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Improving Solar Energy Utilization Through Plant Distribution Patterns: A Case Study On Faba Bean

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Abstract

A field experiments was carried out in the Research and Experimental Center of the Faculty of Agriculture at Moshtohor, Benha University, Egypt, during 2021/2022 and 2022/2023 winter seasons to study the ridge widths (50 cm, 60 cm and 70 cm) under 4 plant distributions (Single seed in a hill on one side, Single seed in a hill on both sides, Double seeds in a hill on one side and Double seeds in a hill on both sides). A strip-plot design with three replications was assigned to three ridge width rates, the Horizontal factor (A), and four plant Distribution rates, the Vertical factor (B). The results gathered from the two seasons' combined analyses may be stated up as follows:

Ridge widths 70 cm and Planting in Single seed in hill on both sides were the highest values of Chlorophyll content index (SPAD value), plant height (cm), number of branches/ plant, Plant weight (g)/plant, Pod length (cm) /plant, Number of pods/plant, Weight of pods/plant (g), Number of seed/plant, Seed yield/plant (g), Harvest index (%), Weight of 100-seed (g), Biological yield/fed (kg), Seed yield/fed (kg), Seed nitrogen content (%), Seed phosphorus content (%) ,Seed potassium content (%) and reduced of Shedding in the flowers.

In general, it can be said that, given the circumstances of the current study, ridge widths of 70 cm planted with a single seed in the hill on both sides may be the suggested treatment to increase the productivity of the faba bean crop.

Keywords: Faba bean, Ridge widths, plant distributions, Yield and yield components.

Introduction

Faba bean (*Vicia faba* L.) is a key winter crop in Egypt, particularly valued in the local diet for its high caloric and nutritional content, as well as being an affordable source of protein. However, despite increasing domestic demand, faba bean production in Egypt remains limited. This decline is primarily due to the small area cultivated, as the crop competes with other major winter crops—such as wheat and clover—for the limited arable land available in the Nile Valley and Delta. Several factors affect faba bean yield, including plant distribution, ridge width, and soil fertility. Therefore, this study aimed to investigate the effect of ridge width on plant distribution and its impact on faba bean productivity. **Crépon *et al.*, (2010) ; Cazzato *et al.*, (2012) and Singh *et al.*, (2013).**

Modifying the ridge widths significantly influences faba bean cultivation by enabling better spatial distribution of plants. This adjustment helps achieve the ideal plant density per unit area. Reduced competition among plants enhances the efficiency of solar radiation utilization, thereby improving the conversion of light into chemical energy and ultimately increasing the accumulation of dry matter. (**Gadallah *et al.*, 2006**). The number of rows per ridge has a substantial impact on the output of faba beans and their constituent parts, according to several authors. (**Ageeb, 1984, Saleh, 1985; El-Tohami and Hussein, 1986) ; El-Douby *et al.*, (2000) ; Refaey *et al.*, (2016) and Mohamed *et al.*, (2018**).

The distribution of field bean plants is critical, whether in newly farmed or established lands, and is heavily influenced by stand establishment. Plants compete for environmental resources based on their spatial arrangement, which is determined by both plant density (the number of plants per unit area) and row spacing. Studies have indicated that reducing row space or increasing plant population density tends to boost the seed yield. On the other hand, previous studies of **Caballero (1987) ; Mc Ewen *et al.*, (1988) ; Thalji (2006) ;Under Newly (2011) ;Mehasen and Ahmed (2012) ;El-Rahman and Rehab (2014) ; El-Karamity *et al.*, (2017) and Haddad and Abahri (2022).**

Materials and Methods

A field experiments was carried out in the Farm of Agricultural Research and the Experimental Center of the Faculty of Agriculture at Moshtohor, (Toukh Directorate, Kalyubia Governorate) Benha University, Egypt, during the two successive winter seasons of 2021/2022 and 2022/2023. The objective of this investigation was to study the effect of ridge

width (50 cm, 60 cm, and 70cm), different systems of plant distribution:- 1. Single seed in a hill on one side,2. Single seed in a hill on both sides, 3. Double seeds in hill on one side, 4. Double seeds in a hill on both sides. On vegetative growth, yield, yield components, as well as some seeds chemical properties of (*Vicia faba*) Faba bean seeds, Giza 716 variety. The factors under study, which were arranged in a strip-plot design with three replications, were assigned to three ridge width rates Horizontal factor (A) and four plant Distribution rates Vertical factor (B). Samples of soil were taken before sowing of faba bean to depth of 0-30 cm for mechanical and chemical properties analysis of the experimental soil were determined according to the methods of Association of Official Analytical Chemists described in (**A.O.A.C., 2005**) Soil analysis indicated clay texture with pH values of 7.97 and 7.86, total N 0.31 and 0.28%, total P 0.21 and 0.18% and total K 0.71 and 0.73% in the first and second seasons, respectively. The preceding crop was corn in both seasons.

The Experimental plot area was 14.7 m^2. Faba bean seeds were planted on 11th November in the first season 2021/2022 and 1th November in the second season 2022/2023. Faba bean plants were harvested on 21th and 10 th of April in the first and the second seasons, respectively. All recommended cultural practices for growing faba bean according to Agricultural Research Center recommendation followed.

Characters studied:

A. Vegetative Growth characters

1- Chlorophyll content index (SPAD value) at 85 days after sowing, three plants in three different ridges were randomly selected, and the chlorophyll content index (CCI) of upper, middle, and lower leaves was measured by a Minolta Chlorophyll Meter SPAD-502 (MINOLTA CO., LTD. JAPAN).

At harvest, a random sample of ten guarded plants from every plot in both seasons was taken to determine the following measurements:

2- Plant height (cm).
3- Height to 1st pod (cm).
4- Number of branches/plant on the main stem.
5- Plant weight (g)
6- Shedding

B. Yield and yield components:

1- Pod length (cm).
2- Number of pods/plant.
3- Weight of pods/plant (g).
4- Number of seed/plant.
5- Seed yield/plant (g).
6- Harvest index (%).
7- Weight of 100-seed (g).
8- Biological yield/fed (kg).
9- Seed yield/fed (kg).
10- Straw yield fed (kg).

C. **Seed chemical properties**:

1- Seed nitrogen content (%), Seed phosphorus content (%) and Seed potassium content (%) : calculated according to **(A. O. A. C., 2005).**

2- Protein yield/fed (kg) = (seed yield kg x seed protein content)/100.

Statistical analysis:

The analysis of variance was carried out according to the procedure described by **Gomez and Gomez (1984).** Data were statistically analyzed according to using the MSTAT-C Statistical Software Package **(Freed, 1991).** Where the F-test showed significant differences among means L. S. D. test at 0.05 level was used to compare between means.

Result and Discussions

-Effect of ridge width

Data in **Table 1** shows that in the 2021/2022 and 2022/2023 seasons, the Ridge width levels improved significantly in most vegetative growth. Plant height (cm), plant weight (g)/plant, and number of branches/plant were the characteristics of the faba bean under research, while the height to the first pod was dramatically decreased with increasing ridge width rates at 70 cm. This shows that ridge width had a positive effect on plant development .provided more favorable basic growing conditions for faba bean development than the narrow one. Among environmental factors, light plays a particularly critical role, as it influences both photosynthetic uptake and the distribution of resources within the plant **(Slewinski and Braun, 2010).** Additionally, various leaf tissues in faba beans have differing nutritional requirements to support their growth.

-Effect of Plant Distribution Pattern

Data in **Table 1**: Significant increases in the majority of vegetative growth were seen in both seasons as a result of the plant distribution strategy. The characteristics of the faba bean under study showed that single seeds in a hill on both sides had the lowest values for plant height (cm), plant weight (g)/plant, number of branches/plant, and height to st 1 pod (cm), respectively, while double seeds in a hill on one side had the lowest values for these same characteristics. This suggests that the choice of distribution pattern can significantly impact plant growth, with certain patterns (Single seed in hill on both sides) proving more effective than others in promoting growth. These results was agreement with **El-Douby *et al,*. (2000)** Plant Distribution significantly influences vegetative growth Characters in faba beans. Effective proper distribution can lead to enhanced photosynthesis, better nutrient use, and more efficient biomass partitioning, ultimately increasing vegetative growth. Results was agreement with **Cerqueira *et al,*. (2019).**

Table 1. Influence of ridge width and Plant distribution pattern on plant height (cm), Plant weight (g)/plant, number of branches/ plant and height to st [1] pod (cm) of faba bean, combined data across 2021/2022 and 2022/2023 seasons.

Treatment	Trait	Plant Height(cm)		Plant weight(g)		No / of branches/plant		height to st [1] pod	
		2021/2022	2022/2023	2021/2022	2022/2023	2021/2022	2022/2023	2021/2022	2022/2023
Ridge width	50 cm	105.46	100.95	81.84	78.28	3.39	3.06	27.58	28.20
	60 cm	108.12	104.92	110.15	106.51	4.92	4.50	22.31	22.87
	70 cm	110.93	106.89	116.44	114.49	5.71	5.75	21.83	22.21
	Mean	**108.17**	**104.25**	**102.81**	**99.76**	**4.67**	**4.44**	**23.91**	**24.43**
	L .S. D	**8.867**	**3.506**	**13.37**	**8.588**	**0.4379**	**0.678**	**2.661**	**2.620**
Plant distribution pattern	D1	106.06	101.60	100.47	98.28	4.46	4.26	24.35	24.96
	D2	115.09	111.50	110.16	106.02	5.47	5.09	22.37	22.88
	D3	103.81	100.08	97.77	95.16	3.93	3.85	25.27	25.84
	D4	107.73	103.83	102.83	99.58	4.84	4.54	23.63	24.05
	Mean	**108.17**	**104.25**	**102.81**	**99.76**	**4.67**	**4.44**	**23.91**	**24.43**
	L .S. D	**10.06**	**8.049**	**9.974**	**10.22**	**0.8541**	**1.062**	**2.990**	**1.806**

D1= Single seed in hill on one side. **D2=** Single seed in hill on both sides.
D3= Double seeds in hill on one side. **D4=** Double seeds in hill on both sides.

-Effect of ridge width

Results presented in **Table 2** indicate that chlorophyll content index, number of pod/ plant and pod length (cm) were significantly affected by increasing ridge Width rates during the two experimental seasons. The results also showed that ridge Width significantly affected all the studied characters of ridge Width rates from (50, 60 and 70 cm) in both seasons. Lower to Shedding was significantly decreased with rising ridge width rates, with the 70 cm. Ridge width in faba bean cultivation can affect flowering and shedding (flower drop) through its influence on soil conditions, light interception, and plant competition. Wider ridges may improve soil aeration and drainage, potentially reducing water stress and promoting better root development, which can positively impact flowering and pod set. The results obtained agree with those achieved by **Smith (1982).**

-Effect of Plant Distribution Pattern

Results in **Table 2.** For the effect of the Plant distribution pattern for both seasons, the maximum chlorophyll content index, number of pod/ plant, and pod length (cm) were obtained from in the Single seed in hill on both sides, while Lower to Shedding was significantly decreased with Double seeds in hill on one side. Proving more effective than others in promoting chlorophyll content. Plant distribution and arrangement have a direct impact on light interception, food uptake, and competition—all of which have an impact on chlorophyll synthesis and hence on the chlorophyll content index of faba bean plants. Plant distribution has a major impact on the faba bean plants' chlorophyll content index; increased chlorophyll content is the outcome of proper spacing. **Jarecki *et al.* (2016) and Haddad and Abahri (2022)**. Plant distribution in faba bean significantly impacts flowering and shedding (shedding of plant parts). Spacing and density affect the number of flowers produced, the rate of flower and pod shedding (dropping), and ultimately, seed yield. Appropriate plant distribution can minimize flower and pod drop, leading to increased yields. These results are in agreement with those obtained by **El-Karamity *et al.*, (2017) ; Stoddard (2017) and Kyllönen (2018).**

Table 2. Influence of ridge width and Plant distribution pattern on SPAD, Shedding, number of pod/ plant and pod length (cm) of faba bean, combined data across 2021/2022 and 2022/2023 seasons.

Trait		SPAD		Shedding		No of pod/plant		pod length(cm)	
Treatment		2021/2022	2022/2023	2021/2022	2022/2023	2021/2022	2022/2023	2021/2022	2022/2023
Ridge width	50 cm	34.13	33.25	91.22	92.02	11.69	9.38	8.96	8.35
	60 cm	36.39	35.42	89.62	90.47	12.23	11.24	11.22	10.39
	70 cm	38.14	36.97	87.54	88.11	14.32	12.43	12.17	11.35
	Mean	**36.22**	**35.21**	**89.46**	**90.20**	**12.75**	**11.02**	**10.78**	**10.03**
	L .S. D	**3.139**	**3.139**	**0.446**	**0.601**	**2.612**	**1.092**	**1.177**	**1.011**
Plant distribution pattern	D1	35.65	34.64	90.35	91.14	12.09	10.75	10.70	9.80
	D2	39.53	38.53	87.11	87.90	13.95	11.99	11.58	10.72
	D3	32.87	31.87	91.86	92.48	12.39	10.55	10.38	9.44
	D4	36.82	35.82	88.53	89.26	12.56	10.79	10.46	10.16
	Mean	**36.22**	**35.21**	**89.46**	**90.20**	**12.75**	**11.02**	**10.78**	**10.03**
	L .S. D	**5.801**	**5.801**	**0.9659**	**0.9493**	**2.672**	**1.645**	**1.445**	**2.040**

D1= Single seed in hill on one side. **D2=** Single seed in hill on both sides.
D3= Double seeds in hill on one side. **D4=** Double seeds in hill on both sides.

-Effect of ridge width

Data in **Table 3** indicated that 100-seed/weight (g), Weight of pods/plant (g), number of seeds/plant, and seed yield/plant (g) of faba bean were highest in Ridge Width 70 cm during the two seasons. On the other hand, the lowest values in all of the studied characters in both seasons, respectively, were noticed with faba bean plant under Ridge Width 50 cm. Generally, moderate to wider ridge widths tend to promote heavier seeds per pod. These results are in agreement with those obtained by **Salem *et al*,. (2014) and Under Newly (2011).**

Table 3. Influence of ridge width and Plant distribution pattern on 100- seed /weight(g), Weight of pods/plant (g),number of seeds/plant and seed yield/plant(g) of faba bean, combined data across 2021/2022 and 2022/2023 seasons.

Trait		100- seed /weight(g)		Weight of pods/plant (g)		No of seeds/plant		seed yield/plant(g)	
Treatment		2021/2022	2022/2023	2021/2022	2022/2023	2021/2022	2022/2023	2021/2022	2022/2023
Ridge width	50 cm	82.225	79.831	31.807	26.939	31.284	27.653	25.828	22.064
	60 cm	87.141	85.598	41.544	36.343	40.270	35.928	35.356	31.072
	70 cm	88.332	86.715	52.049	44.166	51.025	43.431	45.281	37.916
	Mean	85.899	84.048	41.800	35.816	40.860	35.671	35.488	30.350
	L .S. D	**1.534**	**4.333**	**1.189**	**4.118**	**2.185**	**4.793**	**1.831**	**4.160**
Plant distribution pattern	D1	85.687	83.802	39.244	34.993	38.248	34.667	33.072	29.354
	D2	87.496	85.338	48.913	41.492	47.883	40.983	42.366	35.409
	D3	84.186	82.809	37.019	30.481	36.172	30.682	30.680	25.648
	D4	86.228	84.243	42.022	36.296	41.136	36.350	35.836	30.990
	Mean	85.899	84.048	41.800	35.816	40.860	35.671	35.488	30.350
	L .S. D	**1.386**	**1.508**	**4.500**	**8.964**	**4.993**	**10.05**	**4.332**	**8.438**

D1= Single seed in hill on one side. **D2=** Single seed in hill on both sides.
D3= Double seeds in hill on one side. **D4=** Double seeds in hill on both sides.

Effect of Plant Distribution Pattern

Results presented in **Table 3** indicated that the effect of Plant distribution pattern on 100-seed/ weight (g), Weight of pods/plant (g), number of seeds/plant and seed yield/plant(g) significantly increased all of the studied characters were recorded from a Single seed in the hill on both sides in both seasons. Whereas, faba bean plants from Double Seeds on the hill on one side gave the lowest value of all the studied characters in both seasons, respectively. This is due to low competition among plants, which reflected on growth vigor, increased assimilates and its translocation from source to sink, and increased the mass of seeds. Similar results were

also reported by **Nawar *et al.*, (2010) ; Under Newly (2011) ; Amany (2014) ; Derogar and Mojaddam (2014) ;El-Karamity *etal*,. (2017)and Gezahegn (2019).**

Effect of ridge width

Data in **Table 4** indicated that Harvest index (%), seed yield (kg /fed), Straw yield (kg/fed) and biological yield (kg/fed) of faba bean were highest in ridge width 70 cm during the two seasons. On the other hand, the lowest values in all of the studied characters in both seasons, respectively, was noticed with faba bean plant under Ridge Width 50 cm. Generally, wider ridge widths tend to promote heavier seed yield, Straw yield, and biological yield. These results are in agreement with those obtained by **Under Newly (2011) ; Salem *et al*,. (2014) ; Abou-El-Seba *et al*,. (2016) ;Refaey *et al*.,(2016) and Safina (2017).**

Effect of Plant Distribution Pattern

Results presented in **Table 4** indicated that the effect of Plant distribution pattern on Harvest index (%), seed yield (kg /fed), Straw yield (kg/fed) and biological yield (kg/fed) significantly increased all of the studied characters was recorded from Single seed in the hill on both sides in the two seasons. Whereas, faba bean plants from Double Seeds on the hill on one side gave the lowest of all the studied characters in both seasons, respectively .The results agree with those reported by **Stützel and Aufhammer (1992) and Abd El-Rahman (2014).**

Table 4. Influence of ridge width and Plant distribution pattern on Harvest index (%), seed yield (kg /fed), Straw yield (kg/fed) and biological yield(kg/fed)of faba bean, combined data across 2021/2022 and 2022/2023 seasons.

	Trait	Harvest index (%)		seed yield(kg /fed)		Straw yield (kg/fed)		biological yield(kg/fed)	
		2021/2022	2022/2023	2021/2022	2022/2023	2021/2022	2022/2023	2021/2022	2022/2023
Treatment									
Ridge width	**50 cm**	31.30	27.79	727.05	609.594	1548.53	1511.83	2275.59	2121.42
	60 cm	32.11	28.79	1115.43	948.462	2237.95	2221.24	3353.39	3169.70
	70 cm	38.76	32.70	1487.64	1221.373	2298.06	2388.15	3785.71	3609.52
	Mean	34.06	29.76	1110.04	926.476	2028.18	2040.40	3138.23	2966.88
	L .S. D	**4.997**	**3.794**	**102.700**	**186.90**	**446.80**	**155.00**	**488.60**	**251.40**
Plant distribution pattern	**D1**	32.72	29.42	999.62	847.285	1997.36	1948.54	2996.98	2795.83
	D2	37.86	32.71	1438.23	1191.472	2225.79	2307.65	3664.02	3499.12
	D3	31.29	26.53	818.41	661.145	1746.69	1766.39	2565.10	2427.54
	D4	34.36	30.38	1183.91	1006.003	2142.90	2139.03	3326.81	3145.03
	Mean	34.06	29.76	1110.04	926.476	2028.18	2040.40	3138.23	2966.88
	L .S. D	**5.63**	**6.52**	**185.40**	**313.60**	**507.50**	**403.90**	**530.90**	**510.20**

D1= Single seed in hill on one side. **D2=** Single seed in hill on both sides.
D3= Double seeds in hill on one side. **D4=** Double seeds in hill on both sides.

-Effect of ridge width

the following **table 5** data showed that during the two seasons, the maximum levels of faba bean seed chemical analysis (N content (%), protein yield, P content (%), and K content (%)) were found in Ridge Width 70 cm. Conversely, the faba bean plant under Ridge Width 50 cm showed the lowest values in both seasons for all of the seed chemical attributes. Wider ridge widths generally encourage the chemical characteristics of seeds. The broader ridges may boost root growth, water infiltration, and soil aeration, which may improve nutrient uptake and utilization and result in seeds with higher levels of potassium, phosphorus, and nitrogen. The final results are consistent with those attained by **Slewinski and Braun (2010) and Safina (2017).**

-Effect of Plant Distribution Pattern

Results reported in **Table 5** showed that the Plant the distribution pattern on Seed nitrogen content (%), Seed yield of protein (kg/fed), Seed phosphor content (%), and Seed potassium content (%) significantly increased all of the Seed chemical properties in both seasons was recorded from Single seed in the hill on both sides in the two seasons. Conversely, in both seasons, the faba bean plants from Double Seeds on one side of the slope produced the lowest of all the traits that were examined. These outcomes concur with those acquired by **Abd El-Rahman (2014) E Maaty *et al*,. (2014).**

Table 5. Influence of ridge width and Plant distribution pattern on Seed N content (%), Seed protein yield (kg/fed), Seed P content (%)and Seed K content (%) of faba bean, combined data across 2021/2022 and 2022/2023 seasons

Trait		Seed N content (%)		Seed protein yield (kg/fed)		Seed P content (%)		Seed K content (%)	
Treatment		2021/2022	2022/2023	2021/2022	2022/2023	2021/2022	2022/2023	2021/2022	2022/2023
Ridge width	50 cm	3.46	3.12	168.87	125.62	0.48	0.48	1.46	0.88
	60 cm	3.87	3.65	290.96	232.64	0.58	0.56	1.36	1.07
	70 cm	4.00	3.81	389.12	303.49	0.67	0.63	1.50	1.22
	Mean	**3.78**	**3.53**	**282.98**	**220.59**	**0.57**	**0.56**	**1.44**	**1.06**
	L .S. D	**0.4461**	**0.448**	**77.39**	**70.48**	**0.0481**	**0.048**	**0.117**	**0.117**
Plant distribution pattern	D1	3.71	3.36	245.30	191.88	0.53	0.51	1.32	0.93
	D2	4.17	3.79	395.03	293.58	0.69	0.67	1.75	1.37
	D3	3.26	3.38	176.85	147.82	0.48	0.46	1.14	0.75
	D4	3.96	3.58	314.75	249.06	0.60	0.58	1.55	1.16
	Mean	**3.78**	**3.53**	**282.98**	**220.59**	**0.57**	**0.56**	**1.44**	**1.06**
	L .S. D	**0.4947**	**0.148**	**61.87**	**57.27**	**0.0410**	**0.0410**	**0.041**	**0.041**

D1= Single seed in hill on one side. **D2=** Single seed in hill on both sides.
D3= Double seeds in hill on one side. **D4=** Double seeds in hill on both sides.

Conclusion

Generally, it can be concluded that a ridge width of 70 cm, with a Single seed in hill on both sides, could be recommended to improve the productivity of the faba bean crop under the prevailing environmental conditions of Toukh Directorate, Kalyubia Governorate, Egypt.

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