Study On the Relative Preference for Development by Tribolium Castaneum in Dehulled Wheat Flour of Different Wheat Varieties

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ABSTRACT

The red-rust flour beetle, *Tribolium castaneum* is a serious pest of stored wheat flour in Nigeria. The study assessed the relative preference for development by *T. castaneum* in dehulled-fine flour of eight wheat varieties. The experiment was conducted between 24th February to 20th April, 2017, in the laboratory of Biological Science Department of University of Maiduguri, under ambient temperature (24±1.13 ^{o}C) and relative humidity (30.7±1.38 RH). The varieties consisted of Reyna-28, Nejmah, Soonot-5, Debeira, Faris-30, Imam, Reyna-19 and Nabuq-4. Randomized Complete Block Design with three replicate was used to compare the biology, population, population growth rate, and the susceptibility index in the eight varieties of wheat. The results showed that effect of variety on the biology of *T. castaneum* was not significant (P<0.05), thus developmental periods of larvae, pupae, and adult stages, closely ranged from 8.3 - 9.0 days, 30.0 - 32.7 days and 35.7 - 37.3 days, respectively, and was at par among the eight varieties. The average developmental periods of the larval, pupal, and adult stages were 9.0 days, 30.8 days, and 36.4 days, respectively. The study also compared the peak population of larvae, pupae, and adults among the eight wheat varieties. Results indicated a significant (P<0.05) difference in the population of larvae, pupae, and adults, which ranged from 47 - 100.7, 32.3 - 62.0, and 21.7 - 47.0 among the different wheat varieties, respectively. The highest population of larvae, pupae, and adults was consistently recorded from Debeira, while the lowest was from Nabuq-4 and Imam. The varieties, Faris-30, Soonot-5, Reyna-19, and Nejmah also gave a higher population than Nabuq-4 and Imam. The study also investigated larvae and adult population growth rates in the eight different wheat varieties. Larvae exhibited a polynomial growth pattern, in which the build-up phase from 10 - 28 DAI, was at the rate of 5.644 - 15.759, and population growth was higher and faster in Debeira, Nejmah, Soonot-5 and Faris-30 than in Nabuq-4 and Imam. The result indicated population decline at the rate of 0.4162 - 1.0739 larvae as from 28 - 55 DAI. The highest rate of larvae population decrease was in Debeira and the lowest was in Nabuq-4, closely followed by Imam. The adult population growth followed the sigmoid (logarithmic) pattern, which increased at the rate of 10.816 - 25.810 beetles. The highest rate of growth occurred in Faris-30, followed by Soonot-5 and Debeira. Conversely, the lowest growth rate was in Imam, closely followed by Nabuq-4. The study also assessed the susceptibility of the eight varieties to infestation by *T. castaneum*, and the susceptibility index significantly (P<0.05) differed from 7.57 - 11.31%. From the results, Debeira, followed by Nejmah and Soonot-5 were significantly more susceptible compared to the least susceptible varieties, Imam and Nabuq-4. From the foregoing results, therefore, Debeira, Nejmah, and Soonot-5 were the most susceptible wheat varieties, while Imam and Nabuq-4 were the least susceptible.

KEYWORDS: Varieties, Flour, T.castenum, Susceptibility, Population, Adult, Larvae, Pupae, Wheat.

INTRODUCTION

The red flour beetle, *Tribolium castaneum* (Herbst) is worldwide and most destructive pest of stored products and is cosmopolitan in distribution. It is the most common pest of wheat flour. Collectively known as flour beetles, several species of Tribolium which belong to the family Tenebrionidae (darkling beetles) in the order Coleoptera, are ubiquitous pests of stored grain, flour, and other cereal products.

Although little is known of their ecological niche before the introduction of human food stores, the entire clade is thought to have adapted to feed on fungi (Hunt et al. 2007). Their tolerance for hot, dry environments; reduced visual system; and remarkable expansion of odorant and gustatory receptor genes (Abdel-Latief, 2007; Engsontia et al. 2008) suggests an underground lifestyle in arid subtropical regions, possibly infesting animal food stores. Their popularity as research organisms arose because they are easy to culture and handle and they reproduce rapidly. As the only beetle for which the genome sequence is now available, the red flour beetle, T. castaneum, is one of the best-known members of this family.

Tribolium castaneum is frequently referred to as secondary pests since it is unable to feed or attack sound grains, but cause considerable damage to grains previously attacked by internal feeders (primary pests) or mechanically damaged (Mebarkia et. al., 2010). The red flour beetle, *Tribolium castaneum* is a polyphagous, cosmopolitan pest of stored products, flour mills and has had a long association with stored food and has been known as a major pest in facilities used for the processing and storage of stored-products (Kheradpir, 2014). Although its pest status is considered to be secondary, requiring prior infestation by an internal feeder, it can readily infest wheat or other grains damaged in the harvesting operation.

Grains can be infested by pests at all stages following their harvest until they are processed and consumed. The most commonly attacked products are those of food grains and the least are the dried fruits. Cereals are a major source of dietary protein for humans. Cereal grains and wheat in particular, are among the most important crops globally (Mebarkia et. al. 2010). Cereal grains are the main source of food for humans in many countries and constitute about 71% of the staple diets of local populations in Africa (Shareif, 2002). It also causes serious damage upon dried fruits, pulses, and prepared cereal foods, such as cornflake, pasta, biscuit, beans, nuts, etc.

In all African countries, wheat consumption has been steadily increasing during the past 20 years as a result of a growing population, changing food preferences, and a strong urbanization. Based on production, wheat is ranked the 3rd among cereal crops production and 4th among the top 50 agricultural commodities (FAOSAT, 2014). The damage caused by insect pests to wheat grain has been estimated at 10 to 20% (Khanzada et al., 2011). Apart from the loss of weight and quality of food grains, insects of the genus *Tribolium* secrete a variety of toxic quinones which are said to be carcinogenic. The presence of *Tribolium castaneum* in the food grains gives pungent smell and infested flour becomes dirty yellow and negatively affects the baking quality of flour.

The word quality as applied to food materials refers to those attributes of food, which make it agreeable to persons who eat them. It involves color, flavor, texture, nutritive value, and freedom from harmful substances such as pesticide residues, biochemical changes, and contamination by insect body fragments or excreta (Shareif, 2002). This beetle has been focused on because of several significant features such as short lifetime, ability to compete in using limited sources, survival in poor condition, and adaptation to fluctuated climate (Kheradpir, 2014).

The use of resistant varieties is one of the environmentally safe methods of pest control in stored product pest management. Varietal resistance in wheat against *Tribolium castaneum* has been studied by different workers (Khanzada et al., 2011). The world population gets most of its daily energy needs from wheat and rice (Awadalla et al., 2014). The mainstay of mankind and one-quarter of energy is obtained from these cereals grains (Khaliq et. al., 2014).

MATERIALS AND METHODS

The experiment was conducted to assess the relative preference for development by *T. castaneum* in dehulled-fine flour of eight wheat varieties. The experiment was conducted in the Biological Science Department Laboratory of Faculty of Science, University of Maiduguri under (ambient temperature and relative humidity) uncontrolled laboratory conditions.

Source of Wheat and Flour Preparation

The eight varieties of wheat, Reyna-28, Nejmah, Soonot-5, Debeira Faris-30, Imam, Reyna-19, and Nabuq-4 where obtained from the germs plasm of the lake chad Research Institute, Maiduguri. 500g of each of the varieties were drilled and milled into fine flour. Dehulling was done at home manual ling using pestle and mortar, while milling was done at the Lake Chad Research Institute Maiduguri, using a Brabender Miller (Quadrumat® senior).

Establishment and Stock Culture Maintenance of T.castaneum

The stock culture of *T. castaneum* was maintained on semolina flour in the laboratory throughout the study period in Maiduguri (hot dry season: Feb – April: 24±1.13 ^{o}C, 30.7±1.38 RH). Culture method involved initial infestation of 480g semolina flour drilled and milled into fine flour, in the ratio of 2:3 with 100 females and 50 males in 500 ml plastic container. As the larvae start to emerge the sample was sieved on a daily bases and larvae was transferred using aspirator into a new container containing 100 g semolina for them to develop in to new adult. As soon as adults emerged the stock culture was sieved daily and newly emerged adults were used for the experiment. The males and females were sexed based on their relative sizes (Females are larger) and also adult males are distinguished from females by a hairy puncture on the ventral surface of the anterior femur.

Infestation Procedure

At the beginning of the experiment two males and females were introduced into 10 cm in diameter Petri dishes on 20 g of the wheat varieties. Male and females were sexed based on their relative sizes (females are larger) and also the adult male is distinguished from the females by a hairy puncture on the ventral surface of the anterior femur. The top of each petri dish was screened with fine mesh to prevent escape of infested *T.castaneum*. The parental adults were removed after 31 days of infestation. The experiment was terminated after 55days.

Experimental Design and Treatments

The experiment was laid out in a Randomized Complete Block Design to assess the development of *T.castaneum* using different wheat varieties. The experiment was replicated three times using the wheat varieties as the treatment namely; Reyna-28, Nejmah, Soonot-5, Debera, Faris-30, Imam, Reyna-19, and Nabuq-4.

Data Collection Analysis

The number of adults that developed in each of the samples was counted at 55daysvafyer infestation for each treatment. Data on the larvae, pupae, and adults were pooled and subjected to. Analysis of variance (ANOVA) using analytical software Statistics Version 8.0 (SX). Index Susceptibility of different varieties of flour to infestation by T.castaneum was computed. Treatment means were separated using the least significant (P<0.05%) difference (LSD) at the level of 5% probability.

Susceptibility index (SI) was computed as:

$$SI = \frac{logf1}{D} \times 100\%$$

Where, F1 = total number of emerging adults

D = median development period, estimated from the middle of oviposition to the emergence of 50% of the F_1 generation.

RESULTS

Table 1 shows the biology of *Tribolium castaneum* in dehulled-fine flour of the eight different varieties of wheat. The result indicated that larvae, pupae and adult developmental periods in the eight varieties ranged from 8.3 - 9.0 days, 30.0 - 32.7 days, and 35.7 - 37.3 days, respectively. However, the developmental period of the larval, pupal, and adult stages of *T. castaneum* among the eight varieties did not differ significantly. The overall mean developmental periods of the larval, pupal, and adult stages were 9.0 days, 30.8 days, and 36.4 days, respectively.

Table 1. Mean developmental period of the different stages of *Tribolium castaneum* in flours of the eight wheat varieties

	Developmental period (days)

Variety	Larvae	Pupae	Adults
Reyna-28	9.0 ± 1.00	32.7 ± 4.62	37.3 ± 1.53
Nejmah	9.3 ± 1.16	30.0 ± 1.73	35.7 ± 4.51
Soonot-5	8.7 ± 0.58	30.7 ± 1.16	37.0 ± 0.00
Debeira	8.7 ± 0.58	30.0 ± 1.00	36.7 ± 0.58
Faris-30	9.7 ± 0.58	30.3 ± 1.16	36.0 ± 1.73
Imam	9.3 ± 0.58	31.0 ± 0.00	36.3 ± 0.58
Reyna-19	8.3 ± 0.58	30.7 ± 0.58	35.7 ± 1.53
Nabuq-4	9.0 ± 1.00	31.0 ± 0.00	36.3 ± 1.16
Mean	9.0 ± 0.78	30.8 ± 1.77	36.4 ± 1.72
SE±	0.4629	1.1163	1.1233
F-test	0.5401	0.7580	0.9480
$LSD_{0.05}$	Ns	Ns	Ns
CV%	8.91	6.25	5.35

Ns = Not significant at 5% probability level of the F-test

Fig. 1 shows the pattern (trend) of larvae population growth in dehulled-fine flour of the eight wheat varieties. The chart depicted a unimodal growth pattern, with distinct rising (increasing), peak and falling (decreasing) paths. The growth pattern was similar in all wheat varieties, in which the larvae population increased as from 10 DAI, peaked at 28 DAI, and thereafter decreased up to 55 DAI. The chart consistently showed that the larvae population was higher in Debeira, followed by Nejmah and Reyna-19, especially when compared with the lowest population build-up in Nabuq-4 and Imam.

Fig. 2 depicts the rate of growth in the larvae population for the different varieties. The 2nd-order polynomial best fit (R^2 = 0.6061 - 0.7308) regression curves and equations for the eight varieties generally expressed that the population increased at the rate of 5.644 - 15.759 larvae every three days, from 10 - 28 DAI. The highest (fastest) recorded rate of increase in larvae population (15.8 larvae) was in Debeira, however Nejmah, Soonot-5, and Faris-30 also exhibited higher (faster) larvae growth rate. In contrast, the lowest (slowest) rate of increase in the larvae population was in Nabuq-4, while Imam also exhibited a lower (slower) rate of larvae increase. There was a decrease in larvae population after the peak at 28 DAI, consequently, the rate of decrease (decline) in the population of larvae in the eight wheat varieties ranged from 0.4162 - 1.0739 larvae every three days. The highest rate of larvae population decrease was in Debeira and the lowest was in Nabuq-4, closely followed by Imam.

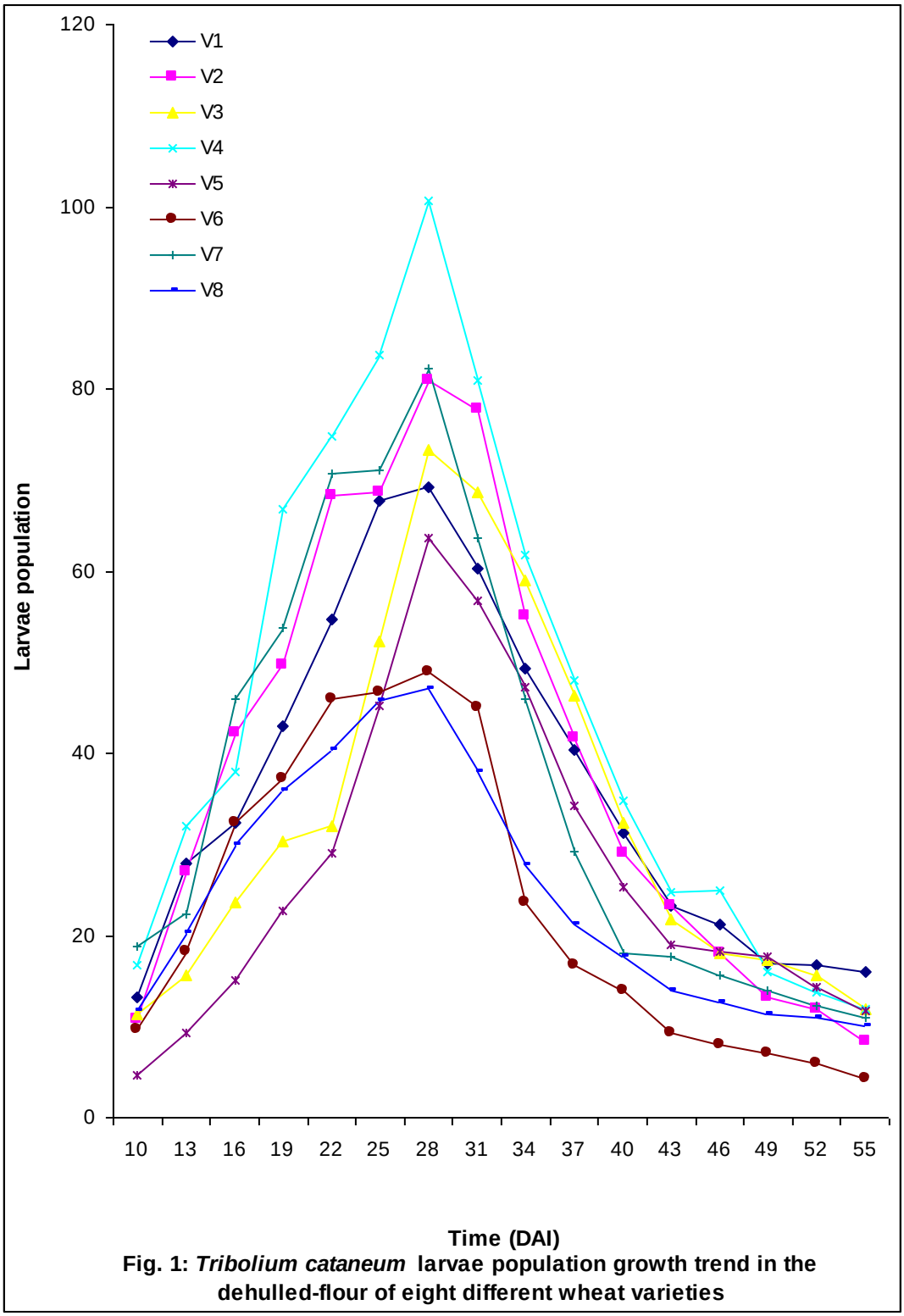

Fig. 1: *Tribolium cataneum* larvae population growth trend in the dehulled-flour of eight different wheat varieties

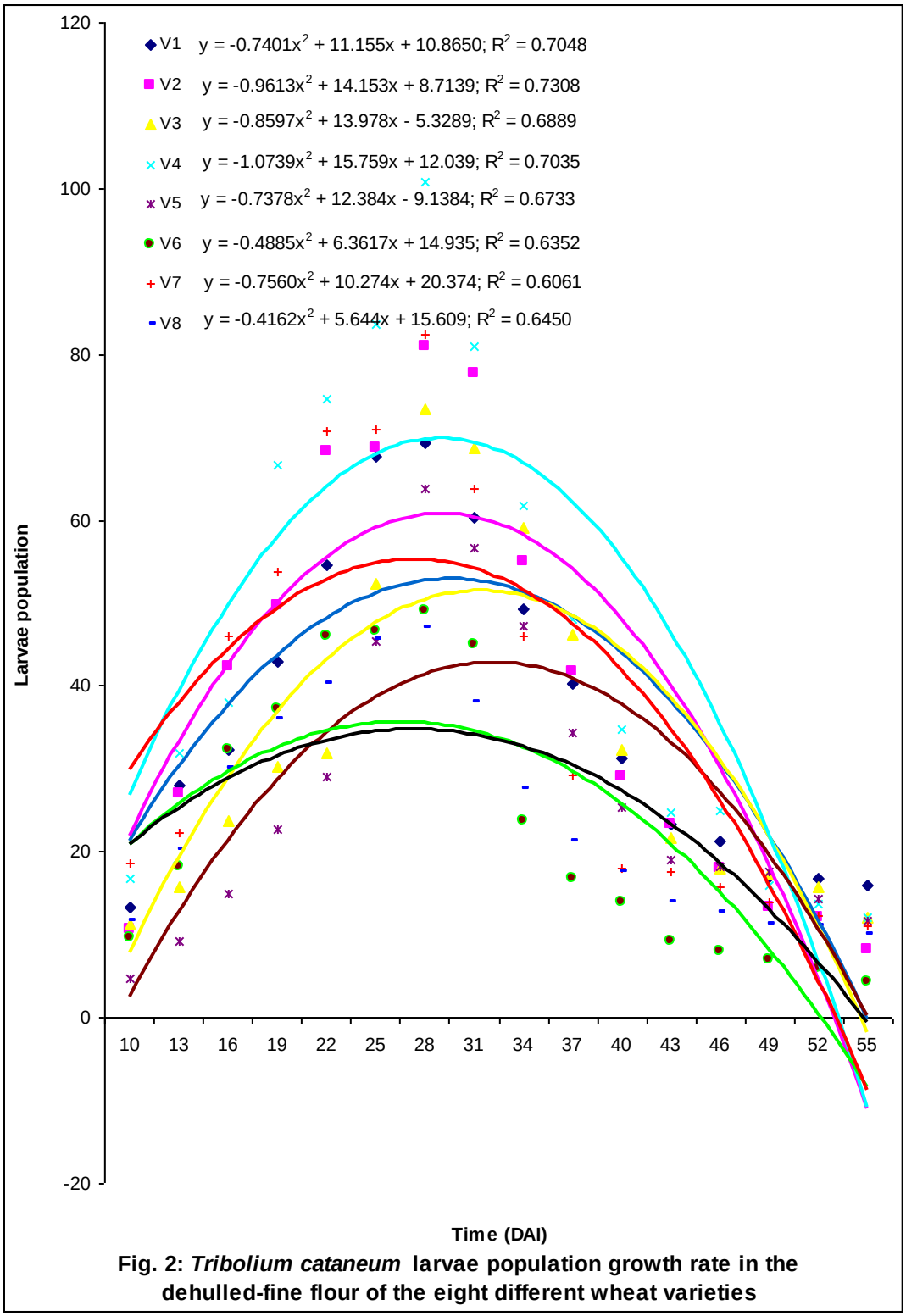

Fig. 2: *Tribolium cataneum* larvae population growth rate in the dehulled-fine flour of the eight different wheat varieties

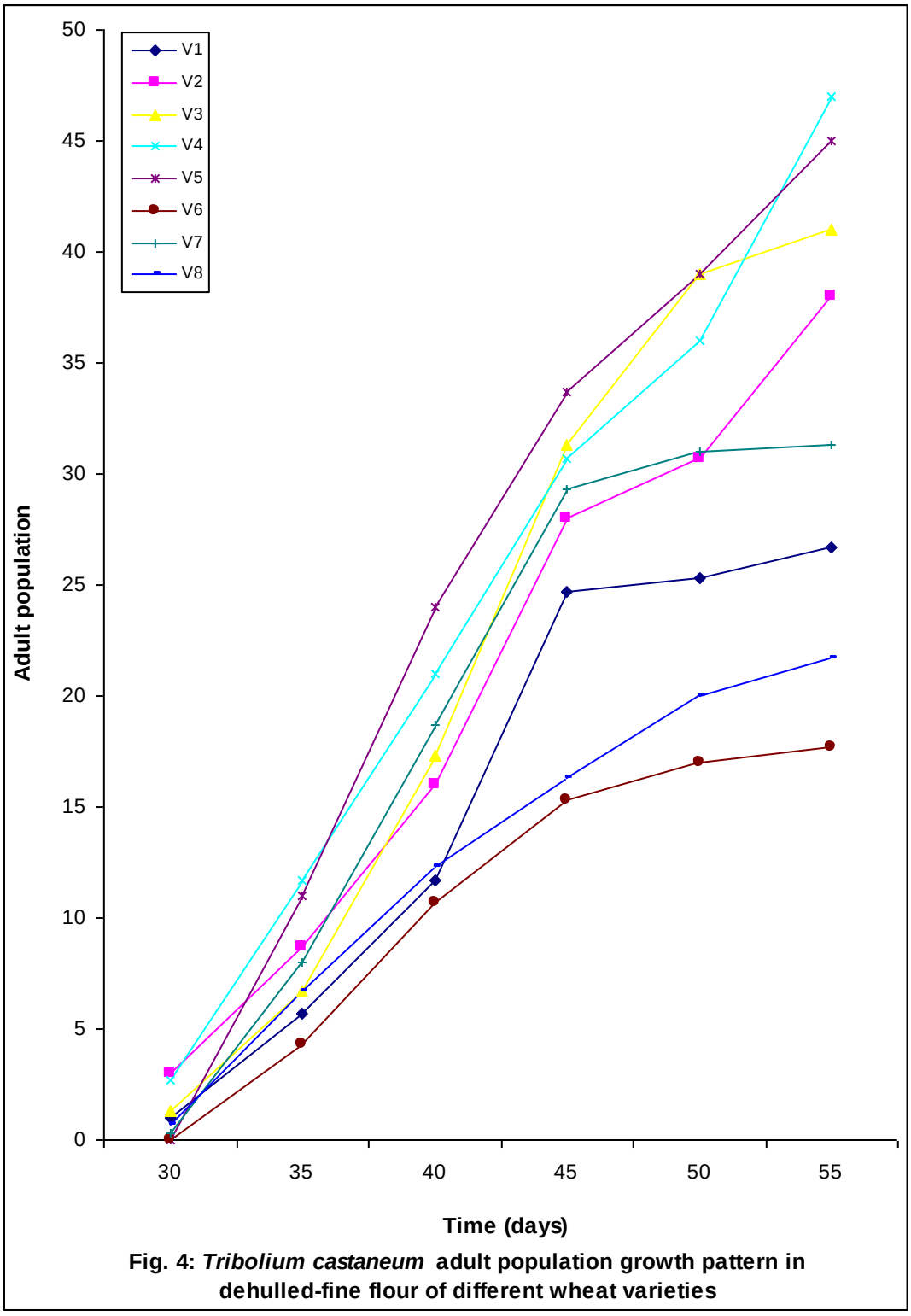

Fig. 4: *Tribolium castaneum* adult population growth pattern in dehulled-fine flour of different wheat varieties

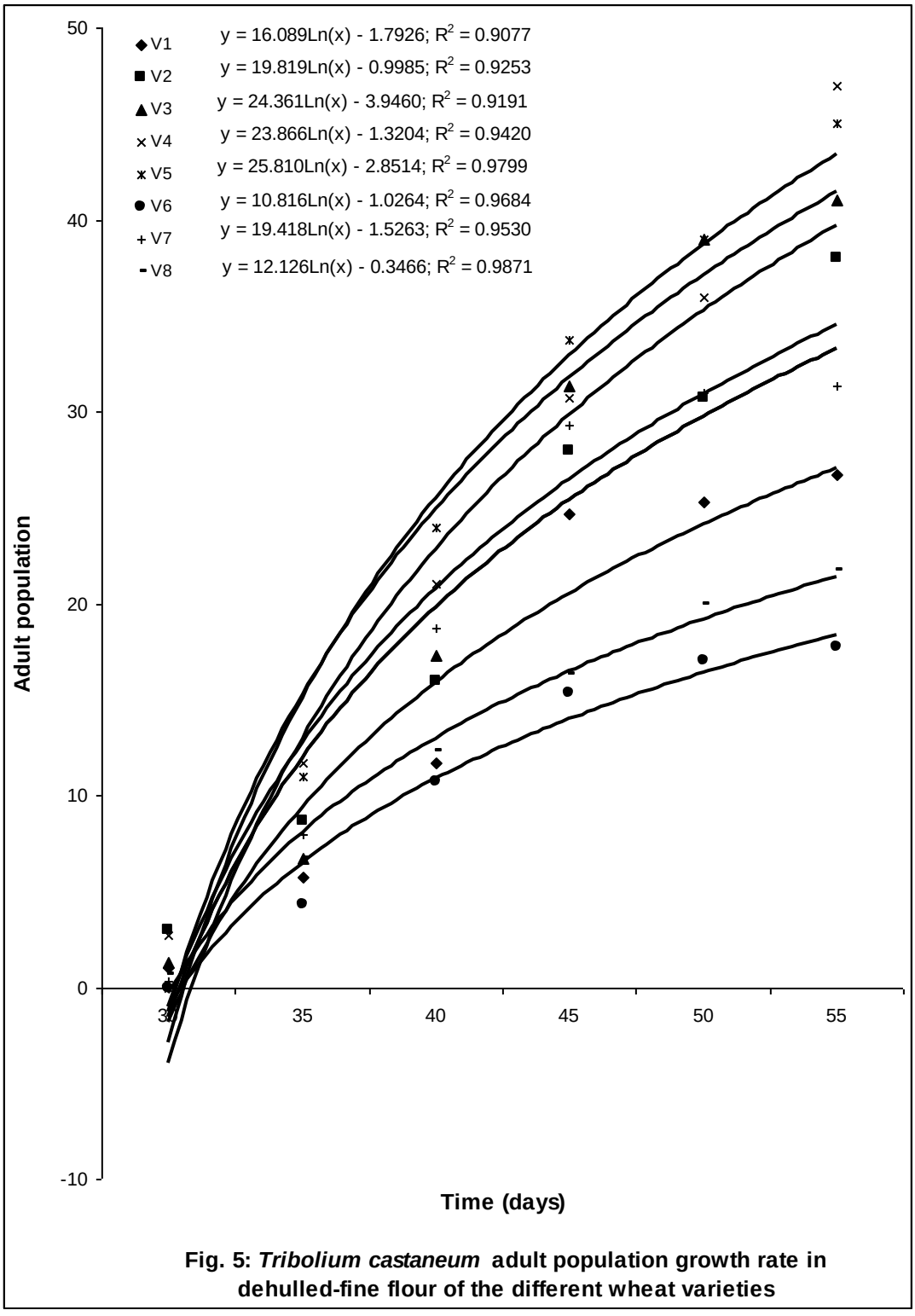

Fig. 5: *Tribolium castaneum* adult population growth rate in dehulled-fine flour of the different wheat varieties

Fig. 3 shows the population growth pattern of adult *T. castaneum* in the dehulled-fine flour of the eight varieties. The chart depicts the sigmoid (logarithmic) pattern of adult population growth, in which Debeira, Faris-30, and Soonot-5 exhibited higher population growth, in contrast to Imam and Nabuq-4 with lower population growth. Fig. 4 shows the best-fit (R2 = 0.9077 - 0.9817) logarithmic population growth curves and equations for the eight wheat varieties. The regression equation indicates that the rate of

population growth ranged from 10.816 - 25.810 beetles every three days. The highest rate of adult population growth was obtained in Faris-30, followed by Soonot-5 and Debeira. Conversely, the lowest growth rate was in Imam, closely followed by Nabuq-4.

Table 2 shows the peak population of *T. castaneum* larvae, pupae, and adults recorded in dehulled-fine flour of the eight different wheat varieties. The results indicated a significant (P<0.05) difference in the larvae population among the different wheat varieties, which ranged from 47 - 100.7 larvae recorded in Nabuq-4 and Debeira, respectively. The result expressed that Debeira gave significantly higher larvae count compared to all other varieties. This was followed by Reyna-19 and Nejmah with a significantly higher larvae population than the remaining varieties, except Soonot-5. In contrast, V8 gave significantly lower larvae count than all the varieties, except Imam. However, there was no significant difference in the larvae population among Reyna-28, Nejmah, V3, and Reyna-19, as was also the case among Reyna-28, Soonot-5 and Faris-30. The result also did not show a significant difference in the larvae population between Faris-30 and Nabuq-4, and between Imam and Nabuq-4.

The result further indicated a significant (P<0.05) difference in the population of pupae which ranged from 32.3 - 62.0 among the different varieties (Table 2). The highest pupae count was from Debeira and the lowest was from Nabuq-4. The result indicated a significantly higher population in Debeira than the other wheat varieties, except Soonot-5 and Reyna-19. In contrast, the population of pupae recorded from Nabuq-4 was comparably lower than other varieties, except Reyna-28 and Imam. However, there was no significant difference in pupae count among Soonot-5, Debeira, and Nabuq-4, as was also observed among Nejmah, Soonot-5, Faris-30, and Reyna-19. Similarly, the population of pupae among Nejmah, Faris-30, and Imam or Reyna-28, Imam, and Nabuq-4 did not differ significantly.

The result of the adult population in the fine flour of the different wheat varieties is as shown in Table 2. The result showed a significant (P<0.05) difference in the recorded number of adult beetles which ranged from 21.7 - 47.0 among varieties, with the lowest and highest from Imam and Debeira, respectively. The result showed that the population of adults in Debeira was significantly higher than all the varieties, except Faris-30 also with a significantly higher population than the remaining varieties, except Soonot-5. The lowest adult population was obtained from Imam, closely followed by Nabuq-4. Results did not show a significant difference in the larvae population of Debeira and Faris-30, as the case also was between Soonot-5 and Faris-30. The result also did not indicate a significant difference in the population between Nejmah and Soonot-5 or Reyna-28 and Reyna-19 or Imam and Nabuq-4.

Table 2. Mean population of *T. castaneum* larvae, pupae and adult in the eight different wheat varieties

Variety	Mean population		
	Larvae	Pupae	Adult
Reyna-28	69.3	41.0	29.0
Nejmah	81.0	44.3	38.0
Soonot-5	73.3	54.7	41.0
Debeira	100.7	62.0	47.0
Faris-30	63.7	47.7	45.0
Imam	49.0	40.0	17.7
Reyna-19	82.3	52.7	31.3
Nabuq-4	47.0	32.3	21.7
Mean	70.8	46.8	33.8
SE±	5.05	3.65	1.68
F-test	0.0000**	0.0013**	0.0000**
$LSD_{0.05}$	15.32	11.06	5.09
CV%	12.36	13.49	8.60

***Significant at 1% probability level of the F-test*

Table 3 depicts the susceptibility index of the different varieties to infestation by *T. castaneum*. The results indicated significant ($P<0.05$) differences in the susceptibilities of the dehulled-fine flour of the eight wheat varieties. The susceptibility of the eight varieties ranged from 7.57 - 11.31%. Imam was the least susceptible variety, while Debeira was the most susceptible. However, Nejmah and Soonot-5 were equally as susceptible as the most susceptible variety, Debeira. Conversely, the Nabuq-4 was equally as susceptible as the least susceptible variety, Imam.

Table 3. Susceptibility of the dehulled-fine flour of the eight wheat varieties to infestation by *T. castaneum*

Variety	Susceptibility index (%)
Reyna-28	9.22
Nejmah	10.23
Soonot-5	10.80
Debeira	11.31
Faris-30	9.95
Imam	7.57
Reyna-19	9.51
Nabuq-4	8.44
Mean	9.63
SE±	0.54
F-test	0.0046
$LSD_{0.05}$	1.64
CV%	9.73

***Significant at 1% probability level of the F-test*

DISCUSSION

The red-rust flour beetle, *Tribolium castaneum* is a serious pest of stored wheat flour in Nigeria. The present study compared *T. castaneum* biology, population and population growth rate, and the susceptibility in the dehulled-fine flour of the eight wheat varieties. The results of the present study did not show a significant difference in the pest's biology in the eight studied wheat varieties. In the present study, developmental periods of larvae, pupae, and adults were 8.3 - 9.0 days, 30.0 - 32.7 days and 35.7 - 37.3 days, and on the average were 9.0 days, 30.8 days and 36.4 days, respectively. This result agrees with the findings of Scharf et al. (2015), while William (2000) reported that the male and female pupal periods ranged from 6-7 days for males and 7-9 days for females. William (2000) reported that the pupal period was about 8 days. In contrast, Devi and Devi (2015) reported the incubation period was 4 to 5 days and grub underwent seven instars and the total developmental period of the immature stages ranged from 70 to 83 days with an average of 76.5 days, and pupal period ranged from 6 to 9 days. Dhaliwal (2006) found that the grub period lasts on an average from 70 to 83 days to reach the pupal stage. William (2000) reported that the length of the larval period varied from 22 to

more than 100. Shafique et al. (2006). Also In our study, the number of *Tribolium* larvae developed to the adult stage was 23.33 to 50, and the development period was 24 to 70 days causing weight loss of 0.40 to 3.41% in various wheat products. Earlier studies suggested that the biology of *T. castaneum* is dependent on food supply, temperature, and humidity (William, 2000). Lhaloni *et a1*. (1988) reported that the reproduction of *T. castaneum* increased with increasing temperature (20 - 30°C) and moisture content (10 - 16%); to peak at 27°C and 16% moisture.

The result on population in the present study revealed that population larvae, pupae, and adults varied significantly from 47 - 100.7, 32.3 - 62.0, and 21.7 - 47.0, respectively. The result consistently showed a higher number of larvae, pupae, and adults population in the flour of Debeira, thus it was the most preferred variety. However, Faris-30, Soonot-5, Reyna-19, and Nejmah also gave higher larvae, pupae, and adult population than Nabuq-4 and Imam with the lowest population. This result corroborates the findings in earlier studies that there was variability in different wheat cultivars which turned out to be resistant or susceptible against red flour beetle (Aheer and Ahmad, 1993); Syed et al., 2001; Sarwar et al., 2004; Sarwar, 2009 and Ali et al., 2011). Fatima et al. (2010) reported that fecundity and egg hatching of *T. castaneum* differed among the nine wheat varieties. The preference by Tribolium sp had been attributed to starch, mannitol, raffinose, sucrose, maltose, and cellobiose, as well as various monosaccharides, protein and carbohydrate content and flour extraction (Chapman, 1998). Wong and Lee (2011) reported that different types of flour or starch influence the developmental rate of *T. castaneum* in different ways. When the protein content in the diet was high, more adult beetles emerged; in contrast, fewer adults developed in diets with high carbohydrate content.

The present study further investigated *T. castaneum* population growth in the eight different wheat varieties. The result expressed that larvae population growth generally followed the polynomial pattern, with distinct rising (increasing), peak, and falling (decreasing) paths. Larvae emergence started at 10 DAI, attained at 28 DAI, regression depicted that population growth during the build-up phase from 10 - 28 DAI, was at the rate of 5.644 - 15.759 larvae every three days. The results expressed that rates of larvae population build-up in Debeira, Nejmah, Soonot-5, and Faris-30 were significantly higher and faster than in Nabuq-4 and Imam. Subsequently, the larvae population declined at the rate of 0.4162 - 1.0739 larvae every three days as from 28 - 55 DAI. The highest rate of larvae population decrease was in Debeira and the lowest was in Nabuq-4, closely followed by Imam. In contrast, adult population growth generally followed the sigmoid (logarithmic) pattern, and the regression results indicated that the rate of growth ranged from 10.816 - 25.810 beetles every three days. The highest rate of growth occurred in Faris-30, followed by Soonot-5 and Debeira. Conversely, the lowest growth rate was in Imam, closely followed by Nabuq-4. In a similar study, Ali et al. (2011) evaluated fifteen wheat varieties, Barani 70 wheat variety was highly tolerant to attack by the flour beetle and variety Wafaq-2001was more sensitive than other trailed varieties. Sawar (2015) evaluated 12 different advanced local wheat germplasms against red flour beetle and found that all the wheat germplasms were susceptible to *T. castaneum*, but NIA-MB-02, NIA-MB-03 and NIA-MN-01, while NIA-MB-01, NIAMN-08 and Khirman were tolerant to the pest infestation.

The study also assessed the susceptibility of the eight varieties to infestation by *T. castaneum*, and the susceptibility index ranged from 7.57 - 11.31%. From the results, Debeira, followed by Nejmah and Soonot-5 were the most susceptible varieties, while Imam and Nabuq-4 were the least susceptible varieties. In a related study, Ajayi and Rahman (2006) reported Susceptibility indices of 8.65, 6.26, 4.46, and 3.19 in wheat, millet, sorghum, and maize. In conclusion, the results on biology, population, population growth rate and susceptibility, indicated that Imam and Nabuq-4 were resistant to T. castaneum infestation, while Debeira, was the most susceptible, followed by Nejmah and Soonot-5. The differences in susceptibility and tolerance attributable to wheat varieties to the development of the pests could assist in the selection of resistant varieties of wheat for cultivation. Therefore, Imam and Nabuq-4 being the most resistant are recommended, to checkmate huge losses to this storage pest.

Conclusion

The foregoing results revealed that variety did not have a remarkable effect on the biology of *T. castaneum*. However, red flour beetle exhibited a higher and faster population and population build-up rate of larvae, pupae, and adults in Debeira, Nejmah, Soonot-5, and Faris-30, while Nabuq-4 and Imam were the lowest. The result on susceptibility indices further expressed that Debeira, followed by Nejmah and Soonot-5 were the most susceptible varieties, while Imam and Nabuq-4 were the least susceptible varieties. In conclusion, the results on population, population growth rate, and susceptibility, indicated that Imam and Nabuq-4 were resistant to *T. castaneum* infestation, while Debeira, followed by Nejmah and Soonot-5 were the most susceptible. Therefore, *T. castaneum* showed preferences for infestation to some wheat varieties, which suggest that such varieties were more vulnerable than those that were resistant.

Recommendation

The present study has revealed that wheat varieties differed in the susceptibility to infestation by *T. castaneum*. The varieties, Debeira, Nejmah, Soonot-5, and Faris-30 were found to be susceptible. It is therefore, recommended that adequate attention should be accorded to such varieties, especially during storage against the pest. In contrast, Imam and Nabuq-4 were the least infested and were therefore resistant, and their patronage would reduce the cost of pest control, as well as damage to stored flour and losses. With the continuous screening of varieties, chances are high that more resistant varieties would emerge, therefore such studies should be expanded to more varieties.

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