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Nutritional indices parameters of large white butterfly *Pieris brassicae* (Lepidoptera: Pieridae) on different cabbage crops

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The effects of four cabbage crops including: white cabbage (*Brassica oleracea* var. *capitata* f. *Alba*), cauliflower (*Brassica oleracea* var. *botrytis*), red cabbage (*Brassica oleracea* var. *Viridis* f. Rubra) and broccoli (*Brassica oleracea* var. *italica*) on nutritional indices of *Pieris brassicae* (Lepidoptera: Pieridae) were determined at 26 ± 1°C, 65 ± 5% RH and a photoperiod of 16:8 (L:D) h. Nutritional indices of third to fifth larval instars indicated that, *B. oleracea.* Var*. Capitata* is more nutritionally rich food and even small amount of this food could successfully support maximum value of efficiency of conversion of ingested food (*ECI*) (14.764 ± 0.500%) and efficiency of conversion of digested food (*ECD*) (14.713 ± 0.600%) among the Brassicae spices. The lowest values of these parameters were found on *B. O. Var. Botrytis* spices. The results indicate that, *B. O. Var. Capitata* spices was the most nutritive and as a partially susceptible varieties among cabbage crops, in due to the highest value of *FP* (0.055 ± .008 g) *ECI* and *ECD*, in conversely, *B. O. Var. Botrytis* variety were recorded as partially resistant and the least nutritive for *P. brassicae*, this is due to the fact that the least value of relative growth rate *(RGR), ECI, ECD* and *FP* were recorded.

Key words: Nutritional indices, *Pieris brassicae*, food consumption, resistance, biomass.

INTRODUCTION

The crucifer and mustard family are known as cole crops, which is including broccoli, brussels sprouts, cabbage, cauliflower and kohlrabi. The cole crops are extensively grown in tropical and subtropical regions of the world (Arshad and Rizvi, 2007). Growing of these crops are widespread in Urmia (West Azarbaijan-Iran), too. The webworm (*Hellula undalis* Fab.), cabbage butterflies (*Pieris brassicae* and *Pieris rapae* Linn.), diamondback moth (*Plutella xylostella* Linn.), head caterpillar (*Crocidolomia binotalis* Zeller), aphids (*Lipaphis erysimi* Kaltenbach, *Brevicoryne brassicae* Linn., *Aphis brassicae* and *Athalia proxima*) and flea beetle (*Phyllotreta brassicae* Goeze), are the tremendous of insect pests, that attack at various stages of cole crops (Srinivasan and Murthy, 1991; Pajmon, 1999; Chaudhuri et al., 2001; Arshad and Rizvi, 2007; Kaygin et al., 2009; Hasan and Ansari, 2010, 2011a, b, c). Among them, *P. brassicae* is the most serious pest (Lal and Ram, 2004; Sood, 2007; Bhandari et al., 2009). This is due to the fact that the large white butterfly is a cosmopolitan insect, which has palearctic distribution and attend to members of family brassicaceae which contain mustard oil glucosides

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(Hill, 1987; Newkirk et al., 1997; Raqib, 2004; Jainulabdeen and Prasad, 2004).

It is an oligophagous pest, which feed on 15 species (Dethier, 1947; Hwang et al., 2008). It causes damage at all the growing stages such as seedling, vegetative and flowering stage, and sometimes can bores the head of cabbage and cauliflower, as the high abundance of *P. brassicae* can destroy foliage of plants and can completely defoliated and kill a plant (Hill, 1987; Aslam, 1984, 1994; Frasher, 1997; Siraj, 1999; Lal and Ram, 2004; Hasan, 2008; Hasan and Ansari, 2010, 2011a, b, c). Younas et al. (2004) reported that, the consumption rate of each larvae is about 74 to 80 cm^2 leaf area. In spite of the economic importance of *P. brassicae*, there is some related studies have been conducted on the effects of host plants, apart from cabbage varieties, on brassicaceous host plants (Hasan and Ansari, 2011a, b, c), development (Arshad and Rizvi, 2007), host plant preference (Aslam et al., 2000) influence of food on growth and hibernation and oviposition preference (Metspalu et al., 2003, 2009) and feeding response (Rather and Azim, 2009) of *P. brassicae*, is conduced.

Therefore, the present study provides new information on the nutritional indices of *P. brassicae* on different cabbage varieties. The study of nutritional indices could be have some practical applications including comparing the insect's performance on different host plants (Klein and Kogan, 1974), measuring the effects of physiological stress on insects (Dauglas and Reese 1986), estimation of the quantity of food consumed by larvae with the purpose of forecasting damage by insects (Kozhanchikov, 1950) and determining the host-plant resistance (Klein and Kogan, 1974). Calculation of the basic nutritional indices (e.g. approximate digestibility of food (*AD*), efficiency of conversion of ingested food (*ECI*) and efficiency of conversion of digested food (*ECD*) has opened new opportunities for research of the power of feeding (Andreeva, 2010).

The goal of this laboratory study was to determine the performance of *P. brassicae* on various Brassica crops that will enable growers to employ the most appropriate control tactics towards integrated crop management (ICM) of a particular brassica crops in the field. The finding of this research may help evolve varieties of brassica resistant and susceptible against this serious pest of cruciferous plants.

MATERIALS AND METHODS

Host plants

Different cole crops including: white cabbage (*Brassica oleracea* var. *capitata* f. *Alba*), cauliflower (*B. oleracea var. botrytis*), red cabbage (*B. oleracea var. Viridis* f. *Rubra*) and broccoli (*B. oleracea var. italica*) were raised in the spring season of year 2012 at experimental field of the Department of Plant Protection, Faculty of Agriculture, Urmia University (Urmia-West Azarbaijan, Iran). Selection of these varieties was based on their importance as most commercial cultivated cultivars in different regions of Iran.

Insect culture

White cabbage butterfly larvae were collected from cabbage field in Urmia (37° 34' N, 44° 58' E), west Azerbaijan province (west northern of Iran) in June 2012. The larvae were divided into four groups and reared for one generation on each cabbage crops before using in the experiments. The experiments were held in growth chambers at temperature of 26 ± 1°C, 60±5% R. H. and a photoperiod of 16: 8 (L:D) h.

Experiments

The neonate larvae were taken out and were reared till they reached the third instar. From this culture, third instar larvae were collected and divided into 5 replicates (10 larvae in each replicate). Larval feeding on the 4 different cabbage crops was tested by placing third instar larvae on a weighed leaf, which was placed inside a plastic container (length 14 cm, width11 cm and height 6 cm) with a hole covered by fine mesh net for ventilation, containing the fresh leaves of each examined plant, because of the thickness of cabbage leaves, it is not necessary to use a cotton for providing a moisture. After 24 h, feces were removed from the uneaten leaves and weighed again. The containers were cleaned, and new weighed leaves were supplied. This process was continued each day for each replicate until feeding ceased in the pre-pupal stage.

Daily food consumption per larva was estimated by subtracting weight of remaining leaf tissue from weight of leaf provided and correcting for evaporation. Nutritional indices were measured on the dry weight basis. The pupa and adults from the larvae reared on each variety were weighed as well. The weight of feces produced by the larvae fed on each cabbage variety was recorded daily. To find the dry weights of the leaves, feces, and larval to adult stages, were weighed, oven-dried (72 h at 60°C), and then re-weighed to establish a percentage of their dry weight. Nutritional indices were calculated on the basis of dry weight, as suggested by Waldbauer (1968) and Huang and Ho (1998) to calculate relative consumption rate (RCR), relative growth rate (RGR), approximate digestibility (AD), efficiency of conversion of ingested food (ECI) and efficiency of conversion of digested (ECD) food:

$$RCR = I/b \times T \quad (1)$$

$$RGR = B/b \times T \quad (2)$$

$$ECI\ (\%) = B/I \times 100 \quad (3)$$

$$ECD\ (\%) = B/(I-F) \times 100 \quad (4)$$

$$AD(\%) = (I-F)/I \times 100 \quad (5)$$

Where, *I* is the dry weight of food consumed, *F* is the dry weight of feces produced, *T* is the duration of feeding period (days), *b* is the mean larval weight gained in duration of feeding period and *B* is the larval biomass.

Data analysis

Data were checked for normality prior to analysis. Statistical processing of results was carried out by standard methods using the statistical software SPSS ver.19 (SPSS, 2010). If significant differences were detected, means were compared suing Tukey's test at α = 0.05.

Table 1. The mean (±SE) nutritional indices of whole instar larvae of *Pieris brassicae* on different cabbage crops in 2012.

Spices	FC (g)	FP (g)	RCR (g/g/day)	RGR (g/g/day)	ECI (%)	ECD (%)	AD (%)
B. O. Var. Capitata	1.273 ± 0.441[c]	0.055 ± .008[a]	5.136 ± 0.607[d]	0.051 ± 0.008[a]	14.764 ± 0.500[a]	14.713 ± 0.600[a]	83.467 ± 1.170[a]
B. O. Var. Botrytis	7.779 ± 1.251[a]	0.012 ± 0.003[b]	77.047 ± 8.66[a]	0.071 ± 0.007[a]	0.110 ± 0.030[b]	0.110 ± 0.035[b]	99.84 ± 0.027[a]
B. O. Var. Italica	5.660 ± 1.116[ab]	0.022 ± 0.001[ab]	51.873 ± 12.446[b]	0.068 ± 0.005[a]	0.161 ± 0.000[b]	0.161± 0.113[b]	99.598 ± 0.295[a]
B. O. Var. Viridis	2.572 ± 0.332[bc]	0.008 ± 0.002[b]	11.913 ± 1.524[c]	0.055 ± .012[a]	0.494 ± 0.014[ab]	0.493 ± 0.147[ab]	99.66 ± 0.177[a]

The means followed by different letters in the same columns are significantly different ([**]P < 0.01, Tukey's test). *FC* = dry weight of food consumed, *FP* = dry weight of feceal produced, *RCR* = relative consumption rate, *RGR*= relative growth rate, *ECI* = efficiency of conversion of ingested food, *ECD* = efficiency of conversion of digested food and *AD* = approximate digestibility.

RESULTS AND DISCUSSION

Results of the nutritional indices of whole larval instars (third tofifth) of *P. brassicae* have been shown in Table 1. There were significant differences among cabbage crops nutritionally indices parameters. Nutritional indices including food consumed (F=11.168; df=12; P<0.05), dry weight of feceal produced (F=2.995; df= 12; P<0.01), *RCR* (F=15.668; df=12; P<0.01), *ECI* (F=1.159; df=12; P<0.01) and *ECD* (F=1.071; df=12; P<0.01) for whole larval instar were significantly different on cabbage crops (Table, 1). Although, There were no significant differences regarding to larval weight gain (larval biomass) (F= 0.337; df= 12; P > 0.01), *RGR* (F=0.131; df=12; P>0.01) and *AD* (F=1.518; df =12; P>0.01) between cabbage varieties.

The highest rate of food consumed by larval of *P. brassicae* on *B. O. Var. Botrytis* (7.779 ± 1.251 g), while the lowest of this parameter was obtained on *B. O. Var. Capitata* (1.273 ± 0.441 g), crop. In parallel of food consumption, the highest and lowest relative consumption rate by larvae has been recorded on *B. O. Var. Botrytis* (77.040 ± 8.66 g/g/day) and *B. O. Var. Capitata* (4.633 ± 0.607 g/g/day), respectively. The highest value of feceal produced by larvae of *P. brassicae* was recorded on *B. O. Var. Capitata* (0.055 ± .008 g). Two important parameters of nutritional indices including *ECI* and *ECD* by larval of *P. brassicae*, which is reared on *B. O. Var. Capitata* were the higher rate than other varieties. The efficiency of conversion of ingested food was varied from (0.110 ± 0.03%) to (14.764 ± 0.500%) on *B. O. Var. Botrytis* and *B. O. Var. Capitata* crop, respectively (Table 1). There is a significant differences regarding to pupal (F=21.30; df=12; P<0.01) and adult (F=43.87; df=12; P<0.01) weights of *P. brassicae* among cabbage crops. The pupal (0.400 ± 0.001 g) and adult (0.164 ± 0.00 g) weights of *P. brassicae* were the highest rate on *B. O. Var. Botrytis*than other cole crops (Figure 1).

Significant differences were found within the nutritional indices, mainly *ECI*, *ECD, FC, FP* and *RCR* values of *P. brassicae* reared on different Cole crops, suggesting that the spices have different nutritional value. Growth of an insect depends primarily on the extent to which it can feed. Thus, difference in consumption, nutritive values and utilization of food from various plants would affect its establishment on them (Singh et al., 2008). The most useful nutritional indices were found to be *AD*, *ECD* and *ECI* (Reese, 1978). *AD* measures the assimilation of food, *EC*D measures the efficiency with which assimilated food is converted into insect biomass and *ECI* measures the overall conversion of ingested food into biomass (Waldbauer, 1968). *ECI* and *ECD* measure the insect's ability to utilize the food ingested and digested for growth, development and the proportion of digested food metabolized for energy (Nathan et al., 2005). Although the lowest rate (1.273 ± 0.441 g) of food consumed by larvae of *P. brassicae* was recorded on *B. O. Var. Capitata*, but this food could successfully support maximum insect growth (*DW* 0.012 ± .001g/g/day) as evidenced by high *ECI* (14.764 ± 0.500%), *ECD* (14.713 ± 0.600%) among the cole crops. It could be the fact that, this variety is more nutritionally rich food and even small amount of it, supported the maximum rate of these parameters. The low consumption rates (*RCR* 4.633 ± 0.607 g/g/day) observed on *B. O. Var. Capitata*. Among different cabbage crops, the highest value of *RCR* (77.040 ± 8.66 g/g/day) were obtained on *B. O. Var. Botrytis* crop, indicating that, although the amount of foodconsumed (7.779 ± 1.251 g) was increased by larvae, the rate of fecal excreted (0.012 ± 0.003 g) was decreased, and it causes the increasing proportion of ingested food into feces excreted (Karimpour et al., 2005). There is no differences regarding to *RGR* among cabbage

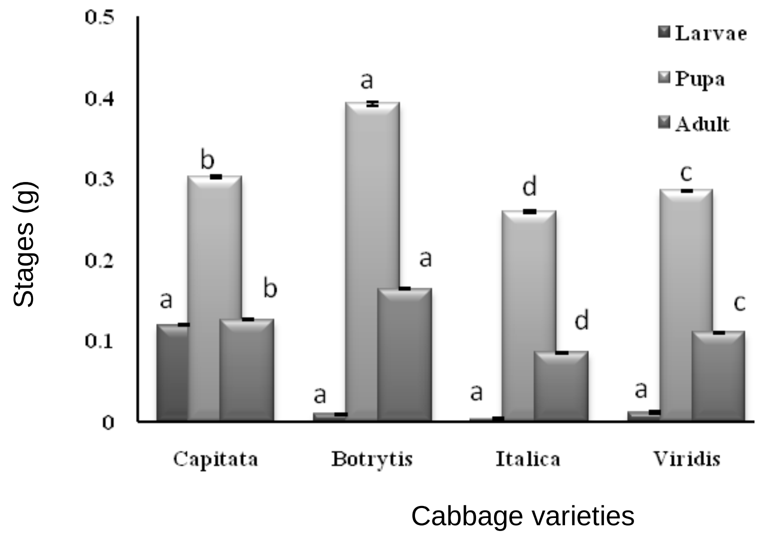

Figure 1. The mean (±SE) body weights of larval, pupal and adult stages of *Pieris brassicae* on different cabbage crops in 2012.

crops, it could be related to the feces produced by larvae. It means that, larvae which is feed on *B. O. Var. Capitata* produces the large amount of fecal products, while the larvae reared on *B. O. Var. Botrytis* produces the lower rate of fecal matter, then we did not observed differences regarding to relative growth rate. The highest value of *ECI* of whole larval instars on *B. O. Var. Capitata* spices of cole crops, suggests that, it was more efficient at the conversion of ingested food to biomass and weight gained by larvae (Nathan et al., 2005). The larvae reared on other cole crops had the lowest value of *ECD*, which indicate that, these larvae were apparently not as efficient in turning digested food into biomass.

The pupal (0.400 ± 0.001 g) and adult (0.164 ± 0.00 g) weights of *P. brassicae* were the highest rate on *B. O. Var. Botrytis* than other cole crops. It is due to the fact that, the developmental time period was the lowest rate in comparison of other cabbage crops, and this parameter can effect on *RGR*, pupal and adult weight, as evidenced by Waldbauer (1968) and Huang and Ho (1998). The effect of different cole crops on consumption and utilization of food (Ansari et al., 2012), survivial, reproduction (Hassan and Ansari, 2011), life history (Shafqat et al., 2010), host plant preference (Rather and Azim, 2009), oviposition preference (Metspalu, 2009), the developmental stages, mortality (Arshad and Rizvi, 2007), growth and hibernation (Metspalu et al., 2003) of *P. brassicae* has been studied. Ansari et al. (2012) studied the influence of various host plants on the consumption and utilization of food by *Pieris brassicae*, who measured the factors including *CI*, *RG*R, *ECI* and *ECD*, their finding showed that all of these parameters were highest on cabbage, which has similarity to our finding.

Effects of different brassicaceous host plants on the fitness of *P. brassicae* was investigated by Hassan and Ansari (2011c). They found that, cabbage was recognized as the most suitable host for *P. brassicae* because of shorter developmental period, higher percentage survival, lower doubling time (6.00), and higher number of adult emergence (29.7%). Similarly, Shafqat et al. (2010) examined effect of host plants (cauliflower, wheat and pea) on life-history traits of *S. exigua*, who reported that, the higher pupal weight on cauliflower (88.7 mg) suggest that it provides better food quality to *S. exigua*. Rather and Azim (2009) studied the feeding behaviour of *P. brassicae* larvae under laboratory conditions in response to different varieties of *Brassica oleracea* (*B. o. capitata/ B. o. botrytis*). Their results indicated that *B. oleracea* was highly preffered by the larvae as compared to *Raphanus sativus* and *Lycopersicon esculentum*. Different cole crops could be affected by the developmental time and mortality of *P. brassicae*, which has been evidenced by Arshad and Rizvi (2007). They found that, all the developmental stages (egg, larval instar, prepupal and pupal) of *P. brassicae* were recorded significantly lower on cabbages under laboratory condition. Variation in the nutritive values of the diet from different plants and the extent to which they are consumed and utilized by *P. brassicae,* considered as the determining factors of its growth and establishment.

The present study shows significant differences in the capacity of *P. brassicae* reared on different cabbage crops. Such observations will help in selection of host-plant-resistance of test insect as well as for constructing mathematical model, which will be helpful in developing strategy for sustainable management against this pest.

Quantitative analysis of consumption and utilization of host plants by insect herbivores is a commonly used tool in studies of plant insect interactions (Scriber and Slansky, 1981). Variables describing the consumption of food by an insect, how well this food is converted to insect biomass and the rate at which the insect growth can lead to an understanding of how particular insect species respond to variation in host plant suitability. Study of the effect of food on the biology of insects is of particular importance in understanding host suitability of plant infesting species and evaluating the magnitude of injury to the crops attacked by them. This may help, accordingly, in designing more economic control strategies (Greenberg et al., 2001).

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