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Effect of silicon on food consumption and utilisation indices of fall armyworm in Maize

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Abstract
Fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), a native species of tropical and subtropical regions of the America invaded into India quite recently. A study was conducted to know the effect of silicon on food consumption and utilization pattern of FAW in maize under laboratory conditions.FAW revealed the lowest consumption and utilization indices when fed on maize leaves treated with soil application of calcium silicate @ 200 kg/ha and foliar application of silicic acid @ 0.50 % (CI-0.88, GR-0.13 mg/day, ECI-8.75 %, ECD-19.25 % and AD-24.25 %).Similar effect was noticed when larvae fed withsoil application of calcium silicate @ 100 kg/ha(CI-1.27, GR-0.18 mg/day, ECI-12.75 %, ECD-28.25 % and AD-37.25 %).While, the highest consumption indices (CI-1.73, GR- 0.24 mg/day, ECI-17.05 %, ECD-38.25 % and AD-49.25 %) were indicated by fifth instar larvae when fed with untreated leaves of a maize. Also, the sixth instar larvae registered the lowest consumption and utilization indices when fed on maize leaves treated with soil application of calcium silicate @ 200 kg/ha and foliar application of silicic acid @ 0.50 % (CI-0.93, GR-0.14 mg/day, ECI-8.75 %, ECD-19.35 % and AD-25.35 %) followed by soil application of calcium silicate @ 100 kg/ha (CI-1.37, GR-0.21 mg/day, ECI-13.25 %, ECD-29.40 % and AD-38.60 %). While, the highest consumption indices (CI-1.85, GR- 0.28 mg/day, ECI-17.75 %, ECD-39.25 % and AD-51.75 %) were indicated by untreated control. Hence, the use of silicon had a clear adverse effect on FAW development.

Keywords: Fall armyworm, food consumption, silicon, maize, resistance

Introduction
Maize (*Zea mays* L.) is one of the most important cereal crops in the world agriculture economy both as food for man and feed for animals and is also known as "Queen of cereals" because of high yield potential. At present, the average yield of cereal grains is lower in India due to various biotic and abiotic factors. Among biotic factors, insect pests have been considered as one of the prime reasons for curtailing the yield of the crop. In India, as many as 141 insect pests are known to cause varying degrees of damage to maize crop right from sowing to harvest (Reddy and Trivedi, 2008) [8]. Of the 141 insect pests, the lepidopteran insect pests are known to cause great economic damage in many of the maize growing states throughout the country and are major constraints in its productivity.
Among which, the stem borers, *Chilopartellus*(Swinhoe)and *Sesamiainferens*(Walker), cob borer (*Helicoverpaarmigera*) (Hubner) and armyworm (*Mythimna separata*) (Walker) are major pests causing losses up to 25-40 per cent (Ahad *et al*., 2012) [1]. Recently, the fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith) (Noctuidae: Lepidoptera) is considered as serious pest of maize in India. For the first time in India, the pest is reported on maize from Karnataka during May-June, 2018 (Sharanabasappa*et al.,* 2018) [10]. Destruction could occur within overnight, because of its nocturnal feeding habit and later instars require large amount of food.From Northern Karnataka, the pest has been reported to cause infestation ranging from 6.00 to 100 per cent on maize during *kharif,* 2018 (Mallapur*et al.,* 2018) [5]. To manage fall armyworm, an array of management strategies has been implemented in the world. However, synthetic insecticides have been widely used as an emergence response to destroy the pest and minimize damage to maize crop. Nevertheless, fall armyworm has developed resistance to several insecticides (Yu, 1991) [12]. Keeping in view the expenses for control of fall armyworm, the use of resistance inducers is a promising alternative since the induction of resistance can keep the population of insect pests below the economic injury level, with minimum side effects on the environment. One such resistance inducer is the use of silicon.FAW could be considered as potential threat to maize in India as a main host. Based on its historical association of FAW with maize, the preparedness has been felt essential to combat its incidence on maize in India. To understand the pestiferous nature knowing about the effect of silicon on food consumption and utilization of host plant is important. Thus, present study was conducted involving different instars of larvae of fall armyworm and maize.

Material and Methods
The studies on pattern of consumption, digestion and utilization of food by larvae of *S. frugiperda*were conducted during 2021-22 for fifth and sixth instar. Treatments composed of various silicon sources were applied to the maize plants in pots. The treatment details were as follows: T_1- soil application of calcium silicate at the rate of 200 kg/ha followed by foliar spray of silicic acid at 0.50 per cent at 20 days after sowing of maize in pots, T_2- soil application of calcium silicate at the rate of 100 kg/ha and T_3- untreated control (no silicon application). Maize leaves were subjected for food consumption and utilization assessment.
The procedure of experimentation and observations recording was done according to Waldbauer (1968) [11]. The

larvae were fed with leaf discs of treated plants in the laboratory of Department of Agricultural Entomology at College of Agriculture, Dharwad. Ten larvae per treatment were taken and each treatment was replicated four times thus consist of 40 larvae per treatment for food consumption and utilisation study. The larvae were starved for about four hours and weighed individually before release. The fresh weight of food provided was weighed before release of larvae. After 48 hours (2 days) uneaten food material, larvae and faecal matter were separated and weighed on wet weight basis. In case of control treatment, only fresh food after weighing were kept under the same set of condition to determine the natural loss of moisture, which was used for calculating the corrected weight of consumed leaves by equitation as described by Ghanema (2000) [3].

Corrected weight of consumed food = (Cb/Ca) × Ta

Cb = Initial fresh weight of food without larvae;

Ca = Final weight of food without larvae;

Ta = Final weight of food with larvae after feeding.

To compute various consumption and utilization indices following observations were recorded,

1. Weight of food provided for feeding larvae (mg)
2. Weight of larvae released for feeding on food (mg)
3. Weight of larvae after two days of feeding (mg)
4. Weight of uneaten food material (mg)
5. Weight of the eaten food material (mg)
6. Weight of faecal matter (mg)
7. Weight gained by larvae after feeding (mg)
8. Mean weight of larvae during feeding period (mg)
9. Weight of the food ingested by the larvae was calculated by the formula, Weight of food ingested by the larvae Weight of the food provided for feeding Weight of uneaten – food

The mean weight gained by the larvae was calculated by summing up the initial and final weights of the larva and divided by the duration of feeding period. The measurements were recorded to compute various indices relating to consumption, digestion and utilization as detailed below.

1. $$\text{Growth rate (GR) (mg/day)} = \frac{\text{Weight gained by larvae (mg)}}{\text{Duration of feeding period (days)}}$$

2. $$\text{Consumption index (CI) (mg/day)} = \frac{\text{Weight of food consumed (mg)}}{\text{Duration of feeding period (days) x Mean larval weight during the feeding period}}$$

3. $$\text{Approximate digestibility (AD) (\%)} = \frac{\text{Weight of food ingested (mg) - Faecal matter weight} \times 100}{\text{Duration of feeding period (days)}}$$

4. $$\text{Efficiency of conversion of digested food (ECD) (\%)} = \frac{\text{Weight gained by larvae (mg)}}{\text{Weight of food eaten (mg) – Faecal matter weight (mg)}} \times 100$$

5. $$\text{Efficiency of conversion of ingested food (ECI) (\%)} = \frac{\text{Weight gained by the larva (mg)}}{\text{Weight of food consumed (mg)}} \times 100$$

Results and discussion

The lowest CI was recorded in treatment with soil application of calcium silicate @ 200 kg/ha and foliar application of silicic acid @ 0.50 per cent (0.93 and 0.88 mg/day) followed by soil application of calcium silicate @ 100 kg/ha (1.37 and 1.27 mg/day), respectivelyfor the fifth and sixth instar larvae of FAW. While,the highest CI was recorded in untreated control (1.85 and 1.73 mg/day), respectivelyfor the fifth and sixth instar larvae of FAW (Table 1).

Reduced consumption has led to reduced growth rate. So, the lowest GR was recorded in soil application of calcium silicate @ 200 kg/ha and foliar application of silicic acid @ 0.50 per cent (0.14 and 0.13 mg/day) followed by soil application of calcium silicate @ 100 kg/ha with 0.21 and 0.18 mg/day, respectivelyfor the fifth and sixth instar larvae of FAW. While, the highest GR was recorded in untreated control with 0.28 and 0.24 mg/day, respectivelyfor the fifth and sixth instar larvae of FAW (Table 1).

The lowest AD was recorded in soil application of calcium silicate @ 200 kg/ha and foliar application of silicic acid @ 0.50 per cent (25.35 and 24.25 %) followed by soil application of calcium silicate @ 100 kg/ha (38.60 and 37.25 %). Whereas, the highest AD was recorded in untreated control (51.75 and 49.25 %), respectively for the fifth and sixth instar larvae of FAW (Table 1).

Soil application of calcium silicate @ 200 kg/ha followed by foliar application of silicic acid @ 0.50 per cent recorded the lowest ECD of 19.35 and 19.25 per cent, respectively for the fifth and sixth instar larvae of FAW. This is followed by soil application of calcium silicate @ 100 kg/ha (29.40 and 28.25 %). While, the untreated control recorded the highest ECD of 39.25 and 38.25 per cent, respectively for the fifth and sixth instar larvae of FAW (Table 1).

The highest ECI was recorded in untreated control (17.75 and 17.05 %) and it was lowest in soil application of calcium silicate @ 200 kg/ha followed by foliar application of silicic acid @ 0.50 per cent (8.75 and 8.75 %) and in soil application of calcium silicate @ 100 kg/ha with 13.25 and 12.75 per cent, respectively for the fifth and sixth instar larvae of FAW (Table 1).

Findings are well supported by the reports of Nascimento *et al.* (2018) [6] who documented that leaf consumption by FAW larvae was substantially decreased in rice treated with foliar-applied Si (14.00 %) than with soil-applied Si (11.50 %).Also, Han *et al.* (2015) [4] reported significantly decreased per cent of ECD and ECI in third instar larvae of *C.medinalis*in rice. In the same way, Chand and Muralirangan (2000) [2] reported the Si content in rice had a negative role with respect to the food consumption by *O. nitidula.* Likewise, Salim and Saxena (1992) [9] also reported the reduced food intake, assimilation and growth rate of *S. furcifera*due to Si treatment in rice.Peterson *et al.* (1988) [7] also reported that last instar larvae of the southern armyworm fed on artificial diet containing silicic acid at 10 per cent caused reduced digestibility.

Increased Si content make the leaves more rigid, hence the feeding by *S. frugiperda*decreased. Thus, the consumption index was found decreased and this may be the reason for reduced growth rate. Reason for decreased approximate digestibility may be either due to reduced fitness or any physiological changes might occur in midgut of insect and this may be the reason for decreased efficiency in conversion of digested food and ingested food.

Conclusion

The observations on food consumption and utilization pattern of FAW larvae on leaves of maize convey the message that untreated maize have an edge over silicon

treated maize in supporting the growth and development. However, silicon treatments come in the way of lesser nutritious food due to reduced food consumption and utilization indices. Hence, it is likely that FAW may get establish on silicon treated maize fields but its feeding damage get decreased due to reduced food consumption. Hence, the usage of silicon can induce resistance and protectmaize against FAW.

Table 1: Effect of silicon on food consumption and utilisation indices of fifth and sixth instar larvae of fall armyworm

Tr. No.	Treatment details	Fifth instar larvae					Sixth instar larvae				
		CI (mg/day)	GR (mg/day)	AD (%)	ECD (%)	ECI (%)	CI (mg/day)	GR (mg/day)	AD (%)	ECD (%)	ECI (%)
T_1	SA of calcium silicate @ 200 kg/ha + FA of silicic acid @ 0.50 %	0.88[a]	0.13[a]	24.25 (29.50)[a]	19.25 (26.02)[a]	8.75 (17.20)[a]	0.93[a]	0.14[a]	25.35 (30.22)[a]	19.35 (26.09)[a]	8.75 (17.20)[a]
T_2	SA of calcium silicate @ 100 kg/ha	1.27[b]	0.18[b]	37.25 (37.61)[b]	28.25 (32.42)[b]	12.75 (20.92)[b]	1.37[b]	0.21[b]	38.60 (38.41)[b]	29.40 (32.83)[b]	13.25 (21.34)[b]
T_3	Untreated check	1.73[c]	0.24[c]	49.25 (44.57)[c]	38.25 (38.20)[c]	17.05 (28.38)[c]	1.85[c]	0.28[c]	51.75 (46.00)[c]	39.25 (38.79)[c]	17.75 (24.91)[c]
S.Em ±		0.03	0.004	0.26	0.24	0.196	0.03	0.005	0.294	0.197	0.193
CD @ 1 %		0.06	0.013	0.79	0.73	0.59	0.09	0.017	0.884	0.592	0.581
CV (%)		2.09	3.17	0.93	0.98	1.23	2.95	3.57	1.007	0.79	1.19

SA-Soil application; FA- Foliar application; CI- Consumption index; GR- Growth rate; AD- Approximate digestibility; ECD- Efficiency of conversion of digested food; ECI- Efficiency of conversion of ingested food; Figures in AD, ECD and ECI are arcsine transformed values; Means showing same alphabet do not differ significantly by DMRT (p=0.05).

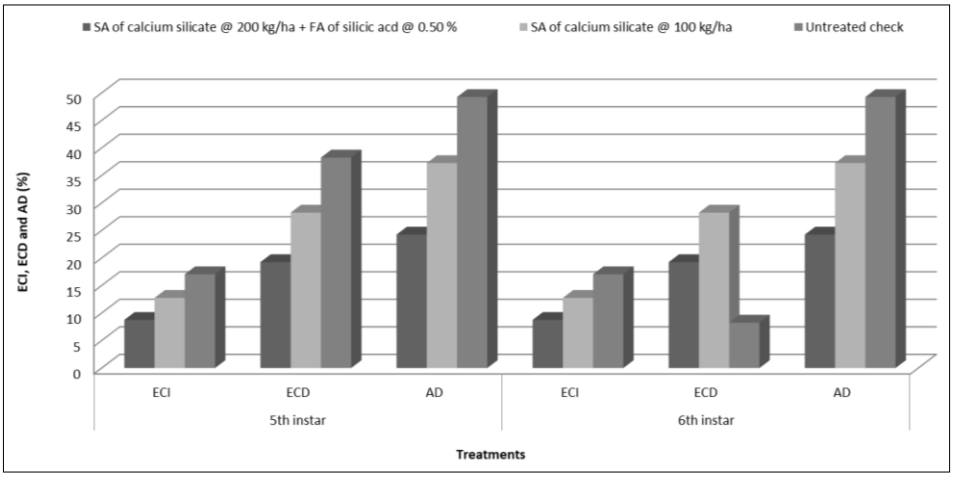

Fig 1: Food consumption and utilisation indices of fall armyworm as influenced by silicon

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