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RESEARCH PAPER

Food consumption and utilization pattern of fall armyworm *(Spodoptera frugiperda* J. E. Smith) in different genotypes of cotton

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Abstract: Fall army worm (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 food consumption and utilization pattern of fall armyworm (FAW) in cotton under laboratory conditions. Highest consumption indices (CI-1.18, GR- 0.23 mg/day, ECI-17.50 %, ECD-42.81 % and AD-51.32 %) were indicated by larvae when fed with leaves of a non-Bt cotton genotype DHH-11. *S. frugiperda* Bt revealed the lowest consumption and utilization indices when fed on leaves of cotton hybrid Bindas BG II (CI-0.21, GR- 0.07mg/day, ECI-7.32 %, ECD-18.44 % and AD-22.44 %).When larvae were fed with squares of non-Bt cotton genotype DHH-11 showed highest indices (CI -0.87, GR- 0.27 mg/day, ECI-38.51 %, ECD-53.37 % and AD-64.55 %) while lowest indices recorded on Bindas BG II Bt (CI -0.30, GR- 0.09 mg/day, ECI-17.57 %, ECD-22.53 % and AD-31.52 %). Similar effect was noticed when larvae fed with cotton bolls Non-Bt cotton genotype DHH-11 could lead to highest indices (CI - 0.87, GR-0.46 mg/day, ECI-38.80 %, ECD-59.44 % and AD-74.31 %) whereas Bindas BG II Bt cotton genotype was not well accepted by the larvae and led to the lowest food intake, utilization and assimilation indices (CI-0.16, GR-0.10 mg/day, ECI-22.49 %, ECD-28.41 % and AD-40.22 %). Among non-Bt genotypes Suvin indicated the lowest value for all the parameters. Among leaf, square and boll fed to the larvae the highest CI (1.18) was noticed for leaves and lowest (0.16) for boll. But highest GR (0.46 mg/day) was indicated when larvae were fed on the bolls followed by squares (0.27 mg/day). Hence, bolls and squares found to be more nutritious than leaves to larvae of *S. frugiperda*.

Keywords: Cotton, Fall army worm, Food consumption, Utilization

Introduction

Invasion of new pests in any agro-ecosystem are potential threats to pest management. Cotton in India suffered lot due to invasion of mealy bug, *Phenacoccus solenopsis* (Tinesly) (Nagrare *et al*., 2009) during last decade. Now another potential threat for cotton is expected due to recent invasion of fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), a native species of tropical and subtropical regions of the America invaded into India quite recently. In the Indian subcontinent, fall armyworm has been detected for the first time in mid-May 2018 in maize fields at the College of Agriculture, (UAHS), Shivamogga, Karnataka by Sharanabasappa *et al.* (2018). FAW is geographically wide spread and known to feed on a wide range of cultivated plants (Luginbill, 1928). Notorious pestiferous nature with high dispersal ability, wide host range and high fecundity makes the FAW as one of the most severe economic pest. Being a polyphagous pest, FAW is known to cause severe damage to economically important crops such as rice, sorghum, and sugarcane as well as cotton, peanut, soybean, cabbage, beet, alfalfa, onion, pasture grasses, millet, tomato and potato (Chormule *et al.*, 2019). Fall armyworm is a sporadic but damaging pest on cotton. The corn strain of FAW feeds predominantly on maize, sorghum and cotton (Prasanna *et al.,* 2018). This pest has been reported as a severe economic pest of cotton in Alabama, Florida, Georgia and Louisiana regions of USA (Smith, 1985). FAW caused economic damage to cotton throughout the southeastern United States during 1977 and in 1984, caused significant damage in the Winter Garden area of Texas. In 1985, it was reported as the single most destructive pest of cotton in Mississippi (King *et al*., 1986). In 2009, FAW has been reported to have infested over 45,000 acres of cotton field and due to its infestation, 124 bales of cotton were lost in Lousiana. It has been ranked as fifth dreaded pest of cotton. Cotton, *Gossypium* spp. (F: Malvaeceae) is an important natural fibre crop. It plays a key role in the national economy of the country in terms of generation of direct and indirect employment in the agricultural and industrial sectors. The first ever occurrence of fall armyworm on cotton crop was reported from Susare village of Ahmednagar district in Western Maharashtra in 2019. Thus, due to favorable climatic conditions FAW could be considered as potential threat to cotton in India as an already relished host in its nativity. Based on its historical association of FAW with cotton, the preparedness has been felt essential to combat its incidence on cotton in India. To understand the pestiferous nature knowing about food consumption and utilization of various parts of host plant is important. Thus, present study was conducted involving different Bt and non-Bt cotton genotypes.

Material and methods

The studies on pattern of consumption, digestion and utilization of food by larvae of *S. frugiperda* were conducted during 2019-20 for third instar. The study involved ten genotypes having both BG-I and BG-II cotton hybrids along with non Bt cotton genotypes. The stage of the crop during the study was around 80-90 days. Cotton leaves (mid canopy-fully opened), squares and bolls were subjected for food consumption and utilization assessment.

The procedure of experimentation and observations followed were according to Waldbauer (1968) and Somashekara (2009). Ten larvae were used per treatment and replicated four times. The larvae were fed with fully opened leaves (taken from the middle region of the plant canopy), squares and tender bolls in the laboratory at ARS, Dharwad. 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 fecal matter was separated and weighed out 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 described by Ghanema (2002).

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 the observations recorded were weight of food provided for feeding larvae (mg), weight of larvae released for feeding on food (mg), weight of larvae after two days of feeding (mg), weight of uneaten food material (mg), weight of the eaten food material (mg), weight of fecal matter (mg), Weight gained by larvae after feeding (mg) and mean weight of larvae during feeding period (mg)

Weight of the food ingested by the larvae was calculated as the weight of the food provided for feeding minus weight of uneaten food.

The mean weight gained by the larvae was calculated by summing up the initial and final weights determined 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. $$\text{Consumption index (CI)} = \frac{\text{Weight of food consumed (mg)}}{\text{Duration of feeding period (days) x Mean larval weight during the feeding period}}$$

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

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

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

Food consumption and utilization parameters *viz.,* consumption index (CI), growth rate (GR), efficacy of conversion of ingested food (ECI), efficacy of conversion of digested food (ECD) and approximate digestibility (AD) were calculated with respect to leaves, squares and bolls of different cotton genotypes.

The consumption index (CI) was found to be significantly lowest when larvae were fed with leaves of Bindas BG II (0.21) cotton and was on par with MRC -7918 BG II (0.23) (Table 1). Lower CI was recorded when larvae fed with Arjun-21 (1.03) a fusion gene Bt cotton genotype and MRC-6918 BG I (1.04) cotton genotype and both were found on par with each other. Both non- Bt cotton genotypes RAhS-14 and DHH-11 (1.18) recorded highest CI followed by DCH-32 (1.16) and Sahana (1.15) all these genotypes were found on par to each other. Among non-Bt cotton genotypes, DLSa-17 and Suvin (1.14) recorded lowest CI.

Reduced food consumption has led to reduced growth indices. Therefore, lowest growth rate (GR) was observed in Bindas and MRC-7918 with 0.07 and 0.08 mg/day, respectively. Larvae fed on Arjun-21 and MRC-6918 recorded GR 0.15 and 0.16 mg/day, respectively and both were on par with each other. Non-Bt cotton genotypes, RAhS-14 and DHH-11 recorded highest (0.23 mg/day) GR followed by Sahana (0.22 mg/day), DCH-32 (0.22 mg/day), DLSa-17 (0.21 mg/day) and Suvin (0.19 mg/day).

Compared to BG I and BG II genotypes, non-Bt genotypes recorded highest efficiency of conversion of ingested food (ECI). It was found to be highest in DHH-11 (17.50 %) followed by RAhS-14 (17.25 %). DCH-32 (16.99 %) and Sahana (16.56 %) and DLSa-17 (16.01 %).

Non-Bt cotton genotype DHH-11 indicated the highest ECD of 42.81 per cent followed by RAhS-14 (41.31 %) and DCH-32 (41.16 %) which were on par with each other. Further, Sahana (40.35 %), DLSa-17 (37.65 %) and Suvin (33.17 %) fall in the row. Bindas recorded the lowest ECD of 18.44 per cent and found on par with MRC-7918 (19.20 %), Arjun-21(29.84 %) and MRC-6918 (30.14 %).

AD was found to be significantly lowest in Bindas (22.44 %) and MRC-7918 (23.21 %) both being on par. Arjun-21 and MRC-6718 recorded lower AD values of 37.84 and 38.12 per cent, respectively. Highest AD was indicated by DHH-11 (51.32 %) which was found on par with RAhS-14 (51.16 %) followed by DCH-32 (50.35 %), Sahana (47.81 %) and DLSa-17 (47.66 %). Among the non-Bt cotton genotypes Suvin (43.17%) recorded the minimum AD.

Non-Bt cotton genotypes rendered highest consumption index (0.83 to 0.87) (Table 2). DHH-11 recorded maximum CI of 0.87 and Suvin recorded minimum CI of 0.83. Bindas BG II (0.30) cotton genotype recorded the lowest CI and MRC-7918 BG II (0.32) followed by an on par record in case Arjun-21 (0.53) fusion gene Bt cotton genotype which revealed lower CI followed by BG I Bt cotton genotype MRC-6918 (0.59).

Table 1. Food consumption and utilization indices of *S. frugiperda* third instar larvae fed on leaves of different cotton genotypes

Genotypes	CI	GR (mg/day)	ECI (%)	ECD (%)	AD (%)
Sahana	1.15[ab]	0.22[a]	16.56(23.99)[abc]	40.35(39.42)[b]	47.81(40.84)[a]
DLSa-17	1.14[b]	0.21[ab]	16.01(23.56) [abcd]	37.65(37.83)[c]	47.66(37.83)[bc]
DCH-32	1.16[ab]	0.22[a]	16.99(24.32)[abc]	41.16(39.89)[ab]	50.35(39.42)[ab]
Suvin	1.14[b]	0.19[b]	15.26(22.96)[bcd]	33.17(35.15)[d]	43.17(36.15)[c]
DHH-11	1.18[a]	0.23[a]	17.50(24.71)[a]	42.81(40.84)[a]	51.32(39.97)[ab]
RAhS-14	1.18[a]	0.23[a]	17.25(24.52)[ab]	41.31(39.98)[ab]	51.16(39.89)[ab]
Arjun-21 Bt	1.03[c]	0.15[c]	14.41(22.28)[d]	29.84(33.09)[e]	37.84(33.09)[d]
MRC-6918 Bt	1.04[c]	0.16[c]	14.93(22.71)[cd]	30.14(33.28)[e]	38.12(32.29)[d]
MRC-7918 Bt	0.23[d]	0.08[d]	7.46(15.82)[e]	19.20(25.97)[e]	23.21(28.78)[e]
Bindas (7213-2) Bt	0.21[d]	0.07[d]	7.32(15.66)[e]	18.44(25.41)[e]	22.44(28.26)[e]
S.Em.±	0.01	0.004	0.53	0.44	0.89
C.D. @ 5%	0.03	0.012	1.54	1.26	2.59
C.V. (%)	2.48	4.87	4.85	2.49	4.51

Figures in the parenthesis are arc sine transformations.

Means showing similar alphabets in the column do not differ significantly by DMRT (p=0.05)

CI: Consumption index GR: Growth rate ECI: Efficiency of conversion of ingested food

ECD: Efficiency of conversion of digested food AD: Approximate digestibility

The GR found to be significantly least when larvae were fed with the squares of Bindas BG II (0.09 mg/day) Bt cotton genotype and MRC-7918 BG II (0.10 mg/day) both being on par statistically. Arjun-21 fusion gene Bt cotton recorded GR of 0.17 mg/day and found on par with MRC-6198 (0.18 mg/day). Conventional non-Bt cotton genotypes indicated highest GR (0.23 to 0.27 mg/day). DHH-11 recorded the highest GR of 0.27 mg/day. It was followed by RAhS-14 (0.26 mg/day), Sahana (0.25 mg/day), whereas, DLSa-17 and DCH-32 recorded similar GR of 0.24 mg/day and Suvin recorded the least GR of 0.23 mg/day. Bindas BG II (17.57 %) Bt cotton genotype revealed the least ECI and MRC-7918 (19.62 %) found on par to it followed by Arjun-21 (26.58 %) and MRC-6918 (28.52 %). While non-Bt cotton genotypes recorded highest ECI (34.52 % to 38.51 %). Among the non-Bt genotypes DHH-11 and Suvin revealed the maximum and minimum ECI of 38.51 and 34.52 per cent, respectively, whereas Sahana (35.71 %), DLSa-17 (35.93 %), DCH-32 (36.52 %) and RAhS-14 (37.47 %) found on par.

ECD found to be significantly highest in DHH-11 (53.37 %) followed by RAhS-14 (52.59 %) and found on par with Sahana (50.53 %), DLSa-17 (50.62 %) and DCH-32 (50.44 %) followed by Suvin (49.76 %). Lowest ECD was recorded from Bindas (22.53 %) followed by MRC-7918 (25.78 %) whereas, Arjun-21 and MRC 6918 recorded the lower ECD values of 39.48 and 41.66 per cent, respectively.

Approximate digestibility (AD) found to be highest in DHH-11 (64.55 %) and RAhS-14 (64.09 %), DCH-32 (63.76 %) and Sahana (62.69 %) statistically all being on par. Lowest AD was observed in Bindas BG II (31.52 %) followed by MRC-7918 BG II (32.15 %) Arjun-21 (58.20 %) and MRC-6918 (59.57 %).

The CI was found to be least for Bindas BG II (0.16) and MRC-7918 BG II (0.18) both being on par to each other (Table 3). Similarly, Arjun-21 (0.46) and MRC-6918 (0.47) were also on par with each other with respect to CI values. Highest CI was indicated by DHH-11 (0.87) and RAhS-14 (0.85) and these two were on par with each other. DCH-32 (0.84), Sahana (0.83), DLSa-17 (0.81) and Suvin (0.79) were next in the order of CI values. Highest GR was recorded from DHH-11 (0.46 mg/day) followed by RAhS-14 (0.45 mg/day), DCH-32 (0.44 mg/day), Sahana (0.43 mg/day), DLSa-17 (0.42 mg/day) and Suvin (0.40 mg/day). Least GR was revealed by Bindas (0.10 mg/day) followed by MRC-7918 (0.13 mg/day), Arjun-21(0.14 mg/day) and MRC-6918 (0.16 mg/day).

Efficiency of conversion of ingested food (ECI) was found to be lowest when larvae were fed with the bolls of Bindas BG II (22.49 %) Bt cotton genotype and found on par with MRC-7918 (23.67 %) followed by Arjun-21 (28.18 %) and MRC-6918 (30.30 %). Highest ECI war recorded from non-Bt cotton genotype DHH-11 (38.80 %) and found on par with RAhS-14 (38.24 %). Among the non-Bt genotypes Suvin recorded minimum ECI of 34.36 per cent.

Efficiency of conversion of digested food (ECD) indicates the assimilated food that converted into biomass. ECD was found to be highest in DHH-11 (59.44 %) followed by RAhS-14 (58.64 %). Further, DCH-32 (57.45 %) and Sahana (56.74 %) were found on par to each other followed by DLSa-17 (55.71 %) and Suvin (54.62 %). Lowest ECD (28.41 %) was recorded from Bindas followed by MRC-7918 (31.39 %), Arjun-21 (39.12 %) and MRC-6918 (42.38 %).

The lowest AD was revealed from Bindas (40.22 %) and found on par with MRC-7918 (42.12 %) followed by Arjun-21 and MRC-6918 with 58.42 and 60.59 per cent, respectively. While conventional cotton genotypes recorded the highest AD of 74.31 per cent (DHH-11) to 70.24 per cent (Suvin).

The literature pertaining to food consumption and utilization of FAW on different cotton genotypes is scanty. The results of the present study are in close approximation with the findings of Ramalho *et al.* (2011) who opined that

Table 2. Food consumption and utilization indices of *S. frugiperda* third instar larvae fed on squares of different cotton genotypes

Genotypes	CI	GR (mg/day)	ECI (%)	ECD (%)	AD (%)
Sahana	0.85[abc]	0.25[bc]	35.71(36.67)[ab]	50.53(45.29)[ab]	62.69(52.34)[a]
DLSa-17	0.85[abc]	0.24[cd]	35.93(36.81)[ab]	50.62(45.34)[ab]	63.39(52.75)[a]
DCH-32	0.84[bc]	0.24[cd]	36.52(37.16)[ab]	51.44(45.81)[ab]	63.76[a](52.97)[a]
Suvin	0.83[c]	0.23[d]	34.52(35.97)[b]	49.76(44.85)[b]	62.35(52.13)[ab]
DHH-11	0.87[a]	0.27[a]	38.51(38.34)[a]	53.37(46.91)[a]	64.55(53.44)[a]
RAhS-14	0.86[ab]	0.26[ab]	37.47(37.73)[ab]	52.59(46.47)[ab]	64.09(53.16)[a]
Arjun-21Bt	0.53[e]	0.17[e]	26.58(31.01)[c]	39.48(38.91)[c]	58.20(49.70)[c]
MRC-6918 Bt	0.59[d]	0.18[e]	28.52 (32.26)[c]	41.66(40.18)[c]	59.57(50.49)[bc]
MRC-7918 Bt	0.32[f]	0.10[f]	19.62(26.26)[d]	25.78(30.48)[d]	32.15(34.52)[d]
BINDAS (7213-2) Bt	0.30[f]	0.09[f]	17.57(24.75)[d]	22.53(28.31)[e]	31.52(34.13)[e]
S.Em. ±	0.01	0.01	0.57	0.58	0.59
C.D. @ 5%	0.03	0.015	1.65	1.68	1.71
C.V. (%)	2.61	4.85	3.39	2.82	2.44

Figures in the parenthesis are arc sine transformations..

Means showing similar alphabets in the column do not differ significantly by DMRT (p=0.05)

CI: Consumption index GR: Growth rate ECI: Efficiency of conversion of ingested food

ECD: Efficiency of conversion of digested food AD: Approximate digestibility

Table 3. Food consumption and utilization indices of *S. frugiperda* third instar larvae fed on bolls of different cotton genotypes

Genotypes	CI	GR (mg/day)	ECI (%)	ECD (%)	AD (%)
Sahana	0.83[bc]	0.43[cd]	35.54(36.58)[ab]	56.74(48.85)[abc]	71.58(57.77)[ab]
DLSa- 17	0.81[cd]	0.42[d]	34.83(36.15)[b]	55.71(48.26)[bc]	71.48(57.70)[ab]
DCH-32	0.84[b]	0.44[bc]	37.20(37.56)[ab]	57.45(49.27)[abc]	72.41(58.30)[ab]
SUVIN	0.79[d]	0.40[e]	34.36(35.86)[b]	54.62(47.64)[c]	70.24(56.92)[b]
DHH-11	0.87[a]	0.46[a]	38.80(38.51)[a]	59.44(50.42)[a]	74.31(59.53)[a]
RAhS-14	0.85[ab]	0.45[ab]	38.24(38.18)[a]	58.64(49.96)[ab]	73.61(59.07)[a]
ARJUN-21Bt	0.46[e]	0.14[g]	28.18(32.04)[c]	39.1240.60)[d]	58.42(49.83)[c]
MRC-6918 Bt	0.47[e]	0.16[f]	30.30(33.37)[c]	42.38(38.70)[e]	60.59(51.10)[c]
MRC-7918Bt	0.18[f]	0.13[g]	23.67(29.09)[d]	31.39(32.18)[g]	42.12(40.45)[d]
BINDAS (7213-2) Bt	0.16[f]	0.10[h]	22.49(28.29)[d]	28.41(34.05)[f]	40.22(39.34)[d]
S.Em. ±	0.01	0.01	0.62	0.55	0.58
C.D. @5%	0.02	0.02	1.78	1.59	1.67
C.V. (%)	2.59	4.15	3.57	2.50	2.18

Figures in the parenthesis are arc sine transformations.

Means showing similar alphabets in the column do not differ significantly by DMRT (p=0.05)

CI: Consumption index GR: Growth rate ECI: Efficiency of conversion of ingested food

ECD: Efficiency of conversion of digested food AD: Approximate digestibility

relative growth, consumption and metabolic rates as well as other nutritional indices were lower when larvae fed with Bt cotton leaves than those fed on non-Bt cotton. Similar kind of investigation was also carried on rice by Pantoja *et al.* (1987) on two strains of fall armyworm who reported that there were no significant differences in approximate digestibility or efficiency of conversion of ingested food. Further, it was said that ECD was identical for both FAW strains. Thus, the strain whichever is invasive into India is likely to relish all host crops including cotton. However, quite recently (Firake and Behare, 2020) when growth and development of FAW was observed in ginger and maize, it was opined that maize favours the FAW larvae.

Conclusion

The observations on food consumption and utilization pattern of FAW larvae on foliage and reproductive parts convey the message that cotton could be a relishable host. Of course the conventional genotypes have an edge over Bt genotypes in supporting the growth and development. However, Bt toxins come in the way of efficient utilization of digested food. Hence, it is likely that FAW may get establish on refugia portion of cotton fields when refugia is planted around Bt plants and not protected for the Lepidopteran pests. In such instances seed mixtures appears ideal where non-Bt cotton seeds are planted randomly as admixtures.

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