EFFECT OF PLANT AGE AND SPECIES ON POPULATION GROWTH OF TWO *RHOPALOSIPHUM MAIDIS* (FITCH) LINEAGES

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SUMMARY

The corn leaf aphid *Rhopalosiphum maidis* (Fitch) can feed on various cereal crops and transmit viruses that may cause serious economic losses. To test the impact of host plant species and age on *R. maidis*, we identified the survival and reproduction rates of two *R. maidis* populations (Beijing and Mangshi) via a direct observation method in laboratory on 10 cm high maize seedlings (small maize), 50 cm high maize seedlings (high maize) and 10 cm high barley seedlings (barley). The Beijing (BJ) population performed significantly better than the Mangshi (MS) one on 50 cm high maize seedlings and barley seedlings, while both populations could not survive on maize seedlings in 10 cm height. As smaller maize seedlings were fatal to the corn leaf aphid, we hypothesized that it may be due to the secondary metabolites synthesized by maize seedlings and our results also give the implication for aphid control on maize which will be discussed.

Key words: corn leaf aphid, barley, maize, plant age, population

INTRODUCTION

Rhopalosiphum maidis (Fitch) is a species of a severe sap-sucking pest on maize that occurs worldwidely (Foott and Timmins, 1973; Tzin *et al*., 2015). This insect also attacks barley and some other cereal crops such as sorghum, oats, and wheat (Carena and Glogoza, 2004; Tabikha, 2016). Except for the direct damage to the host plant, *R. maidis* can also transmit viruses including *Maize dwarf mosaic virus* (MDMV) and *Barley yellow dwarf virus* (BYDV) (Parry *et al*., 2012; Saksena *et al*., 1964; Thongmeearkom *et al*., 1976) which may lead to serious damages of maize production.

Although *R. maidis* can survive on different cereal crops, the aphid may perform diversely on different host plants, consequently some hosts may exhibit a certain degree of resistance. For instance, *Toxoptera citricida* developed slower on sour orange, Duncan grapefruit and Mexican lime than Carrizo and sweet orange (Tang *et al*., 1999). Also, previous studies on *R. maidis* showed different survival and reproductive rates on different host plants of barley and wheat

(Hirano and Ito, 1964; Singh and Painter, 1964). Besides, compared with *Trifolium subter-raneum* cultivars and *Medicago minima*, *Aphis craccivora* Koch showed the best population growth potential on *Vicia faba* at 25 °C (Berg, 1984). In this way, resistant host plants or genotypes can be screened out to obtain a better biological control effect (Narang and Rana, 1999).

Additionally, different aphid populations can have various performances on the same host plant (Broeke *et al*., 2013) such as *Sitobion avenae* (Barrios-SanMartín *et al*., 2016), *Acyrthosiphon pisum* (Sandström and Pettersson, 1994), *Myzus persicae* and *A. craccivora* (Edwards, 2001), demonstrating that long-term population differentiation may endow diverse biological characters to different populations living in variant surroundings. Here we aimed at assessing the effects of plant age and species on survival and reproduction of *R. maidis* by investigating the performance of two *R. maidis* populations on barley (10 cm high), small maize seedlings (10 cm high) and high maize seedlings (50 cm high).

MATERIALS AND METHODS

Aphids

Two clones of *R. maidis*, namely MS (Mangshi population) and BJ (Beijing population) were collected from Mangshi city, Yunnan province and Beijing city of China separately in October 2014 and then reared under laboratory conditions (23±1℃, L16: D8 photoperiod and 60-80% relative humidity) on barley seedlings for more than ten generations.

Host plants

Barley, small maize and high maize seedlings were used as experimental host plants for *R. maidis*. Accelerating germination treatment was used for maize seeds before sowing into the soil to ensure the germination rate and uniformity. The seedlings before inoculation were reared under condition of 20°C, L16: D8 photoperiod and 60-80% relative humidity.

Treatment settings

Ten replicates were set for each treatment. All the seeds were sown in 10 × 10 cm square pots. Five adult apterous aphids were inoculated to the seedlings in each pot and different pots were separated with a 10 cm diameter plastic tube covered by gauze element. Then, the survival number of aphids was observed everyday at the same time for one week.

Statistical analysis

Generalised linear mixed effect models (package 'lme4', function 'glmer', (Bates *et al*., 2014)) with Poisson error distribution (log-link function) were fitted to test whether the two populations (BJ, MS) affected the number of aphids on the different host plants. The two populations were analysed as fixed effects and the observed plants (i.e., 10 replicates per crop) were included as random effects as measurements were repeated each time on the same plant. The effect of the populations on aphid abundance was tested using a likelihood-ratio test ($p < 0.05$). The statistical analyses were performed using R program (R Core Team, 2013).

RESULTS

Survival and reproduction on small maize seedlings

Both MS and BJ populations did not survive on 10 cm high maize seedlings (Figure 1). The aphid number of the two populations decreased rapidly from the 3rd to 7th day although several offspring individuals had reproduced during the first three days. There was only one survival of MS population and no survival of BJ population on the 7th day. Hence, no statistical analyses were performed to compare these two populations.

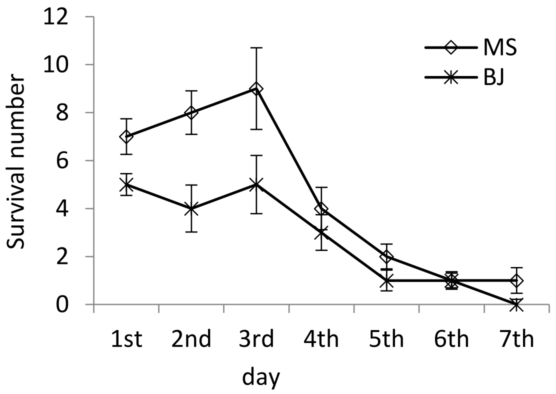

Figure 1. Survival number of *R. maidis* on small maize seedlings

Survival and reproduction on high maize seedlings

The two populations of *R. maidis* survived on high maize seedlings (Figure 2), but the total aphid number increased slower than on barley (Figure 3). BJ *R. maidis* had a higher fecundity than MS population (X^2 = 937. 61, *df* = 1, $p < 0.001$) especially from the 6th to 7th day and the total number of BJ and MS populations reached 57 and 18 respectively on the 7th day.

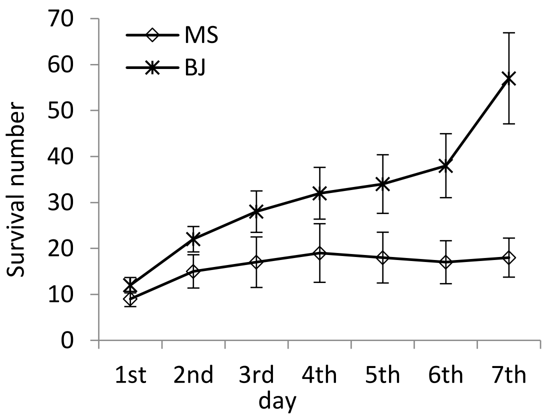

Figure 2. Survival number of *R. maidis* on high maize seedlings

Survival and reproduction on barley seedlings

Both populations were able to survive and reproduce on barley seedlings (Figure 3). The two populations had similar fecundity from the 1st to 6th day, then BJ *R. maidis* had a sharp increase on the 7th day reaching 134 individuals whereas MS population rose more gently up to 78 on the 7th day (X^2 = 72.27, *df* = 1, p < 0.001).

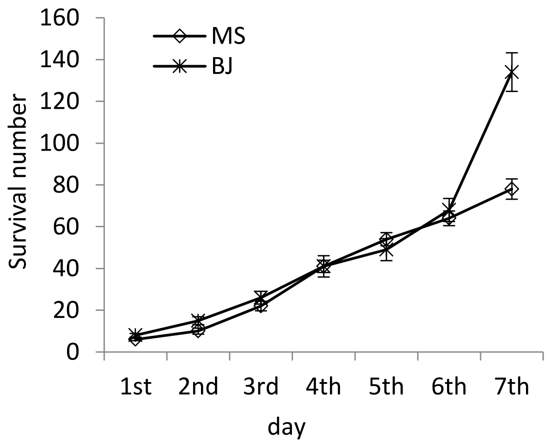

Figure 3. Survival number of *R. maidis* on barley seedlings

DISCUSSION

Although *R. maidis* is one of the major pests on maize in the field, our laboratory data showed that both BJ and MS *R. maidis* had the best performance on barley seedlings and a lower growing speed on 50 cm high maize seedlings, based on which, we can infer that the maize field could be surrounded by guard rows of aphid-attractive plants such as barley seedlings or through intercropping agricultural control method (Ogengalatigo *et al*., 1992) to reduce the losses of maize yield caused by *R. maidis*. As proved previously, the survival rates of *R. maidis* were different on barley and wheat and the aphid performed differently as well on wheat of variant ages (Hirano and Ito, 1964). Our study demonstrated that 10 cm high maize seedlings were fatal to both populations, the unsuccessful colonization may be due to some detrimental chemicals in young maize seedlings (10 cm high) such as DIMBOA (2,4-Dihydroxy-7-methoxy-1,4-benzoxazin-3-one). DIMBOA, a secondary metabolite in many cereals, is a hydroxamic acid that plays an important role in insect resistance (Pérez and Niemeyer, 1989; Yan *et al*., 1995; Klun *et al*., 1967). The concentration of DIMBOA varies according to the age and plant organ. For instance, DIMBOA is synthetized concurrently with germination in maize and the concentration reaches to the highest 24-36 h after germination (Ebisui *et al*., 2000), then decreases with plant growing, however, the biosynthesis still continues 6±10 days after germination (Cambier *et al*., 2000). In this study, *R. maidis* was inoculated 4-5 days after germination of the 10 cm high maize seedling treatment, during this time, DIMBOA was still biosynthesized. As for maize seedlings in 50 cm height, inoculation of *R. maidis* was implemented 19-20 days after germination. In addition, the barley seeds used were from a cultivar that was unable to biosynthesize DIMBOA because of the elimination of the *Bx* gene (Nomura *et al*., 2003). However, the resistant effect of DIMBOA in small maize seedlings needs further verification.

Previous study found that the performance of different populations of *A. craccivora* were significantly different on faba bean, field pea as well as narrow-leafed lupin (Edwards, 2001). Also, when highly defended wheat seedlings were used as host plant, the population growth rate of one superclone of *S. avenae* was significantly higher than non-superclone (Barrios-SanMartín *et al*., 2016). Moreover, different genotypes from microsatellite analysis of *S. avenae* performed diversely on wheat (Figueroa *et al*., 2004). In the present research, the aphid number of the MS population increased slowly on 50 cm high maize seedlings compared with the BJ population especially after the 4th day, the total number even decreased from 19 on the 4th day to 18 on the 7th day rather than increasing. Similarly, BJ *R. maidis* showed a better performance on barley that reached a much higher number on the 7th day than the MS population, which indicated that BJ *R. maidis* had a stronger adaptability than the MS population. Nikolakakis *et al*. (2003) found a significant effect of 'region / host plant origin' based on the different performance of various *M. persicae* clones. The two populations of *R. maidis* in our study were from different regions of the same plant and the effect of "host plant origin" could be tested in the future research.

ACKNOWLEDGEMENTS

We thank the University of Liège-Gembloux Agro-Bio Tech and more specifically the research platform AgricultureIsLife for the funding of the scientific stay in Belgium that made this paper possible.

REFERENCES

BARRIOS-SANMARTÍN J., FIGUEROA C.C. & RAMÍREZ C.C. (2016). Evidence of plastic probing behavior in a 'superclone' of the grain aphid *Sitobion avenae*. Bulletin of Entomological Research **106(6)**: 801-808.

BATES D., MAECHLER M., BOLKER B. & WALKER S. (2014). lme4: Linear mixed-effects models using Eigen and S4. R package.

BERG G.N. (1984). The Effect of Temperature and Host Species on the Population Growth Potential of the Cowpea Aphid, *Aphis Craccivora* Koch (Homoptera: Aphididae). Australian Journal of Zoology **32(3)**: 345-352.

BROEKE C.J.M.T., DICKE M. & LOON J.J.A.V. (2013). Feeding behaviour and performance of different populations of the black currant-lettuce aphid, *Nasonovia ribisnigri*, on resistant and susceptible lettuce. Entomologia Experimentalis et Applicata **148(2)**: 130-141.

CAMBIER V., HANCE T. & DE H.E. (2000). Variation of DIMBOA and related compounds content in relation to the age and plant organ in maize. Phytochemistry **53(2)**: 223-229.

CARENA M.J. & GLOGOZA P. (2004). Resistance of maize to the corn leaf aphid: a review. Maydica **49(4)**: 241-254.

EBISUI K., ISHIHARA A., HIRAI N. & IWAMURA H. (2000). Occurrence of 2,4-Dihydroxy-7-methoxy-1,4-benzoxazin-3-one (DIMBOA) and a β-Glucosidase Specific for Its Glucoside in Maize Seedlings. Zeitschrift für Naturforschung C **53(9-10)**: 793-798.

EDWARDS O.R. (2001). Interspecific and intraspecific variation in the performance of three pest aphid species on five grain legume hosts. Entomologia Experimentalis et Applicata **100(1)**: 21-30.

FIGUEROA C.C., SIMON J.C., LE GALLIC J.F., PRUNIER-LETERME N., BRIONES L.M., DEDRYVER C.A. & NIEMEYER H.M. (2004). Effect of host defense chemicals on clonal distribution and performance of different genotypes of the cereal aphid *Sitobion avenae*. Journal of Chemical Ecology **30(12)**: 2515-2525.

FOOTT W.H. & TIMMINS P.R. (1973). Effects of infestations by the corn leaf aphid, *Rhopalosiphum maidis* (Homoptera: Aphididae), on field corn in southwestern Ontario. The Canadian Entomologist **105(03)**: 449-458.

HIRANO C. & ITO Y. (1964). Effect of Plant Age on Survival and Reproduction of *Rhopalosiphum maidis* FITCH (Homoptera*:* Aphididae). Japanese Journal of Applied Entomology & Zoology **8(4)**: 317-323.

KLUN J.A., TIPTON C.L. & BRINDLEY T.A. (1967). 2,4-Dihydroxy-7-methoxy-I,4-benzoxazin-3-one (DIMBOA), an Active Agent in the Resistance of Maize to the European Corn Borer. Journal of Economic Entomology **60(6)**: 1529-1533.

NARANG S. & RANA J.S. (1999). Screening of barley genotypes against corn leaf aphid, *Rhopalosiphum maidis* (Fitch.). Cereal Research Communications **27(1)**: 131-138.

NIKOLAKAKIS N., MARGARITOPOULOS J. & TSITSIPIS J. (2003). Performance of *Myzus persicae* (Hemiptera: Aphididae) clones on different host-plants and their host preference. Bulletin of Entomological Research **93(03)**: 235-242.

NOMURA T., ISHIHARA A., IMAISHI H., OHKAWA H., ENDO T. R. & IWAMURA H. (2003). Rearrangement of the genes for the biosynthesis of benzoxazinones in the evolution of Triticeae species. Planta **217(5)**: 776-782.

OGENGALATIGO M.W., BALIDDAWA C.W. & AMPOFO J.K.O. (1992). Influence of maize row spacing on infestation and damage of intercropped beans by the bean aphid *Aphis fabae* (Scop.). II. Reduction in bean yields. Field Crops Research **30(1-2)**: 123-130.

PARRY H.R., MACFADYEN S. & KRITICOS D.J. (2012). The geographical distribution of Yellow dwarf viruses and their aphid vectors in Australian grasslands and wheat. Australasian Plant Pathology **41(4)**: 375-387.

PÉREZ F.J. & NIEMEYER H.M. (1989). Reaction of dimboa, a resistance factor from cereals, with papain. Phytochemistry **28(6)**: 1597-1600.

R Core Team. (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

SAKSENA K.N., SINGH S.R. & SILL JR.W.H. (1964). Transmission of Barley Yellow-Dwarf Virus by Four Biotypes of the Corn Leaf Aphid, *Rhopalosiphum maidis*. Journal of Economic Entomology **57(4)**: 569-571.

SANDSTRÖM J. & PETTERSSON J. (1994). Amino acid composition of phloem sap and the relation to intraspecific variation in pea aphid (*Acyrthosiphon pisum*) performance. Journal of Insect Physiology **40(11)**: 947-955.

SINGH S.R. & PAINTER R.H. (1964). Effect of Temperature and Host Plants on Progeny Production of Four Biotypes of Corn Leaf Aphid, *Rhopalosiphum maidis*. Journal of Economic Entomology **57(3)**: 348-350.

TABIKHA R.M.M. (2016). Impacts of temporal and spatial climatic changes on annual generations of *Rhopalosiphum maidis* and *R. padi* (Hemiptera: Aphididae) in Egypt, using Geographical Information System (GIS). Journal of Agricultural Informatics.

TANG Y.Q., LAPOINTE S.L., BROWN L.G. & HUNTER W.B. (1999). Effects of Host Plant and Temperature on the Biology of *Toxoptera citricida* (Homoptera: Aphididae). Environmental Entomology **92(5)**: 895-900.

THONGMEEARKOM P., FORD R.E. & JEDLINSKI H. (1976). Aphid transmission of maize dwarf mosaic virus strains. Phytopathology **66(3)**: 332-335.

Tzin V., Fernandez-Pozo N., Richter A., Schmelz E.A., Schoettner M., Schäfer M., Ahern K.R., Meihls L.N., Kaur H., Huffaker A., Mori N., Degenhardt J., Mueller L.A. & Jander G. (2015). Dynamic maize responses to aphid feeding are revealed by a time series of transcriptomic and metabolomic assays. Plant Physiology: pp.01039.02015.

YAN F., XU C., LI S., LIN C. & LI J. (1995). Effects of DIMBOA on several enzymatic systems in Asian corn borer, *Ostrinia furnacalis* (Guenée). Journal of Chemical Ecology **21(12)**: 2047-2056.