Influence of Apple Cultivars on the Development and Fecundity of the Two-Spotted Spider Mite, *Tetranychus urticae* (Koch)

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Abstract

Development and reproduction of two-spotted spider mite, *Tetranychus urticae* Koch (Acarina: Tetranychidae) were studied under laboratory conditions (Temp.25±1°C; RH 70-80%; LD 16:8) to determine the influence of three apple cultivars (Fuji, Tsugaru and Hongro). The results indicated that the development of the mite increased more rapidly on Fuji than rest of the studied cultivars. Developmental periods of the mite were 7.06±0.14, 7.14±0.09 and 7.58±0.17 days in the cultivars of Fuji, Tsugaru and Hongro, respectively. Mortality (%) was 26.00±0.36, 30.11±0.73 and 40.11±0.53 and sex ratio were 75.88±0.60, 74.05±0.46 and 80:07±0.61 on Fuji, Tsugaru and Hongro, in that sequence. Oviposition periods were 17.28±0.28, 22.06±0.36 and 27.72±0.62 days with the adult longevity of 20.89±0.30, 26.22±0.31 and 31.44±1.00 days on Fuji, Tsugaru and Hongro cultivars, respectively. Those completed their lifecycle around the average of 27.94±0.37, 33.36±0.37 and 39.03±0.97 days, on Fuji, Tsugaru and Hongro cultivars, correspondingly. *T. urticae* performed better fecundity on Tsugaru than on the other cultivars, due mainly to high egg production (75.20±1.16 eggs/female) followed by Fuji (71.17±1.17 eggs female^{-1}) and Hongro (45.44±1.62 eggs/female). Mean generation time (T) of the population ranged from 16.73 days on Fuji while 20.18 days on Hongro. The net reproduction rate R_o was high on Fuji (47.36) and low on Hongro (32.72). The highest r_m occurred on Fuji (0.23 ♀/♀/day) and the lowest on Hongro (0.18♀/♀/day).

1. Introduction

The two-spotted spider mite *Tetranychus urticae* Koch (Acarina: Tetranychidae) is widely distributed and a common pest of apple orchard and nursery plants. It is considered to be one of the most economically important pests of apple orchards and in greenhouses though this mite has been reported infesting over 200 species of plants (Fasulo Thomas and Denmark, 2004). Heavy mite feeding early in the season can reduce tree growth, yield, and also affect fruit bud formation for the following year. Necrotic spots occur in the advanced stages of leaf damage. When two-spotted spider mites remove the sap, the mesophyll tissue collapses and a small chlorotic spot form at each feeding site. It is estimated that 18 to 22 cells are destroyed per minute. Continued feeding causes a stippled-bleached effect and later, the leaves turn yellow, gray or bronze. Complete defoliation may occur if the mites are not controlled. Mite damage to the open flower causes a browning and withering of the petals that resembles spray burn. Under hot and dry conditions, spider mites thrive on plants that are under stress. In apple orchards, the potential of *T. urticae* to cause economic damage necessitates chemical control several times a year. Acaricide resistance in spider mite populations has been observed in some commercial apple orchards (Song et al., 1995; Park et al., 1994; Koh et al., 2009) and the tendency of spider mites to develop resistance to a wide range of pesticides has been well documented (Dennehy and Granett, 1982; Dennehy et al., 1983; Helle, 1985; Welty et al., 1987; Herron et al., 1994). This has led to intensive studies of the mite's biology and of alternative control methods. The short development time and high fecundity can increase *T. urticae* population in a short time, by up to 40% per day (Shih et al., 1976). Longevity and fecundity of *T. urticae* depend on ecological conditions, such as temperature and host plants (Düzgünes and Cobanoglu 1983, Güven and Madanlar 2000). The chemical contents and morphology of the leaf surface of host plants affect the reproductive potential, mortality and development rate of the mite (Toros, 1974). Apple producers have come up with numerous varieties of apples, thus providing an impetus to the popularity of this fruit all around the world. There are over 7,500 known cultivars of apples. Korea is a country with rich soil, fresh air and dazzling sunlight favorable for apple cultivation. Hongro is an early-mid maturing Korean apple cultivar with good quality and like `Tsugaru` and it has not pre-harvest drop. On the other hand, Fuji is a Japanese cultivar and has a dense flesh that is sweeter and crisper than many other apple cultivars, making them popular with consumers around the world including Korea. Evaluate pest susceptibilities of apple cultivars to determine both the limitations and the positive attributes of these cultivars.

The present study was designed primarily to provide data on development and fecundity of *T. urticae* on different apple cultivars under laboratory conditions. This knowledge may provide useful information related to growth and development for understanding the population dynamics on three cultivars of apple on the basis of less chance of infestation by the mite.

2. Materials and Methods

An experiment was conducted at Insect Ecology laboratory, Department of Agricultural Biology, Andong National University, Andong, Republic of Korea during 2009 to study the effect of Apple cultivars on the development and fecundity of the two-spotted spider mite.

2.1. Tetranychus urticae rearing

To initiate the stock culture, *T. urticae* was collected from apple leaves (*Malus communis* L.) of Andong city Agriculture and Extension center, Andong city, Korea in 2009. The stock culture was then maintained using all stages of *T. urticae* on apple leaves in the laboratory. After establishment of kidney bean plant in a rearing chamber (plate 1), spider mites were released on soybean plants for mass rearing of spider mites.

Plate 1: Kidney bean plants for mass rearing of *T. urticae*

2.2. Immature development and adult performance

Development and adult performance of the mite was tested on three apple cultivars (Fuji, Tsugaru and Hongro) at the same laboratory. Rearing units were kept in the environmental room at 25 ± 2^{0}C, 60-65% RH and 16L: 8D photoperiod.

Mite infested kidney bean leaves were detached from rearing plants and 50 gravid females for each treatment were taken randomly from the infested leaves and transferred them to fresh leaves of three different cultivars which were placed upside down on wet cotton set on polyurathane foam in a plastic container (9.5×4 cm^2). Females were allowed to lay eggs for 12 hours. Individual egg was transferred by fine hair brush to apple leaf discs (dia. 2.9cm) of three apple cultivars on a wet cotton pad in a small Petridish (5.5×1.5 cm^2) retaining 70-80% R.H.. Apple leaf discs were used as experimental arena for the experiment. Regular moisturizing of cotton was made by water to keep the leaf fresh. Fifty Petri dishes were maintained for each apple cultivar and each Petri dish consisted of one egg. Petri dishes were kept inside an incubator under 25 ± 1^{o}C temperature and 60-70% RH. Different life stages of the mite were studied on the above treated leaves. The observations were made at 12 hours interval using the dissection microscope (Olympus Optical Co., Ltd., Tokyo, Japan). As the leaf discs became aged, fresh apple leaves were supplied, removing the old ones at interval of 5 days until the mite died. The presence of an exuvium was used as the criterion of successful molting to the next development stage and another confirmation sign of changing stages were initiation of chrysalis instars. Newly-emerged female adults were mated individually by one active male from the same condition. Upon counting and collection of newly-laid eggs on each leaf, the eggs of each female were daily transferred to fresh leaf discs where they were reared up to adulthood to determine the sex ratio of the offspring.

2.3. Life table analysis

The life tables of *T. urticae* under three cultivars were constructed from the life history and fecundity data. The actual death occurred in the egg and immature stages were taken into account when the female survival rate at each cultivar was determined. The life table parameters computed by life table analysis using the Birch (1948) equation: $\sum e^{-r_m x} l_x m_x = 1$ where x = age in days, l_x = the age-specific survival rate, m_x = the age-specific fecundity, the intrinsic rate of natural increase ($r_m = \ln(\sum l_x m_x)/T$), the finite rate of increase ($\lambda = e^r$), the net reproductive rate ($R_0 = \sum l_x m_x$), the mean generation time ($T = \sum X l_x m_x / R_0$), and the gross reproductive rate ($GRR = \sum m_x$). Doubling time [DT = (ln 2)/r] was calculated as described by Mackauer (1983).

2.4. Statistical analysis

Means and standard errors (SE) of data were calculated from 30 observations for each case. The collected data were statistically analyzed and the mean differences were tested by the Duncan Multiple Range test (Gomez and Gomez, 1984).

3. Results and Discussions

The present study demonstrated that there are significant differences in performance of the two-spotted spider mite among three apple cultivars. *T. urticae* showed better performance on Fuji than on the other cultivars, due mainly to high fecundity and the intrinsic rate of natural increase.

The developmental periods and reproductive potentials are presented in Table 1. Newly hatched larvae of *T. urticae* have three pair of legs. On the other hand nymphs and adults have four pair of legs. The photography of studied adult female mite is presented in plate 2. From the results of this experiment it follows that apple cultivars have significant effect on the time needed for immature development (egg to adult) of *T. urticae* (df =2,34; F=7.46; p=0.0001). Kasap (2004) also experimented similar result and found significant difference among the immature development times of *T. urticae* while fed on five apple cultivars (Amasya, Golden Delicious, Granny Smith, Starking Delicious and Starkrimson Delicious). For all immature life stages of *T. urticae* (egg through deutonymph), developmental rate was the fastest in Tsugaru followed by Fuji and Hongro with minor variation among life stages (Figure 1). Karaat (unpub. Ph.D. thesis) also observed negligible variation in development rate of tetranychids on different apple cultivars. The differences in the development of the mite on different cultivars of apple might have been caused by quality, accessibility or actual ratio of nutrients, as indicated by Wermelinger et al. (1985). But the adult longevity of the studied mite showed significant differences among the cultivars (df =2,34; F= 59.16; p<0.0001).

The preoviposition (df=2,34; F= 45.03; p<0.0001), oviposition (df =2,34; F= 127.53; p<0.0001) and post oviposition periods (df =2,34; F= 7.62; p<0.0001) were showed remarkable differences among the cultivars. Hongro cultivar showed a little higher (2.58±0.12 days) pre-oviposition period followed by Tsugaru (1.58±0.04 days) and Fuji (1.53±0.07 days). Oviposition period was observed the longest (27.72±0.62 days) on Hongro and the shortest (17.28±0.28 days) on Fuji. The highest post-oviposition period (2.47±0.05 days) recorded on Tsugaru while the lowest on Fuji (2.08±0.10 days). Kasap (2004) and Karaat (unpub. Ph.D. thesis) reported significant differences among the reproduction potentials of two-spotted spider mite among different apple cultivars.

The influence of apple cultivars on the fecundity of *T. urticae* is summarized in Figure 2. Fecundity of spider mites differed among the studied apple cultivars (df =2.34; F= 194.53; p<0.0001). The highest fecundity was recorded on Tsugaru (75 eggs) followed by Fuji (71.17 eggs) and Hongro (45.44 eggs). Bengston (1970) reported that apple cultivars have a significant effect on reproductive potential of *T. urticae*. Kasap (2004) observed total fecundity of *T. urticae* and found significant difference on five cultivars of apple (Amasya, Golden Delicious, Granny Smith, Starking Delicious).

Female *T. urticae* took long time for completing their life cycle (Egg to adult death) on Hongro (39.03±0.97 days), where as it was too short on Fuji (27.94±0.37 days) but Tsugaru

Table 1: Developmental time, adult longevity, reproductive phases (day), fecundity and sex ratio of *T. urticae* on three cultivars of apple at 25±1^{0}C

Stages and life cycle	Fuji Mean ± SE	Tsugaru Mean ± SE	Hongro Mean ± SE
E	3.64 ± 0.13a	4.00 ± 0.09a	4.11 ± 0.12a
L	1.08 ± 0.04a	1.06 ± 0.03a	1.11 ± 0.05a
P	1.11 ± 0.05a	1.00± 0.00a	1.14 ± 0.08a
D	1.22 ± 0.07a	1.08 ± 0.04a	1.22 ± 0.07a
T	7.06 ± 0.14a	7.14 ± 0.09a	7.58 ± 0.17a
Pre-ovi	1.53 ± 0.07a	1.58 ± 0.04b	2.58 ± 0.12b
Ovi	17.28 ± 0.28c	22.06 ± 0.36b	27.72 ± 0.62a
Post-ovi	2.08 ± 0.10b	2.47 ± 0.05a	2.36 ± 0.09ab
AL	20.89 ± 0.30c	26.22 ± 0.31b	31.44 ± 1.00a
LE	27.94 ± 0.37c	33.36 ± 0.37b	39.03 ± 0.97a
Sex ratio (F:M)	75.88 ± 0.60	74.05 ± 0.46	80.07± 0.61

E: egg; L: Larvae and protochrysalis; P: protonymph and deutochrysalis; D: deutonymph and tritochrysalis; T: total developmental time (egg to adult); Pre-ovi: preoviposition period; Ovi: oviposition period; AL: Adult longevity; Post-ovi: post-oviposition period; LE: Life cycle (Egg to adult death); same letter indicates non-significance each other & different letters differ significantly (p≤0.05).

Plate 2: Two spotted spider mite, *T. urticae*

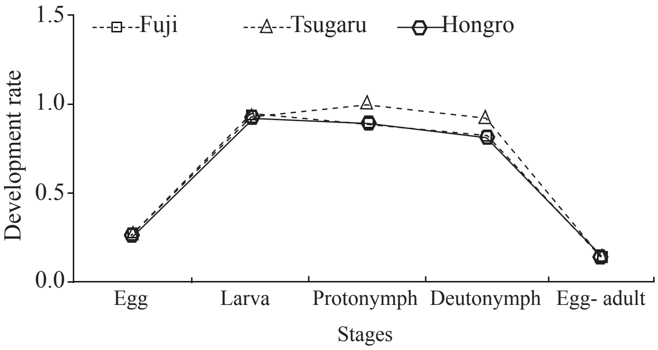

Figure 1: Curves of developmental rate of female *T. urticae* fed by three apple cultivars

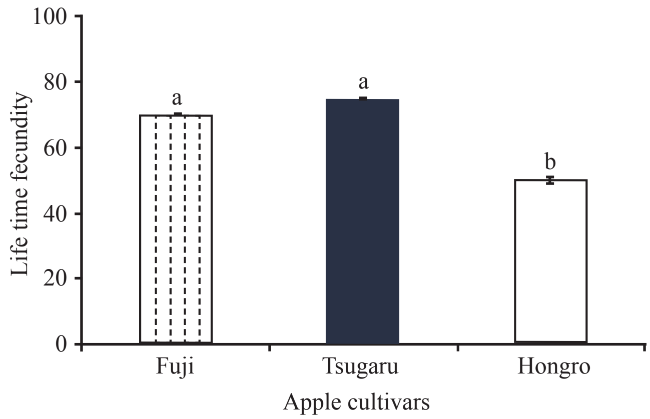

Figure 2: Life time fecundity of female *T. urticae* on three apple cultivars

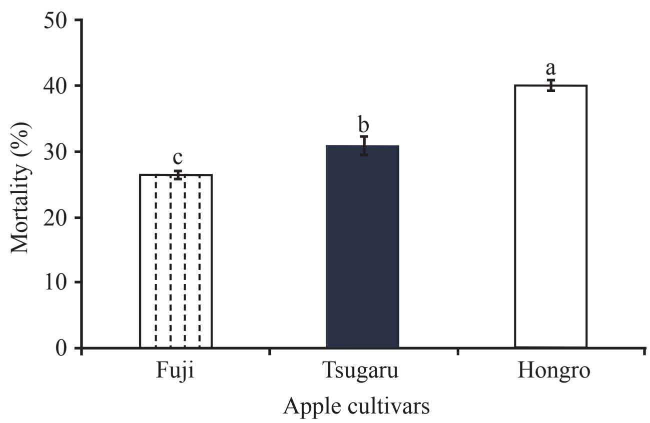

Figure 3: Mortality observed in *T. urticae* while developed through three apple cultivars

variety (33.36±0.37 days) showed intermediates in between the Hongro and Fuji which were statistically different. It was interesting that though Hongro cultivar took long oviposition period and life cycle but regarding fecundity performance the Hongro cultivar (45.44±1.62 eggs female^{-1}) was found poor. In this connection, Tsugaru cultivar (75.20±1.16 eggs female^{-1}) showed a very good performance of oviposition which are statistically identical with Fuji cultivar (71.17±1.16 eggs female^{-1}).

Table 2: Life table parameters for *T. urticae* on three apple cultivars under 25±1^{0}C with a photoperiod of 16L: 8D

Apple Cultivars	R_0	r_m	T	λ	DT	GRR
Fuji	47.36	0.23	16.73	1.26	3.00	57.45
Tsugaru	47.00	0.21	18.34	1.23	3.30	54.25
Hongro	32.72	0.18	20.18	1.07	3.78	37.53

The mortality rate of the two-spotted spider mite from the immature stage to adult emergence among the cultivars is presented in Figure 3. It was found that mortality of *T. urticae* differed among the apple varieties and the highest mortality was recorded on Hongro (40%) and the lowest on Fuji (26%).

In addition to that sex ratio was varied among the cultivars of apple (Table 1). It was observed that percentage of female was higher on Hongro (80.07±0.61) but fewer on Tsugaru cultivar (74.05±0.46). Variation for each life table parameter was estimated on three apple cultivars (Table 2). These parameters were affected by the cultivars. Net reproduction rate (*Ro*) of *T. urticae* was highest on Fuji (47.36 females generation^{-1}) and lowest on Hongro (32.72 females generation). Hence, the *Ro* values indicated that both Fuji and Tsugaru were the favorable cultivars for *T.urticae* development. The longest mean generation time (*T*) occurred on Hongro (20.18), followed closely by Tsugaru (18.34); the shortest *T* was recorded on Fuji (16.73).

The intrinsic rate of natural increase (r_m) was highest 0.23 when fed on Fuji followed by Tsugaru (0.21) and Hongro (0.18). Normally, higher r_m is related to shorter developmental and generation times (Tanigoshi et al., 1975; Sabelis, 1981) which is true in our case. The intrinsic rate of natural increase is an important parameter, describing the growth potential of a population under climatic and food conditions, because it reflects the overall effects of temperature and food on development, reproduction and survival characteristics of the population (Southwood, 1978). Preceding studies of the two-spotted spider mite also demonstrated that the r_m values varied significantly with host plants. The reported r_m values of *T. urticae* on the delicious apple leaves were 0.372 and 0.199 (Bengston, 1970; Herbert, 1981), on Granny Smith 0.170 (Bengston, 1970), on Gravenstein 0.130 (Bengston, 1970) and on Jonathan 0.163 (Bengston, 1970), on bean 0.336 and 0.265 (Kasap, 2002 ; Shih et al., 1976), on cucumber 0.247 (Kasap, 2002), on rose 0.200 (Kasap, 2002). This variation might be due to the chemical contents, food quality, secondary metabolites and leaf texture of the host plants, and to the geographical differences between collection sites. These leaf characteristics of the host plants are significantly related to oviposition rates of *T. urticae* and can play a role in the direct defense against *T. urticae* (Peters and Berry, 1980a; Peters and Berry, 1980b; Yano et al., 1998). Patterson et al. (1974) reported that sticky glandular hairs of tobacco varieties prevent the mobility of *T. urticae* and the spider mite larvae may have been poisoned by toxic components or entrapped by the sticky exudate of the glandular hairs. In addition, van den Boom et al. (2003) stated that *T. urticae* does not accept all plants to the same degree because of differences in nutritive and toxic constituents, the secondary metabolites and the morphology of the leaf surface.

Moreover, *T. urticae* has a much lower survival rate on a tobacco cultivar with high rather than low glandular hair density. However, the oviposition rate of *T. urticae* increased on leaves of hop cultivars with a higher density of hairs (Peters and Berry, 1980a). These results are consistent with the findings in studies of other spider mites (Toros, 1974; Peters and Berry, 1980b).

4. Conclusion

From the results of the current study, we can be concluded that as *T. urticae* showed the slowest speed of development, higher mortality and lowest fecundity on Hongro cultivar of apple, so the Korean origin Hongro could be the suitable cultivar among the three cultivars for less chance of infestation by two-spotted spider mite.

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