Iran. J. Plant Path., Vol. 48, No. 4, 2013: 155-160

DIFFERENCES IN THE LIFE PARAMETERS RELATED TO POPULATION INCREASE OF SOME MAJOR GENOTYPES OF SCOTTISH *Myzus persicae*, THE MAIN VECTOR OF *Potato leafroll virus*[*]

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(Received 6.8.2011; Accepted : 20.6.2012)

Abstract

Different clones of *Myzus persicae*, the main vector of *Potato leafroll virus* (PLRV), vary in reproductive performance, host-plant adaptation, insecticide resistance and vector efficiency. In this study some important life parameters related to population increase of five major genotypes of Scottish *M. persicae*, characterized by the ribosomal DNA intergenic spacer fingerprinting technique, denoted type A, B, C, J, and I along with clone 4010 of *M. antirrhinii* were analyzed. The life parameters measured were average daily offspring production, reproduction time, total offspring production and longevity. These were measured by putting fourth instar nymphs from each genotype on detached leaves of oilseed rape and potato, recording the number of offspring produced by each individual and removing them from the leaves daily until each individual died. The developmental time of the genotypes was also determined by putting one day old offspring of each genotype on detached leaves of the same plants and recording the period from birth to maturity. Significant differences in life parameters of the genotypes were observed. Genotype A was one of the most reproductive genotypes on both hosts and genotype B was so, on potato. It has already been shown that these two genotypes were resistant to insecticides and more efficient vectors of PLRV. Taking these matters into account, it is clear that the existence of such genotypes that are very reproductive, resistant to insecticides and efficient in transmitting PLRV, can potentially increase the spread of the virus if they become established as the predominant genotypes in each area. This in turn, further reinforces the necessity of monitoring *M. persicae* genotypes with regard to resistance to insecticides, virus transmission efficiency and reproduction capacity in each specific region.

Keywords: *Myzus persicae*, Genotype, Life parameter, PLRV.

*: A Part of PhD. Thesis of the First Author, Submitted to the University of Dundee, Scotland and Part of a Research Program at the Scottish Crop Research Institute, Scotland.

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Introduction

Different clones of *Myzus persicae* (Homoptera: Aphididae), the most efficient vector of *Potato leafroll virus* (PLRV), vary in host-plant adaptation (Weber, 1985; Nikolakakis *et al*., 2003; Fenton *et al*., 2010), insecticide resistance (Devonshire *et al*., 1986; Bolandandam *et al*., 2004) and vector efficiency (Woodford *et al*., 1999; Robert & Bourdin, 2001; Nikan *et al*., 2008). Using a ribosomal DNA intergenic spacer fingerprinting technique, Fenton *et al*. (1998) examined 276 samples of Scottish *M. persicae* and found at least 80 different genotypes among the samples tested. A large number (30%) of samples were the same genotype (genotype J). Genotype J (formerly known as Mp1S) which has long been used as the standard *M. persicae* clone at JHRI(James Hutton Research Institute (formerly Scottish Crop Research Institute), Scotland, UK) is sensitive to insecticides (Woodford *et al*., 1999). As, a negative association between the levels of resistance to insecticides and the ability of *M. persicae* to survive winter low temperatures has been found (Foster *et al*., 1996), it seems plausible that genotype J is able to withstand winter better and consequently, maintains its dominance over the insecticide-resistant genotypes. Transmission efficiency of PLRV by aphid vectors has been shown to depend not only on species, but also on clones, morphs and instars of the aphid vector (Upreti & Nagaich, 1971; Singh *et al*., 1982; Woodford *et al.,* 1999; Nikan *et al*, 2008). The spread of a plant virus by an aphid vector is not only dependent on the efficiency with which the aphid vector transmits the virus, but also on the extent to which the vector spreads in crops. In turn, the extent of spread of a vector depends on the speed of its population increase. In addition to the interclonal variations in virus transmission efficiency of *M. persicae* populations, such variations in fecundity and population increase have also been reported.

Weber (1985) assessed the genetic variability in field populations of *M. persicae* with respect to their adaptation to sugar beet and potato by measuring the population increase in 12 days (P12). This was done by confining a single apterous fourth instar of each clone on the leaves of sugar beet or potato and counting the number of aphids produced from one apterous aphid 12 days after the onset of offspring production. The P12 was taken as a measure of population increase. Weber (1985) argues that the P12 is a complex index, including several parameters such as fecundity, reproduction time, developmental time and larval mortality. The influence of these parameters on P12 was tested by Weber (1985) who found that the fecundity was positively correlated with reproduction time and negatively with developmental time. He also found that the P12 was highly dependent on the fecundity, the number of offspring production per day and the developmental time (from birth to the time of maturity). Goundoudaki *et al*. (2003) studied the life parameters (performance, developmental time, intrinsic rate of increase and longevity) of two Greek *M. persicae* clones (a red and a green clone) on different varieties of tobacco plant. They found an interclonal variation in performance. The analysis concerning the pooled data of the two clones obtained from all tested varieties showed significantly better life parameters for the red clone than the green one. Here the results of the studies on some aspects of the biology of five genetically different major genotypes of Scottish *M. persicae* are reported. The aim of these studies was to reveal if the arrival of insecticide resistant genotypes amongst the *M. persicae* population could pose an increased threat of PLRV spread.

Materials and methods

The aphid genotypes studied were genotypes A, B, C, I and J of Scottish *M. persicae* (Fenton *et al*., 1998) and clone 4010 of *M. antirrhinii* (Woodford *et al*., 1999). For these studies genotypes C, J and I were chosen because in 2001, they comprised nearly 22%, 20% and 20% of the population of *M. persicae* in Scotland, respectively (B Fenton personal communication). Genotypes A and B were studied because they are the most insecticide-resistant genotypes of Scottish *M. persicae* (Bolandandam *et al*., 2004). In our studies, the life parameters that affect the P12 (the reproduction time, the total offspring production, the average daily offspring production and the developmental time) were measured. Another life parameter that was measured in our experiments was longevity (from birth to death) that is related directly to virus spread.

The rate of offspring production was studied by transferring some fourth instar nymphs (seven days old) of the aphid genotypes (11 individuals

from each genotype) to excised leaves of oilseed rape and potato cv. Désirée in sealed cages (each individual on a separate leaf). The cages were kept in a controlled environment room at 18˚C with a 16 h photoperiod. Each day the number of offspring produced by each individual was recorded and they were then removed from the leaves. Recording was continued until each individual aphid died. The total number of offspring production for each individual was calculated by adding its daily production during the reproduction time. The reproduction time was considered as the period from the day of starting to the day of ceasing reproduction. Moreover, the longevity for each individual was calculated by adding 7 days to the period that each individual was alive on the leaves.

To study the developmental time, two one-day old nymphs of each genotype were transferred on detached leaves of oilseed rape and potato and allowed to grow. Each day thereafter, the condition of each individual nymph was examined. For each individual, the time (days) from birth to the time of maturity was recorded. The individuals were considered as mature either when they started producing offspring, or turned into alate forms. The average developmental times for the genotypes were calculated from the developmental times recorded for 20 or more individuals for each genotype. Analysis of variance was used to compare the life parameters of genotypes on the two hosts (oilseed rape and potato). Plots of the residuals indicated that there was no need for a normalizing transformation of the variables before analysis.

Results and discussion

The results of the statistical analysis of the data and the means of the life parameters of the aphid genotypes under test are shown in table1 and table 2, respectively. We found significant differences in the performance of *M. persicae* genotypes tested in our experiments. Such differences had been found by other researchers (Nikolakakis *et al*., 2003; Fenton *et al*., 2010). The genotypes also performed significantly differently on the two hosts used in the experiments which are in agreement with the works of Weber (1985) and Goundoudaki *et al*. (2003).

There was a significant interaction ($P<0.001$) between the host and the genotype for total offspring production (Table 1). Genotype 4010 produced significantly more total offspring on potato while genotypes C and I produced significantly more on oilseed rape. For genotypes A, B and J the difference between the two hosts was not significant. On oilseed rape, genotype 4010 produced significantly fewer than any other genotype. Genotype B produced significantly fewer than genotypes A and J, which in turn produced fewer than genotypes C and I (Table 2). On potato, the smallest total production belonged to genotype 4010 which was significantly lower than the amount produced by genotype J. No other significant differences for total production of genotypes on this host were seen (Table 2).

Both host and genotype had a significant effect on reproduction time ($P<0.001$) but no significant interaction between the host and genotype was seen for this parameter (Table 1). The genotypes had significantly longer reproduction time on potato (average 21.4 days) than on oilseed rape (average 18.8 days). For the average daily offspring production there was a significant interaction ($P = 0.013$) between the host and the genotype (Table 1). The average daily offspring production on potato was significantly lower than on oilseed rape for genotypes A, C and I, while for the other genotypes there were no significant differences between the two hosts. There was a significant interaction ($P<0.001$) between the host and genotype for developmental time (Table 1). The developmental time for genotypes B, J and 4010 was significantly longer on oilseed rape while for genotypes C and I it was significantly longer on potato. For genotype A there was no significant difference in developmental time on the two hosts (Table 2).

Developmental time, the time required by an aphid nymph to become mature, is one of the aphid's life parameters that have an impact on the P12. Weber (1985) found a negative correlation between the developmental time and the fecundity which in turn influences the P12. Therefore, in a fixed period of time the genotypes with shorter developmental times (e.g. genotypes C and A on oilseed rape and genotypes B and J on potato) can build up a larger population.

For the parameter longevity, there was a significant interaction ($P<0.001$) between the host and the genotype (Table 1). Genotype 4010 of *M. antirrhinii* lived significantly longer on potato while genotype I lived significantly longer on oilseed rape. There was no significant difference

Table 1. Analysis of variance for the life parameters of genotypes

Sources of variance	Degrees of freedom[a]	Variance ratio				
		Daily offspring production	Total offspring production	Reproduction time	Longevity	Developmental time
Crop	1	41.83***	1.06^{ns}	36.85***	1.23^{ns}	5.68*
Genotype	5	10.75***	18.56***	7.60***	9.84***	24.93***
Crop x genotype	5	3.07*	8.13***	2.17^{ns}	5.38***	81.86***

[a] Degrees of freedom for residual were 258 for Longevity and 87 for other parameters
* P<.05; ** P<.01; *** P<.001; *** P<.001; ^{ns} No significant difference

Table 2. Comparison of means for the life parameters of the genotypes on detached leaves of oilseed rape and potato

Genotype	ADOP		TOP		RT		DT		L	
	oilseed rape	potato	oilseed rape	potato	oilseed rape	potato	oilseed rape	potato	oilseed rape	potato
Ma 4010	3.70^{d}	3.39^{b}	60.2^{d}	73.33^{b}	16.3^{c}	21.67^{ab}	9.96^{ab}	7.55^{d}	26.10^{d}	30.33^{a}
A	4.90^{a}	4.19^{a}	82.82^{b}	83.33^{ab}	17.09^{c}	19.83^{b}	9.48^{cd}	9.13^{b}	28.09^{c}	28.67^{a}
B	3.98^{cd}	3.66^{ab}	73.6^{c}	82.17^{ab}	19^{b}	22.5^{a}	10.18^{a}	8.22^{c}	29.1^{bc}	29.80^{a}
C	4.99^{a}	3.65^{ab}	92.18^{a}	75.5^{ab}	18.55^{bc}	20.67^{ab}	8.88^{e}	11.57^{a}	30^{b}	29.17^{a}
I	4.60^{ba}	3.66^{ab}	99.2^{a}	81.5^{ab}	21.6^{a}	22.33^{a}	9.52^{cd}	11.82^{a}	33^{a}	30.33^{a}
J	4.19^{bc}	3.94^{ab}	83.45^{b}	85.5^{a}	20^{ab}	21.67^{ab}	9.86^{bc}	8.65^{c}	29.27^{bc}	29.83^{a}

Numbers in each column followed by different superscript letters are significantly different
ADOT: average daily offspring production; TOP: total offspring production; RT: reproduction time
DT: developmental time; L: longevity

between the longevity on oilseed rape and on potato for the other genotypes. The effect of longevity on P12 was already taken into account through the effect of reproduction time on this index. However, longevity can also directly affect the virus spread because the genotypes that live longer are potentially more capable in spreading the viruses they transmit.

The P12 (population increase in 12 days) a suitable index of population build up for aphids, was shown to be highly dependent on the total offspring production, the average daily offspring production and the developmental time (Weber, 1985). In the studies on the life parameters of the major genotypes of Scottish *M. persicae*, genotype A had one of the highest rates of daily offspring production on oilseed rape. On this plant, it had the second shortest developmental time and the second highest total offspring production. On potato, its total and daily offspring productions were the same as other *M. persicae* genotypes and had the third shortest developmental time. Overall, genotype A was one of the most reproductive genotypes on oilseed rape and was nearly the same as others on potato. Having the smallest total offspring production, the lowest rate of daily offspring production and the longest developmental time, genotype B was the least reproductive genotype on oilseed rape. However, on potato, it could be more reproductive than others because with the same total and daily offspring productions it had one of the shortest developmental times. Weber (1985)

showed that the fecundity was negatively correlated with developmental time.

Among the *M. persicae* genotypes studied here, the most efficient and the poorest PLRV transmitter have been genotypes A and J, respectively (Nikan *et al*, 2008). Genotype A is also the most resistant and genotype J is the most sensitive ones to insecticides (Bolandandam *et al*. 2004; B Fenton, personal communication). During the growing season, due to the selection for resistance to insecticides following frequent applications of these chemicals, the population of resistant genotypes compared to the sensitive ones will increase. This means that the presence of an insecticide resistant genotype such as genotype A that is also a very efficient vector will increase the spread of PLRV in potato crops. Although, at the end of the growing season, particularly in the seed potato growing areas, the population of insecticide resistant genotypes is relatively higher than that of sensitive ones, they cannot maintain their dominance over the sensitive genotypes. This is most probably because they incur a greater mortality during the winter. It has been demonstrated that there is a negative association between the insecticide resistance due to elevated esterase level and the ability of *M. persicae* to survive exposure to low temperature in field trials during winter (Foster *et al*., 1996). That is why 30% of the *M. persicae* samples in Scotland were identified as the same genotype (genotype J) that is an insecticide sensitive aphid genotype (Fenton *et al*., 1998).

However, climate changes such as increases in the average global temperature might change the current selective effects of differential winter survival in *M. persicae* populations. Therefore, in the long term, climate change might escalate the problem caused by insecticide resistant genotypes. This necessitates the continuous monitoring of *M. persicae* genotypes in respect of their reactions to insecticides combined with their abilities to transmit plant viruses.

In virus transmission experiments it was shown that genotypes A, B and C were the most efficient vectors of PLRV with the highest transmission rate of 65% for genotype A (Nikan *et al* 2008). Genotypes A and B also carry all three known insecticide-resistance mechanisms (elevated esterase, modified acetylcholinestrase and knockdown resistance) (B Fenton, personal communication). Due to these mechanisms they are highly resistant to most insecticides, as in a bioassay test genotype A proved to be virtually immune to the insecticide Lambda-cyhalothrin followed by genotype B that was also very resistant (Bolandandam *et al*. 2004).

Taking these matters into account, it is clear that the existence of such genotypes (e.g. genotypes A and B) that are very reproductive, resistant to insecticides and efficient in transmitting PLRV, can potentially increase the spread of the virus if they become established as the predominant genotypes in each area. This in turn, further reinforces the necessity of monitoring *M. persicae* genotypes in each region with regard to their resistance to insecticides, virus transmission efficiency and reproduction capacity. Such efficient vectors of PLRV, however, may also transmit other potato viruses more efficiently.

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