by the interaction between cultivars and phosphorus fertilization levels during combined seasons of 2013/2014, 2014/2015 and 2017/2018.

Conclusion

According to the obtained results from this study, it can be concluded that fertilizing broad bean Giza 716 cultivar with kg 45 or 30 P2O5/fed could be recommend to achieve maximum growth, seed yield and its components under the environmental conditions of Dakahlia Governorate, Egypt.

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