Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.7, No.22, 2017

Differential Response of Cultivar-Morphological Status Combination on Damage Severity of Stored Dates Infested with Oryzaephilus Surinamensis L (Coleoptera: Silvanidae)

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Abstract
Three locally sourced date cultivars, *Jigawa*, *Deglet Noor* and *Mali*, were divided into those with and without calyces and infested with 10 pairs of 2-3 days old *Oryzaephilus surinamensis* to determine their differential response to insect activities and formulate a damage severity scale across 14 weeks. Mean damage severity period (weeks) revealed that date cultivars without calyx significantly ($P<0.05$) depredated faster than date cultivars with calyx as presence of calyx covering was found to confer protection against infestation and delayed rate of development. Deglet Noor with calyx recorded the longest mean of 11.8 weeks to ferment at damage scale 5, which was statistically different ($P<0.05$) from Jigawa cultivar without calyx with a mean of 9.0 weeks to reach same damage scale. The result shows significant differences ($P<0.05$) in the influence of *O. surinamensis* infestation on stored dates across time where the six date samples recorded varying time periods (weeks) for damage as arranged in decreasing order: Deglet Noor with calyx (DC) > Deglet Noor without calyx (DNC) > Mali with calyx (MC) > Mali without calyx (MNC) > Jigawa with calyx (JC) > Jigawa without calyx (JNC). Thus, the best cultivar-morphological status combination that showed longer quality date storability against *O. surinamensis* infestation was Deglet Noor cultivar with calyx (DC) while Jigawa cultivar without calyx (JNC) was the least.
Keywords: *Oryzaephilus surinamensis*, date cultivars, calyx, damage severity scale

1. Introduction

Date palm tree (*Phoenix dactylifera* L.) is a horticultural and economic plant (Omotesho *et al*., 2015) and one of the earliest crop plants Known to man (Khalid *et al*., 2011), whose origin is believed to be the Middle East, especially Mesopotamia, and Western India (Barrow, 1998; Ahmed *et al*., 2015). The date palm industry has provided farmers with plant husbandry options in Nigeria, the United States (Swingle, 1904) and many other countries of the world (Copley *et al*., 2001; Al-Qarawi *et al*., 2004; Al-Farsi *et al*., 2005). Date palm is ranked among the top five tree crops, and it is the most important dried fruit worldwide (Shauket, 2003; GOP, 2013; Popoola, 2013). This worldwide recognition is mainly due to its immense nutritional values and providing millions with many necessities of life (Hodel and Pittenger, 2003; Movahed *et al*., 2011; Sadiq *et al*., 2013). Hence the date palm tree has been nicknamed the 'tree of life' or 'blessed tree' by those that benefit from it (Augstburger *et al*., 2002; Hodel and Pittenger, 2003; Abul-Soad, 2010; Reilly *et al*., 2010).

In Nigeria, the growing popularity of the date palm fruit is due to its social, cultural, religious, nutritional, medicinal and industrial importance (Jahromi *et al*., 2008; Sani *et al*., 2009; Baliga *et al*., 2011; Anjum *et al*., 2012; Vayalil, 2012, Dhulappa, 2016) and its ability to generate employment through the different activities associated with its production and value chain (Blench, 2007; Dada *et al*., 2012). The value chain begins from the time dates are harvested to the time they are consumed (Lipinski *et al*., 2013; TEIU., 2014; Omotesho *et al*., 2015). During this journey, dates become predisposed to damage, insect infestation and waste. About 18 to 50% of the total date production can be potentially lost due to pests and diseases (Youdeowei, 1989; Seshu and Walker, 1990; Zabar and Borowy, 2012; USDS, 2013) which pose a serious threat to food production, especially in the world's arid and semi-arid regions (Chamchalow, 2003), where it is majorly cultivated.

Dates often come under intense attack from a vast array of insect pests (Kader and Hussein, 2009; Hashim *et al*., 2011; Bhubaneshwari and Devi, 2015) especially the saw-toothed grain beetle, *O. surinamensis*, which attacks dates both in and outside of stores causing an irreversible damage in both quantity and quality (Kader and Hussein, 2009; Calvin, 2001; Al-Deeb, 2012). Female of this beetle is particularly attracted to commodities through odours emitted by the products (White, 1989, Trematerra *et al*., 2000). Infestation affects the fruits' market value, reduces its nutritional value, and ability to germinate (Okiwelu *et al*., 1987; Lale, 2002; Ahmed *et al*., 2015) because insect pests feed on seed's germ of grains (Lale, 2002). Produce quality can also be reduced due to pest activities as a result of contamination with cocoon, frass, and larval exuviae (Lale, 2002). Adults and larvae of *O. surinamensis* bore into dates during infestation, hence making tunnels within the mesocarp thereby reducing fruits' market value

(Lorini, 2005; Ahmed *et al*., 2015). It is worthy of note that low quality dates, damaged dates and those without calyces are the most vulnerable for the saw-toothed grain beetle to infest (Al-Hafidh *et al*., 1987). Due to its association with other insect pests like *Sitophilus oryzae*, *Necrobia rufipes*, and *Cryptolestes pusillus* (Hill and Waller, 1990; Mason, 2015), whole grains are not spared from *O. surinamensis* infestation. Microorganisms also tend to flourish where *O. surinamensis* are found (Trdan *et al*., 2005). This is corroborated by Al-Dosary (2009) who reported that an explosion in population of *O. surinamensis* increases degradation and decay in stored commodities.

O. surinamensis has been reported to be a hazardous pest of stored agricultural and some industrial products such as packaged chocolates, wheat, oat, sorghum, corn and cornflakes (Trematerra and Throne, 2012; Mason, 2015; Trematerra *et al*., 2016). Klys (2012) described *O. surinamensis* as a very irrepressible insect pest species. *O. surinamensis* is a small, flat insect measuring 1.7 to 3.2 mm long (Rees, 1996) that moves rapidly (Rees, 2007; Mason, 2015) and hides in-between commodities and in crevices, openings and under tree barks (Linsley, 1944; Sengupta *et al*., 1984). Its control is made difficult by the beetle's longevity, being recorded to live for up to 7 months (Mason, 2015), and even up to 3-5 years in extreme cases (Howe, 1956; Kilpatrick *et al*., 2004). Females lay about 400 eggs either singly or in batches (Khamrunissa *et al*., 2006; Rees, 2007) and oviposition drops after 2 months (Mason, 2015).

Stored dates become infested with *O. surinamensis* and this leads to various types and degrees of depredation which range from becoming puffy, to visible presence and movements of insects and becoming severely physically damaged. This study was carried out to determine the types and degrees of damages done to different cultivars of stored dates by *O. surinamensis* and time period taken for these damages to manifest,

2. Materials and methods

2.1 Dates preparation

Three date cultivars, *Jigawa*, *Deglet Noor* and *Mali* were purchased from Gombe Central market, North East Nigeria, and divided into those with intact calyces and those without calyces to obtain 6 different date cultivars – morphological status combinations. 200g of each of the six date samples were replicated 5 times, emptied onto an aluminium foil paper and heat-sterilized at 60°C for 2 hours using a hot air oven, by dry sterilization. The sterilized dates were afterward spread on a new cardboard paper and left for 8 hours to cool. Sterilized date samples were put into 30 coded 1-L glass jars, each jar containing 200g dates.

2.2 Sexing and oviposition of O. surinamensis

Adult *O. surinamensis* were recovered from a date culture in the Plant Protection Laboratory, Faculty of Agriculture, University of Port Harcourt, and sexed by observing a spine on the femur of the hind leg of males which is absent in females. 10 pairs of adult *O. surinamensis* were introduced into the coded 1-L glass jars for infestation of date samples and secured with perforated lids, muslin and rubber bands. These were left undisturbed in the laboratory in a Completely Randomised Design (CRD) for 8 days so that mating and oviposition could take place after which adult *O. surinamensis* were removed from the date samples.

2.3 Determining damage scale on O. surinamensis-infested date cultivars

Weekly observation was carried out on *O. surinamensis*-infested dates for emergence, characterization of damage types and severity at ambient temperature and relative humidity of 32±2°C and 85±5% respectively. Characterization was subjective (Appert, 1987; Zaid and Arias-Jimenez, 2002; I T C, 2012; Utono, 2013) and was done at weekly intervals starting from week 1 after removal of adult *O. surinamensis* from infested samples. Observation was achieved by emptying date samples in a rectangular glass box measuring 55 x 25 x 50 cm (in order to trap insects from escaping) and carrying out visual damage observation. A scale of 0 to 5 was drafted and damages were scored in line with this as shown in Table 1:

Table 1: Description of damage severity scale on stored dates infested with *O. surinamensis* over a period of fourteen weeks

Scale	Damage level	Description
0	Un-damage	Dates in good condition for consumption with no insect presence or any sign of damage
1	Slight damage	Dates become puffy due to increased absorption of moisture from the storage environment
2	Slight-moderate damage	Heightened insect presence and activities due increased adult emergence
3	Moderate damage	Physical damage visible as a result of insect feeding activities by causing injury to fruit's exocarp and mesocarp
4	Severe damage	Detritus accumulates at bottom of jar as a result of food debris, dejecta and dead insects
5	Very severe damage	Fermentation sets with a characteristic odour

Modified after Compton and Sherington (1999)

Mean period of infestation of dates from week 1 to 14 was calculated by the weighted mean formula:

$$\text{Weighted mean} = \frac{\sum fx}{\sum x}$$

Where:
f = weeks
x = damage severity scale
Modified after Appiah *et al*. (2007).

Calculated means were subjected to one-way analysis of variance using Minitab 16 (Minitab Inc. USA) and significant differences between the date samples were confirmed by Tukey's test at 95% confidence level.

2.4 Testing dates for firmness

Date samples belonging to the three cultivars: Jigawa, Deglet Noor and Mali, were selected at random and kept under ambient temperature of 28°C – 32°C for 24 hours to achieve uniform internal temperature and thereafter tested for firmness using a digital penetrometer. A steel piece, weighing 150g was put on the penetrometer and penetration after 10 seconds were recorded in millimetre (mm). Tests were replicated 5 times for each date cultivar and data tabulated and thereafter analysed statistically using Minitab 16. Tukey's test at 95% confidence level was used to separate the means.

3. Results

Table 2 shows the degree of damage attributed to *O. surinamensis* on date cultivars with morphological differences (with or without calyx) over a period of 14 weeks. The result revealed that *O. surinamensis* did not emerge from all the cultivars up to the end of 4^{th} week. However, slight damages were observed on Jigawa without calyx (JNC) and Jigawa with calyx (JC) at week 5 followed by Deglet Noor without calyx (DNC) and Mali cultivar without calyx (MNC) at week 6 and lastly by Mali cultivar with calyx (MC) and Deglet Noor cultivar with calyx (DC) at week 7. Slight moderate damage occasioned by increasing *O. surinamensis* emergence commenced on JC and JNC at week 7 and on DNC and MNC on week 8 while it was recorded at weeks 9 and 10 for MC and DC respectively. Physical damage started at week 8 on JC and JNC, week 10 on MC and MNC and lastly at weeks 11 and 12 on DNC and DC respectively. Similarly, severe damage evidenced by accumulation of detritus commenced on JC and JNC at week 10, followed by MC and MNC at week 12 and lastly by DC and DNC at week 13. Very severe damage characterised by fermentation commenced on JC and JNC at week 12 and at week 13 on MC and MNC, lastly followed by DC and DNC at week 14. In all the cultivars, the damage severity increases significantly ($P<0.05$) with time (Weeks). On the over all, the result showed that the most resistant dates sample to *O. surinamensis* infestation arranged in decreasing order are: Deglet Noor with calyx > Mali with calyx > Deglet Noor without calyx > Mali without calyx >Jigawa with calyx >Jigawa without calyx.

Also, considering the damage scale, the result of the mean severe damage on the six date samples from week 1 to 14 revealed a significant lowest mean of 9 weeks for Jigawa date cultivar without calyx which is statistically different ($P<0.05$) from the highest mean of 11.8 weeks for Deglet Noor cultivar with calyx (Fig. 1). The mean number of weeks taken by *O. surinamensis* to severely damage the six date samples in decreasing order were DC (11.8 weeks) > DNC (11.2 weeks) > MC (11.0 weeks) > MNC (10.6 weeks) > JC (9.6weeks) > JNC (9.0 weeks) as presented in Fig. 1

Table 2: Damage scale on three date cultivars with two morphological status infested with *O. surinamensis* over a period of fourteen weeks

Week	Date sample					
	JC	JNC	DC	DNC	MC	MNC
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	1	1	0	0	0	0
6	1	1	0	1	0	1
7	2	2	1	1	1	1
8	3	3	1	2	1	2
9	3	3	1	2	2	2
10	4	4	2	2	3	3
11	4	5	2	3	3	3
12	5	5	3	3	4	4
13	5	5	4	4	5	5
14	5	5	5	5	5	5

Keys: 0 – No effect on dates (undamaged), 1 – Date become soft (slight damaged), 2 – Adult insect activity noticed (slight moderate damage), 3 – Physical damage noticed on dates (moderate damage), 4 – Detritus seen at container bottom (severe damage), 5 – Dates began to ferment (very severe damage).

Figure 1 shows scale of damage severity of six date samples infested with *O. surinamensis* where it took only 9 weeks for Jigawa date cultivar without calyx to reach the final damage scale but 11.8 weeks for Deglet Noor cultivar with calyx to reach same. However, the following is the arrangement, in decreasing order of the date samples based on the number of weeks taken to hit the final damage scale: DC > DNC > MC > MNC > JC > JNC.

Penetration depth (mm) was highest (2.26±0.29) in Mali date cultivar though not significantly (P>0.05) different from Jigawa date cultivar (1.95±0.25). However, both Mali and Jigawa date cultivars had significantly (P<0.05) higher penetration compared with Deglet Noor date cultivar (1.23±0.12) (Fig. 2).

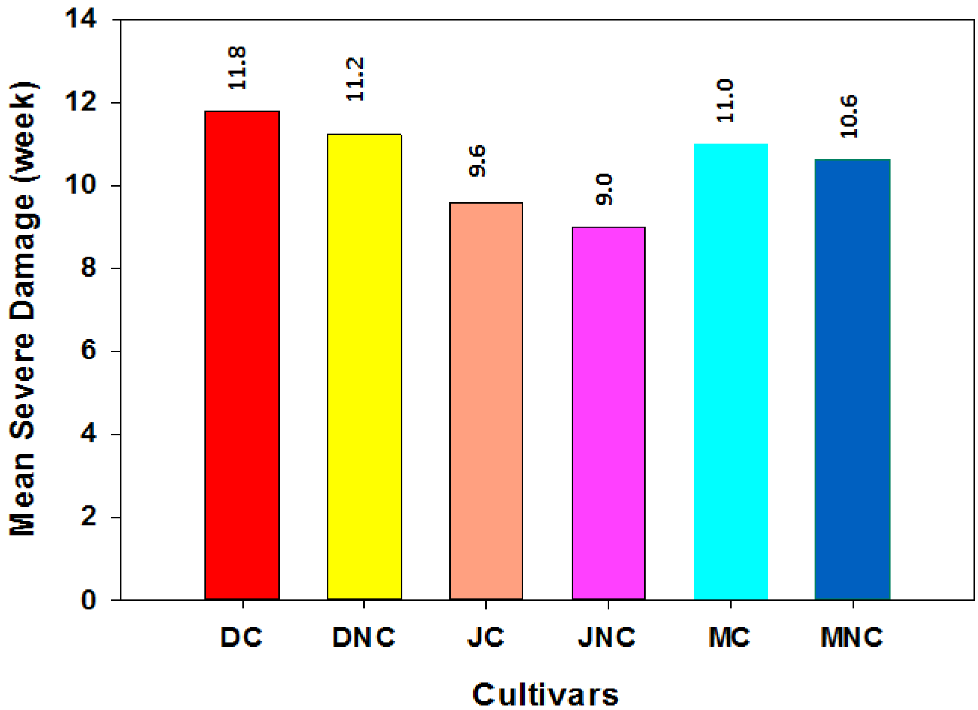

Fig. 1: Scale of damage severity of 6 date samples due to *O. surinamensis* infestation across 14 weeks

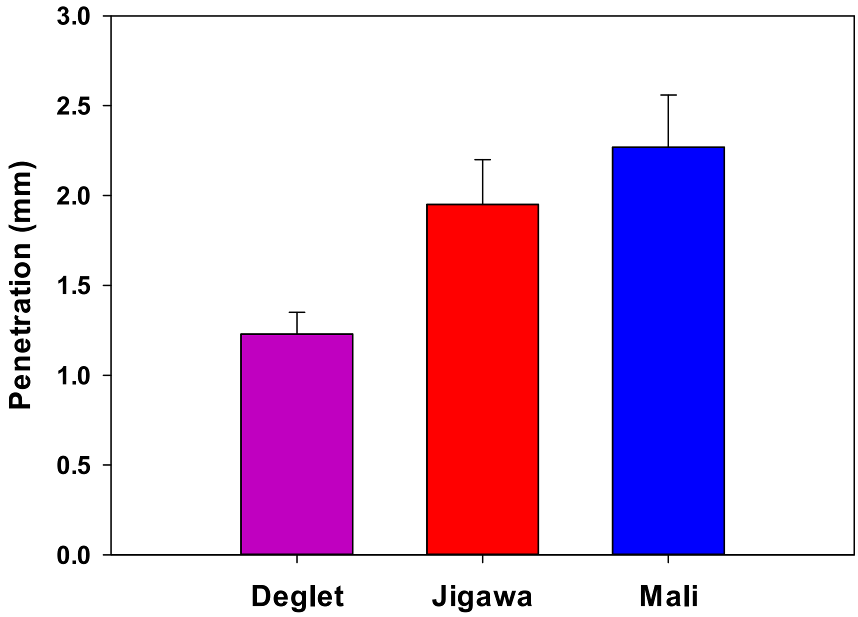

Fig. 2: Mean penetration depth (mm) of a penetrometer in three date cultivars after 10 seconds

4. Discussion

Three date cultivars commonly sold by vendors in Nigeria's streets are *Jigawa* (*Yar Jigawa*), *Deglet Noor* (*Digila*) and *Mali* (*Yar Mali*) date cultivars (Aviara *et al*., 2014). Firmness tests showed Deglet Noor being the firmest date cultivar among the three studied. The penetration depth of a penetrometer was significantly lowest in Deglet Noor compared to the other two date cultivars (Jigawa and Mali). This property of firmness among others might have greatly influenced the degree of depredation due to *O. surinamensis* infestation on dates which is in concord with the report of Mowery *et al*. (2002) that *O. surinamensis* prefers pulpy dates to firm ones.

Fresh dates when put under storage, subsequently become exposed to *O. surinamensis* infestation and will slowly, but steadily begin to show signs of damage which usually comes in various shades and forms, depending on a host of factors (Lale, 2002). This study revealed that Jigawa date cultivar took shorter time to depredate, when infested with *O. surinamensis* compared with the other cultivars. This may be as a result of the pulpiness of Jigawa cultivar which readily harbours insects and favours their activities. It has also been reported that *O. surinamensis* infests date mesocarp and cause severe damage through burrowing and tunnelling activities (Al-Hafidh *et* al., 1987; Lorini, 2005; Ahmed *et al*., 2015).

The experimental result also showed that dates' morphological differences (with or without calyx) play a major role in the degree of *O. surinamensis* infestation. The mean number of weeks taken by *O. surinamensis* to severely damage the six date samples in decreasing order were DC (11.8 weeks) >DNC (11.2 weeks) >MC (11.0) > MNC (10.6) > JC (9.6) > JNC (9.0). It is worthy to note from this study that dates without calyx deteriorated faster than their counterparts with calyx. This finding emphasizes the importance of physical protection conferred by calyx on stored dates against insect infestation (Mathlein, 1971). Thus, morphological covering such as calyx could reduce the activities of *O. surinamensis* on stored dates. This aligns with the findings of Al-Hafidh *et al*. (1987) that date without calyx or with injury are easily infested by insect pests.

The accumulation of detritus (Mignon *et al*., 1996) or conditioned media which appeared first on week 8 in Jigawa cultivar (JC and JNC) and last on week 12 on Deglet Noor cultivar (DC) was an indication of heightened activity of insect pest which is as a result of prolonged insect pest presence and high population index (Hughes, 1982). Since detritus or conditioned media can be used as an index for ascertaining rapid insect population build-up and heightened insect pest activities such as eggs, larval exuviae, faeces, debris and other products, it therefore suggests Deglet Noor may have a longer storability period, especially when the calyx is intact.

The process of fermentation that stated in Week 12 in Jigawa date (JC and JNC), Week 13 in Mali date (MC and MNC) and lastly in Deglet Noor date (DC and DNC) suggests the presence of moulds which might be attributed to build-up of ambient moisture content as reported by Kader and Hussein (2009) and Atia (2011) that high atmospheric moisture encourages mouldy conditions in stored commodities thereby encouraging fermentation process as evidenced by an intense objectionable odour. Therefore, higher depredation due to *O. surinamensis* infestation in Jigawa date cultivar with and without calyx suggests a higher the susceptibility of the cultivar to infestation.

5. Conclusion

The study showed that among the three date cultivars used, Deglet Noor was the firmest while Jigawa cultivar was the least firm date and that the quality of being firm or not, when combined with presence or absence of calyx, greatly affected how the date cultivars responded to *O. surinamensis* infestation and subsequent damage. Results from this study suggest that firm dates with calyx covering (DC) tolerated insect infestation better, and were last to be damaged compared to less firm/pulpy dates without calyx (JNC). It can therefore be recommended from this study that both farmers and store owners should be encouraged to store firm date cultivars with their intact calyx so as to extend their shelf lives in store.

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