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Research Paper

Response of vegetable pea varieties to silicon under late-sown conditions

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ABSTRACT

Late-sown vegetable peas often suffer yield loss and higher disease incidence due to unfavourable weather, yet they offer better market returns. The present investigation was undertaken to study the effect of silicon on different varieties of vegetable pea (*Pisum sativum* L.). The results showed that the performance of both varieties (AP-1 and KP) differed significantly for plant height, number of pods/plant, and green pod yield, and they also responded to silicon application. Simple linear regression analysis showed that Si application of more than 2 ml L^{-1} could give detrimental results. Earliness of a variety shows its genetic potential; findings revealed that it could not be altered by the application of silicon. Regarding quality parameters, such as dry matter (%) in green pods and PLW (%) could not be improved by silicon application. Hence, it is obvious from the findings that the variety AP-1 with Si @ 2 ml L^{-1} would be suggested for the North-Western plains of Uttar Pradesh, India.

Key words: Dry matter, PLW, Silicon, Varieties, Vegetable pea, Yield

INTRODUCTION

Vegetable pea (*Pisum sativum* L.) is an important winter legume crop of the Fabaceae family, widely consumed as a fresh, frozen or canned vegetable. It is a starchy, protein-rich crop containing 21-32% protein and serves as an affordable source of essential amino acids such as tryptophan and lysine (Dahl *et al.* 2012, Orzol *et al.* 2022). In addition to its high protein content, peas contain 20-46% carbohydrates – mainly starch and fiber – and are rich in vitamins (A, B_6, C, and K) and minerals (P, Mg, Cu, Fe, and Zn) (Dahl *et al.* 2012). In India, green peas occupy about 567 thousand hectares, producing approximately 5.85 million tonnes of green legumes (FAO 2021).

Silicon has emerged as an agronomically significant element known to enhance plant tolerance against biotic and abiotic stresses (Liang *et al.* 2005). Continuous intensive cropping often depletes the available soil silicon (Si), particularly in Subtropical tropical and subtropical regions where natural Si reserves are low (Meena *et al.* 2014). Traditionally, the use of ash as a fertilizer provided a supplementary source of both potash and silicon. Plants absorb silicon mainly in the form of monosilicic acid (H_4SiO_4), although uptake capacity varies among species (Marschner 1995). On average, plants absorb from 50 to 200 kg of Si ha^{-1} (Bazilevich 1993). Silicon fertilization increases the concentration of soluble Si in soils, particularly in intensively cultivated systems (Tubaña and Heckman 2015). Both soil and foliar applications of Si have shown beneficial effects on crops such as rice, sugarcane, and wheat (Elawad *et al.* 1982, Anderson *et al.* 1991, Savant *et al.* 1997, Matichenkov and Calvert 2002, Gong *et al.* 2003, Singh *et al.* 2006). Moreover, Si fertilization has been recommended as an essential practice for the improvement of vegetable crop production (Kaushik and Saini 2019).

Although the beneficial role of Si in monocotyledonous crops is well documented, its effects on dicotyledonous species, particularly legumes, remain insufficiently explored (Raza *et al.* 2023). Vegetable pea is typically sown in November in the North Indian plains; however, late sowing crops give poor yield performance and are prone to disease incidence due to unfavourable weather conditions such as rising temperature and unexpected rainfall. Despite this, late-sown vegetable peas tend to fetch better returns from the market.

Therefore, the present investigation was undertaken to evaluate the effect of silicon fertilization on the growth, yield, and quality of two different vegetable pea varieties under late-sown conditions, to determine the optimum silicon dose for enhanced performance.

MATERIALS AND METHODS

Experimental site and soil

The field experiment was conducted at the Agriculture Farm of IFTM University, Moradabad, Uttar Pradesh, India (28°21′ N, 78°00′ E; 193 above msl). The site falls under the North-Western plains Zone of Uttar Pradesh, characterized by a subtropical climate typical of Upper Gangetic Plains. The soil of the experimental field was sandy loam in texture, slightly alkaline (pH=7.8), and well-drained. It contained 0.43% organic carbon, low available nitrogen and medium phosphorus and potassium levels,with adequate micro-nutrient status suitable for vegetable pea cultivation. The experimental plots were uniform in topography and fertility, ensuring consistent growing conditions across treatments.

Experimental design and treatments

The experiment comprised eight treatment combinations, involving two vegetable pea varieties viz. Azad Pea-1 (AP-1) and Kashi Purvi (KP), and 4 levels of silicon (0, 1, 2 and 3ml L^{-1}). Silicon was applied in the form of silica gel formulation containing approximately 20% SiO_2 (Hi-Media Laboratories Pvt. Ltd., Mumbai, India). The experimental field was laid out in a split-plot design with three replications, where varieties were assigned to main plots and silicon levels to subplots. Each plot measured 2m × 3m.

Crop management

The crop was sown under late sown conditions on 2 December 2023 at a spacing of 30 cm between rows, using a seed rate of 80 kg ha^{-1}. The crop received the recommended dose of fertilizers (RDF) at 20:60:40 kg N: P_2O_5: K_2O ha^{-1}. The standard agronomic package of practices was followed to ensure a healthy crop stand. During the crop growth period, the maximum and minimum temperatures ranged from 12.9°C-32.8°C and 3.0-12.3°C, respectively. Silicon was applied as a foliar spray by dissolving silica gel thoroughly in water.

Data recording

The crop was harvested in two pickings, completed by 26 March, 2024. Observations were recorded from five randomly selected plants in each plot for growth and yield parameters, including days to 50% flowering, first fruiting node, plant height (cm), number of branches/plant, days to marketable maturity, harvesting span (days), number of pods per plant, number of seeds per pod, green pod yield (q h^{-1}), dry matter (%) and physiological loss in weight (PLW, %).

Dry matter Content (%): Five pods from each variety in each treatment were picked at marketable maturity, weighed and dried in the oven at 55±5°C till constant weight obtained. The percent dry matter was calculated using the formula:

Dry matter (%)= (Dry weight/ Fresh weight) × 100.

***Physiological loss of weight* (PLW):** Physiological loss in weight was determined by keeping freshly harvested green pods at room temperature for five days. The weight loss was computed using the following formula: PLW (%) = (Initial weight - Final weight)/ Initial weight × 100.

Statistical analysis

The recorded data were analysed using the analysis of variance (ANOVA) technique appropriate for a Split-Plot Design as outlined by Gomez and Gomez (1984). The treatment means were compared using the critical difference (CD) at 5% probability level ($p \leq 0.05$). All statistical computations were performed using the OPSTAT software developed by Sheoran *et al.* (1998) at Chaudhary Charan Singh Haryana Agricultural University, Hisar, India.

RESULTS AND DISCUSSION

The results obtained while studying the effect of silicon on vegetable pea (*Pisum sativum* L.) varieties are presented in Tables 1 and 2.

Flowering and fruiting characteristics

Minimum days to 50% flowering were recorded in the variety AP-1 (65 days), followed by KP (≈70 days). Although silicon alone did not significantly affect flowering, the interaction was significant – AP-1 flowered earlier (64.33 days) under Si @ 2 ml L^{-1}.

Varietal variation in flowering agrees with the findings of Dhangrah *et al.* (2023) in garden peas. The inconsistent response of vegetables to silicon depends on the plant's genotype and on several environmental conditions (Epstein 1999: Toresano-Sánchez *et al.* 2012, Raza *et al.* 2023). Silicon is not considered an essential element but may have beneficial roles under stress (Epstein and Bloom 2005, Guntzer *et al.* 2012, El-Sayed *et al.* 2019).

Silicon had no significant effect on the first fruiting node, which averaged 7.32 in the variety

AP-1 and 7.25 in KP. This suggests the trait may be controlled by homozygous genes so less influenced by external nutrient variation. Similar non-significant effects of silicon on growth and yield traits of pea were reported by Angeles *et al.* (2021).

Vegetative growth attributes

AP-1 exhibited a higher plant height (81.16cm) than KP (70.24cm). Foliar application of silicon significantly increased plant height compared to the control, with the maximum height (84.27cm) observed in AP-1 under Si @ 2 ml L^{-1}. A simple linear regression (R^2 = 0.463) indicated that 46% of the variation in plant height could be explained by silicon level (Figure 1).

The increased plant height may be attributed to improved water relations and reduced transpiration, as supported by Gong *et al.* (2003). Recent research also demonstrates that silicon enhances osmotic adjustment and chlorophyll stability in legumes under stress (Gurmani *et al.* 2022, Raza *et al.* 2023). Several studies confirm the beneficial role of Si in crop growth enhancement (Korndörfer and Lepsch 2001, Kaushik and Saini 2019).

No significant differences were recorded between varieties for the number of branches per plant, days to marketable maturity and harvesting span. The average number of branches was 1.49 per plant and both varieties reached marketable maturity in about 95 days.

However, the harvesting span was significantly affected by silicon, with Si @ 2 ml L^{-1} recording the highest span (10.76 days). The beneficial effects of silicon are known to be limited under optimum conditions but crucial under stress (De Li˜nan 2009, Toresano-Sánchez *et al.* 2012).

Yield attributes

The number of pods per plant was higher in AP-1 (12.55) than KP (10.78). Silicon levels significantly affected pod formation, recording the highest 12.80 pods/plant at Si @ 2 ml L^{-1}, with regression analysis (R^2 = 0.438) showing that 44% of the variation in the number of pods/plant was due to silicon level (Figure 2).

The interaction effect was non-significant, confirming that both factors behaved independently.

Table 1. Main Effect of varieties and silicon levels on growth, yield and quality parameters of vegetable pea.

Factors	Days of 50% flowering	First fruiting node	Plant height (cm)	Number of branches/ plant	Days to marketable maturity	Harvesting span (days)	Number of pods/ plant	No. of seeds/ pod	Green Pod Yield (q ha^{-1})	Dry matter (%)	Physiological loss of weight (PLW) (%)
Varieties											
V_1- Azad Pea-1	65.00^{b}	7.32	81.16^{a}	1.53	94.38	9.94	12.55^{a}	5.85	163.86^{a}	19.49^{a}	39.79^{b}
V_2- K.P.	69.67^{a}	7.25	70.24^{b}	1.45	94.73	9.87	10.78^{b}	6.77	152.18^{b}	18.31^{b}	38.49^{a}
SEm±	0.16	0.09	0.14	0.22	0.16	0.14	0.39	0.30	0.21	0.85	0.16
CD (p=0.05)	1.02	N.S.	0.90	N.S.	N.S.	N.S.	2.53	N.S.	1.39	N.S.	1.06
Silicon level											
Si_1-Control	67.17	7.23	72.40^{b}	1.48	94.62	9.52^{b}	10.70^{c}	6.57	149.42^{c}	17.48^{b}	39.21
Si_2- Silicon @ 1ml/l	67.67	7.33	76.33^{a}	1.51	94.67	9.57^{b}	11.43^{b}	6.17	159.58^{b}	20.01^{a}	38.68
Si_3- Silicon @ 2ml/l	67.33	7.23	78.07^{a}	1.49	94.72	10.76^{a}	12.80^{a}	6.13	165.82^{a}	19.94^{a}	39.50
Si_4- Silicon @ 3ml/l	67.17	7.33	76.00^{a}	1.49	94.22	9.78^{b}	11.73^{b}	6.37	157.27^{b}	18.17^{b}	39.13
SEm±	0.21	0.14	0.71	0.17	0.37	0.19	0.82	0.29	0.76	0.35	0.61
CD (p=0.05)	N.S.	N.S.	2.20	N.S.	N.S.	0.59	2.57	N.S.	2.37	1.09	N.S.

Table 2. Interaction effects between varieties and silicon levels for growth, yield and quality parameters of vegetable pea.

Treatment	Days of 50% flowering	First fruiting node	Plant height (cm)	Number of branches/ plant	Days to marketable maturity	Harvesting span (days)	Number of pods/ plant	No. of seeds/pod	Green Pod Yield (q ha^{-1})	Dry matter (%)	Physiological loss of weight (PLW) (%)
T1-V_1Si_1	65.33	7.40	76.60	1.55	94.00	9.80	12.07	6.20	156.33	17.20	40.15
T2-V_1Si_2	65.33	7.20	82.27	1.52	94.33	9.47	12.60	5.87	163.79	20.82	39.80
T3-V_1Si_3	64.33	7.40	84.27	1.56	95.00	10.50	13.07	5.47	170.95	20.86	40.15
T4-V_1Si_4	65.00	7.27	81.50	1.51	94.17	10.00	12.47	5.87	164.33	19.07	39.05
T5-V_2Si_1	69.00	7.07	68.20	1.41	95.23	9.23	9.33	6.93	142.50	17.75	38.29
T6-V_2Si_2	70.00	7.47	70.40	1.49	95.00	9.67	10.27	6.47	155.37	19.20	37.55
T7-V_2Si_3	70.33	7.07	71.87	1.41	94.43	11.02	12.53	6.80	160.67	19.02	38.87
T8-V_2Si_4	69.33	7.40	70.50	1.47	94.27	9.57	11.00	6.87	150.20	17.28	39.23
Grand Mean	67.33	7.29	75.70	1.49	94.55	9.91	11.67	6.31	158.02	18.90	39.14

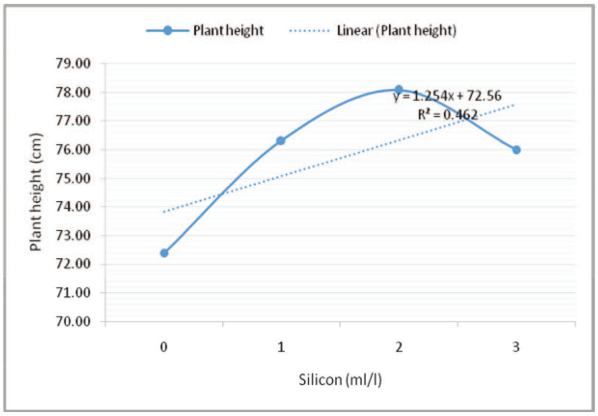

Fig. 1. Effect of silicon on plant height of vegetable pea.

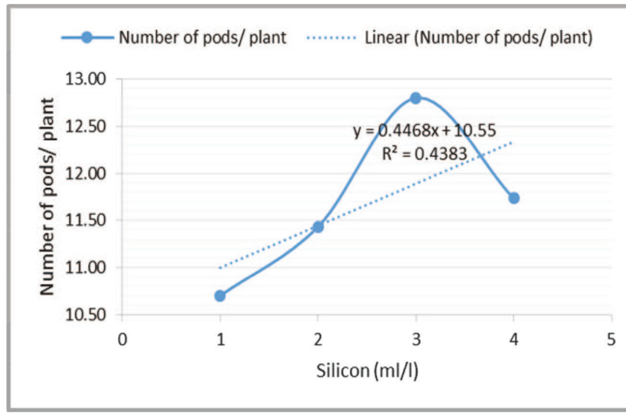

Fig. 2. Effect of silicon on number of pods/plant of vegetable pea.

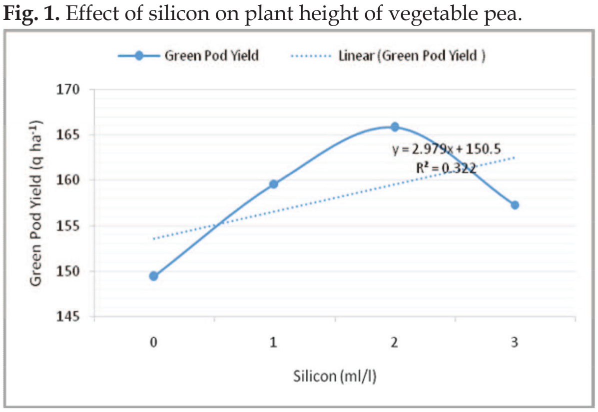

Fig. 3. Effect of silicon on green pod yield of vegetable pea.

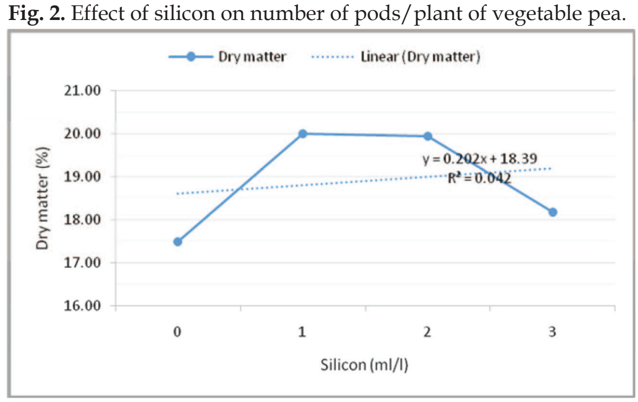

Fig. 4. Effect of silicon on dry matter content of vegetable pea.

Comparable enhancement in fruit set due to silicon application was also observed in cherry tomatoes (Toresano-Sánchez *et al.* 2012) and soybean (Shamshiripour *et al.* 2022).

No significant variation was observed in the number of seeds per pod (6.31 average). This aligns with Angeles *et al.* (2021), who found no significant Si effect on pea yield traits, though Felisberto *et al.* (2021) reported yield improvement in legumes under Si foliar application.

The green pod yield was significantly higher in AP-1 (163.86 q ha^{-1}) than in KP (152.18 q ha^{-1}). Maximum yield (165.82 q ha^{-1}) occurred with Si @ 2 ml L^{-1}, and the regression model (R^2 = 0.322) explained 32% of yield variation by silicon level (Figure 3).

The Si application enhances chlorophyll content and net assimilation, leading to higher yields (Barker and Pilbeam 2007, Raza *et al.* 2023). Similar yield increases under Si fertilization were reported in rice, soybean and tomato (Singh *et al.* 2006, Toresano-Sánchez *et al.* 2012, Meena *et al.* 2014). In tropical soils low in available Si, such responses are often more pronounced.

Dry matter and post-harvest attributes

Silicon significantly influenced dry matter content, with AP-1 (19.49%) showing higher values than KP (18.31%). Maximum dry matter (20.86%) was observed under Si @ 2 ml L^{-1}. Regression (R^2=0.042) showed a weak non-linear relationship with silicon dose (Figure 4), indicating that moderate levels are most effective. Increasing Si supply improves dry weight due to better structural integrity and water retention (Gong *et al.* 2003, Gerami *et al.* 2012). Similar enhancements were reported in barley and soybean (Kudinova 1974, Shamshiripour *et al.* 2022).

For physiological loss in weight (PLW), both varieties performed similarly – AP-1 (39.79%) and KP (38.49%), and Si application had no significant effect. This suggests that postharvest loss in peas is largely independent of foliar Si application. However, Si has been shown to improve postharvest quality in cucumbers (González-García *et al.* 2022), indicating potential for further study in peas.

Summary of interaction significance

Across most traits, the interaction between silicon and variety was statistically non-significant, indicating both factors acted independently for growth, yield, and quality parameters. However, a significant interaction was observed only for days to 50% flowering, where variety and silicon jointly influenced flowering behaviour (Table 2).

CONCLUSION

The vegetable pea variety, AP-1, outperformed KP in growth and yield under the Upper Gangetic Plains of Uttar Pradesh, with foliar silicon at 2 ml L^{-1} significantly boosting performance. While results are location-specific, further studies on nutrient uptake, quality, and economics are needed. Integrating silicon fertilization can enhance pea productivity and resilience in semi-arid regions.

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