ISSN: 2456–5474 RNI No.UPBIL/2016/68367 Vol-2* Issue-7* August- 2017
Innovation The Research Concept

Studies on Food Intake in Relation to Rate of Growth of 'AK' Grasshopper, Poecilocerus Pictus (Fabr.) on Three Dietary Regimes

Suman Godara
Research Scholar,
Deptt.of Zoology,
Jai Narain Vyas University,
Jodhpur, Rajasthan

Abstract

AK grasshopper, *Poecilocerus pictus* is a serious polyphagous pest belong to the family Acrididae, consisting of about 10,000 species. It is distributed throughout the Indo-Pak subcontinents where annual precipitation is below 150 mm. This insect is a habitant of dry conditions and well flourishes on *Calotropies procera* (Aak). The 'AK' grasshopper, *Poecilocerus pictus* is found to occur in all the *kharif* crops and grasses grown during monsoon season in the arid districts of Rajasthan. An overall understanding of the interaction between an insect and its food requirement, measurement of rate of food ingested, digestibility efficiency of conversion of food into body substance and relative growth rate. It is important to know that not only what an insect eats but also how good it is for its food intake and relative rate of growth. This becomes all the more necessary while rearing a polyphagous pest insect like AK grasshopper, *Poecilocerus pictus* in the laboratory. Therefore in the present study an attempt has been made to obtain information on the effect of three dietary regimes (Aak, cotton and papaya laeves) on food ingested and mean weight attained, cumulative live weight versus food consumption, relative consumption rate (RCR), relative defecation rate (RDR), progressive food assimilation (RCR–RDR) and relative growth rate (RGR) of the AK grasshopper, *Poecilocerus pictus*. The results showed that the Aak fed diet have a higher rate of food ingestion, cumulative live weight versus food consumption, relative consumption rate (RCR), relative defecation rate (RDR), progressive food assimilation (RCR–RDR) and relative growth rate (RGR) as followed by cotton and papaya. The minimum RGR recorded 0.30, 0.20 and 0.15 mg/100 mg body weight per day for Aak, Cotton and Papaya fed diet respectively. The ranking of the three dietary regimes in terms of RGR as: Aak > Cotton > Papaya.

Keywords: Poecilocerus Pictus, Calotropies Procera, Relative Growth Rate, Dietary Regimes

Introduction

AK grasshopper (*Poecilocerus pictus)* represents a major group of insect pest in India. Grasshopper consume considerable amount of foliage during their nymphal development stage and as adults when they are abundant, they can damage economically important crops. Food and optimal weather condition also facilitate growth and development of 'AK' grasshopper. The 'AK' grasshopper infestation problem is seasonal, in all the *kharif* crops and grasses grown during rainy season in the Jodhpur district of Rajasthan. Especially in arid part of Rajasthan, the 'AK' grasshopper problem is severe on green fodder plants during rainy season i.e., from July to September. *Poecilocerus pictus* attacked a variety of fodder crops in almost all districts of western Rajasthan in general and in the areas of relatively low rainfall in particular.

The food plants play vital role in the survival and growth potential of orthopteran insects, specially 'AK' grasshopper. The different host plant influence the physiology of insect and thus indirectly affects its biology leading to shortening and lengthening of the duration of different stages of development. No plant species is attacked by all the insect species in an environment, nor it is common, if it occur at all, that an insect species devorce indiscriminating, all the plant in its geographic range (Thorsteinson, 1955 and 1969).

Review of Literature

The food preference for a particular host plant depends on the presence of a particular nutrient or a mixture of nutrients. Nutrients present in the host plant act as phagostimulants and feeding incidents for orthopteran grasshoppers. A phytophagus insect in a presence of a plant located either through its own foraging activities or otherwise does or does not feed on the plant. Thoresteinson (1953), Poonia (1978), Kuntal (1990), Gehlot (2005) and Pipralia (2012) has suggested that the choice of food plant by phytophagus insect was guided by the presence or absence of deterrint or toxic factors rather than by specific attractants.

Despland and Simpson (2000) analyzed the role of food distribution and nutritional quality in behavioural phase change in the desert locust. Andersen *et al.* (2000) studied about the grasshopper (Orthoptera: Acridoidea, Eumastacoidea and Tettigonioidea) fauna of Kakadu National Park in the Australian seasonal tropics, biogeography, habital associations and functional groups. Biology of the *P. pictus* on the basis of its nutritive ecology was observed by living stone and Pugalenthi (1992) and the egg laying behaviour described on the basis of laboratory conditions by Behura and Bohidar (1989). Sayed *et al.* (1994) studied the effects of food plants on the biology of *P. pictus* and its food consumption and rate of development. Feeding preference of *P. pictus* was studied in laboratory by Chandra and Singh (1993). Howard (1995) has discussed the variation in dietary amongst and within polyphagus grasshopper species. Incidence of *P. pictus* (Pyrgomorphidae: Orthoptera) on some new hosts in arid western Rajasthan were studied by Verma (1998), Gehlot (2005), Katoch (2009) and Pipralia (2012).

The various growth indices in different insects were reported by several workers namely Legay (1958) in *Bombyx mori*; Bhat and Bhattacharya (1978) in *Spodoptera litura*; Sachan (1981) in *Diacrisia oblique*; Machanda *et al.* (1982) in *Schistocerca gregaria*, Triphati *et al.* (1986) in *Lipaphis erysimi*, Sharma and Choudhary (1988) in *Heliothis armigera*, Singh and Sachan (1997) in *D. oblique*; Dukas and Bernays (2000) in grasshoppers and Danner and Joern (2004) in *Ageneotettise deorum*.

Perusal of literature revealed that there have been a very few studies on the food intake in relation to relative growth rate of the adult 'AK' grasshopper, *Poecilocerus pictus*. Therefore, present paper deals with a comparative account of the food and feeding behavior of 'AK' grasshopper, *Poecilocerus pictus* on three dietary regimes.

Aim of the Study

The major aspects of present study is to investigate the food ingested and mean weight attained by insect, cumulative live weight versus food consumption, relative consumption rate (RCR), relative defecation rate (RDR), progressive food assimilation (RCR–RDR) and relative growth rate (RGR) of the of three dietary regimes by the adult 'AK' grasshopper, *Poecilocerus pictus*.

Material and Methods

The 'AK' Grasshopper, *Poecilocerus pictus* is usually found during the monsoon and post monsoon season immensely on *calotropics* plants. The adults of *Poecilocerus pictus* were collected from the vicinity of villages around Jodhpur district as well as in field of Central Arid Zone Research Institute, Jodhpur and New Campus of JNV University, Jodhpur. These 'AK' grasshoppers were kept in breeding cage in the laboratory, the bottom of breeding cage was provided with 10 cm layer of moist soil. The soil in the breeding cage was regularly moistened with water for proper breeding. The grasshoppers were kept for culture and breeding which was maintained at 30 to 35°C and with proper relative humidity.

Quantification of Various Growth Indices

The quantification of various growth indices were depends upon daily weight gain by adults 'AK' grasshopper, *Poecilocerus pictus* on three dietary regimes (Aak, Cotton and Papaya). The maximum weight gained and its decline after a certain peck was recorded. The data on dry matter ingestion, mean weight increase, relative consumption rate (RCR) and progressive assimilation (RCR-RDR) were recorded daily on dry weight basis fed on three dietary regimes.

Freshly emerged adult of *Poecilocerus pictus* were selected for experiments on feeding and food utilization profiles. Experiments were conducted at room temperatures. Treatments and control groups had ten grasshoppers each. The grasshoppers, which diet during the experimental period, were discarded for computing various parameters.

'AK' grasshoppers were kept individually in glass jars containing fresh leaves of dietary regimes as food and each grasshopper was considered as a replicate. The grasshoppers were weighed and placed in beakers with known (weighed) quantity of food (leaves) separately. Food supplied was weighed to the nearest second digit of mg. Leaves of the same age, thickness and area were chosen to avoid variation of water content and evaporation. The percent moisture loss from the leaves during the feeding period was determined by keeping the same quantity of leaves in separate beakers under similar experimental conditions and reweighing them at the end of daily feeding period. Moisture loss in food was computed through the difference between the first and second weighs. The weight of uneaten food was corrected for this water loss and the weight of the fresh food consumed each day was obtained by subtracting the corrected weight of uneaten food from weight of the original food.

Each day the weighed uneaten food was dried in an oven at 80°C for 48 hours and weighed again after drying. Every day a fresh supply of leaves was provided. Faeces (excreta) collected from each jar were dried and weighed. After 10 days, the grasshoppers were weighed, killed by heat and dried in an oven to determine the moisture contents. The average food consumed and excreta produced per adult in 10 days and the weight increased during this period

was determined on dry weight basis. The dry weight of food consumed per day by each adult and the weight increased per adult during the experiment period were measured from the mean percent dry matters of aliquots of similar samples.

Result and Discussion

The food utilization can be considered as the amount of food ingested for that remains after the amount voided as excreta as a percentage of total amount ingested. The comparison of utilization of different food and an overall understanding of the relationship between an insect and its food requires measurements of the amount of the food that insect consume in relation to body weight, rate of food intake, relative consumption rate (RCR), relative defecation rate (RDR), progressive food assimilation (RCR–RDR) and relative growth rate (RGR) of the of three dietary regimes by the adult 'AK' grasshopper, *Poecilocerus pictus*.

Food Ingested And Mean Weight Attained

There is significant difference in dry matter ingested values within the three dietary regimes. The declining trend in ingested dry matter was observed as the dietary regimes changed from Aak to Cotton and Cotton to Papaya etc. In order to be able to study the body weight attained by the grasshopper on three dietary regimes, the food ingestion and body weight both were observed in terms of dry weight. The rate of food ingestion was highest during the mid adult age i.e. 29 to 35 days. It was maximum in Aak fed diet in comparison to cotton and papaya diets, while the food ingestion was minimum during the early adult age i.e. 1st to 7th days. These values are in terms of per 100 mg body weight. After attaining the age of 35 days and the amount of food ingestion declines in all the three dietary regimes as shown in Fig. 1, while the pattern of mean weight increase or weight attained in relation to food ingested was more or less similar (Fig. 2). The weight of the grasshopper increased with age and reached to peak between 29 to 35 days of age, thereafter the body weight showed declining trend (Fig. 1 and 2). The weight attained was maximum in Aak fed diet followed by cotton and papaya fed diet

The amount of food invested was proportionately higher than the body weight attained by the grasshopper during the feeding period in all the three dietary regimes. This may probably due to the fact that a lot of food energy is converted into metabolic energy which is being utilized for day to day intermediary metabolism and is also stored for egg laying and body functions.

Similar observations were made by Poonia (1976) in *P. ricini* fed on castor leaves; Joshi (1981) in *P. ricini* fed on castor, tapioca and the combination of these two diets; Kogan and Cope (1974) in soybean looper, Singhal (1977) in *Poecilocerus pictus* fed on calotropis and Abdel Rehman (2001) in *Chrotogonus luguberis*, Kuntal (1990) in *Holotrichia consanguinea* and Gehlot (2005) in *Chrotogonus trychypterus*.

Fig. 1. Dry Matter Ingestion Per 100 Mg Body Wt

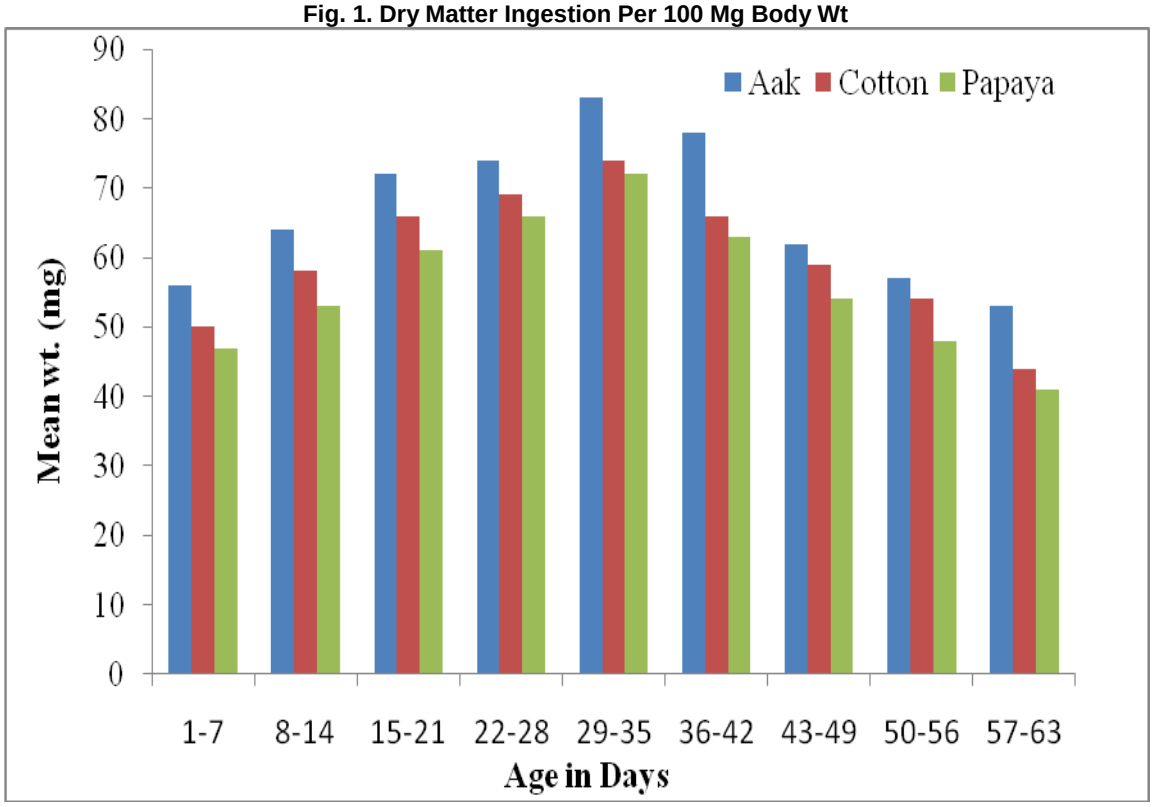
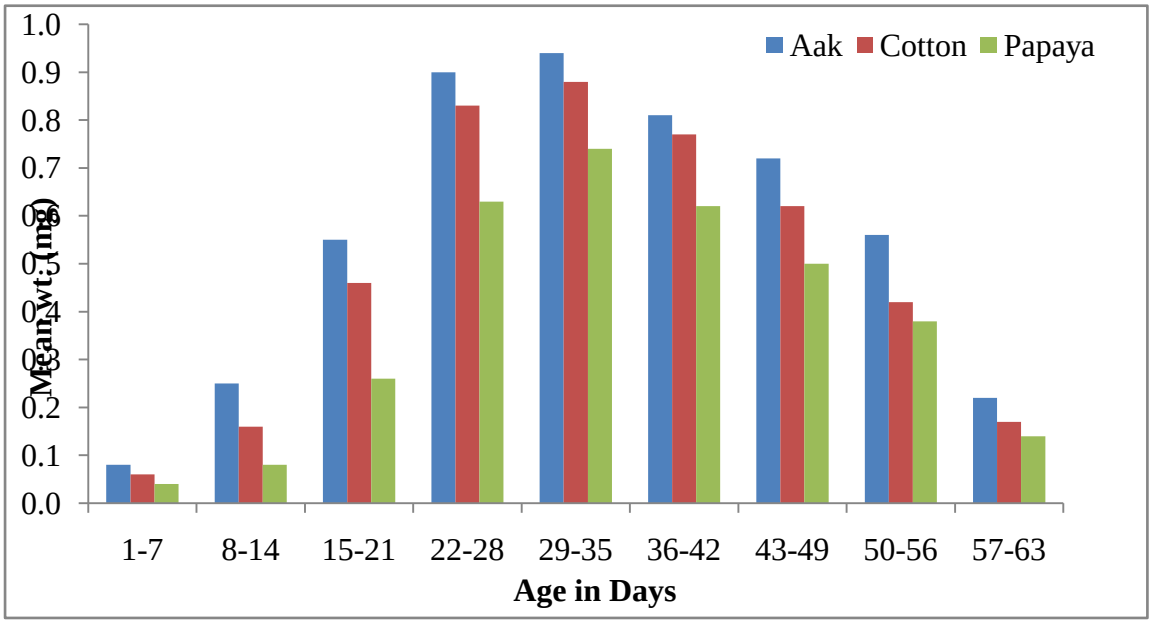


Fig. 2. Mean Wt. of *Poecilocerus Pictus* Fed Upon Aak, Cotton And Papaya Leaves



Cumulative Live Weight Versus Food Consumption

The live weight increased only slightly during the early adult age (i.e. 1 to 7 days) and maximum weight was attained during the middle of the adult age (i.e. 29 to 35 days). It was found to be 2.60 mg on Aak fed diet, 2.45 mg on cotton fed diet and 2.25 mg on Papaya diet. Although the initial weight with each diet were nearly the same, yet peaks of the bars showed that the amount of food consumed during the same period was proportionately higher in comparison to the live weight attained among three diets (Figs. 3, 4 and 5). Similarly, the food consumption was maximum in middle age adult (29 to 35 days) and it was 3.40 mg, 3.10 mg and 2.65 mg on Aak, Cotton and Papaya fed diet respectively.

The amount of food consumption in comparison to live weight attained, increased in a steeper manner from early to late adult age (i.e. 1st to 63 days). The weight gain was gradual and it reached the peaks between 29 to 35 adult age and thereafter showed a declining trend upto 63 days of adult age (Figs. 3, 4 & 5). Thus, it can be concluded that the trend of live weight attained and the food consumed during the entire adult age is more or less same in all the three dietary regimes. The amount of food consumed was much more than the body weight attained and it was utilized particularly noticeable from 7th to 63rd days of adult age. The food consumed and cumulative weights attained were maximum on Aak fed diet and minimum on Papaya diet.

Figs. 3, 4 and 5 shows that the differences are not only in the total live weight attained but also in the rates at which they have been accumulating in the earliar days of the adult life. The live weight attained during this period did not commensurate with the large amount of food taken, while in the older age of the adult of the cumulative live weight increased was faster and commensurate with the food consumption in a better way.

Similar results were reported by earlier workers e.g. Kogan and Cope (1974) in *Pseudoplusia includens*; Poonia (1976) in *P. ricini*, Joshi (1981) in *P. ricini*; Gautam (1981) in *C. trgchypterus*, Idowu and Sonde (2003) in *Zonocerus variegates*, Gehlot (2005) and Bhati (2006) in *C. trachypterus*.

Relative Consumption Rate (RCR)

The Relative Rate of food consumption was calculated in terms of dry weight of food consumed per day grasshopper. This was plotted against the dry matter ingested per 100 mg body weight per day (Fig. 6). The relative consumption rate (RCR) of the grasshopper showed a positive correlation with relative defecation rate (RDR). RCR data revealed that the peak of all the three dietary regimes lies between 29 to 35 days of the adult age with maximum RCR value of 440 mg/100 mg in Aak fed diet followed by cotton (425 mg/100 mg) and papaya (290 mg/100 mg) fed diets as shown in the Fig. 6.

Fig. 3. Daily Cumulative Weights Attained V/S Food Consumed By *P. Pictus* Adults Both on Dry Weights When Feed on Aak leaves

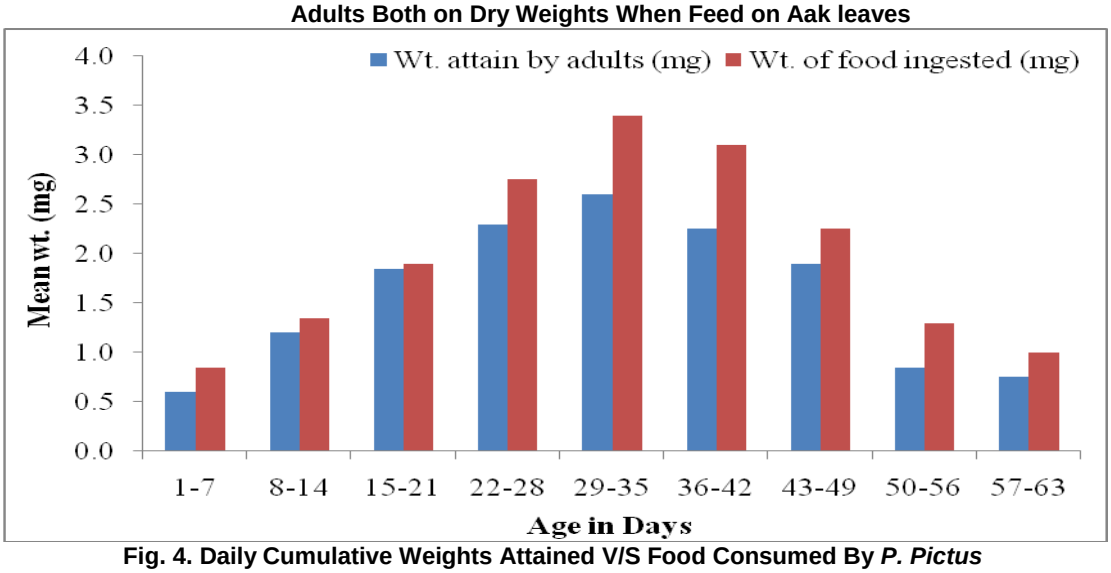


Fig. 4. Daily Cumulative Weights Attained V/S Food Consumed By *P. Pictus* Adults Both on Dry Weights When Feed on Cotton Leave

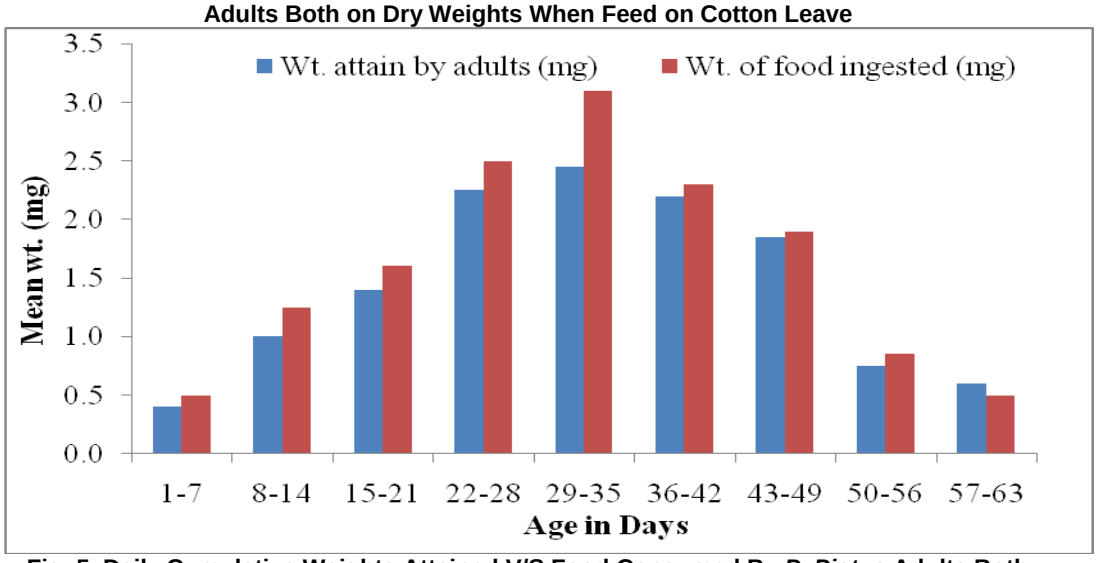


Fig. 5. Daily Cumulative Weights Attained V/S Food Consumed By *P. Pictus* Adults Both on Dry Weights When Feed on Papaya Leaves

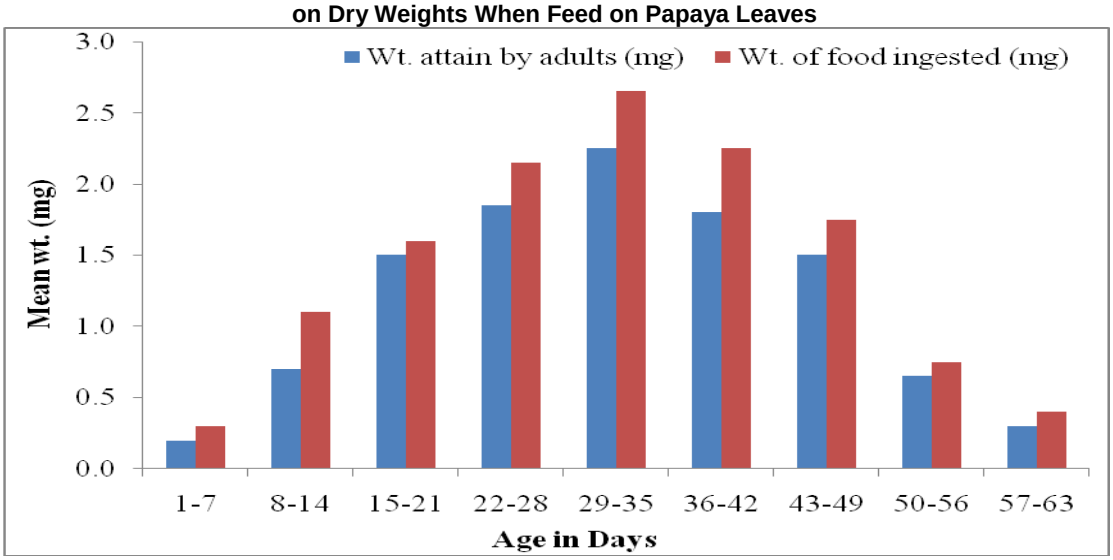
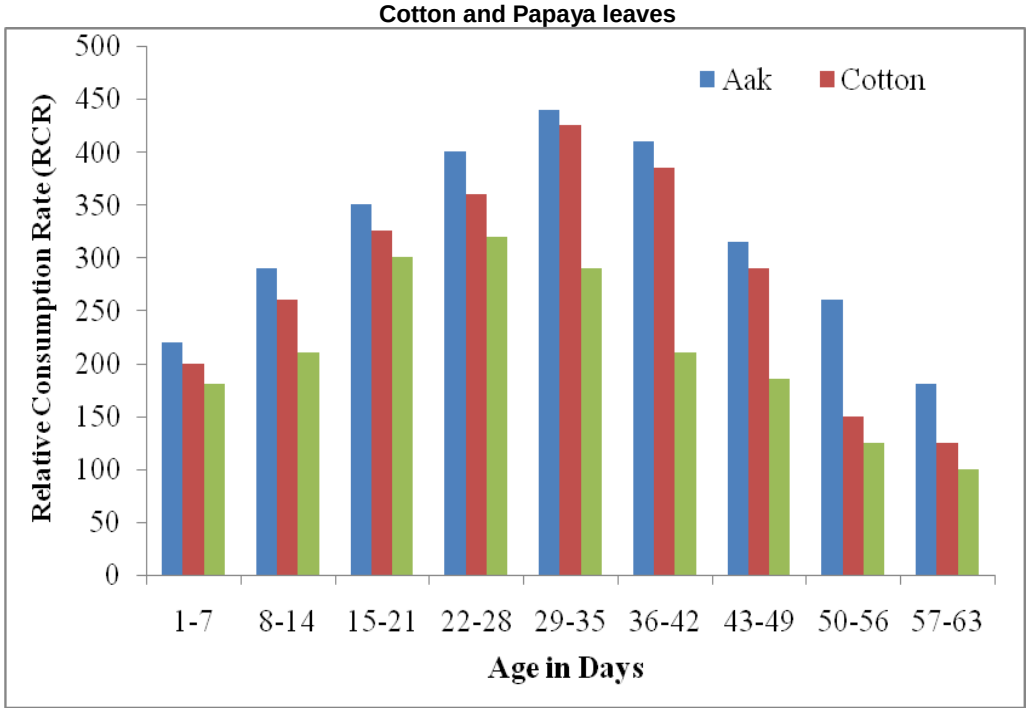


Fig. 6. Relative Consumption Rate (RCR) of *P. pictus* Adults Feed on Aak, Cotton and Papaya leaves



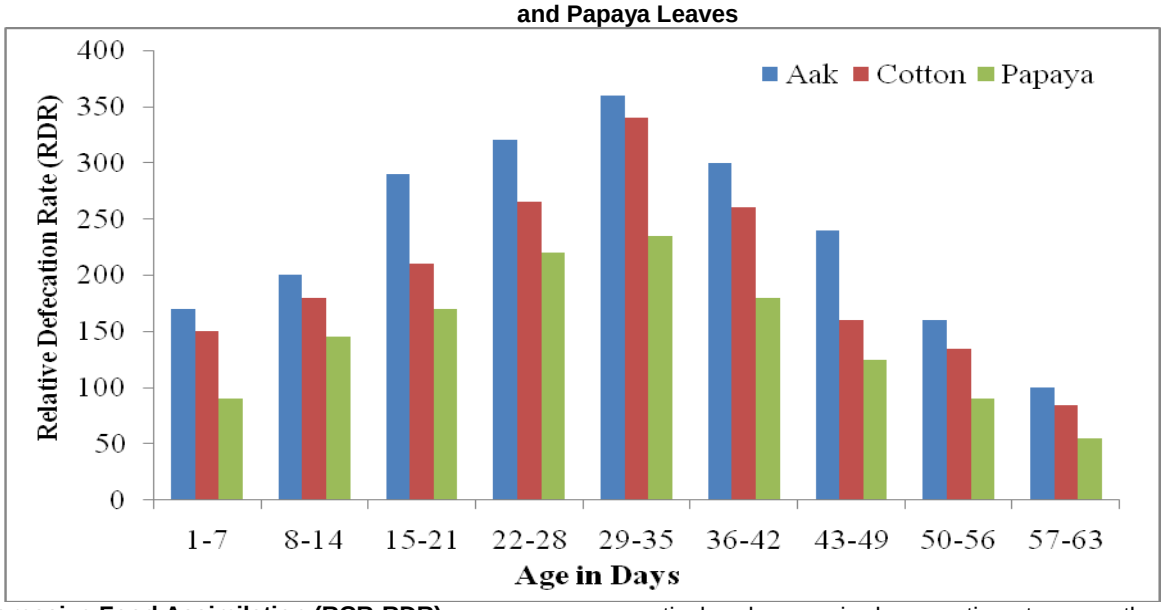
Relative Defecation Rate (RDR)

From the analyzed data it was observed that there is a close relationship between amount of excreta voided and food intake. The amount of excreta voided with adult age and slop of trend line dropped most abruptly after crossing the age of 35 days. (Fig. 7). There was a positive correlation between consumption of food and defecation rate on each dietary regimes (Fig. 7). Relative defecation rate (RDR) will be only clear if the defecation rate computed at the percentage of consumption rate per 100 mg body weight than the actual values obtained. Perusal of data revealed that during the first week of adult age the defecation rate in all the three diets, was in the range of 90-170 mg/100 mg body weight for Aak, cotton and papaya. Whereas the consumption rate was recorded maximum on Aak (360 mg/100 mg body weight) followed by cotton (340 mg/100 mg body weight) and papaya (235 mg/100 mg body weight) diets. Correspondingly the excreta voided was less when grasshopper fed on papaya leaves and maximum when it fed on Aak leaves. Since the production of fecal matter is directly related to the amount of dry matter intake.

From the Figs 6 and 7, it shows that there is positive correlation between consumption and defecation rate on respective dietary regimes. This however, does not say anything about the inherent characteristic of the particular diet to which of the observed defecation rate could be attributed the rationalization will be clear. The defecation rate is computed as the proportion of consumption rate 100 mg body weight rather than the actual values. Thus, even though there is an overall high correlation between consumption and defecating.

The result of the present study are in concurrence with the observations made by many workers on effect of different diets on food intake by insects in relation to defecation rate, on reduced fecal matter production by *H. armigera* larvae when fed on neem derivative have been made by Murrugan *et al.* (1996), Nelson *et al.* (1996) also reported decreased production of fecal matter *Spodoptera litura* and *H. armigera* larvae when they were fed leaves treated with different ajadirachtin which neem fractions. The result of present study are in agreement with the findings of Kuntal (1990) in white grub fed on Khejri, Neem and Ber and Gehlot (2005) in surface grasshopper fed on cabbage, cotton and lucern.

Fig. 7. Relative Defecation Rate (RDR) of *P. Pictus* Adults Feed on Aak, Cotton and Papaya Leaves

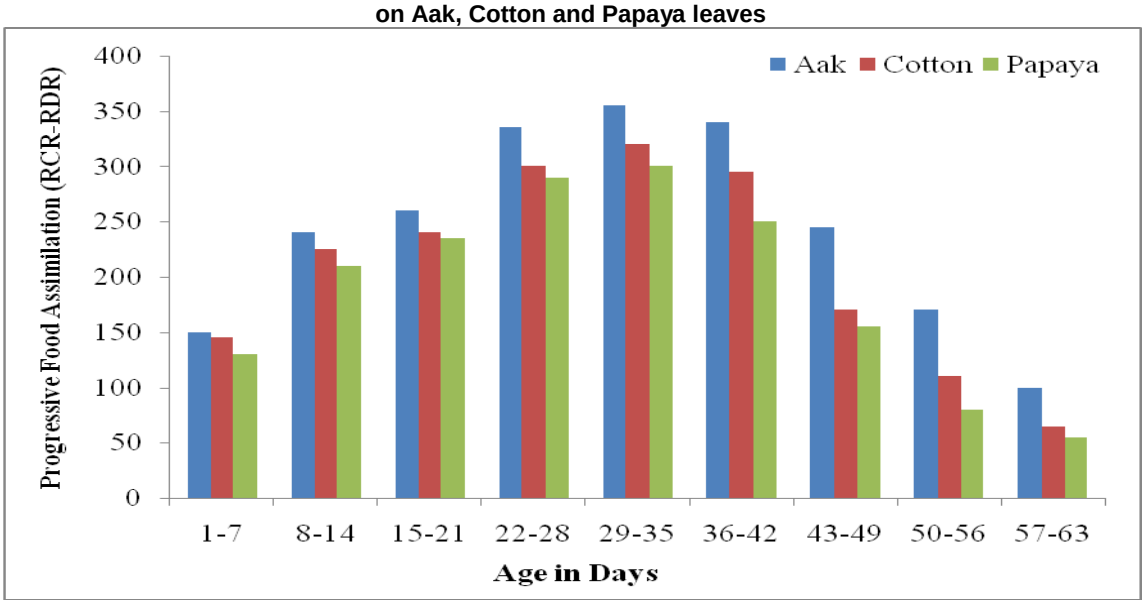


Progressive Food Assimilation (RCR-RDR)

Progressive and assimilation is the resultant of the relative consumption and defecation rate. It was observed that the values of progressive food assimilation were recorded minimum during 57 to 63 days of adult life which were 100, 65 and 55/100 mg body weight for Aak, cotton and papaya respectively. Whereas these values were maximum during 29 to 35 day of adult age, when values of 355, 320 and 300 mg/100 mg body weight for Aak, Cotton and Papaya respectively were recorded. The difference in values for food assimilation in Aak and Cotton diets was 35 mg. Whereas the difference between papaya diet with that of Aak diet was 55 mg and difference between cotton and papaya diet was 20 mg. From the Fig. 8, it was clear that mean daily assimilation rate in terms of dry matter could not show the time lag between consumption of food and defecation resulting in assimilation. Actually the food consumed in a particular day required some time to pass through alimentary canal before it came out as a residue of excreta. The peaks for all the diets showed that assimilated matter at this time is available to fuel the metabolic activities of external and internal machinery, resulting in converting the assimilated matter into adult biomass.

Synchronizing with this peak, which follows the peaks in consumption defecating, the Aak grasshopper is actively foraging and eating. It becomes sluggish at the older age that when it does not move even for feeding. The progressive food assimilation (RCR-RDR) decreases with age (Fig. 8). The present results are in agreement with the findings of Sinha (1958) in some adult stored grain beetles, Poonia (1976) and Joshi (1981) in *P. ricini*, Kuntal (1990) in white grub and Gehlot (2005) in surface grasshopper.

Fig. 8. Progressive Food Assimilation (RCR-RDR) of *P. pictus* Adults Feed on Aak, Cotton and Papaya leaves



Relative Growth Rate (RGR)

The relative growth rate was plotted in terms of biomass gained per 100 mg body weight per day (RGR) with respect to adult age in days. The maximum relative growth rate was recorded between 29 to 35 days of age and then the trend started decline and continue to decline up to 63 days of adult age. The minimum rate of growth recorded was 0.30, 0.25 and 0.15 mg/100 mg body weigh per day for Aak, cotton and papaya fed diets, respectively. Whereas, the highest growth rate recorded was 2.45, 1.90 and 1.45 mg/100 mg body weight per day for Aak, cotton and papaya respectively (Fig. 9).

Perusal of relative growth rate figures revealed that Aak fed adult was gaining more biomass than the adult feeding on other two dietary regimes (cotton and papaya). Similarly, the efficiency of growth and storage of food materials was highest on Aak fed diet and lowest on Papaya fed diet. The ranking of the dietary regimes in terms of relative growth rate was:

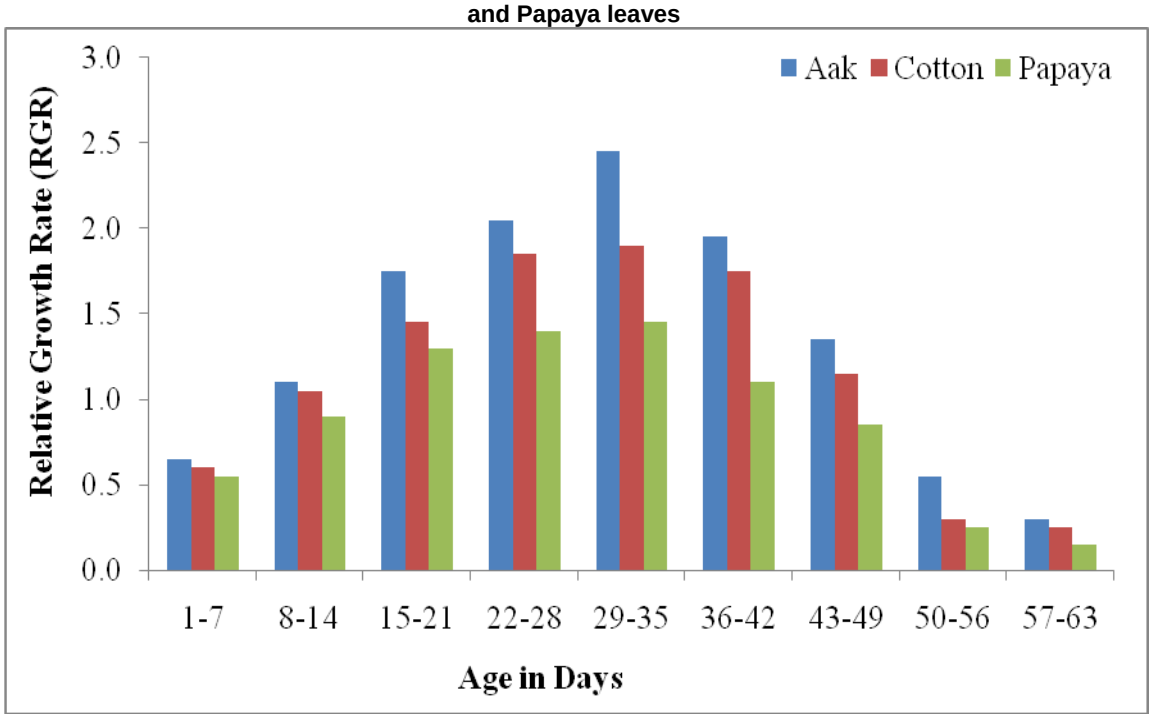
Aak > Cotton > Papaya

The reason for Aak fed adult scoring the highest efficiency was because of its efficiency of conversion of ingested food (ECI), which converting largest part of the ingested food into biomass. Thus, the efficiency of storage was the best in the adult feeding on the Aak on the 1st to 7th day and continuing upto 35 days. The pattern of average RGR of the adult age can be segregated into four distinct phases:

1. The first lasts for very short duration that is 1 to 7 days. During this period growth actually began and it was very slow and gradual.
2. The second phase lasted from the 8th to the 21st days of the adult life. During this phase the relative growth rate relatively increases and reaches maximum in Aak followed by Cotton and Papaya respectively. This peak of relative growth rate during this phase called vegetative or somatic peak.
3. The third phase showed a rapid acceleration in relative growth rate and this lasted from 22nd to 35th day of adult life. The rate of relative growth rate reached the climax during this phase and it was maximum in Aak followed by Cotton and Papaya fed leaves respectively.
4. The fourth phase showed a rapid deaceleration in relative growth rate during this phase, the rate of growth decline steadily. This phase starts from 36 days and lasted upto 63 days of adult life. The growth peak in this phase was much lower than the first growth peak and is known as the reproductive growth peak.

Similar results were reported earlier by many workers: Ludwig (1934) in *Papillio japonica*, Key (1936) in *locusta*, Misra (1962) in *Camnula pellucida*, Srihari (1972) in *Pieris brassicae*, Joshi (1981) and Poonia (1985) in *P. ricini*, Chang *et al.* (1987) in fall armyworm larvae and Gehlot (2005) in *C. trachyptems*.

Fig. 9. Relative Growth Rate (RGR) of *P. Pictus* Adults Feed on Aak, Cotton and Papaya leaves



From an analysis of interaction between food utilization and ecological efficiencies and their parameters in 'AK' Grasshopper, *Poecilocerus pictus*, it revealed that the values of RCR, RDR, RCR-RDR and RGR were maximum under dietary regimes Aak followed by cotton and papaya diets.

Aak > Cotton > Papaya

Conclusion & Findings

The present study revealed that the food ingested and mean weight attained, cumulative live weight versus food consumption, relative consumption rate (RCR), relative defecation rate (RDR),

progressive food assimilation (RCR–RDR) and relative growth rate (RGR) of the AK grasshopper, *Poecilocerus pictus* in three dietary regimes (Aak, cotton and papaya laeves). The results showed that the Aak fed diet have a higher rate of food ingestion, cumulative live weight versus food consumption, relative consumption rate (RCR), relative defecation rate (RDR), progressive food assimilation (RCR–RDR) and relative growth rate (RGR) as followed by cotton and papaya. The minimum RGR recorded 0.30, 0.20 and 0.15 mg/100 mg body weight per day for Aak, cotton and papaya fed diet respectively. The ranking of the three dietary regimes in terms of RGR as: Aak > Cotton > Papaya.

References

1. *Abdel Rehman, K. M. (2001): Food consumption and utilization of the grasshopper Chrotogonus lugubris Blanchard (Orthoptera: Acridoidea, Pyrgomorphidae) and its effect on the egg deposition. J. Central Euro. Agri., 2(3-4): 264-269.*
2. *Andersen, A. N., Lowe, L.M. and Rentz, D.C.F. (2000): The grasshopper (Orthoptera: Acridoidea, Eumastacoidea and Tettignioidea) fauna of Kakadu National Park in the Australian seasonal tropics: biogeography, habitat associations and functional groups. Aust. J. Zool., 48(4): 431-442.*
3. *Behura, B. K. and Bohidar, K. (1989): Egg laying behaviour in Poecilocerus pictus (Fabr.). Ind. J. Entomo. (India), 51(4): 431-433.*
4. *Bhati, N. (2006): Effect of desert plant extracts on feeding, food utilization profiles and mortality of the surface grasshopper, Chrotogonus trachypterus blanch. (Orthoptera: Acridae). Ph. D. Thesis, J. N. V. University, Jodhpur.*
5. *Bhatt, U. S. and Bhattacharya, A. K. (1978): Consumption and utilization of soyabean by Sphodoptera litura Fab. at different temperatures. Ind. J. Ent., 40(1): 16-25.*
6. *Chandra, H. and Singh, R. C. (1993): Laboratory studies on the biology of surface grasshopper Chrotogonus oxypterus (Blanchard). Plant Prot. Bull., Faridabad, 45(5): 31-34.*
7. *Chang, N. T.; Lynch, R. E.; Slansky, F. A.; Wiseman, B. R. and Habeck, D. H. (1987): Quantitative utilization of selected grasses by fall army worm larvae. Ent. Exp. Et. App., 45: 29-35.*
8. *Danner, B. J. and Joern, A. (2004): Development, growth and egg production of Ageneotettix deorum (Orthoptera: Acrididae) in response to spider predation risk and elevated resource quality. Eco. Ento., 29(1): 1-11.*
9. *Despland, J. and Simpson, S. J. (2000): The role of food distribution and nutritional quality in behavioural phase change in the desert locust. Animal Behaviour, 59: 643-652.*
10. *Dukas, R. and Bernays, E. A. (2000): Learning improves growth rate in grasshopper. Proceedings of the National Academy of Sciences, USA, 97: 2637-2640.*
11. *Gautam, D. C. (1981): Food consumption, utilization and ecological efficiencies in nymph and adult Chrotogonus trachypterus Blach. Indian J. Ecol., 8: 229-234.*
12. *Gehlot, K. (2005): Nutritional studies of surface grasshopper, Chrotogonus trachypterus Blanch (Orthoptera: Acrididae) with special reference to consumption, growth and utilization of food material. Ph. D. Thesis J. N. V. University, Jodhpur.*
13. *Howard, J. J. (1995): Variation in dietary patterns among and within polyphagous grasshoppers species (Orthoptera: Acrididae). J. Insect Behav., 8(5): 563-577.*
14. *Idowu, A. B. and Sonde, O. A. (2003): The contribution of food plants to growth, development and fecundity of Zonocerus variegates (L.). African J. Biotech., 2(10): 350-355.*
15. *Joshi, K. L. (1981): Nutritional physiology of Lepidoptera: Evaluation of four dietary regimes for erisilk moth, Philosamia ricini (Lep.: Saturniidae). Ph. D. Thesis, University of Jodhpur, Jodhpur.*
16. *Katoch, S. (2009): Nutritional role of free amino acids and protein metabolism in the digestive tract of the 'AK' grasshopper Poecilocerus pictus Fabr. with reference to different dietary regimes. Ph. D. Thesis, J. N. V. University, Jodhpur.*
17. *Key, K. H. L. (1936): Observations on rate of growth, coloration and the abnormal six instar life-cycle in Locusta migratoria migratorioides R. and F. Bull. Ent. Res., London, 27: 77-85.*
18. *Kogan, M. and Cope, D. (1974): Feeding and nutrition of insects associated with soybean. Food intake, utilization and growth in the soybean looper, Pseudoplusia includens. Am. Entomol. Soc. Amer., 67(1): 66-72.*
19. *Kuntal, J. S. (1990): Nutritional studies of white grub, Holotrichia consanguinea Blanch. with particular reference to consumption, growth and utilization of food material. Ph. D. Thesis J.N.V. University, Jodhpur.*
20. *Legay, J. M. (1958). Recent advances in silkworm nutrition. A. Rev. Ent., 3: 75-86.*
21. *Ludwig, D. (1934): The progression factor in the growth of the Japanese beetle (Papillio japonica). Ent. News Philadelphia., 45: 141-153.*
22. *Manchanda, S. K.; Sachan, G. C. and Rathore, Y. S. (1982): Growth and development of Schistocerca gregaria Forsk on various host plants. Ind. J. Ent., 44(3): 273-279.*
23. *Misra, S. D. (1962): Nutritional ecology of the clear winged grasshopper, Camnula pellucida (Orthoptera: Acrididae). Memoir Indian Museum, 14: 87-172.*
24. *Murugan, K.; Jagammohini, P. and Babu, R. (1996): Effect of neem oil on nutritive and reproduction physiology of Heliothis armigera Hub. In: Neem and Environment Vol. 1 (Eds. R. P. Singh, M. S. Chari, A. K. Raheja and W. Kraus) pp. 321-334.*
25. *Nelson, S. J.; Sunderababu, P. C.; Rajvel, D. S.; Srimannarayana, G. and Geethanjali, Y. (1996): Antifeedant and growth inhabiting effects of Azadirachtin rich neem fractions on rice*

whitebacked plant hopper Sogatella furcifura Horvath, Spodoptera litura Fb. and Helicoverpa armigera Hb. In: Neem and Environment (Vol. 1) (Eds. R. P. Singh, M. S. Chari, A. K. Raheja and W. Kraus). Proc. World Neem Conf. Feb. 1993, Bangalore. Oxford and IBH, New Delhi pp. 243-252.

26. *Pipralia, R. (2012): Nutritional role of carbohydrates and lipids in the food, gut content, Haemolymph pictus (Fabr.) with reference to different dietary regimes. Ph. D. Thesis, J. N. V. University, Jodhpur.*
27. *Poonia, F. S. (1976): Free amino acids in silk gland of fifth instar larva of Erisilkworm, Philosamia ricini Hutt. (Lepidoptera: Saturniidae). Geobios, 3: 33-34.*
28. *Poonia, F. S. (1978): Studies on food utilization and rate of growth during the developmental stage of Eri silkworm, Philosamia ricini Hutt. (Lepidoptera: Saturniidae). Indian J. Seric., 18: 47-60.*
29. *Ricmoldi, O. J.; Pelufto, R. O.; Gonzalez, S. M. and Brenner, R. R. (1985): Lipid digestion, absorption and transport in Tratoma infestans. Comp. Biochem. Physiol., 828(1): 187-190.*
30. *Sachan, G. S. (1981): Growth and development of Diacrisia oblique (Walker) on some vegetables. Indian J. Agric. Sci., 51(8): 579-582.*
31. *Sachan, S. K. and Sachan, G. C. (1991): Differential response of mustard varieties on the growth and development of Lipaphis erysimi (Kalt.). Ind. J. App. Ent., 5: 19-27.*
32. *Sayed, T. S.; Awan, M. S. and Abro, G. H. (1994): Effect of food plant on the biology of Poecilocerus pictus Fab. Food consumption and rate of development. Pak. J. of Zool., 26(2): 105-108.*
33. *Seifter, S.; Dayton, S.; Novic, B. and Muntwyler, G. (1950). The estimation of glycogen with the anthrone reagent. Arch. Biochem., 25: 191.*
34. *Seo, E. W. (1993): Distribution and synthesis of pupal specific cutical specific cutical proteins in tissue of Pieris rapae. Korean J. Ent., 23(2): 83-90.*
35. *Sharma, S. K. and Choudhary, J. P. (1988): Effect of different levels of constant temperature and humidity on the development and survival of Heliothis armigera Hub. Ind. J. Ent., 50(1): 76-81.*
36. *Singhal, R. N. and Vats, L. K. (1977): Effects of starvation on food consumption, assimilation, respiration and ecological efficiencies in adult Poecilocerus pictus Fabr. Ind. J. Entom., 38: 351-356.*
37. *Sinha, R. N. (1958): Movement of food in the gut of some adult stored grain beetles. Can. Entomologist, 90: 202-212.*
38. *Srihari, T. (1972): Observation on the weight and body changes during the growth and metamorphosis of Pieris brassicae. Ann. Soc. Ent. Fr., 8: 359-376.*
39. *Thorsteinson, A. J. (1953): The chaemotactic responses that determine that specificity in an oligophagous insect (Pluteila maculipehsis) (curt.) Lepidoptera. Can. J. Zool., 31: 52-72.*
40. *Thorsteinson, A. J. (1955): The experimental study of the chamotactic basis of host specificity in phytophagous insects. Canad. Ent. Ottawa, 87(2): 49-58.*
41. *Thorsteinson, A. J. (1969): Host selection in phytophagous insects. A. Rev. Ent., 5: 193-218.*
42. *Treherne, J. E. (1958): The absorption of glucose from the alimentary canal of the locust, Schistocerca gregaria (Forsk.). J. Exp. Biol., 35: 611-625.*
43. *Tripathi, N. L. M.; Sachan, G. C.; Verma, S. K. and Pathak, P. K. (1986): Development behaviour of Lipaphis erysimi on different parts/stages of Brassica campestris var. Toria. Ind. J. Ent., 48(3): 295-300.*
44. *Verma, S. K. (1998): Incidence of Poecilocerus pictus (Pyrgomorphidae: Orthoptera) on some new hosts in arid western Rajasthan. Entomon, 23(3): 233-234.*
45. *Wigglesworth, V. B. (1963): The action of moulting and juvenile hormone at the cellular level in Rhodnius Prolicus. J. Exp. Biol., 40: 231-245.*