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Assessment of Faba Bean Productivity Based on Sowing Dates, Seed Sizes and Seed Priming Treatments

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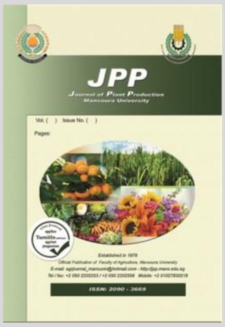

ABSTRACT

The present study aimed to investigate the variation rates between sowing dates, seed sizes and seed priming treatments as well as their interactions on seed vigor, field emergence, yield and it`s components of faba bean. In the laboratory experiment, treatments were arranged in a completely randomized design with three replicates for each experiment of germination temperature (15°C, 22°C and 30°C) included two factors, the first assigned as seed size categories (larger size ≥110g, medium size 70-75g and smaller size ≤45g). The second factor occupied with seed priming treatments (unprimed seed, 100 ppm GA_3 and 200 ppm GA_3). Results revealed that, temperature (22°C), larger size (≥110g) and GA_3 (200 ppm) recorded the highest significant rates of seed vigor indices, while the lowest values were obtained by 30°C, smaller size (≤45g) and the unprimed seed. Regarding field experiment, it was laid in a split plot design with three replicates for each sowing date (1st October, 1st November and 1st December), included seed sizes in the main plots and the seed priming treatments in the subplots, during 2016/2017 and 2017/2018 seasons. Results indicated that; the 1st November, larger size (≥110g) and GA_3 (200 ppm) presented the highest values of field emergence, plant height, No. pods and seed yield plant^{-1}, 100 seed weight and seed yield fed^{-1} during the two growing seasons. More, the triple interaction showed significant variance ($P \leq 0.05$) rates on plant height (2nd season), No. pods plant^{-1} (1st season), seed yield plant^{-1} (1st season) and 100 seed weight (1st season) and seed yield fed^{-1} (1st season).

Keywords: faba bean, seed size, germination temperature, sowing dates, seed vigor, field emergence and productivity.

INTRODUCTION

Faba bean (*Vicia faba* L.) is a cool-season, indeterminate grain legume grown in Mediterranean and temperate environments, where yield loss associated with abiotic and biotic stress is common (Lake *et al*., 2019).

Temperature is one of the major significant environmental factors, affecting seed germination and crops development. The limit temperatures for seed germination characteristics basically range between minimum and maximum, which depend on the species, lot, seed dormancy, etc. Khamassi *et al.* (2013) reported that, the optimum temperature for seed germination in faba bean is 20°C. In general manner, seed germination increases as temperature rises from a minimum to an optimum temperature then declines with increasing temperatures to the maximum and above the maximum temperature the seeds do not germinate (Machado Neto *et al*., 2006). Correlations of laboratory germination and field performance responses corresponding to different temperatures have been examined for many reasons *i.e.*, genotype selection for improved germination at low or high temperatures, modelling crop development in response to air or soil temperature regime and to recognize bean phylogeny and evolution (White and Montes, 1993).

Sowing date or timing of sowing is depending on germination variable conditions such as changes in environmental conditions as temperatures and humidity, it's one of the most important agricultural processes that strongly affect the yield and quality of crops (Satorre, 1999). World widely, earlier researchers found that early sowing date of faba bean have virtually major yield, early sowing in November resulted in a strongly increase yield of faba bean, which was more than double that produced when delayed sowing in January and sowing in January produced higher yield compared with late sowing in February (Ibrahim *et al*., 2009; El-Metwally *et al*., 2013 and Abido and Seadh, 2014).

For effective crop productivity, the use of favorable quality of seed is very fundamental which increase the yield by 15-20%. Seed size is one of the components of seed quality which affects the performance and establishment of crops (Ambika, *et al*., 2014). Seed size is a major physical indicator of seed quality which affected by variety, environment and management practices. Based on size, the seeds are classified to categories, very large, large, medium, small and very small (Crépon *et al*., 2010; Ambika *et al*., 2014 and Pietrzak *et al*., 2016). A wide range of different effects of seed size has been detected on seed germination and vigor, seedling growth, field emergence, seed yield characteristics, performance of crop and related agronomic aspects in many crop species depending on genetic variation between varieties, environmental conditions and cultivation practice (Adebisi *et al*., 2013). Based on faba bean seed size, the larger seed size produced the highest values of length, fresh and dry weight of roots and seedlings and the highest No. of leaves/plant (Ali and Idris, 2015), which led to accelerating the entry of plants to flowering stage, output

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major number of branches, greater leaf area index, higher dry matter yield, increase number of pods, seeds per pod, increase seed weight and higher seed yield of peanut and greater fresh matter and seed yields of faba bean (Rifaee *et al*., 2004).

Gibberellic Acid (GA_3) hormone which is widely used as plant growth promotion. Seed priming in GA_3 hardly change seed quality, one of its important functions is synthesis α-amylase enzyme in the aleurone layer which surrounding the endosperm of cereal grains during seed germination through accelerate starch degradation in the cotyledons and subsequently makes available monosaccharides which provide energy source to growing embryo (Siddiqui *et al*., 2008 and Tsegay and Andargie, 2018). GA_3 is also able to induce a wide range of other genes, which are needful for the production of enzymes such as amylases, proteases and lipases, that have essential role in the early growth and development of embryos. such excess in the activity of these enzymes may led to early vigorous germination and good crop establishment (Nawaz *et al*., 2013).

Therefore, the present study aimed to assessment the variation rates of seed vigor indices, field emergence and subsequently the productivity of faba bean, based on germination temperatures/sowing dates, categories of faba bean seed sizes and seed priming treatments with GA_3 as well as their interactions.

MATERIALS AND METHODS

Raw samples

Seed samples of faba bean (*Sakha* 1 cultivar) were received from Food Legumes Research Department, Field Crops Research Institute, Agricultural Research Center, Giza, Egypt. Seeds were obtained from the harvested season of 2015/2016. The average weight of 100 seeds was 80-85g, with an initial seed moisture content of 11.2%.

Half kg of seed samples was weighed for each treatment, then packed in muslin cloth bags for applying laboratory and field experiments.

Study sites

Laboratory experiment was conducted at Seed Technology Research Unit, Mansoura, Dakhalia Governorate, Field Crops Research Institute, Agricultural Research Center, while the field experiment was carried out at the farm of Sakha Research Station, Kafr El-Sheikh Governorate, Agricultural Research Center, Egypt, during the two growing winter seasons of 2016/2017 and 2017/2018.

Laboratory experiment

Experimental design and treatments

Three experiments of germination based on growth room temperature were conducted in order to converge the sowing dates target in the field experiment, thus the seeds were submitted to three constant temperatures beneath incubator condition *i.e.*, 15° C, 22° C, and 30° C. Each germination temperature was conducted in a separate experiment, every experiment was laid in factorial experiment in a Completely Randomized Design (CRD), which included two factors with three levels of each and replicated three times with combinations of 27 treatments (3 seed sizes × 3 seed priming × 3 replicates). The first factor mobilized with seed sizes categories, which were graded by riddles, the smaller seed size was obtained by using riddle with holes more than 6 ml and less than 8 ml, the medium seed size was obtained by using riddle with holes more than 8 ml and less than 10 ml, while the larger seed size was obtained by using riddle with holes more than 10 ml, then the seeds were classified to three grades size based on mean weights in g/100-seed *i.e.*, large size (≥110 g), medium size (70-75 g) and small size (≤45 g). The second factor included seed priming treatment with plant promoter hormone GA_3 at the rate of 100 and 200 ppm, in additions to the unprimed seed as a control treatment.

Seed priming techniques

Seeds were surface-sterilized with 0.1% mercuric chloride solution for one minute and then rinsed twice with autoclaved distilled water. The ratio of seed weight to solution volume was 1:5 (g ml^{-1}). Hormone solutions of 100 and 200 ppm of GA_3 were prepared separately. 200 gram of seeds were soaked in 1000 mL of respective hormonal solution for 12 hours and dried back to original weight at the room temperature under shade (Basra *et al*., 2006).

Germination procedure

Three replications of 100 seeds from each treatment were sown and uniformly distributed in Petri dishes between two layers of germination paper. Then, Petri dishes placed in the incubator at 15° C, 22° C, and 30° C.

The substrate was kept humid with distilled water. Germination frequencies were enumerated at sequent time intervals during the incubation period of 14 days. Each seedling with the radical length equal or greater than 2 mm were classified as germinated seeds.

Studied traits

Germination percentage (G%): was measured at the end of test period according to international seed testing association (ISTA, 1999);

$$G\ \% = \frac{\text{Total number of germinated seeds}}{\text{Total number of evaluated seeds}} \times 100$$

The days required for 50% germination (T50%): defined as the time required for each replicate to reach 50% of germination. It was calculated to the following formula of Coolbear *et al*. (1984) and modified by Farooq *et al*. (2005) as under;

$$T50\% = t_i + \frac{(\frac{N}{2} - n_i)(t_j - t_i)}{n_j - n_i} \times 100$$

Where N is the final number of germinated seeds; ni and nj are the cumulative number of seed germination by adjacent counts at times ti and tj when ni<N/2<nj.

Mean germination time (MGT): was calculated by using the following equation;

$$MGT = \frac{\Sigma(D \times n)}{\Sigma n}$$

Where n is the number of seeds which were germinated on day time, D is the number of days counted from the beginning of germination test (Ellis and Roberts, 1981).

Seedling growth p arameters: were measured as follow; 10 normal seedlings were selected randomly from each replication to estimate seedling parameters. The seedling length was the total length of radicle and plumule and it was measured in centimeters (AOSA, 1983). Then, the ten normal seedlings were oven-dried at 70˚C for 72 hours to determine dry weight until constant weight was reached and it was measured in milligrams (Agrawal, 1986). Seedling vigor index (SVI-I and SVI-II) were calculated according to Abdul-Baki and Anderson (1970) and Abdul-Baki and Anderson (1973) respectively, by using the following formula;

$$\text{SVI-I} = \text{Seedling length (cm)} \times \text{Germination percentage}$$

$$\text{SVI-II} = \text{Seedling dry weight (g)} \times \text{Germination percentage}$$

Field experiment

Experimental design and treatments

Each of sowing dates *i.e.,* 1st October, 1st November and 1st December was performed in a separate experiment, every experiment of sowing date was carried out in Split Plot Design (SPD) and replicated three times. The main plot factor was assigned to seed size categories *i.e.,* large size (≥110g), medium size (70-75g) and small size (≤45g) and the subplot factor was mobilized within the following seed priming treatments (GA_3 at the rate of 100 and 200 ppm in addition to unprimed seeds as control treatment).

Field procedure

Each experimental unit included five ridges, each of 3.5 m long and 60 cm width, resulted in 10.5 m^2 (1/400 fed, 1 fed = 4200 m^2), the pervious summer crop was maize (*Zea mays* L.). Seeds were sown on both sides of ridges at 25 cm between hills which expressed 112000 plants/fed. Experimental units were fertilized with 100 kg/fed of calcium superphosphate (15.5% P_2O_5) and were added to soil during tillage operation. Potassium sulphate (48% K_2O) at the rate of 48 kg/fed was added to soil in two equal portions, before the first and second irrigations, nitrogen in the form of ammonium sulphate (20% N) at the rate of 15 kg/fed was added before the first irrigation. Thinning was performed at 21 days after sowing leaving healthy two plants/hill. However, the other agricultural practices for growing field bean were performed as commonly followed in the district.

Studied traits

Field emergence percentage (FE%): was expressed by the percentage of seed having the ability of producing normal seedlings, which showed apparent plumule over the soil surface and remained constant after 14 days from sowing, as follow;

$$FE\% = \frac{\text{Emerged Seedling after 14 DAS}}{\text{Total number of planted seeds}} \times 100$$

Yield and it`s components: were measured at the harvest time, ten guarded plants of each plot were taken randomly to determining the; Plant height (cm), No. of pods $plant^{-1}$, seed yield $plant^{-1}$ (g), 100-seed weight (g). Seed yield (ardab fed^{-1}) was determined from the plants in each plot at harvested time and left for air drying until moisture content of seeds reached 12%, then weighted (kg) and converted to ardab fed^{-1} (one ardab = 155 kg).

Statistical analysis

All the data were statistically analyzed according to the analysis of variance (ANOVA) under significant level of 0.05. Factorial experiment in a completely randomized design over each experiment of germination temperature was taken place in the laboratory experiment. While, split plot design was conducted over each experiment of sowing date in the field experiment. Then, combined analysis was achieved among germination temperatures in the laboratory experiments and among sowing dates in the field experiments, as outlined by Gomes and Gomes (1984) using the statistical analysis system program (SAS ver. 8.1, 2008). To achieve the significance among means of different treatments, LSD test at 0.05 level of probability was applied as described by Snedecor and Cochran (1980).

RESULTS AND DISCUSSIONS

Isolated data presented in Table 1 showed significant differences (P≤0.05) among the three tested germination temperatures of faba bean for seed vigor indices; germination percentage (%), time to 50% of germination ($T_{50\%}$), mean germination time (MGT_{day}), seedling length (SL_{cm}), seedling dry weight (SDW_g) and seedling vigor index (SVI-I and SVI-II). Concerning the germination temperatures effects, it could be observed that the germination temperature of 22°C was the optimum temperature for seed germination and recorded the greatest response of seed vigor indices compared to the other temperatures of 15°C and 30°C treatments. More, the highest temperature of 30°C recorded the lowest values of all seed vigor indices. Respecting the relationship between temperature and germination indices of faba bean under 15 different temperature regimes (5-33°C), the optimum temperature for germination power and period, field emergence speed, power and period was 18.2°C (Balkaya, 2004). Moreover, the germination indices of faba bean seed recorded a great variation related to temperature regimes. The minimum, optimum and maximum germination temperature were 3°C, 20-25°C and 30-35°C, respectively (Sepetoglu, 1994 and Khamassi *et al*., 2013).

The analysis of variance for seed vigor indices exposed statistically significant differences (P≤0.05) between seed sizes treatments, as shown in Table (1). The larger (≥110g) and medium (70-75g) seed sizes markedly recorded the superior values upon the smaller size (≤45g) with regard to all seed vigor indices (G%, $T_{50\%}$, MGT_{day}, SL_{cm}, SDW_g, SVI-I and SVI-II). The larger seed size (≥110g) substantially recorded the highest significant increase of all seed vigor indices followed by the other grading seed of medium (70-75g) and smaller size (≤45g), while shares the same value of MGT_{day} with medium seed size. More, there were no significant differences among the larger size and medium size with respect to G% and MGT_{day}. These results are in agreement with those obtained by Houssard and Escarre (1991), they reported that, grading of seed based upon their size and weights is a common practice in a majority of many crops as it has been found to organize the germination, seedling growth and mature plants. The relative performance of individual plants during germination and seedling establishment based on their seed size, can have important effects on subsequent adult growth and efficiency. More, larger seeds compared to other medium and small sizes tend to produce more seedlings vigor index and high seeding survival growth (Jerlin and Vadivelu, 2004; Ali and Idris, 2015). As generally, decreasing seed size reduced germination speed and seedling establishment which influence the time required for seedlings to reach the autotrophic phase. Irregular levels of starch and other food storage related to different seed size hardly influences the expression of number of germinated seeds in faba bean (Girish *et al*., 2001). Large seeds have more food storage for embryo growth and development which lead to vigorous growth of the seedling before weeds can emerge and create competition (Ambika *et al*., 2014). Excessive and rapid germination and the high-rise in seed vigor in the bigger seed size more than in medium and small seed size could be due to the presence of higher amount of the larger food reserves in these seeds, their ability to store greater amounts of carbohydrate and other nutrients in endosperm or cotyledons than small seeds and greater supply of stored energy to support early seedling growth and subsequently affected mature plant development (Milberg and Lamont, 1997 and Gunaga *et al*., 2011).

As respect to seed priming treatments, the highest response of seed vigor indices was resulted from primed seed with GA_3 of 200 ppm followed by GA_3 of 100 ppm, as compared to the unprimed seeds. The highest increase due to seed priming with GA_3 at the rate of 100 and 200 ppm treatments over unprimed seeds were 3.1 and 5.4% for G%, 10.8 and 15.4% for SL_{cm}, 6.7 and 13.3% for SDW_g, 13.2 and 21.2% for SVI-I, 10.6 and 19.2% for SVI-II, while decrease $T_{50\%}$ by 6.5 and 13% and MGT_{day} by 5.6 and 9.3%, respectively (Table 1). Earlier researches reported that, treated faba bean seeds with 300 ppm of GA_3 priming solution significantly achieved the maximum germination percentage and recorded 100% after 5 days compared with the control which recorded 80% and significantly increased seedling dry weight (Cetinbas and Koyuncu, 2006; Abdeen and Mancy, 2014). Gibberellins play a major role in all growth processes such as seed germination and seed germination rate (Rathod *et al*., 2015). Seed germination could be enhanced due to the activation of specific genes for α-amylase mRNA transcription by absorbing GA_3. The hormone is also able to prompt a range of other genes, which are necessary for the production of enzymes such as amylases, proteases and lipases, that have vital roles in the development of embryo, vigorous germination, early growth and good crop establishment (Nawaz *et al*., 2013; Tsegay and Andargie, 2018). These finding are homogenized to those presented by other researchers on broad bean (Raeisi *et al*., 2013).

Table 1. Means of germination percentage (G%), time to 50% germination ($T_{50\%}$), mean germination time (MGT_{day}), seedling length (SL_{cm}), seedling dry weight (SDW_g), seedling vigor index (SVI-I and II) as affected by germination temperatures, seed sizes and seed priming treatments and their interactions on faba bean seeds.

Treatments / Traits	G%	$T_{50\%}$	MGT_{day}	SL (cm)	SDW (g)	SVI-I	SVI-II
Main factors							
Germination temperatures							
30°C	79.8	5.0	5.8	6.2	0.30	502.8	24.3
22°C	84.4	3.5	4.5	7.8	0.35	664.6	29.6
15°C	81.9	4.3	5.2	7.2	0.32	594.7	26.9
F test	*	*	*	*	*	*	*
LSD 0.05	0.25	0.06	0.14	0.16	0.01	15.9	0.59
Seed sizes							
Larger size (≥110g)	82.7	4.1	5.0	7.9	0.37	662.2	30.7
Medium size (70-75 g)	82.5	4.3	5.0	7.1	0.34	593.7	28.4
Small size (≤45g)	80.9	4.5	5.4	6.2	0.26	506.2	21.7
F test	*	*	*	*	*	*	*
LSD 0.05	0.47	0.02	0.08	0.10	0.01	8.84	0.57
Seed priming treatments							
Unprimed seed (Control)	79.8	4.6	5.4	6.5	0.30	527.0	24.5
GA_3 (100 ppm)	82.3	4.3	5.1	7.2	0.32	596.4	27.1
GA_3 (200 ppm)	84.1	4.0	4.9	7.5	0.34	638.7	29.2
F test	*	*	*	*	*	*	*
LSD 0.05	0.55	0.06	0.07	0.07	0.01	6.93	0.59
Interactions							
GT × SS	Ns	*	*	*	*	*	*
GT × SP	Ns	*	*	*	Ns	*	Ns
SS × SP	Ns	*	Ns	*	Ns	*	Ns
GT × SS × SP	*	*	Ns	*	Ns	*	Ns

- GT: Germination temperatures; SS: Seed sizes; SP: Seed priming.
***Significant at 0.05 level of probability and Ns: Non-significant at 0.05 level of probability.**

Data presented in Table 2 showed that, the sowing dates of 1st October, 1st November and 1st December showed significant (P≤0.05) differences on the parameters of field emergence (FE%), plant height (cm), No. pods $plant^{-1}$, seed yield $plant^{-1}$ (g), 100 seed weight (g) and seed yield (ardab fed^{-1}). The sowing date of faba bean on 1st Nov significantly increased plant height, No. pods $plant^{-1}$, seed yield $plant^{-1}$ (g), 100 seed weight (g) and seed yield (ardab fed^{-1}) while compared with the sowing dates in 1st Dec and 1st Oct, respectively, during the 1st and 2nd growing seasons (Table 2). Attia *et al.* (2009), Badran and Ahmed (2010), El-Degwy *et al.* (2010), El-Metwally *et al.* (2013) and Abido and Seadh (2014) reported that, the enhancement in faba bean plant height, seed yield and its characteristics, induced by planting in the first of November, might be related with the favorable environmental conditions during this period such as temperature, light intensity, day length and photoperiod, which allowed plants to produce more photosynthesis products and finally causes increase of vegetative growth, development and ripening, consequently increasing dry matter accumulation, yield and its characteristics. Moreover, the delayed of sowing date of field bean over mid-November resulted in gradual reduction in plant growth and seed yield (Mohamed, 2003 and Grenz *et al*., 2005).

Data insulated in Table 2 demonstrated that, the larger seed size (≥110g) slightly increased field emergence percentage, plant height (cm), No. pods plant^{-1}, seed yield plant^{-1} (g), 100 seed weight (g) and Seed yield (ardab fed^{-1}) parameters upon the other seed sizes categories, while the medium size (70-75g) showed significantly increment compared to the smaller seed size (≤45g), during the 1st and 2nd seasons. Earlier researches pointed that, the larger seeds compared to other medium and small sizes tend to produce more highly seedling growth and establishment and higher seed yield (Jerlin and Vadivelu, 2004). Plants grown from small seed had less fertile than those grown from large seed and hardly affected field emergence and establishment, which finally causes decrease in grain and biological yield (Rifaee *et al*., 2004).

Data presented in Table 2 indicated that, seed priming treatments of GA_3 at the rate of 100 and 200 ppm significantly surpass the unprimed seeds related to field emergence percentage, plant height (cm) and subsequently yield and it`s components. More, calculated increases as a percentage due to applying seed priming treatment of GA_3 at the rate of 100 and 200 ppm over control were 3.1% and 5.8% for field emergence percentage, 2.2% and 4% for plant height (cm), 8.3% and 15% for No. pods plant^{-1}, 6% and 9.6% for seed yield plant^{-1}, 1.9% and 2.9% for 100-seed weight (g) and 2.4% and 3.7% for seed yield ardab fed^{-1}, respectively in the 1st growing season. While were, 4.6% and 7.7% for field emergence percentage, 2.1% and 4.8% for plant height (cm), 12.1% and 22% for No. pods plant^{-1}, 6.2% and 11.3% for seed yield plant^{-1}, 2.3% and 4.0% for 100-seed weight (g) and 2.4% and 4.8% for seed yield ardab fed^{-1} of GA_3 at the rate of 100 and 200 ppm over control, respectively in the 2nd growing season. Finally, treatment of GA_3 (200 ppm) was the superior treatment over all seed priming treatments with respect of all field experiment parameters. As pointed before, gibberellins (GA_3) have some great function roles in respect of promote cell extension and cell division, increased the synthesis of carbohydrates which ultimately promoted greater growth and yield (Brown *et al*., 1993).

More, the stimulatory effect of GA_3 on field bean growth and yield characteristics may be due to its functions to promote the catabolism of ABA which minimize shedding as well as alter the source-sink metabolism through their effect on photosynthesis and sink formation, which stimulated plant growth, more dry matter accumulation, increase the building of metabolic products, hence increasing seeds yield per plant and unit area (Kandil *et al*., 2011 and Ghalandari *et al*., 2011), stimulating stem and root growth, control of flowering time and even organ elongation and enhanced plant growth productivity such as plant height, number of branches, number of leaves, leaf area, fresh and dry weights (Rathod *et al*., 2015).

Table 2. Means of field emergence (FE%), plant height (cm), No. pods plant^{-1}, seed yield plant^{-1} (g), 100 seed weight (g) and seed yield (ardab fed^{-1}) as affected by sowing dates, seed sizes and seed priming treatments and their interactions on faba bean plant during the two growing seasons 2016/2017 and 2017/2018.

Treat. / Traits	FE (%)		Plant height (cm)		No. pods plant^{-1}		Seed yield plant^{-1} (g)		100 seed weight (g)		Seed yield (ardab fed^{-1})	
	2016 / 2017	2017 / 2018	2016 / 2017	2017 / 2018	2016 / 2017	2017 / 2018	2016 / 2017	2017 / 2018	2016 / 2017	2017 / 2018	201 6/ 2017	2017 / 2018
Sowing dates												
1st October	78.7	78.0	84.9	84.1	13.7	13.3	24.6	25.6	71.9	72.4	7.85	8.06
1st November	82.3	82.1	93.9	93.7	15.3	16.1	28.9	29.3	75.3	75.7	8.92	8.95
1st December	80.4	79.1	86.7	86.1	14.1	14.7	25.4	26.7	72.8	73.1	8.29	8.32
F test	*	*	*	*	*	*	*	*	*	*	*	*
LSD 0.05	0.70	0.58	0.97	0.74	0.37	0.43	0.69	0.38	0.50	0.37	0.16	0.14
Seed sizes												
Larger (≥110g)	81.2	81.1	91.2	91.2	15.3	16.6	28.3	30.0	74.6	76.4	8.60	8.71
Medium (70-75g)	80.9	81.0	89.6	89.9	14.5	14.3	26.4	27.6	73.8	73.4	8.37	8.49
Small (≤45g)	79.3	77.1	84.6	82.8	13.2	13.2	24.1	24.0	71.6	71.4	8.10	8.12
F test	*	*	*	*	*	*	*	*	*	*	*	*
LSD 0.05	0.49	0.79	0.62	0.77	0.37	0.45	0.47	0.45	0.45	0.34	0.10	0.09
Seed priming treatments												
Unprimed seed	78.2	76.6	86.7	86.0	13.3	13.2	25.0	25.7	72.2	72.2	8.10	8.21
GA_3 (100 ppm)	80.6	80.1	88.6	87.8	14.4	14.8	26.5	27.3	73.6	73.9	8.43	8.47
GA_3 (200 ppm)	82.7	82.5	90.2	90.1	15.3	16.1	27.4	28.6	74.3	75.1	8.53	8.64
F test	*	*	*	*	*	*	*	*	*	*	*	*
LSD 0.05	0.47	0.51	0.62	0.74	0.26	0.37	0.38	0.44	0.40	0.42	0.12	0.10
Interactions												
SD × SS	*	*	*	*	*	*	*	*	*	*	*	*
SD × SP	*	Ns	*	Ns	*	Ns	*	*	Ns	Ns	*	Ns
SS × SP	Ns	*	Ns	Ns	*	*	Ns	Ns	Ns	Ns	Ns	Ns
SD × SS × SP	Ns	Ns	Ns	*	*	Ns	*	Ns	*	Ns	*	Ns

- SD: Sowing dates; SS: Seed sizes and SP: Seed priming.

*** Significant at 0.05 level of probability and Ns: Non-significant at 0.05 level of probability.**

Interaction effects

Regarding the interaction effects, there were many significant effects between studies factors on all studied germination and seedling characters as shown in Table 1. All studied seed vigor traits expect the germination percentage significantly (P≤0.05) affected by the he interaction between germination temperatures as well as seed sizes, while the interaction between germination temperatures and seed priming recorded significant effects on $T_{50\%}$, MGT_{day}, Sl_{cm} and SVI-I. Moreover, there was a significant interaction effect between seed sizes and seed priming concerning $T_{50\%}$, Sl_{cm} and SVI-I. According to the triple interactions effects among studied factors, data graphically illustrated in Figures from (1-4) showed the highest significant values of G% (Fig. 1), $T_{50\%}$ (Fig. 2), Sl_{cm} (Fig. 3) and SVI-I (Fig. 4), which were obtained from the germination temperature of 22° C for sowing the larger seed size (≥110g) with applying seed priming of GA_3 at the rate of 200 ppm (22° C. × ≥110g × GA_3 200 ppm). On the other hand, the lowest values of these traits were obtained by the germination temperature of 30° C for sowing the smaller seed size (≤45g) without applying seed priming (30° C. × ≤45g × unprimed seed).

Regarding to the binary interactions effects on the field experiment traits, there was a significant (P≤0.05) interaction effects among sowing dates and seed sizes for all studied traits in both of 1st and 2nd seasons. While the interaction between sowing dates and seed priming indicated significant effects for FE%, plant height (cm), No. pods plant^{-1} and seed yield ardab fed^{-1} in the 1st season, seed yield plant^{-1} g in the 1st and 2nd seasons (Table 2). With respect to the interaction between seed sizes and seed priming, isolated data showed significant (P≤0.05) effects on FE% (2nd season) and No. pods plant^{-1} (1st and 2nd seasons) as shown in Table 2.

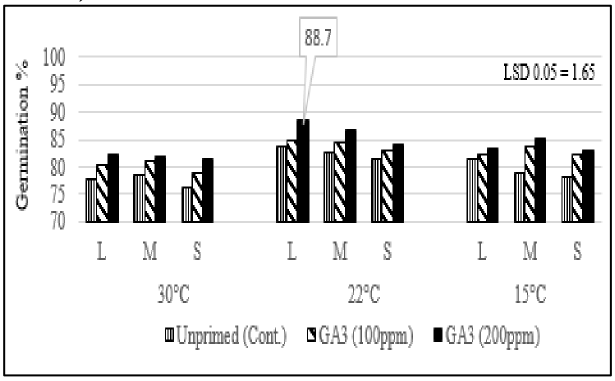

Fig. 1. Means of germination (%) as affected by the interaction among germination temperatures (30 °C, 22 °C and 15 °C), seed sizes (L, M and S) and seed priming (Cont., GA_3 100 and GA_3 200 ppm) treatments on faba bean seeds.

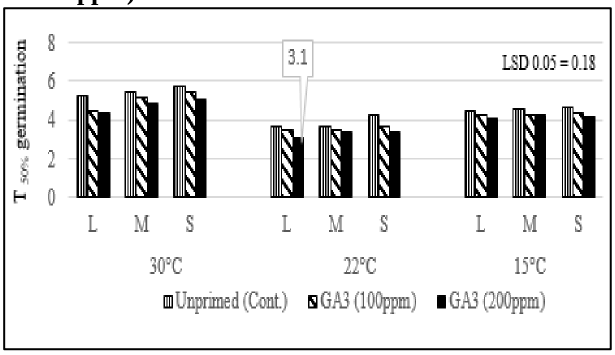

Fig. 2. Means of time to 50% germination ($T_{50\%}$) as affected by the interaction among germination temperatures (30 °C, 22 °C and 15 °C), seed sizes (L, M and S) and seed priming (Cont., GA_3 100 and GA_3 200 ppm) treatments on faba bean seeds.

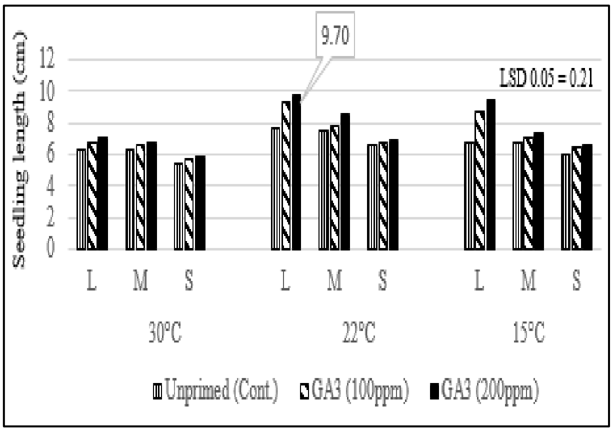

Fig. 3. Means of seedling length (cm) as affected by the interaction among germination temperatures (30 °C, 22 °C and 15 °C), seed sizes (L, M and S) and seed priming (Cont., GA_3 100 and GA_3 200 ppm) treatments on faba bean seeds.

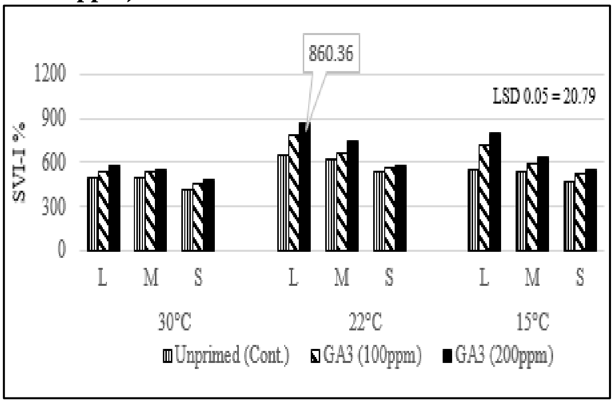

Fig. 4. Means of seedling vigor index (SVI-I) as affected by the interaction among germination temperatures (30 °C, 22 °C and 15 °C), seed sizes (L, M and S) and seed priming (Cont., GA_3 100 and GA_3 200 ppm) treatments on faba bean seeds.

Respecting the triple interaction effects among sowing dates, seed sizes and seed priming treatments on yield and it`s components, as shown Figures from (5-9).

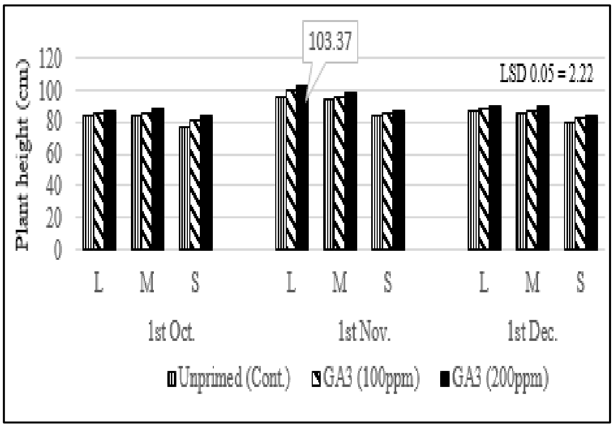

Fig. 5. Means of plant height (cm) as affected by the interaction among sowing dates (1st Oct, 1st Nov and 1st Dec), seed sizes (L, M and S) and seed priming (Cont., GA_3 100 and GA_3 200 ppm) treatments on faba bean plant during the 2nd growing season.

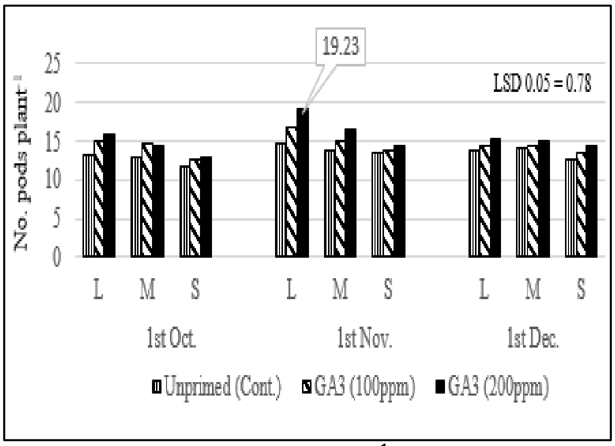

Fig. 6. Means of No. pods plant^{-1} as affected by the interaction among sowing dates (1st Oct, 1st Nov and 1st Dec), seed sizes (L, M and S) and seed priming (Cont., GA_3 100 and GA_3 200 ppm) treatments on faba bean plant during the 1st growing season.

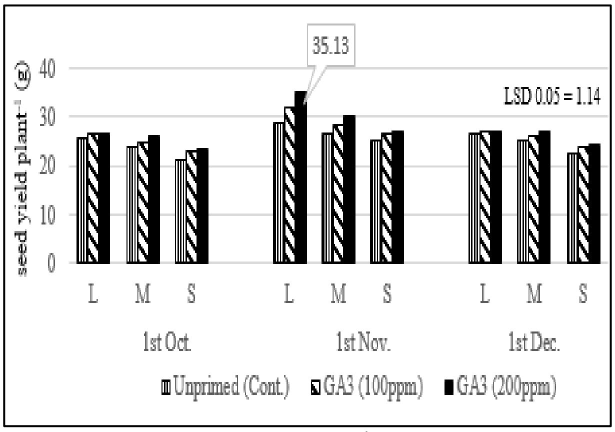

Fig. 7. Means of seed yield plant^{-1} (g) as affected by the interaction among sowing dates (1st Oct, 1st Nov and 1st Dec), seed sizes (L, M and S) and seed priming (Cont., GA_3 100 and GA_3 200 ppm) treatments on faba bean plant during the 1st growing season.

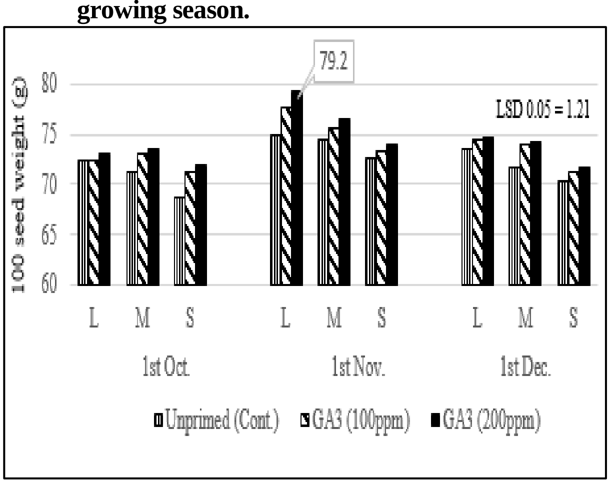

Fig. 8. Means of 100-seed weight (g) as affected by the interaction among sowing dates (1st Oct, 1st Nov and 1st Dec), seed sizes (L, M and S) and seed priming (Cont., GA_3 100 and GA_3 200 ppm) treatments on faba bean plant during the 1st growing season.

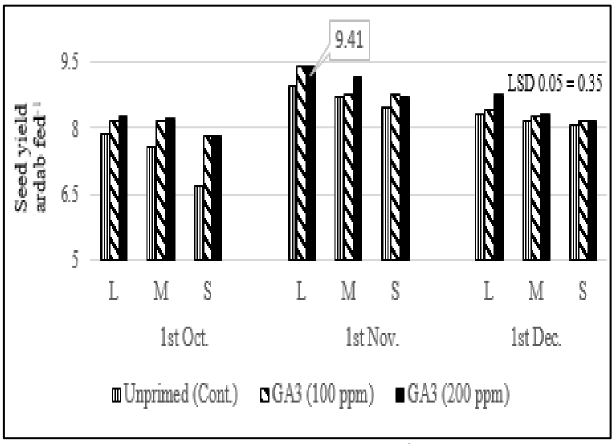

Fig. 9. Means of seed yield ardab fed^{-1} as affected by the interaction among sowing dates (1st Oct, 1st Nov and 1st Dec), seed sizes (L, M and S) and seed priming (Cont., GA_3 100 and GA_3 200 ppm) treatments on faba bean plant during the 1st growing season.

Data graphically presented that, the highest significant values of plant height $_{cm}$ (Fig. 5) in the 2nd season, No. pods plant^{-1} (Fig. 6) in the 1st season, seed yield plant^{-1}g (Fig. 7) in the 1st season, 100-seed weight, g (Fig. 8) in the 1st season and seed yield ardab fed^{-1} in the 1st season (Fig. 9), were obtained by the date of 1st Nov. for sowing the larger seed size category (≥110g) with applying seed priming treatment of GA_3 at the rate of 200 ppm (1st Nov. × ≥110g × GA_3 200 ppm), while compared with the lowest values of those characters induced by the date of 1st Oct. for sowing the smaller seed size category (≤45g) without applying seed priming treatment (1st Oct. × ≤45g × unprimed seed).

CONCLUSION

Generally, on account of our experimental observations it could be concluded that, selecting the date of 1st November for sowing the larger category of faba bean seed size (≥110g) with applying seed priming with a growth hormone GA_3 at the rate of 200 ppm were significantly enhanced seed vigor, yield and its components of faba bean plant in contrast to the other treatments and were preferably recommended because of its superior favorable response to such conditions.

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تقدير إنتاجية الفول البلدي اعتماداً على مواعيد الزراعة، أحجام البذور ومعاملات تهيئة البذور

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تهدف هذه الدراسة لتقييم معدلات وقيم الاختلاف بين ثلاثة عوامل شملت مواعيد الزراعة، احجام البذور وتهيئة البذور بحمض الجبريلين وأيضا تأثير التفاعل بينهما على صفات جودة البذور، الانبثاق الحقلي، المحصول ومكوناته للفول البلدي صنف سخا 1. في التجربة المعملية، تم ترتيب المعاملات في تصميم تام العشوائية ذو ثلاث مكررات لكل تجربة من تجارب الإنبات المعملي على أساس درجة حرارة غرفة الإنبات حيث كانت، إنبات في درجة حرارة 15 درجة مئوية، 22 درجة مئوية و30 درجة مئوية. احتوت كل تجربة على عاملين، العامل الأول احتوي على ثلاث درجات لأحجام البذور بناءً على وزن 100 بذرة (بذور كبيرة الحجم بمعدل ≤110جم، بذور متوسطة الحجم بمعدل 70-75 جم وبذور صغيرة الحجم بمعدل ≥45 جم)؛ العامل الثاني احتوي على ثلاث مستويات لتهيئة البذور (بدون معاملة، حمض الجبريلين بتركيز100 جزء في المليون، حمض الجبريلين بتركيز 200 جزء في المليون). أشارت نتائج التحليل الإحصائي للتجربة المعملية، إلى وجود معدلات تباين كبيرة عند أقل فرق معنوي (0.05) بسبب تأثيرات درجات حرارة الإنبات المعملي، أحجام البذور ومعاملات تهيئة البذور فيما يتعلق بنسبة الإنبات (%)، والوقت اللازم للوصول إلى 50% من نسبة الإنبات، متوسط زمن الانبات باليوم، طول البادرات، الوزن الجاف للبادرات، دليل قوة البادرات. كما أوضحت النتائج أن درجة حرارة الإنبات 22 درجة مئوية، البذور الكبيرة الحجم ≤110جم ومعاملة البذور بالجبريلين بمعدل 200 جزء في المليون كان لها التأثير الأكبر على جميع صفات جودة البذور، حيث سجلت أعلي القيم. كما أظهرت نتائج التفاعل الثلاثي بين عوامل التجربة تأثيراُ معنوياً (0.05) على جميع صفات جودة البذور، فيما عدا متوسط زمن الإنبات (يوم)، الوزن الجاف للبادرات ودليل قوة البادرات المعتمد على الوزن الجاف للبادرات. فيما يتعلق بالتجربة الحقلية، تم إجراء تجربتين حقليتين خلال موسمي الزراعة 2017/2016 و2018/2017. تم اختيار نفس المعاملات لأحجام البذور ومعاملات تهيئة البذور بينما تم اختيار ثلاث مواعيد للزراعة لتحل محل درجات حرارة الإنبات المعملي حيث كانت، الأول من شهر أكتوبر، الأول من شهر نوفمبر والأول من شهر ديسمبر. تم ترتيب المعاملات في تصميم القطع المشنقة في ثلاث مكررات لكل موعد من مواعيد الزراعة في تجربة منفصلة، حيث شغلت معاملة أحجام البذور القطع الرئيسية ومعاملة تهيئة البذور بالجبريلين القطع المنشقة. أشارت نتائج التحليل الإحصائي للبيانات إلى وجود معدلات تباين كبيرة بسبب تأثيرات مواعيد الزراعة، أحجام البذور ومعاملات تهيئة البذور بالجبريلين على الانبثاق الحقلي وصفات النمو والمحصول ومكوناته. حيث سجل موعد الزراعة في الأول من نوفمبر، البذور الكبيرة الحجم ≤110جم وتهيئة البذور بالجبريلين بمعدل 200 جزء في المليون أعلى قيم الانبثاق الحقلي (٪)، ارتفاع النبات، عدد القرون على النبات، إنتاجية النبات من البذور ووزن 100 بذرة خلال موسمي الزراعة. أخيرًا، أظهرت نتائج التفاعل الثلاثي بين عوامل التجربة الحقلية وجود معدلات تباين معنوية (0.05) على عدد القرون على النبات، إنتاجية النبات من البذور، وزن 100 بذرة ومحصول البذور أردب/ فدان في الموسم الأول، وعلى صفة ارتفاع النبات في الموسم الثاني. أخيراً، أشارت نتائج التفاعل إلي أن تهيئة البذور كبيرة الحجم بحمض الجبريلين بتركيز 200 جزء في المليون والزراعة في الأول من نوفمبر كانت المعاملة المثلي، حيث أعطت أعلى القيم للانبثاق الحقلي والمحصول ومكوناته لبنات الفول البلدي (صنف سخا 1).