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Impact of water and nitrogen depletion on the Peach orchard infestation by green peach aphid (*Myzus persicae*) and its relation with the useful fauna

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Abstract

This work aims to establish an ecologically integrated pest management strategy to assess the effect of water and nitrogen depletion on *Myzus persicae* infestation in the peach orchard. The results showed a significant effect of level of water and nitrogen supplies on the green peach aphid infestation in the orchard. Indeed, the fertigation regime T1 (100%) proved to be much more favorable to a prominent development of aphidian populations compared to 25% water and nitrogen restricted regime. Moreover, the infestation degree was lower in the regime T2 (~75%) than that observed in the regime T1. The evolution of wingless and winged green aphid populations was similar in both regimes. The effect of branch orientation on the aphids infestation was significant with those oriented to the North, West and South were more infested than those oriented to the East. Concerning the useful fauna, we noticed the same predators species for all the tested regimes. A negative effect on *Stethorus sp* and *Chrysoperla carnea* densities was appeared under water and nitrogen depletion.

1. Introduction

Under normal conditions, plants are exposed to various biotic and abiotic that affects their physiology, biochemical composition and growth. The plant-pest interactions are modulated by these changes [1,2]. In fact, the ability of a pest to settle, feed itself and multiply is affected by water and nutritional status of the plant [3,4]. This finding is also specific to each insect. In the case of aphids phloem-feeding insects, the resistance of the plant dependent on cell turgor pressure [5], which may determine in part the sap flow and its nutritional value for the insect (amino acid composition and soluble sugars) [6].

In Morocco, green aphid (*Myzus persicae*) is among the pests that must be monitored and controlled in peach orchard. This insect is well known for its polyphagia and resistance to several active substances such as pyrethroid and neonicotinoid. It is considered to be the second major scourge of peach after the medfly [7]. *M. persicae* can affect the physiological functions of the plant and it is considered a sink for assimilates that might change the pattern of allocation or the nutritional status of tissues [8].

Previous studies have shown the effect of aphids on plant photosynthesis [9] as well as on the induction of gene involved in the senescence of leaves [10]. In contrast, the abundance of aphids was affected by the physiological state of host plant [11], in particular, the nitrogenie status of the plant [12,13]. Moreover, the water status plant tissues can affects the growth of aphid by rendering difficult of tapping the phloem exudate [14]. In addition, several studies reported that development of pests is favored by the performance of plant growth [15,16].

The soil and plants water stress influenced the growth rate of aphid's population on Cowpea [17]. Thus, the number of aphids per plant was significantly lower in the aphid-resistant varieties than that observed in the aphid-susceptible varieties [17]. Therefore, in this work we will evaluate the ability of strategically using nitrogen fertilization and irrigation practices through their positive impact plant growth and water and nitrogen status of the plant tissues to control the green peach green aphid infestations.

2. Experimental details

The study aims to monitor the development of *Myzus persicae* under two different regimes of fertigation. An experimental device was installed on two peach orchards in Sais region (Fig.1).

The first fertigation regime T1 was favorable to the normal development of fruit trees as it contains high quantities (100%) of water and nutrients requirement (nitrogen), which are made available through two emitters and each with 8 liters per hour. The second fertigation regime (T2) was deficient in these elements (75%) due to a restriction of the amounts of water and nitrogen made available by changing one of the emitters of 8 liters/hour at the sheath by another dripper of a flow rate of 4 liters / hour to reduce 25% of the water resources and nitrogen given to trees.

The data collected through this experimental device concerns the evaluation of the infestation rate by *Myzus persicae* species. The data was collected through a scorecard monitoring the pre-established card in scoring the green peach.

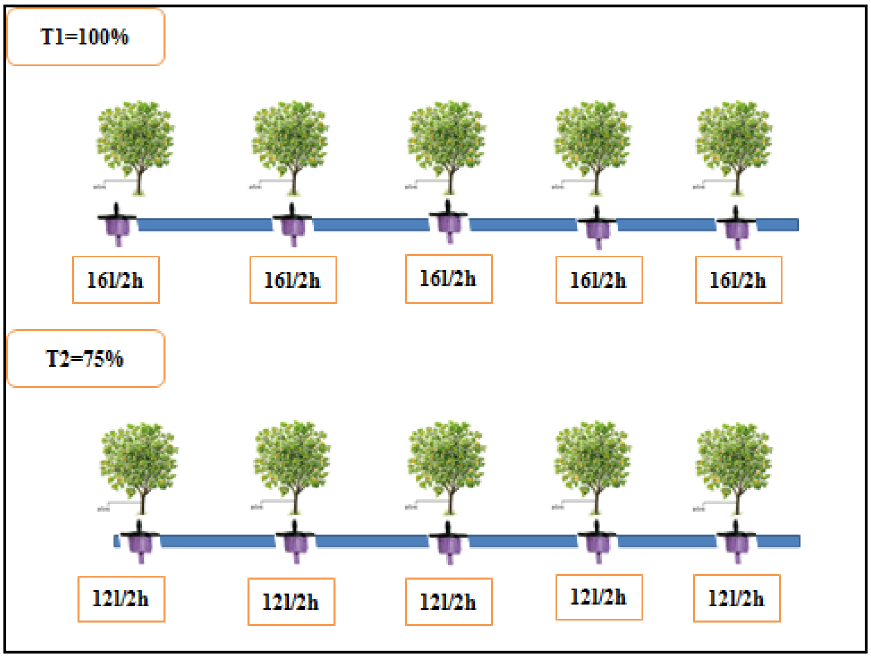

Figure 1: Illustration of the experimental device on the peach orchard

2.1 Determination of the amounts and methods of fertilizer inputs

The fertilization program was established taking into account the soil analyze. So, all treatments received adequate amounts of nutrients during the growing season: 120 Kg/ha of N as ammonium nitrate and diammonium phosphate (DAP), 60 Kg/ha of P2O5 as DAP, 140 Kg/ha of K2O as potassium sulfate. Also, it should be noted that N is supplied by fertigation, while the other elements were brought manually under the tree.

2.2.Monitoring aphid populations

To assess the infestation rate of wingless aphids in the scale of trees, a monitoring was performed weekly on joint branches where the infestation was recorded for each type of branch (vegetative and fruiting stages) at four cardinal directions and two fertigation regimes according to the classification of LECLANT (1970) (table 1).

By reporting the infestation throughout the tree's scale (number of infested shoots) and the degree of infestation (number of individuals per shoot), the infestation index (IF) was calculated using the following formula:

IF= Σ (d x fd)/ (5 x Σfd)[18].

D = degree of infestation between 0 and 5 and fd = shaft frequency shoots with the degree of infestation between 0 and 5.

As for the winged aphids, they were counted visually on every branch and scored at each direction at the same time of scoring the degree of infestation of all wingless aphid throughout the test period.

Table 1: Infestation scales adopted to evaluate the infestation rate of the peach tree by aphids [18].

Degree of infestation	Number of aphids	Average in class
0	0	0
1	50 to 51 = 1 à 5	50.5 = 2.2
2	1+51to 52 = 6 à 25	51.5 = 11.2
3	1+52 to 53 = 26 à 125	52.5 = 55.9
4	1+53 to 54 = 126 à 625	53.5 = 279.5
5	1+54 to55 = 626 à 3125	54.5 = 1397

2.3 Statistical Analyses

All the datasets collected was subjected to analysis of variance (ANOVA) procedure of the statistical software SAS (SAS Institute, Cary, NC, USA), SPSS (Version 20), and Excel 2010 version. The test of Shapiro-Wilk normality allowed us to verify the normality of the infestation index before subjecting it to the analysis of variance.

3. Results and discussion

3.1. Effect of water and nitrogen depletion on wingless green peach aphid infestations.

The variance analysis revealed significant effect of fertigation treatment on the aphids infestation during the first week of June (01/06/2014). This significant difference in infestation disappeared 15 days later (towards mid-June). Also, from that time until the end of July (total aphid migration to secondary hosts), the recorded infestations in the two regimes of fertigation were substantially similar.

No significant difference between the two regimes was noted. Reducing water and nitrogen decreases the degrees of infestation. This can be considered an effective alternative for using integrated strategy of controlling the aphid species.

From an economical perspective, the reduction of water and nitrogen inputs can reduce the treatments costs against aphids, of course in the absence of any secondary effects of this reduction regarding the production level (**Table 2 and Figure 2**).

Table 2: Analysis of variance of the infestation index in 01/06/2014 (** indicates a highly significant effect).

Source	**DDL**	**Type III SS**	**Square's means**	**Value F**	**Pr > F**
Fertigation	1	0.240250	0.240250	9.95	0.0034**
Error	38	0.138500	0.034625	1.43	0.2440
Total	40	0.821000	0.024147		

Figure 2 clearly shows the importance of green aphid peach infestations under treatment T1 (100%) compared to those assigned to treatment T2 (75%). This difference is might due to the amount of nitrogen applied in each regime. A fast and correlated growth was observed with significant nitrogen content of tissues, which is favorable to rapid multiplication of Aphididae [19]. In addition, the ingestion of an excessive amount of nitrogen is important for the insect, which must maintain a correct osmotic potential [20].

The reduction of infestation has the same level In T1 and T2, although T1 is very rich in terms of water and nitrogen. This can be attributed to senescence and severe leaves drop caused by high density of aphids in the leaves and branches. This brought a rapid appearance of winged individuals ready to leave peach to other secondary shelter.

Further research in this direction have shown that the water deficit could equally affect the composition and concentration of secondary plant compounds leading to marked effects on the survival of aphid larvae [17].

However, if the sugar concentration of the sap is too high, it can have negative effects on the aphid population [21], because it increases the osmotic potential of the hemolymph of aphids until a stress disorder situation [22].

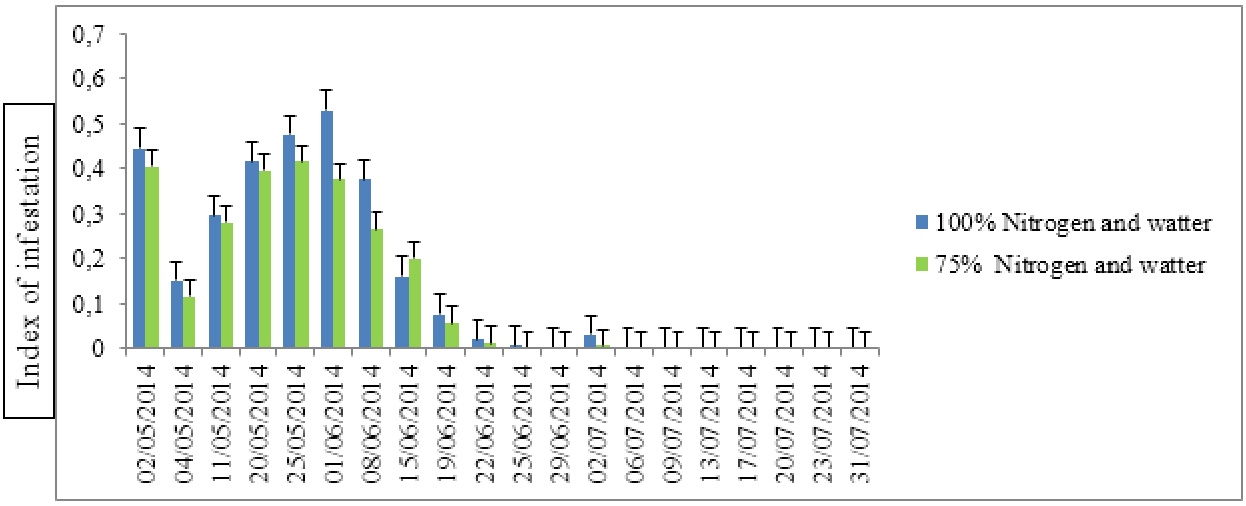

Figure 2: Comparison of the mean of infestation index (mean ± standard error) of the populations of *Myzus persicae* on peach between both regimes of fertigation (T1 and T2).

Induced variations in the status of host plants may have important consequences on the dynamics of the population of herbivores through the effects on the development and survival of immature individuals [23]. Laboratory studies have shown that water stress, as a result, has a decrease in abundance, survival and fecundity of insects, together with an increase in populations of winged aphids, which make them, thus, able to migrate to long distances [24]. Other studies in Australia have reported conflicting results with those previously cited. The authors reported, also, an increase in abundance, fertility and survival of aphid Chou on the rape plants subjected to water stress [17]. In addition, Nevo and al(2000)[25] obtained a higher mortality, slow growth and decreased fertility of high aphid *A. pisum* on plants subjected to water deficit.
The reappearance of some individuals was noticed towards early July after disappearance at the end of June. This may be due to a rise of these individuals from the very rich glutton in water and nitrogen; hence, the need to ensure their elimination at each time, since they suck huge amounts of water and fertilizing elements and constituents that are potential reservoirs of aphids.
The abundance of *M. persicae* at the T1 can be explained by the richness of trees in nutrients and in particular nitrogen necessary for oogenesis aphid and which is also responsible for the rapid growth of vegetation. These results are similar to those obtained by Agelee and al[17] who reported that a maximum of aphid survival was achieved in the wet conditions at the peak of the vegetative growth of cowpea and that drought stress reduced significantly the size of aphid colonies. Similarly, Jahn and al)[26] found that nitrogen fertilization of cotton has greatly affected the morphology, fertility and the intrinsic growth rate of the populations of *A. gossypii*. The same conclusions were also made by Rafalimanana [27] with regard to the nitrogen effect on fertility, the intrinsic growth rate, survival and the length of the body *H. setariae* on the plants of rice in the wetlands of the tropical forest of Nigeria.

3.2. The Effect of water and nitrogen depletion on the fluctuation of the populations of winged green peach aphid.

The first appearance of winged aphids, in T2 regime started by the first week of May, while for T1 (most favorable), the first winged aphids appeared 16 days after. Towards the beginning of the third decade of May (exactly 5/20/2014), we found a highly significant effect in water and nitrogen on the development of winged individuals. Thus, the main differences between the two-fertigation systems regarding the winged individuals of the green peach aphid emerged. These differences remained significant until mid-June, always with number of aphids with wings, which are most prominent at the well-supplied trees for water and nitrogen at the level of those under stress of these elements.

As for the disappearance of winged forms, it was relatively precocious in the regime T2 compared to the regime T1. Indeed, a full output of aphids of the T2 regime was observed as early as 19/06/2014 while the departure of those of the T1 regime held a week afterwards (25/06/2014) (Fig3).
The general appearance of winged aphids' evolution of curves is similar to the curves of evolution of wingless ones with some differences (Figure 5). The number of wingless aphids was higher in the T1 regime compared to T2, while, normally, the opposite that should happen since the nutrient richness is greater in T1. However, this finding is quite obvious because the development of the winged aphids is not explained only by the provision of food, but also by the high population's density of the wingless aphids at a limited space. Indeed, a linear relationship between the index of infestation by winged aphids and the numbers of the wingless ones showed that a good share of variability ($R^2 = 0.509$ to $P < 0.05$) is explained by the index of infestation and a high correlation coefficient ($R = 0.71$) links the two variables (Fig. 4).

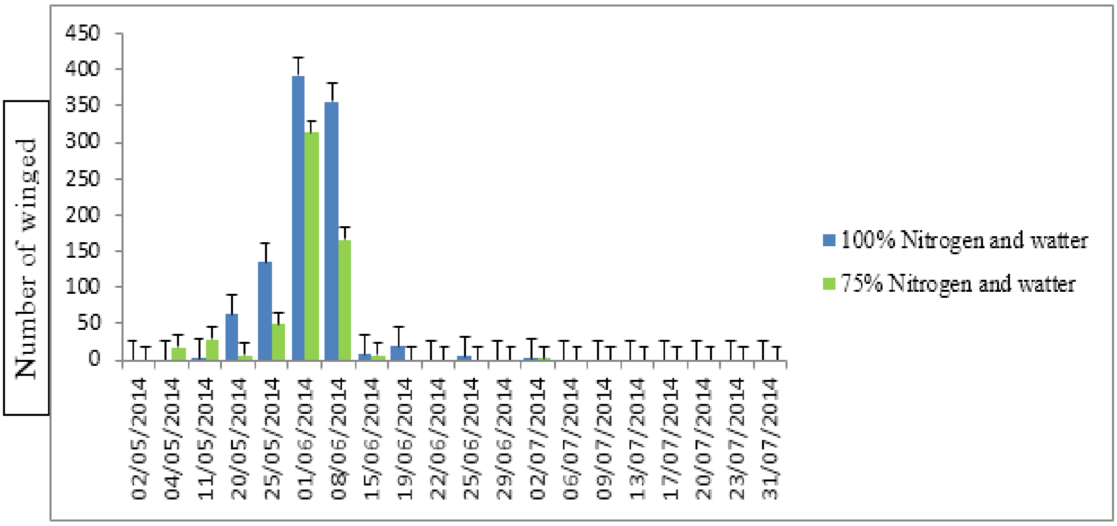

Figure 3: Accumulated winged *Myzus persicae* (total number ± standard error) under the two peach's fertigation systems.

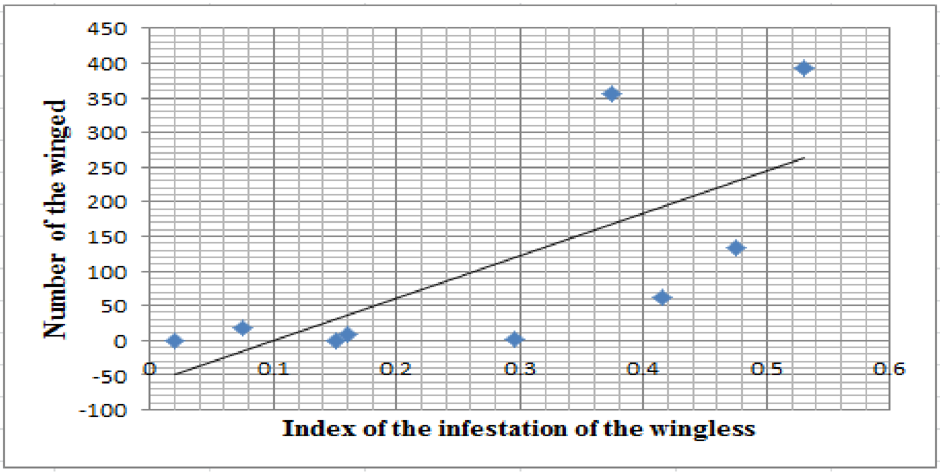

Figure 4: Statistical relationship between the number of the winged aphids of *Myzus persicae* and the index of the infestation of the wingless.

T1. Indeed, a full output of aphids of the T2 regime was observed as early as 19/06/2014 while The departure of those of the T1 regime held a week afterwards (25/06/2014) (Fig.4). Nevo and al[26] found that the effect of nitrogen fertilization on cotton plant morphology, fertility and the intrinsic growth rate of *Aphis gossypii* could be detected through the generations, and found that the nitrogen contents of host plants have a greater effect than the quality of these food plants. However, Rafalimanana [27] found that the extra nitrogen, in the regime of *H. asetariae*, Thomas (Homoptera: Aphididae), on rice had no apparent effect on the survival, fecundity and intrinsic growth rate of aphid, while the nitrogen content of their host plants greatly affect these factors.

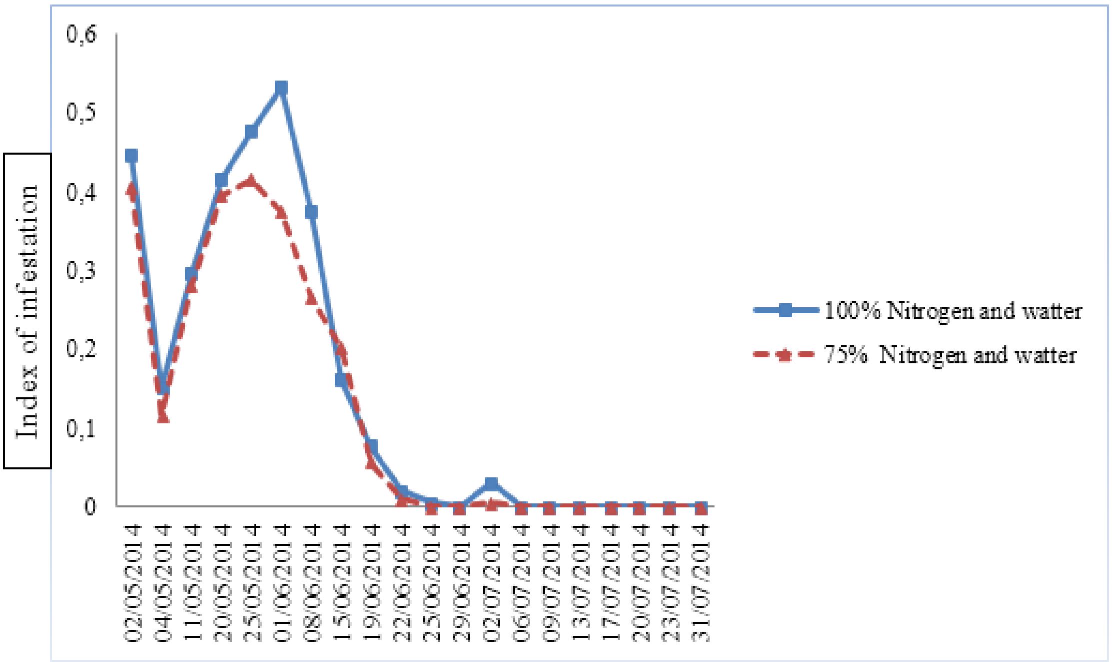

Figure 5: Evolution of the total number of winged aphids (mean ± standard error) for the two regimes.

Contrary to the results obtained for *A. gossypii* on cotton, the nitrogen levels have no effect on the width of the head *H. setariae* on rice. The length of the body of this aphid species was affected by nitrogen levels in rice and other host plants, although no cumulative effect has been detected [27]. These authors were able to conclude that the application of high levels of nitrogen fertilization increases the survival, fertility, the intrinsic growth rate and the length of the *H. setariae*.
The important aptitude of aphids at the high regime in nitrogen, combined with decreased predation, could contribute to a significant increase in the population of aphids. In addition, during drought, ants are able to penetrate into the fields and protect aphids of natural enemies [20].

a b

Figure 6: Damage caused by *M. persicae* in T1 regime (a) and T2 regime (b) regimes.

3.3.The impact of the cardinal directions orientation on the infestation of aphids in both fertigation treatments.
During this study, the four cardinal directions of the tree were taken into account. Thus, at each direction two branches (vegetative and fruiting) were marked and monitored in order to have a good representation of the data collected on one side, and to see also if there is a possible impact of the orientation on the distribution of infestations of aphid populations in the tree. Data was grouped and organized in figure7 and 8.

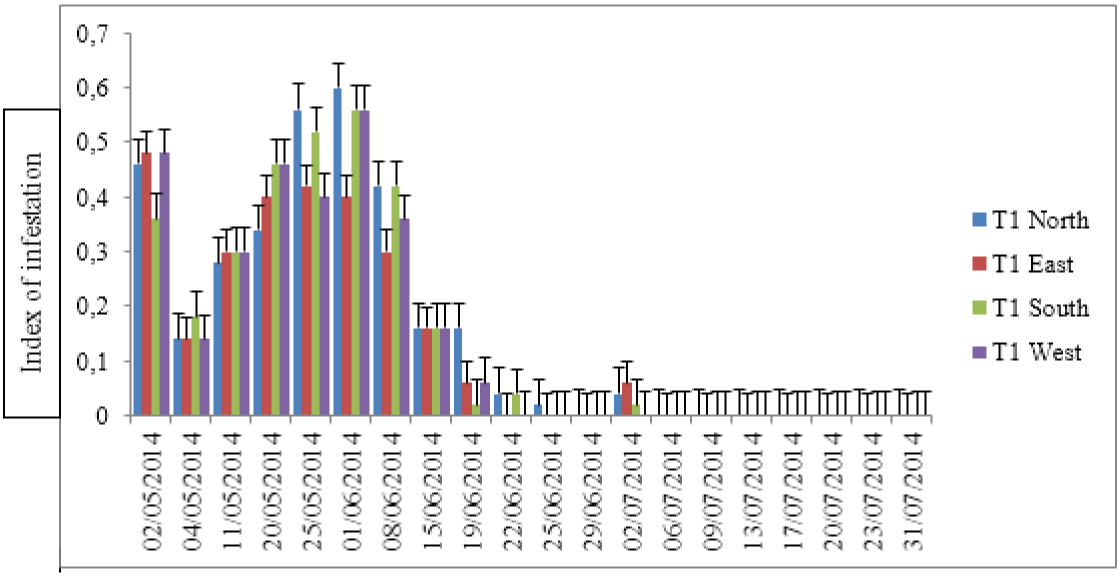

Figure 7: The infestation index (IF ± standard error) as related to the four cardinal positions in the T1 fertigation regime.

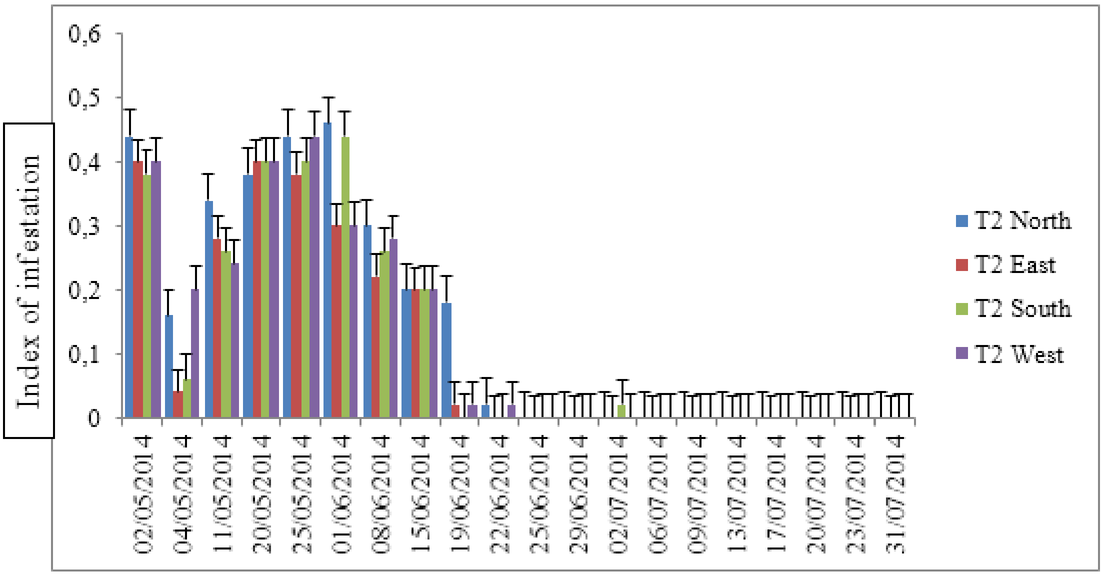

Figure 8: The infestation index (IF ± standard error) as related to the four cardinal positions in the fertigation regime T2.

The results obtained from the above graphs show clearly that there was a significant difference in infestation among the cardinal positions in both the two regimes of fertigation. Indeed, during the first half of May, no impact of the orientation on the infestation index was recorded at the T1 regime since the survival conditions of aphids were still favorable (Figure 7). However, the same period of May has known a significant impact of the orientation on the populations of aphids at the T2 regime where the survival's circumstances were not adequate for normal development. The first week of this month has shown a significant concentration of aphids on the North and West orientation, while the second week of the same month has shown a high concentration, only, on the North direction (Figure 8).

In another side, from the second half of May till the first week of June, there was a significant impact of the orientation factor on the rate of infestation of aphids; also, a prominent difference among the different cardinal positions has been shown in the trees as a result of the two fertigation treatments (T1 and T2); this difference was that of the directions of North, West and South were the most infested, while the East has remained relatively less infested with respect to the others (Fig.7 and 8).

However, the infestation has become similar in the four cardinal directions and at both treatments (favorable and deficit) to the second week of June; after that, a recurrence of the significant impact of the orientation on the index infestation occurred directly after 4 days, always with a higher infestation in the North position than in the other positions of the tree (Fig.7 and 8).

3.4. The interaction between Myzuspersicae and useful fauna in the T1 and T2 regimes.

In this study, monitoring of trees subjected to fertigation systems (T1 and T2) was visually assured by direct counting of individuals at the marked shoots and during the same dates as those where we noted the degrees of infestation by aphids. The objective was to compare the variety of auxiliary at the two regimes and see also if there is a change in their action on the aphid populations between the richer diet of water and nitrogen. The results are shown in Figures 9, 10 and 11.

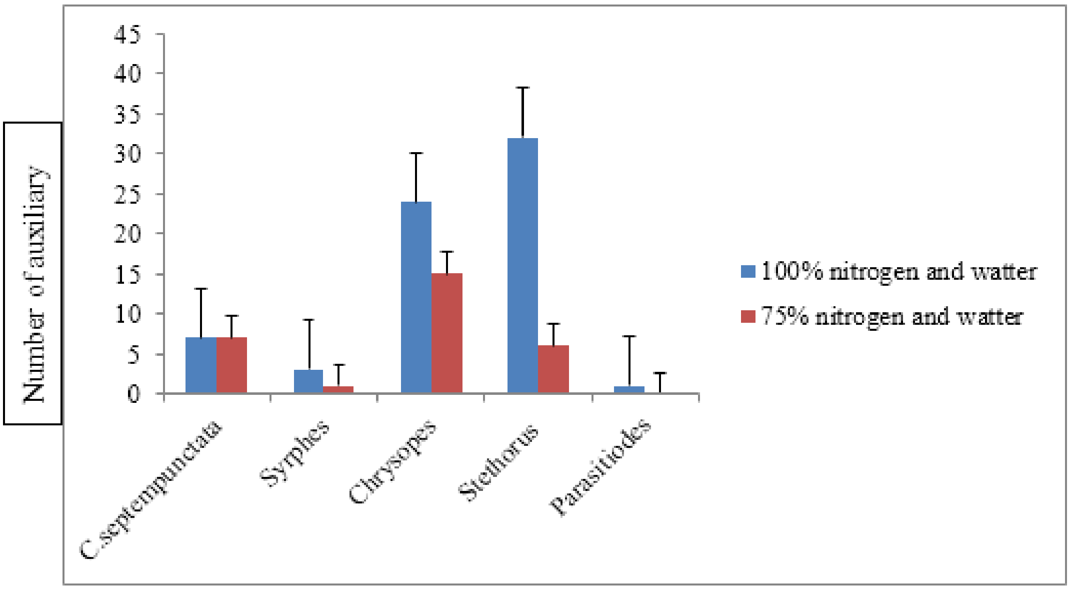

Figure 9: Total auxiliary (all stages) recorded in all monitored by the fertigation system.

As for diversity of useful fauna, the same predators were observed in the two regimes with different densities, while a small number of parasitoids was registered only at the T1 regime and not in T2 regime. The striking difference between the two-fertigation systems can be easily noted with regard to the number of individual auxiliaries. As it can be seen from Figure 10, there was an effect of water and nitrogen on the diversity of all the auxiliary taxa encountered except ladybugs with seven points. However, and according to the standard bars we note that there was a significant effect of fertigation system on lacewings and ladybugs gender Stethorus (predatory mites), but not on hoverflies and parasitoids. This effect can be explained by the abundance of aphids at the T1 regime witch represent an attractive food support for predators and parasitoids, therefore it is an indirect effect of water and nitrogen on wildlife useful.

Thus, the more favorable draws more natural enemies of aphids through the establishment of large aphid populations, something the T2 regime does not guarantee or assure but not of the same magnitude as the T1 regime because of large infestations of aphids in this regime.

The first predators observed during May are ladybirds and hoverflies (all stages) with relatively low numbers compared to the level of infestation of aphids in both fertigation regimes. These species are considered as polyphagous species admitting main prey aphids, and are able, therefore, to regulate their population when they are low density [28]. Initially, when the aphid population densities were relatively low at the beginning of May at both fertigation regimes, ladybirds and hoverflies played an important role in regulation of these populations. However, predators were unable to control heavy infestations of the aphid populations in trees subjected to both plans fertigation (T1 and T2) towards the end of May until mid-June.

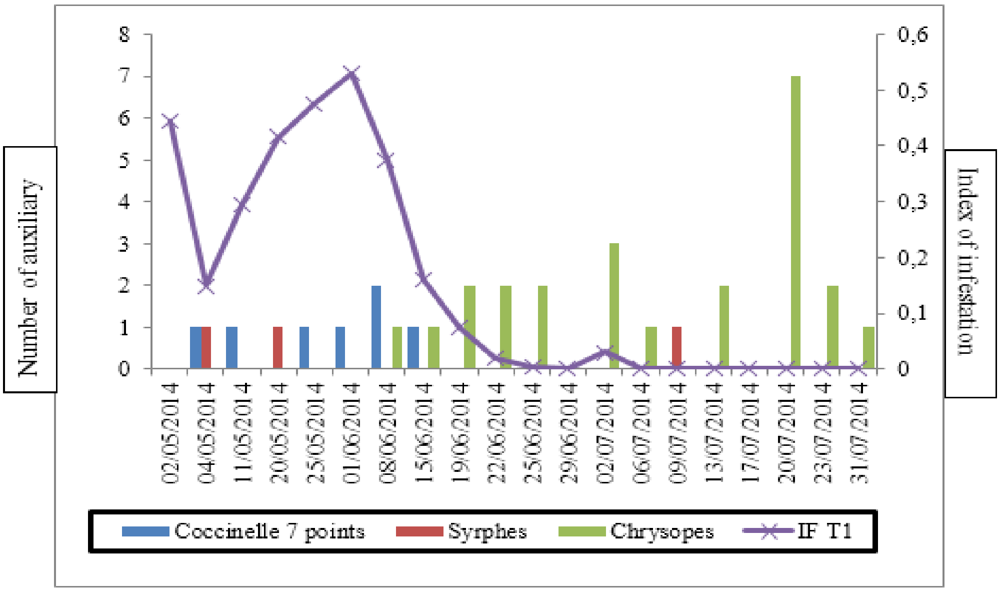

Figure 10: Impact of auxiliary fauna on the index of infestation of aphids in T1.

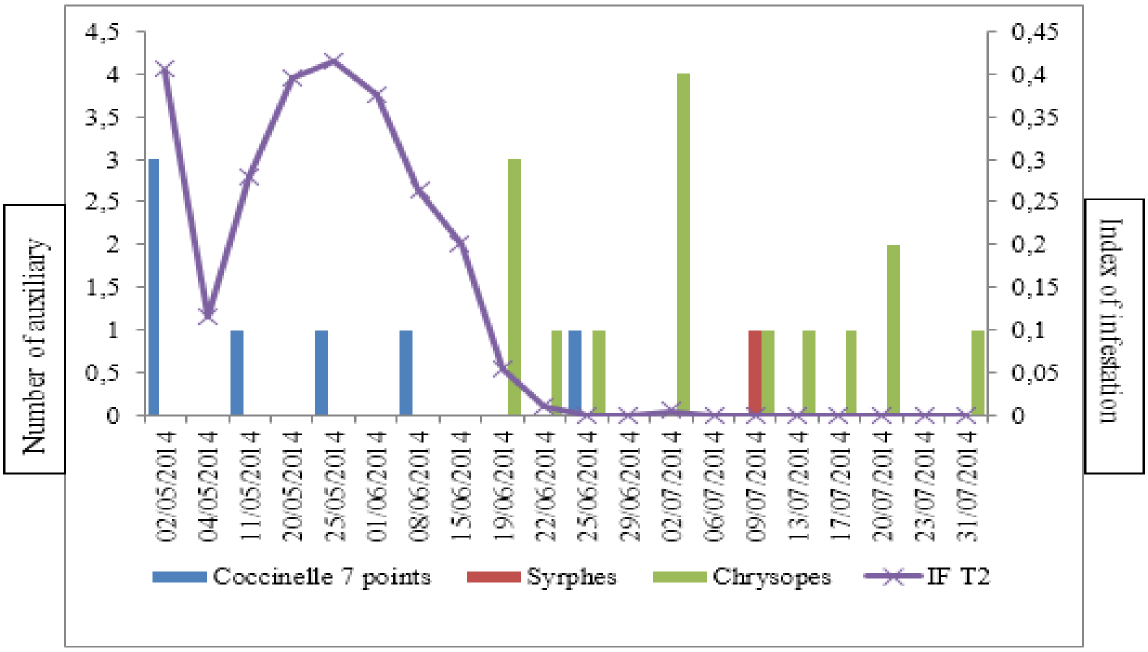

Figure 11: Impact of auxiliary fauna on the index of infestation of aphids in T2

Beyond that date, specifically around the second week of June, there was the appearance of a polyphage *Nevroptera* recognized as a predator of aphids, psyllids and mites, it is the *Chrysoperla carnea*, measuring about 12 to 20mm length [29]. Its wings arranged roof resting. This appearance was observed only in the T1 diet (Figure 10), while it has been held at the T2 in second decade of June (Figure11). Lacewings have contributed their part in mitigating weak individuals of aphid populations witch were still on the trees to the fish late June - early July (Figures 10 and 11).

Other types of ladybugs were encountered in large numbers in trees of peach to the second decade of July. *Stethorus* kind witch are known as major predators of spider mites (Figures 10 and 11) were observed. The same results were obtained by Stara and al[29]. These authors reported that populations of ladybugs, lacewings and hoverflies are positively correlated with indices of infestation of brown cigar makers and aphids.

Conclusion

The species *Myzus persicae* has strongly proven that they are dependent on water and trophic status of peach trees. In fact, a fairly large infestation was recorded in the two considered regimes of fertigation, especially between mid-May and mid-June. However, the distinction between the levels of infestation of the wingless aphids of the two fertigation regimes appeared statistically in early June. On the other hand, the winged aphids were too affected by water and nitrogen condition. Thus, the first winged individuals were being recorded on the trees of the second fertigation system (75%) towards the second week of May. However, as they occur in the first regime (100%) during in late May, the winged population was always more important than that recorded in the other regime. The importance of winged individuals is directly related to the availability of water and nitrogen supply of trees as well as the density of the wingless aphids.

Concerning the cardinal positions of the tree, a significant impact was demonstrated during the study period. The aphids seem to be attached particularly to the North orientation and secondly to that of the West. The other two directions remained less infested than the first ones.

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