Theme: Sustainable Agricultural Innovations for One Health and Environmental Resilience

RESEARCH ARTICLE Indian Journal of Agricultural Research, Volume 60 Special Issue: 58-66 (2026)

Effect of Silicon Spraying on the Growth and Yield of Several Broad Bean (*Vicia faba* L.) Cultivars Grown in Desert Soils

Khawla Dawood[1], Rawafid H. Al-Obaidi[1], Yaseen Obaid Noori Ahmed Sharif[2] **10.18805/IJARe.AF-1089**

ABSTRACT

Background: Broad bean (*Vicia faba* L.) is an important legume crop, but its productivity in desert soils is often limited by adverse soil conditions. Silicon application may improve plant growth and yield under such conditions. Therefore, this study aimed to evaluate the response of different broad bean cultivars to silicon spraying under desert soil conditions in Basrah, Iraq.

Methods: A field experiment was conducted during the winter season of 2024-2025 at Al-Faris Agricultural Research Station, Al-Zubair, Basrah (30.23°N, 47.42°E). The Trial was arranged a two-factors factorial experiment based on a randomized complete block design (RCBD) with three replications. Three cultivars were evaluated: Spanish 'Luz de Otono' (V1), Dutch 'Histal' (V2) and a Local (V3), combined with three silicon concentrations: 0, 1.5 and 3 mL L^{-1} (Si1, Si2 and Si3, respectively).

Result: Cultivars and silicon treatments significantly affected all studied traits ($P \leq 0.05$). Main effect analysis revealed that Spanish cultivar 'Luz de Otono' (V1) significantly outperformed the other cultivars, recording the highest values for pod number (10.32 pod $plant^{-1}$),100-seed weight (132.12 g) and total yield (4587 kg ha^{-1}). Foliar application of silicon at 3 mL L^{-1} produced the highest overall values for pods per plant (10.04), seeds per pod (7.44), 100-seeds weight (129.38 g and total yield (4850 kg ha^{-1}). The cultivar × silicon interaction was significant for several traits; specifically, the combination of Luz de Otono with 1.5 mL L^{-1} Si recorded the highest number of pods per plant (11.63), whereas no significant difference was observed between Luz de Otono' and 'Histal' at 3 mL L^{-1} Si for 100-seeds weight (132.18 and 132.74 g, respectively) and total seed yield.

Key words: Cultivars, Growth yield, Silicon, *Vicia faba*, Yield and its components.

INTRODUCTION

Legumes are important components of sustainable agricultural systems because of their ability to improve soil fertility through biological nitrogen fixation and enhance nutrient cycling. Their inclusion in crop rotation with cereals can reduce dependence on external nitrogen inputs and contribute to the sustainability and productivity of cropping systems (Alshamary *et al*., 2025). Among grain legumes, broad bean (*Vicia faba* L.) is an important winter crop with considerable nutritional and agronomic value. Its seeds contain approximately 25-40% protein and 48-54% carbohydrates, making it an important source of plant-based protein and energy (Karkanis *et al*., 2018; Dhull *et al*., 2022). In addition, its capacity for biological nitrogen fixation makes broad bean particularly valuable for improving soil fertility and maintaining nutrient availability within crop rotations (Sharif *et al*., 2026).

The importance of broad bean cultivation is increasing in regions affected by climate change, water scarcity, soil degradation and salinity. However, production in Iraq is constrained by several factors, including the deterioration of local genetic resources and limited adaptation of some introduced cultivation too local environmental conditions (El Hadj *et al*., 2022). These limitations are particularly relevant in desert and arid environments, where high temperatures, water deficits and salinity can occur simultaneously and adversely affect plant growth, photosynthetic activity, nutrient acquisition and biological nitrogen fixation (Ben Gaied *et al*., 2024).

[1]Department of Field Crops, College of Agriculture, University of Basrah, Basrah, Iraq.
[2]Department of Field Crops, College of Agriculture, University of Kirkuk, Kirkuk, Iraq.

Corresponding Author: Yaseen Obaid Noori Ahmed Sharif, Department of Field Crops, College of Agriculture, University of Kirkuk, Kirkuk, Iraq. Email: yaseenobaidnoori@uokirkuk.edu.iq

ORCIDs: https://orcid.org/0009-0002-9716-2876, https://orcid.org/0009-0006-4436-2806, https://orcid.org/0009-0001-2581-9448

How to cite this article: Dawood, K., Al-Obaidi, R.H. and Sharif, Y.O.N.A. (2026). Effect of Silicon Spraying on the Growth and Yield of Several Broad Bean (*Vicia faba* L.) Cultivars Grown in Desert Soils. *Indian Journal of Agricultural Research.* **60(Special Issue):** 58-66. doi: 10.18805/IJARe.AF-1089.

Submitted: 25-08-2026 **Accepted:** 14-09-2026 **Online:** 21-09-2026

Consequently, the identification of cultivars with superior adaptation to these environments, together with appropriate agronomic strategies for improving their stress tolerance, represents an important research priority.

Recent research has increasingly focused on the use of silicon a beneficial element for improving crop performance under abiotic stress. Silicon can enhance plant structural strength and contribute to stress tolerance through effects on cell wall stability, water relations, antioxidant activity and physiological processes associated with drought and salinity tolerance (Kumar *et al*., 2021).

In broad bean, previous studies have reported positive effects of silicon application on growth and yield- related characteristics (Al-Badrawi *et al*., 2022). However, the response to silicon is not necessarily uniform among cultivars and its effectiveness may depend on the genetic background of the cultivar and the severity of prevailing environmental stress.

This knowledge gap is important because the identification of an effective silicon concentration cannot be considered independently of cultivar adaptation. A cultivar that is inherently better adapted to desert conditions may respond differently to silicon than a less-adapted cultivar and the most effective cultivar-silicon combination may therefore provide greater benefits than either factor consider separately. The novelty of the present study lies in evaluating the interactive response of different broad bean cultivars to graded silicon concentration under desert soil conditions, to identify a cultivar- silicon combination that can enhance crop productivity under abiotic stress. Such information may contribute to development of more efficient agronomic strategies for broad bean production in arid and desert environments and provide a basis for selecting cultivars and silicon management practices better suited to stress-prone agricultural systems. Although silicon application has been studied in broad bean under salt or drought stress, the cultivar-specific response to foliar silicon under hyper-arid, high-temperature and saline desert soil conditions of Basrah, southern Iraq, remains under-explored. Evaluating how modern introduced cultivars (such as Luz de Otono and Histal) compare with adapted local landrace under graded silicon application provides crucial insights into genotype- specific silicon uptake and utilization. The silicon concentrations (0,1.5 and 3 mL L^{-1}) were selected based on preliminary dose-response field screening and commercial recommendations for Armurox to avoid osmotic shock while optimizing physiological stress relief.

Therefore, this study aimed to evaluate the response of different broad bean cultivars grown under desert-soil conditions to different concentrations of silicon and to determine the most effective cultivar-silicon combination for improving growth, yield and yield- related characteristics under this condition.

MATERIALS AND METHODS

A field experiment was conducted during the 2024-2025 growing season at Al-Faris Agricultural Research Station, Al-Zubair District, Basrah, Iraq (30.23°N, 47.42°E). The experiment was arranged as a factorial experiment using a randomized complete block design (RCBD) with three replications. Each experimental unit measured 2 × 3 m (6 m^2) and comprised 4 rows spaced 75cm apart with a 25 cm spacing between hills, leaving 1m alley between plots, with a 1 m gap between plots.

Three broad bean cultivars were evaluated: Spanish 'Luz de Otono' (V_1), Dutch 'Histal' (V_2) and a Local (V_3). Plants were sprayed with three silicon concentrations: 0, 1.5 and 3 mL L^{-1} (Si_1, Si_2 and Si_3, respectively). Silicon (8% SiO, ; commercial formulation ARMUROX) was applied as a foliar spray with Tween-20 (0.05% v/v) as a non- ionic surfactant to reduce surface tension and enhance absorption. Foliar application was carried out in two equals stages: the first at the vegetative branching stage and the second at the initiation of flowering.

Seeds were sown after soaking in distilled water for 12 hours, placing 2-3 seeds per hill. Two weeks after emergence, seedling were thinned to one healthy plant per hill. S standard agronomic practices, including drip irrigation and pest/ disease management, were uniformly applied. Basal fertilization included 75 kg P_2O_5 ha^{-1} and 60 kg ha^{-1} K_2O applied prior to planting, whereas 45 N ha^{-1} was applied once at sowing.

Before planting, representative soil samples were collected from the upper layer (0-30 cm depth), air-dried, passed through a 2-mm sieve and analyzed for physical and chemical properties according to standard soil analysis procedure (Table 1).

The studied traits

At maturity, ten inner plants were randomly tagged from each experimental unit (excluding border rows) to determine physiological, vegetative, yield and quality traits:

Vegetative growth traits

- **Plant height (cm):** Measured from the soil surface to the plant apex using a measuring tape.
- **Number of leaves and branches:** counted as leaf $plant^{-1}$ and branch $plant^{-1}$.
- **Leaf area (cm^2):** Measured for total leaf canopy per plant.
- **Pod length:** Measured average length of mature pods.

Photosynthetic pigments

Total chlorophyll and total carotenoids in green plant tissues (leaf) were extracted using 80% acetone according to the method described by Lichtenthaler (1987). Fresh leaf tissue (50 mg) was immersed in 10 mL of 80% acetone

Table 1: Physical and chemical properties of the soil of the experimental field (2024-2025).

Property	Value	Unit
pH	7.19	-
Electrical conductivity (E.C.)	6.86	dS m^{-1}
Available nutrient		
Nitrogen (N)	2.11	mg kg^{-1} soil
Phosphorus (P)	0.35	mg kg^{-1} soil
Potassium (K)	12.34	mg kg^{-1} soil
Practical size distribution		
Clay	77.90	g kg^{-1} soil
Silt	116.70	g kg^{-1} soil
Sand	805.40	g kg^{-1} soil
Soil texture	Sandy loam	

and stored in completely darkness at 4°C for 24 h until absorbance of extract was measured at 470, 646 and 663nm using UV-visible spectrophotometer. Pigment concentrations were calculated using the standard equation of Haque *et al*. (2021).

Components of yield and yield

Number of pods per plant (pods plant^{-1}).
Number of seeds per pod (seeds pod^{-1}).
Weight of 100 seeds (g)
Total seed yield (kg ha^{-1}).

Crude seed protein content (%)

Estimated by determining total seed nitrogen via the micro-kjeldahl method using the standard conversion factor:

$$\text{Crude protein (\%)} = \text{Seed N (\%)} \times 6.25$$

Statistical analysis

Data were subjected to analysis of variance (ANOVA) for a factorial RCBD using statistical software. Treatment means were compared using the modified least significant difference (LSD) test at a significant level P≤0.05) as described by Al-Zubaidi and Al-Jubouri (2016).

RESULTS AND DISCUSSION

ANOVA analysis

The analysis of variance (ANOVA) presented in Table 2 and 3 revealed significant variations among cultivars, silicon foliar treatments and their interaction for all evaluated vegetative, physiological and yield-related traits.

The main effect of cultivars showed highly significant differences (P≤0.01) for plant height, number of leaves, leaf area, number of branches, total chlorophyll content, number of pods per plant, number of seeds per pod and 100-seed weight, while total yield and seed protein content were significantly affected at P≤0.05. These results indicate the presence of substantial genetic variation among the tested cultivars in terms of vegetative development, photosynthetic performance, yield components and seed quality attributes.

Foliar application of silicon exerted a highly significant effect (P≤0.01) across all evaluated traits, as evidenced by the mean square values. This highlights the influential role of exogenous silicon in stimulating cell elongation, leaf expansion, chlorophyll retention, photo assimilate translocation toward reproductive sinks and nitrogen assimilation during seed filling.

Furthermore, the interaction between cultivars and silicon foliar application was highly significant (P≤0.01) for plant height, leaf area, number of branches, pods per plant, 100-seed weight, seed protein content, number of seeds per pod and total yield. This differential response confirms that silicon responsiveness is genotype-dependent, suggesting that specific cultivars were more efficiency, yield potential and seed nutrition quality.

Vegetative growth traits

The analysis of variance revealed that foliar application of silicon significantly influenced the evaluated vegetative and physiological traits (Table 4).

Among the evaluated silicon levels, application of 3 mL L^{-1} (Si_3) recorded the highest mean values among the tested concentration for plant height (87.67 cm, total chlorophyll content (22.14 mg 100g^{-1} WF) and leaf area (1541.72 cm^2). Conversely, the 1.5 mL L^{-1} concentration (Si_2) produced highest average number of leaves per plant (96.03 leaves plant^{-1}) and number per branches (8.54 branch plant^{-1}). Additionally, as suggested in literature,

Table 2: Analysis of variance (ANOVA) expressed as mean squares.

S.O.V.	D.F.	Plant height	Number of leaves	Leaf area	Number of branches	Total chlorophyll
Block	2	8.016	61.12	1468.99	0.531	2.026
Cultivars	2	1040.880**	20.010**	1240.50**	6.686**	70.380**
Silicon foliar treatments	2	236.840**	108.510**	890.30**	9.708**	7.520**
Cultivars × silicon	4	39.850**	0.794*	215.800**	1.842**	6.17*
Error	16	1.082	0.539	4997.350	0.036	0.465

Table 3: Analysis of variance (ANOVA) expressed as mean squares.

S.O.V.	D.F.	Number of pods plant^{-1}	Number of seeds pod^{-1}	Weight of 100 seeds (g)	Total yield (kg ha^{-1})	Protein content (%)
Block	2	0.393	0.329	226.430	29745.00	6.463
Cultivars	2	11.551**	6.804**	1131.220**	6851.00*	42.438*
Silicon foliar treatments	2	5.493**	6.109**	3981.200**	105523.00**	263.081**
Cultivars × silicon	4	0.762**	0.354*	270.55**	32510.00*	30.545**
Error	16	0.088	0.124	1.826	36214.280	0.319

*Significant at P≤0.05; **Highly significant at P≤0.01.

silicon application might support tissue hydration, optimize nutrient status (such as potassium absorption) and protect chlorophyll stability under stress conditions (Desoky *et al.,* 2020), although direct physiological verification remains to be confirmed.

Regarding genotypic variation, the cultivar Luz de otono demonstrated statistically superior performance (Table 4), achieving the highest average for leaf chlorophyll content (22.17 mg 100 g^{-1} FW), leaf number (99.12 leaves $plant^{-1}$) and leaf area (2434.15 cm^2).

This advantage is likely attributable to inherent genetic differences governing photosynthetic potential and endogenous phytohormone regulation (especially cytokinin) and radiation-use efficiency under desert soil environment (Atab *et al*., 2023). These finding align with previous observations by Alshummary *et al*. (2021) and Merhij and Al-Khafaji (2023).

The interaction between cultivars and silicon levels significantly affected all evaluated vegetative parameters in plant height, leaf area and branch number, while maintaining statistical at P≤0.05 for leaf number and chlorophyll content. The cultivar Histal supplied with either 1.5 or 3 mL L^{-1} silicon (Fig 1) achieved the maximum plant height (89.54 cm), whereas the unsprayed local recorded the lowest mean.

Furthermore, the combination of Luz de otono and Histal at 3 mL L^{-1} silicon recorded the highest averages for leaf chlorophyll content (22.19 and 20.15 mg $100g^{-1}$ FW, Fig 2), leaf number (87.19 and 85.48 leaves $plant^{-1}$, Fig 3) and leaf area (2792,78 and 2686.57 cm^2, Fig 4) respectively. The treatment combination Luz de otono at 1.5 mL L^{-1} silicon yielded the highest branch number (8.41 branches $plant^{-1}$, Fig 5).

Yield and yield components

The results presented in Table 5 reveal that cultivars, silicon concentration and their interaction significantly influenced overall yield and its components.

Regarding the main effect of silicon, the third level (3 mL L^{-1}) demonstrated clear superiority, achieving the highest mean values across all evaluated traits: number of pods per plant (10.04 pods $plant^{-1}$), number of seeds per pod (7.44 seed pod^{-1}), 100-seed weight (129.38 g), total yield (4850.00 kg ha^{-1}) and protein percentage

Table 4: Main effects of spraying silicon on vegetative growth characteristics of Broad bean cultivars.

Cultivar	Plant height (cm)	Total chlorophyll (mg 100 g^{-1} FW)	Number of leaves (leaf $plant^{-1}$)	Leaf area (cm^2 $plant^{-1}$)	Number of branches (Branch $plant^{-1}$)
Luz de Otoño	80.61	22.17	99.12	2434.15	7.12
Histal	85.12	20.67	94.27	2318.04	6.82
Local cultivar	77.89	18.22	87.19	2119.92	5.56
LSD (p≤0.05)	2.21	1.45	1.56	150.21	0.237
Silicon concentration (mL L^{-1})					
0	72.17	17.21	87.12	1202.43	7.06
1.5	83.91	19.56	96.03	1340.67	8.54
3.0	87.67	22.14	94.21	1541.72	8.21
LSD (p≤0.05)	2.21	1.45	1.56	150.21	0.327
LSD for cultivar × silicon (p≤0.05)	3.32	4.09	0.88	102.62	0.59

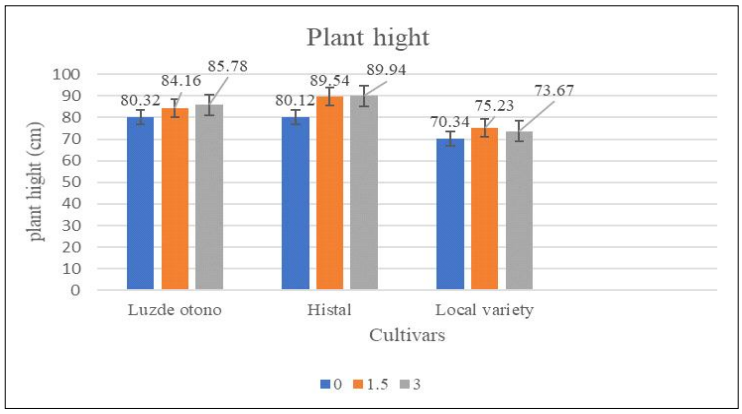


Fig 1: Effect of interaction between cultivars and silicon levels on plant height, ($LSD_{0.05}$ = 3.32).

(24.66%). The enhancement of yield and its attributes under elevated silicon levels can be attributed to improved vegetative growth metrics (Table 5), greater nutrient uptake efficiency and enhanced photosynthetic activity. This improvement positively influenced the translocation and accumulation of photo assimilates and total dry matter, a pattern consistent with the finding of Ben Gaied *et al*. (2024).

Among test cultivars Luz de otono exhibited significant superiority in pod number per plant (10.32 pods plant^{-1}), 100-seed weight (132.12 g), total yield (4587.00 kg ha^{-1}) and seed protein content (24.35%). Variation in yield

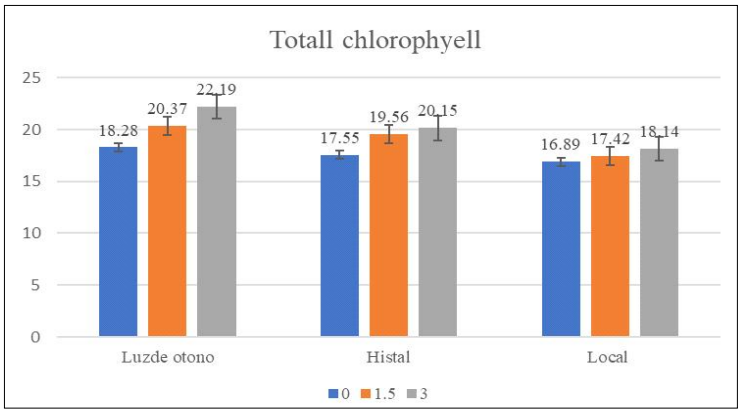


Fig 2: Effect of interaction between cultivars and silicon levels on Total chlorophyll (mg 100 g FW-1). (LSD $_{0.05}$=4.09).

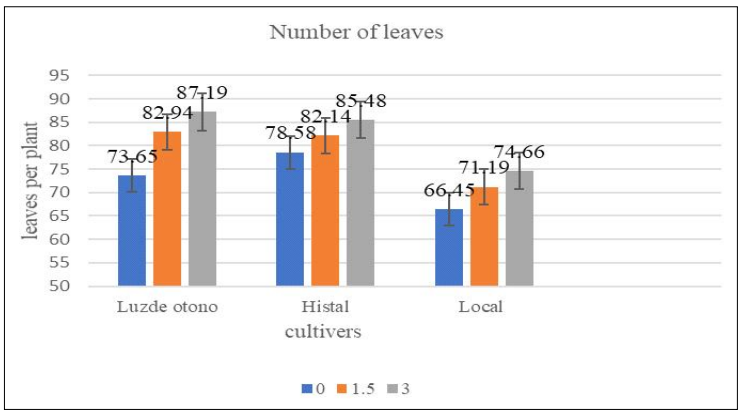


Fig 3: Effect of interaction between cultivars and silicon levels on leaf number, (LSD $_{0.05}$=0.88).

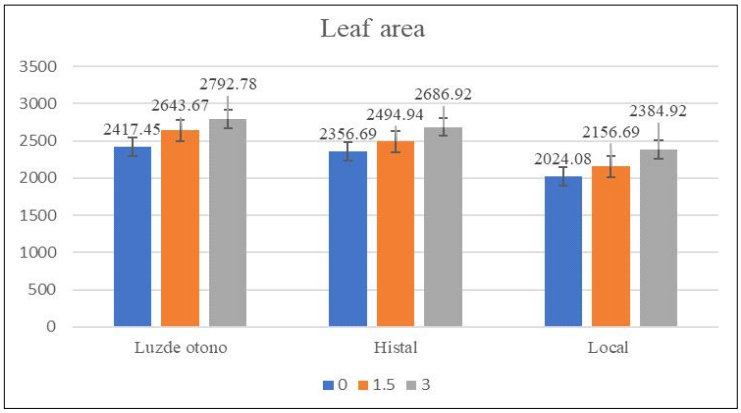


Fig 4: Effect of interaction between cultivars and silicon levels on leaf area, (LSD $_{0.05}$ = 102.62).

components among cultivars likely stem can be linked to higher branch density, leaf number and expanded leaf area (Table 5), which together supply the necessary assimilate sinks for reproductive development (flowering and pod setting). Consequently, this improved the number of seeds per pod and individual seed mass. These observation align with those reported by Alshameri *et al*. (2021); Aleuzayr and Abdulqader (2024); Merhij *et al*. (2024); Madab *et al*. (2025); Hindi *et al*. (2026a); Hindi *et al*. (2026b); Ali *et al*. (2025) and Saleh *et al*. (2026).

Concerning interaction effects, Fig 6 and 7 indicate that applying 1.5 mL L^{-1} silicon (the second concentration) to Luz de otono produced the highest values for pod number (11.63 pod $plant^{-1}$) and seeds per pod (5.89 seeds

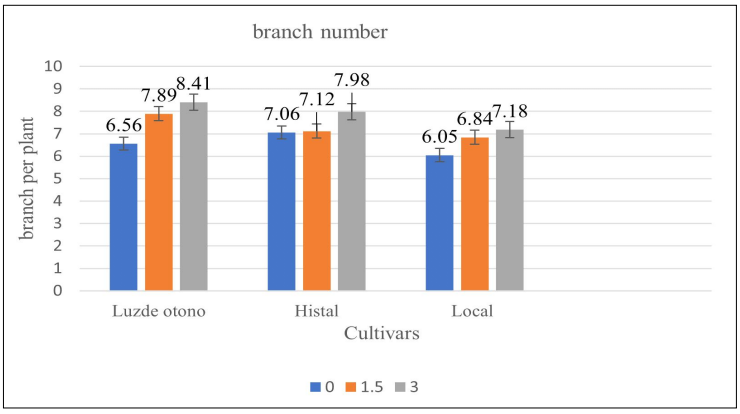


Fig 5: Effect of interaction between cultivars and Silicon levels on number of branches, (LSD 0.05=0.59).

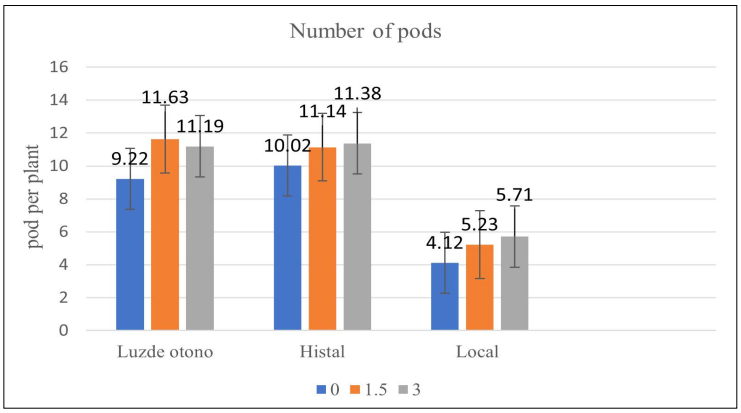


Fig 6: Effect of interaction between cultivars and silicon levels on number of pods. ($LSD_{0.05}$= 1.33).

Table 5: Main effects of spraying silicon on components of yield and yield characteristics of broad bean cultivars.

Cultivar	Number of pods $plant^{-1}$	Number of seeds pod^{-1}	Weight of 100 seeds (g)	Total yield (kg ha^{-1})	Protein content (%)
Luz de Otoño	10.32	5.12	132.12	4587	24.35
Histal	10.11	5.23	125.37	4351	22.58
Local	8.55	4.89	120.26	2147	20.11
LSD (p≤0.05)	0.63	NS	2.87	404.2	1.20
Silicon concentration (mL L^{-1})					
0	7.83	5.16	120.04	3117	20.34
1.5	8.17	6.34	123.45	4232	23.98
3.0	10.04	7.44	129.38	4850	24.66
LSD (p≤0.05)	0.63	0.75	2.87	404.2	1.20

pod^{-1}). Meanwhile, no significant differences were observed between Luz de otono and Histal at highest silicon level (3 mL L^{-1}) regarding 100-seed weight, averaging 132.18 g and 132.74 g, respectively (Fig 8). Similarly, both cultivars showed comparable performances at 3 mL L^{-1} silicon in terms of total yield, reaching 4873.32 kg ha^{-1} and 4843.83 kg ha^{-1}respectivly (Fig 9). Lastly, the combination of Luz de otono with 3 mL L^{-1} silicon yielded the highest seed protein percentage (25.25, Fig 10).

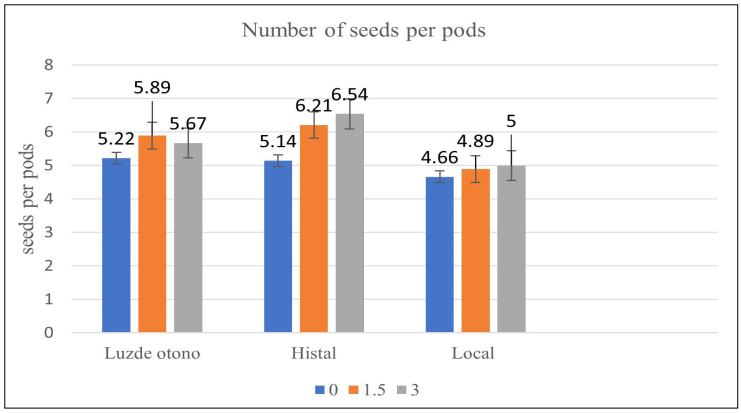


Fig 7: Effect of interaction between cultivars and silicon levels on number of seeds per pod. (LSD0.05= 1.47).

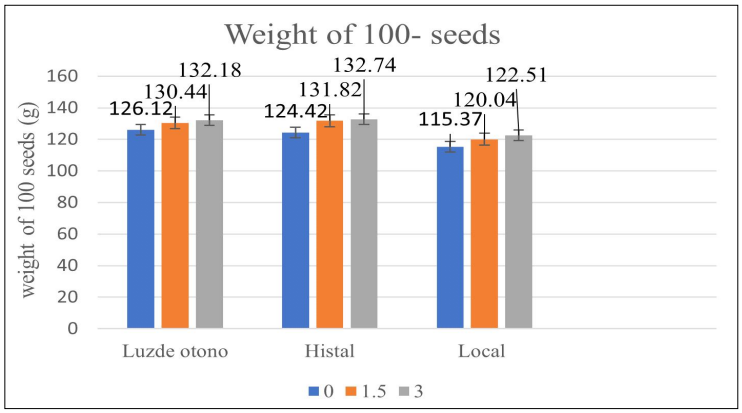


Fig 8: Effect of interaction between cultivars and silicon levels on weight of 100 seeds. (LSD 0.05= 22.34).

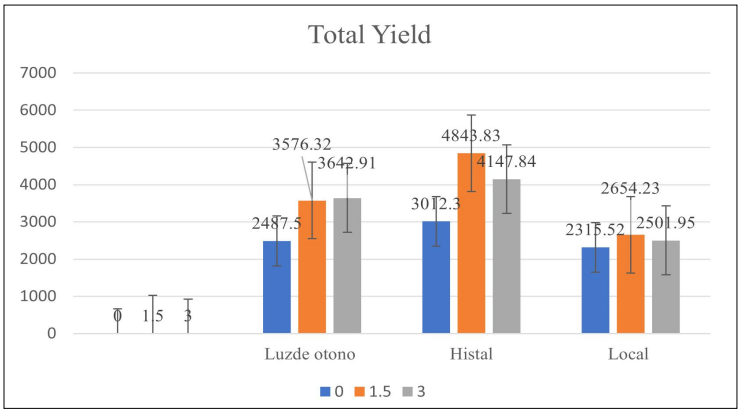


Fig 9: Effect of interaction between cultivars and silicon levels on total yield. (LSD 0.05= 190.41).

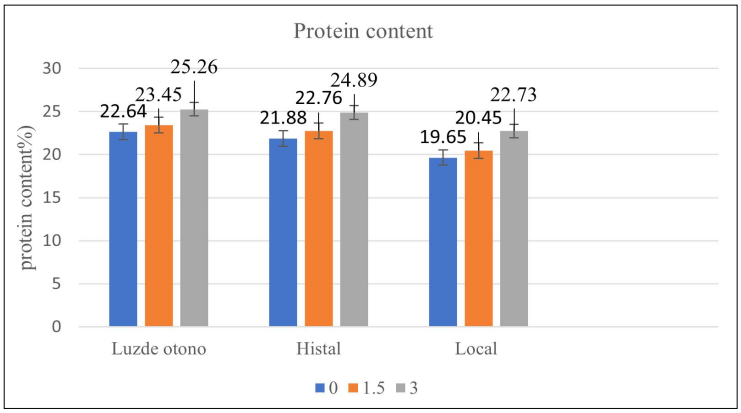


Fig 10: Effect of interaction between cultivars and silicon levels on protein content. (LSD 0.05 = 2.65).

CONCLUSION

This research demonstrates that adding silicon to broad bean production systems is an effective tool for improving biological and productive performance across multiple varieties, with clear variation in cultivar responses and a significant cultivar-treatment interaction. Overall, silicon was associated with improved growth and photosynthetic indicators. The response was most pronounced in environments with moderate stress and in varieties with a higher silicon utilization capacity. The 1.5 ml L^{-1} treatment and the Loz de otono cultivar showed the highest average number of pods per plant and the cultivar Histal showed the highest average in number of seeds per pod. The 3 ml L^{-1} treatment, using the Loz de otono and Histal varieties, showed superior results in 100-seed weight and total yield per unit area. The 3 ml L^{-1} treatment and the Loz de otono cultivar also showed superior results in the percentage of protein content.

ACKNOWLEDGEMENT

The authors acknowledge the support provided by the University of Basrah-College of Agriculture and the Department of Field Crops, which enabled the completion of this study.

Conflict of interest

The authors confirm that there are no conflicts of interest associated with this work.

REFERENCES

Al-Badrawi, R.Y., Huthily, K.H. and Obaid, A.A.R. (2022). Response of faba bean (*Vicia faba* L.) to potassium application and spraying with silicon under salinity stress conditions. *International Journal of Agricultural and Statistical Sciences.* **18(1):** 1467-1471. https://connectjournals.com/03899.2022.18.1467.

Aleuzayr, O.M. and Abdulqader, O.A. (2024). Response of growth and yield of two broad bean (*Vicia faba* L.) varieties to antioxidants and diammonium phosphate (DAP) fertilizer. *Kufa Journal for Agricultural Sciences.* **16(3):** 76-88. https://doi.org/10.36077/kjas/2024/v16i3.11517.

Ali, A.H., Sharif, Y.O.N.A., Raheem, A.H., Hussein, A.A.K. and Al-Mafarji, T.R.T. (2025). The effect of phosphorus levels on growth and yield components in sunflower (*Helianthus annuus* L.). *Agricultural Science Digest*. 1-6. doi: 10.18805/ag.DF-771.

Alshamary, W.F.A., Sharif, Y.O.N.A., Noori, N.E. and Kahlel, A.M.S. (2025). Effect of moisture depletion rate and irrigation water depth on the productivity and water use efficiency of soybean crop (*Glycine max* L.) Merr. under drip irrigation and fixed sprinkler irrigation systems. *Agricultural Science Digest*. **45(2):** 222-227. doi: 10.18805/ag.DF-651.

Alshameri, M.A., Alghamdi, S.S., Gaafar, Z.A., Almunqedhi, M.B., Qahtan, A.A., Hodhod, S. M., and Migdadi, M.H. (2021). Effect of water deficit on yield of different faba bean (*Vicia faba* L.) genotypes. *Legume Research.* **44(6):** 718-722. doi: 10.18805/LR-600.

Alshummary, A.M., Al-Freeh, L.M. and Mohssen, K.H. (2021). Response of faba bean cultivar (*Vicia faba* L.) to phosphorus application. *International Journal of Agricultural and Statistical Sciences.* **17(1):** 329-333. https://connectjournals.com/03899.2021.17.329.

Al-Zubaidi, K.M.D. and Al-Jubouri, K.K.A. (2016). Design and Analysis of Genetic Experiments. Dar Al-Wadhah for Publishing and Dijlah Library for Printing and Publishing.

Atab, H.A., Al-Ubori, R. and Aboohanah, M.A. (2023). Response growth and yield of three broad bean cultivars (*Vicia faba* L.) to spraying with different concentrations of salicylic acid under saline soil conditions. *IOP Conference Series: Earth and Environmental Science.* **1259(1):** 012100. https://doi.org/10.1088/1755-1315/1259/1/012100.

Ben Gaied, R., Brígido, C., Sbissi, I. and Tarhouni, M. (2024). Sustainable strategy to boost legumes growth under salinity and drought stress in semi-arid and arid regions. *Soil Systems.* **8(3):** 84. https://doi.org/10.3390/soilsystems8030084.

Desoky, E.M., Mansour, E., Yasin, M.A.T., El-Sobky, E.E.A. and Rady, M.M. (2020). Improvement of drought tolerance in five different cultivars of *Vicia faba* with foliar application of ascorbic acid or silicon. *Spanish Journal of Agricultural Research.* **18(2):** e0802. https://doi.org/10.5424/sjar/2020182-16122.

Dhull, S.B., Kidwai, M.K., Noor, R., Chawla, P. and Rose, P.K. (2022). A review of nutritional profile and processing of faba bean (*Vicia faba* L.). *Legume Science.* **4(3):** e129. https://doi.org/10.1002/leg3.129.

El Hadj, D., Tellah, S., Goumeida, K., Aitouakli, S., Tifest, C., Ammi, N., Ratet, P., Pulvento, C. and Sellami, M. H. (2022). Evaluation of adaptability of different faba bean landraces under Mediterranean field conditions of central-northern Algeria. *Agronomy.* **12(7):** 1660. https://doi.org/10.3390/agronomy12071660.

Haque, M.S., Husna, M.T., Uddin, M.N., Hossain, M.A., Golam, A.K.M.G., Ali, O.M., Latef, A. A.H.A. and Hossain, A. (2021). Heat stress at early reproductive stage differentially alters several physiological and biochemical traits of three tomato cultivars. *Horticulturae.* **7(10): 330**. https://doi.org/10.3390/horticulturae7100330.

Hindi, H.A., Faisal, L.N., Sharif, Y.O.N.A. and Al-Mafarji, T.R.T. (2026a). Performance evaluation, estimation of genetic and phenotypic correlation coefficients and path coefficient analysis of quantitative traits in triticale genotypes grown under different seeding rates. *Pakistan Journal of Agricultural Research*. **39(1):** 77-88. https://doi.org/10.17582/j.pjar/2026/39.1.77.88.

Hindi, H., Madab, D., Sharif, Y. and Al-Mafarji, T. (2026b). Effect of boron spraying on flour quality traits of bread wheat (*Triticum aestivum* L.) genotypes and estimation of their genetic parameters. *Egyptian Journal of Agronomy*. **48(1):** 175-184. https://doi.org/10.21608/agro.2025.412351.1807.

Karkanis, A., Ntats, G., Lepse, L., Fernández, J.A., Vågen, I.M., Rewald, B., Alsina, I., Kostecka, J., Bariæ, A., Ozturk, M., Bodner, G., Dubova, L., Rosa, E. and Savvas, D. (2018). Faba bean cultivation-revealing novel managing practices for more sustainable and competitive European cropping systems. *Frontiers in Plant Science.* **9:** 1115. https://doi.org/10.3389/fpls.2018.01115.

Kumar, R., Jannu, N., Das, N., Abhishek, R., Kumar, A., Sachan, S., Singh, J. and Kumar, P. (2021). Role of silicon in organic and inorganic nutrient management for improving growth, yield and quality of black gram (*Vigna mungo* L.): A review. *Legume Research*. **49(8):** 1267-1276. doi: 10.18805/LR-5663.

Lichtenthaler, H.K. (1987). Chlorophylls and carotenoids: Pigments of photosynthetic biomembranes. *Methods in Enzymology.* **148:** 350-382. https://doi.org/10.1016/0076-6879(87)48036-1.

Madab, D.S., Hindi, H.A., Sharif, Y.O.N.A. and Al-Mafarji, T.R.T. (2025). Nature in inheritance of yield and its components in different mating designs of cotton genotypes (*Gossypium hirsutum* L.). *Natural and Engineering Sciences*. **10(2):** 495-509. https://doi.org/10.28978/nesciences.1740074.

Merhij, M.Y. and Al-Khafaji, H.M.K. (2023). Effect of different levels of soil salinity on vegetative growth indicators of four genotypes of broad bean *Vicia faba* L. *IOP Conference Series: Earth and Environmental Science*. **1259(1):** 012111. https://doi.org/10.1088/1755-1315/1259/1/012111.

Merhij, M.Y., Hanoon, M.B., Karbul, M.A. and Atab, H.A. (2024). Genotypic and phenotypic variations and genetic gain in faba bean with influence of nano-silicon. *SABRAO Journal of Breeding and Genetics.* **56(4):** 1484-1491. https://doi.org/10.54910/sabrao2024.56.4.14.

Saleh, A.A., Sharif, Y.O.N.A. and Raheem, A.H. (2026). Abscisic acid exogenous spraying to improve sorghum [*Sorghum bicolor* (L.) Moench] genotypes for tolerance to abiotic stress. *Pertanika Journal of Tropical Agricultural Science*. **49(2):** 863-879. https://doi.org/10.47836/pjtas.49.2.20.

Sharif, Y.O.N.A., AL-Abody, M.A.K., Muhammad, S.T. and Al-Mafarji, T.R.T. (2026). Genetic parameters and stability of soybean [*Glycine max* (L.) Merr.] cultivars under nano-phosphorus foliar fertilization levels. *Indian Journal of Agricultural Research*. **60(4):** 518-524. doi: 10.18805/IJARe.AF-981.