THE IMPACT OF VARYING APHID POPULATIONS IN DIFFERENT SHADEHOUSE STRUCTURES ON SOME PHYSICAL CHARACTERISTICS OF HEAD LETTUCE, CULTIVATED IN THE CENTRAL FREE STATE (SOUTH AFRICA)

R.J. PRETORIUS, S. VD M. LOUW, P. VENTER AND
C. VD. WESTHUIZEN

ABSTRACT

Direct feeding damage to head lettuce (*Lactuca sativa* L.) by varying aphid populations in two differently constructed shadehouse structures (fully- and partially covered) was examined. Fresh lettuce head weight, the number of lettuce leaves formed, and the number of lettuce leaves infested with aphids were compared between the two structures. Warmer months showed a significant lower fresh lettuce head weight in the fully covered structure with more aphid-infested leaves. During June/September, the mean number of aphid-infested leaves and aphid infestation levels were significantly higher in the partially covered structure. Visible feeding damage to the lettuce crop was restricted, but asymptomatic damage in terms of a decrease in head weight did occur under severe infestation levels.

Keywords: Aphid feeding; Damage; Injury; Lettuce head weight

1. INTRODUCTION

Aphids are considered pests of lettuce (*Lactuca sativa* Linnaeus), mainly because they drain plant phloem sap, transmit disease-causing phytopathogenic microbes, and because they inject plant elicitors (Parker *et al.*, 2002; Ng & Perry, 2004). In addition, they also secrete honeydew, which encourages the growth of sooty moulds (Bovi *et al.*, 2004). However, their viral vectoring capabilities and honeydew-producing habits left aside, the direct feeding damage they and other hemipterous pests inflict onto plants is attributed to the removal of plant sap rather than the consumption of solid plant matter as in the case of most other phytophagous insects. Therefore, feeding damage symptoms exhibited by aphid-infested lettuce hosts would differ markedly from the damage symptoms caused by phytophagous insects with a different mode of feeding.

Harm caused through the feeding of aphids has recently been reviewed by Quisenberry & Ni (2007), who noted it necessary to differentiate between the terms 'damage' and 'injury' as a result of aphid feeding. In short, damage (reduction in growth of the host plant or yield loss) can be viewed as a direct result of injury (a change in the physiological processes of the host plant). According to these authors, the damage aphids cause can be either asymptomatic (no obvious feeding damage) or symptomatic. In the case of symptomatic damage, symptoms will range from desistance (stunting, chlorosis, etc.) to neoplasm (leaf curling, formation of galls, etc.).

In most cases, direct feeding damage to lettuce by aphids can be attributed to the morphs which have a high rate of reproduction (Williams & Dixon, 2007). High population densities can lead to the development of symptomatic damage, with lettuce leaves becoming discolored and wilted as a result of plant sap removal (Harris, 1992), and leaves being shaded by aphid bodies and honeydew (Kaakeh *et al.*, 1992). Tjallingii (2004) has shown that even moderate aphid numbers can cause considerable damage in certain cases, implicating that aphid numbers don't necessarily always have to be high in order for these insects to cause damage. The growth stage of the lettuce crop in relation to the time in which the aphids are present will also largely determine the extent of damage conducted (Irwin *et al.*, 2007). Thus, younger plants are far more likely to be damaged to such an extent that they may be unable to recover, whilst older plants are more resistant to such attacks (University of California, 1992).

This study aimed at determining the impact that varying aphid infestation levels in two differently constructed shadehouses has on lettuce head weight and the number of leaves the plant will form under such conditions. In addition, it also investigated the relationship between the number of leaves head lettuce will normally form and the number of leaves that aphids will typically infest under these varying shadehouse conditions.

2. MATERIALS AND METHODS

Area of research and time frame

The study was carried out in the central Free State near the town of Bultfontein (28°25'S 26°13'E). The trial took place from December 2005 until December 2006.

Trial design and experimental layout

Two flat-roofed shadehouse structures were constructed for this study, each measuring 12 x 18 m. They were built using wooden poles and 25% grey shade netting. The one structure was completely covered with shade netting (fully covered shadehouse) while the other had the sides left open (partially covered shadehouse) and was only covered on the roof area with shade netting. Each of the two structures contained eight blocks of head lettuce, with each block containing three rows of the lettuce crop.

Crisphead lettuce seedlings were obtained from a specialized seedling nursery near the city of Bloemfontein. Two cultivars were used for the trial, namely Tropical Emperor (from Hygrotech®) during the warmer months of the year, and Del Oro (also from Hygrotech®) during the cooler months of the year. The choice was based on the tolerance that Tropical Emperor exhibits towards warmer conditions (Jenni & Dubuc, 2003), while Del Oro is more suited for the cooler months of the year. The seedlings were transplanted at a spacing of 30 x 25 cm which is in accordance to the recommended plant spacing suggested by Harris (1992). Six replicates (which will be referred to as planting cycles) were planted throughout the study. Each planting cycle lasted on average two months after which the lettuce was harvested by hand. No herbicides were sprayed during the trial, while Dithane® was the only fungicide applied in order to combat downy mildew.

Plants were randomly selected for monitoring feeding damage and aphid population levels by using a 'cross' sampling procedure. Assessing feeding damage, aphid population levels, and the amount of leaves formed and infested by aphids were conducted four times (referred to as sample occasions) during each of the six planting cycles. This was done in such a manner as to cover all three growth stages of the crop (seedling, vegetative, and heading).

Aphid sampling procedure

Aphid populations in both structures were enumerated on the pre-selected lettuce plants (all morphs, species and life stages combined). Precise aphid numbers weren't determined as such, but rather estimated in order to obtain an aphid infestation level which was, in turn, expressed numerically. The scale of this infestation level estimate ranged from 0-5, where 0 = no aphids present, while 5 = maximum infestation levels. This scale differed for each of the four different sample occasions (e.g. seedling stage, early vegetative growth, late vegetative growth, or heading stage), as bigger lettuce plants are able to tolerate larger aphid populations, and also because aphid populations tend to increase over time. This procedure is similar to that followed by Parker *et al.* (2002).

Head weight measurements

The lettuce plants which were sampled were removed and weighed (in grams) at the end of each individual planting cycle (during the last sample occasion). This was achieved by carefully removing the plant from the soil, cutting off the root-mass just above soil-level, and then immediately weighing the plant on a portable electronic scale.

Leaf formation and infestation levels

Leaves of all the sampled lettuce plants were counted during each of the four sample occasions of a planting cycle. The number of lettuce leaves infested with one or more aphids were also noted and regarded as 'infested'. During the fourth sample occasion of each planting cycle (which was conducted just after harvesting of the heads), the tightly packed, yellow-coloured leaves of the heads were also counted by means of the whole plant destructive sampling method. If heads already started forming during the third sample occasion of a planting cycle, only the wrapper- and loose leaves were counted in order to reduce injury to the plant, and also to keep disturbances to aphids to a minimum.

Statistical analysis

Differences in the mean number of counted leaves between the two structures, and differences in the mean number of leaves infested with aphids between the two structures were both tested using the one-way ANOVA procedure (SAS, 2004). The same procedure was followed to test for differences in fresh head weight of lettuce between the two structures. Means were not separated because only two treatments were tested. Pearson's correlation was employed to compare the mean number of leaves per plant with the mean number of aphid-infested leaves per plant (SAS, 2004).

3. RESULTS

Head weight and aphid infestation level comparisons

Planting cycle 1 (December/January) revealed an extremely significant difference in mean (± SD) lettuce head weight between the two structures ($F = 19.64$, df = 1, $P < 0.001$) (Figure 1A) as a result of an overall higher head mass in the partially covered structure (843.8750 ± 169.2542 vs. 642.7917 ± 144.0957). Aphid infestation levels were significantly higher ($P < 0.05$) in the fully covered structure during this time (Table 1). A similar situation was observed during planting cycle 3 (April/May) ($F = 5.68$, df = 1, $P = 0.0213$) in which the partially covered structure again attained a higher mean (± SD) head mass (168.2917 ± 30.2187 vs. 141.6667 ± 45.6105) (Figure 1C). However, aphid infestation levels were higher in the partially covered structure during this period (Table 1). Planting cycle 6 (October/November) also had a significant difference in head mass between the two structures ($F = 5.70$, df = 1, $P = 0.0211$), again as a consequence of a higher mean (± SD) head mass in the partially covered structure (203.3333 ± 111.7083 vs. 135.7083 ± 82.2977) (Figure 1F). The fully covered structure attained the highest aphid infestation levels here (Table 1).

Relation between counted leaves and aphid-infested leaves

Despite aphid populations reaching higher levels in the fully covered structure during the warmer months, and moderately higher levels in the partially covered structure during the cooler months (Table 1), the mean (± SD) number of leaves counted per plant remained relatively similar between the two structures throughout the study ($P > 0.05$). The only exceptions were observed during planting cycles 5 (Augustus/September) and 6 (Table 2).

Differences in the number of aphid infested leaves between the two structures were more pronounced (Table 3). During planting cycle 1, the last three sample occasions all showed a significant difference ($P < 0.05$) in the mean (± SD) number of leaves infested with aphids between the two structures, as a result of the fully covered structure having on average more aphid-infested leaves (Table 3). During this planting cycle the fully covered structure also had an extremely significant correlation ($P < 0.0001$) between the number of leaves counted and the number of leaves infested with aphids during the last two sample occasions (r = 0.88788 and r = 0.73646, respectively). The aphid infestation rate during the first three sample occasions of planting cycle 6 also differed significantly between the two structures ($P < 0.05$), again as a result of the fully covered structure attaining on average more aphid-infested leaves (Table 3). Sample occasions 2 (r = 0.95954) and 3 (r = 0.82919) of this planting cycle all showed an extremely significant correlation ($P < 0.0001$) between the number of leaves counted and the number of leaves infested with aphids in the fully covered structure. Planting cycles 1 and 6 had the highest mean ambient temperatures recorded for the study period (Figure 2). However, during both planting cycles 4 (June/July: third sample occasion) and 5 (first two sample occasions), the mean (± SD) number of aphid-infested leaves were significantly higher in the partially covered structure (Table 3) when the mean ambient temperature was lower in both structures (Figure 2). Aphid infestation levels were also mostly higher in this structure during these two periods (Table 1). Planting cycle 5 was the only time during which the partially covered structure showed a significant positive correlation between the number of counted leaves and the number of aphid-infested leaves during the third (r = 0.94962, $P < 0.0001$) and fourth (r = 0.70661, $P = 0.0001$) sample occasions.

4. DISCUSSION

Phytophagous insect feeding damage is considered to be a function of their population densities (Bale, 1991), and aphids are known to reach high population numbers, as witnessed during this study. However, direct feeding damage to the host by aphids has been considered not very obvious (Gao *et al.*, 2008). This is due to these insects only feeding on the phloem sieve element, after intercellular probing through the epidermal and mesophyll cell layers has taken place (Gao *et al.*, 2008). In this study, symptomatic feeding damage on the lettuce crop was indeed insignificant, with only some degree of localized necrosis where the aphids had penetrated the plant tissue with their stylets, and a slight degree of leaf curling (neoplasm) in some cases. However, asymptomatic damage symptoms did exist to some extent with regard to head weight reduction.

The differences observed in lettuce head weight between the two structures was actually a combination of both aphid feeding and environmental conditions. Significantly higher aphid densities did partially contribute to the lower head weights in the fully covered structure during planting cycles 1 and 6. High aphid numbers can remove substantial quantities of plant sap, interfering with the physiological processes of the plant which could inevitably lead to a decrease in fresh weight, as observed in other crops (Van Emden, 1990). However, the specific conditions (microclimate) experienced within a particular shadehouse structure also had an influence on this reduction of fresh head weight. This was evident from the fully covered structure which again reached a lower mean head mass during planting cycle 3, despite the fact that there were actually less aphids present compared to the partially covered structure. Lettuce is essentially a cool-weather crop (Harris, 1992) and higher temperature and moisture levels experienced in the fully covered structure during the warmer months of planting cycles 1, 3 and 6 (Figure 2) could also have contributed to the lower head weights in this structure. Therefore, the differences in head weight between the two structures is also partly a function of the microclimate within a particular structure, but high aphid infestation levels could accelerate head weight reduction under the less favourable growing conditions.

Lettuce plantings from a previous planting cycle were removed prior to planting a new cycle, implicating that aphids had to re-infest the crop each time anew. Therefore, their populations were lower during the seedling stage (first sample occasion) and had to increase over the short growth period of the crop. Low aphid densities during the seedling stage, in turn, effectively prevented serious damage, as lettuce is vulnerable to insect attack at this time (Grafton-Cardwell *et al.*, 2005). This explains why even the high aphid infestation levels did not have any real impact on the number of leaves formed by the plant, with the exception of planting cycles 5 (partially covered structure) and 6 (fully covered structure). However, the lettuce plants were able to recover in both cases before harvesting of the crop.

It is to be expected that more lettuce leaves will be infested with aphids under such crowded conditions as those witnessed during the warmer months of planting cycles 1 and 6 in the fully covered structure. This led to the extremely significant differences in the number of aphid-infested leaves observed between the two structures during these periods. Reasons for higher aphid densities in the fully covered structure during these two planting cycles, in short, entails the presence of *Anoplolepis custodiens* Smith which could have preyed on the aphids and removed/killed coccinellid larvae and eggs in the partially covered structure, lower abundance of adult coccinellid (and absence of *A. custodiens*) in the fully covered structure, and the fully covered structure hindering alatae from dispersing. In addition, the fully covered structure also reached a higher mean temperature range (Figure 2) and humidity level which could have favoured the development of certain aphid species (most notably *Acyrthosiphon lactucae* Passerini). In contrast, more aphid-infested leaves in the partially covered structure as opposed to the fully covered structure during planting cycles 4 and 5 was a result of higher aphid populations in this structure. Reasons for this difference included minimum temperatures which were not as low as those measured in the fully covered structure during these planting cycles and the absence of coccinellid larvae and pugnacious ants during these cooler months.

Significant positive correlations between the number of counted leaves and the number of aphid-infested leaves during planting cycles 1, 5 and 6 are also to be expected, since aphids would eventually disperse to most of the leaves under crowded conditions. The implication of this is that most of the leaves will be infested with aphids under high aphid population levels. Quantifying the degree to which leaves are infested with aphids is important because, despite the direct damage aphids are capable of inflicting onto lettuce through extracting phloem sap, their mere presence may also render the crop unattractive and unmarketable from a phytosanitary point of view (Van Helden *et al.*, 1993).

5. CONCLUSIONS

Symptomatic feeding damage to the lettuce crop was restricted, but asymptomatic damage in terms of a decrease in lettuce fresh head weight did occur. However, the microclimate experienced within a particular shadehouse structure also contributed to the decrease in lettuce fresh weight. Therefore, aphid feeding only had any real impact under less favourable growing conditions for the lettuce crop. The physical presence of aphids on the crop is more important from a phytosanitary point of view. Higher aphid densities would imply that more leaves are infested with these insects. Under severe infestation conditions, most of the leaves will be contaminated with the presence of aphids, which could lead to the rejection of the crop in most cases.

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Table 1: Level (mean ± SD) of aphid infestation observed in each structure per growth stage (sample occasion) of the lettuce crop during each planting cycle.

PC	GS	Structure type		*F* value	*P* value	*n*	SL
		FCS	PCS				
PC 1	SS	0.7083 ± 1.3010	0.5417 ± 0.5090	0.34	0.5619	24	ns
	VG 1	1.3333 ± 1.5510	0.5417 ± 0.5882	5.47	0.0238	24	*
	VG 2	3.4583 ± 1.6150	0.5417 ± 0.5090	71.24	<0.0001	24	***
	HS	4.4167 ± 1.1390	0.7917 ± 0.4149	214.66	<0.0001	24	***
PC 2	SS	0.0417 ± 0.2041	0.1250 ± 0.3378	1.07	0.3064	24	ns
	VG 1	0.0833 ± 0.2823	0.1667 ± 0.3807	0.74	0.3935	24	ns
	VG 2	0.3333 ± 0.4815	0.3750 ± 0.4945	0.09	0.7688	24	ns
	HS	0.5417 ± 1.0210	0.4167 ± 0.5036	0.29	0.5931	24	ns
PC 3	SS	0.4167 ± 0.5036	0.2500 ± 0.4423	1.48	0.2294	24	ns
	VG 1	0.0417 ± 0.2041	0.2917 ± 0.4643	5.83	0.0198	24	*
	VG 2	0.4167 ± 0.5036	0.7917 ± 0.4149	7.93	0.0071	24	**
	HS	0.7500 ± 0.4423	0.9167 ± 0.2823	2.42	0.1266	24	ns
PC 4	SS	0.0417 ± 0.2041	0.0417 ± 0.2041	0.00	1.0000	24	ns
	VG 1	0.1667 ± 0.3807	0.5000 ± 0.5108	6.57	0.0137	24	*
	VG 2	0.2500 ± 0.4423	0.5833 ± 0.5036	5.94	0.0188	24	*
	HS	0.7917 ± 0.4149	0.7083 ± 0.4643	0.43	0.5153	24	ns
PC 5	SS	0.2500 ± 0.4423	0.5833 ± 0.5036	5.94	0.0188	24	*
	VG 1	0.9167 ± 0.2823	0.9583 ± 0.2041	0.34	0.5608	24	ns
	VG 2	1.3333 ± 0.5647	1.3333 ± 0.4815	0.00	1.0000	24	ns
	HS	2.5000 ± 0.8847	2.5417 ± 1.0210	0.02	0.8805	24	ns
PC 6	SS	1.6250 ± 1.7150	0.0417 ± 0.2041	20.18	<0.0001	24	***
	VG 1	3.7500 ± 1.4220	0.5833 ± 0.5036	105.77	<0.0001	24	***
	VG 2	3.4167 ± 1.7670	0.0833 ± 0.2823	83.26	<0.0001	24	***
	HS	0.1250 ± 0.3378	0.0417 ± 0.2041	1.07	0.3064	24	ns

PC = Planting Cycle, GS = Growth Stage, FCS = Fully Covered Structure, PCS = Partially Covered Structure, SL = Significance Level, SS = Seedling Stage, EVG = Early Vegetative Growth, LVG = Late Vegetative Growth, HS = Heading Stage, * = Significant Difference, ** = Highly Significant Difference, *** = Extremely Significant Difference

Table 2: Number (mean ± SD) of lettuce leaves counted in each structure per growth stage (sample occasion) of the crop during each planting cycle.

PC	GS	Structure type					
		FCS	PCS	*F* value *P*	value	*n*	SL
PC 1	SS	6.7500 ± 1.7998	6.7500 ± 2.0483	0.00	1.0000	24	ns
	EVG	11.9167 ± 2.3015	12.6667 ± 2.7767	1.04	0.3136	24	ns
	LVG	12.0000 ± 2.9192	12.5417 ± 2.4313	0.49	0.4884	24	ns
	HS	10.0000 ± 2.0430	10.6250 ± 2.6012	0.86	0.3594	24	ns
PC 2	SS	6.0833 ± 1.4720	6.0833 ± 1.3160	0.00	1.0000	24	ns
	EVG	10.1250 ± 1.9630	11.2917 ± 3.3555	2.16	0.1483	24	ns
	LVG	11.0833 ± 2.3759	10.9167 ± 2.5007	0.06	0.8139	24	ns
	HS	13.2083 ± 2.4134	13.7500 ± 2.4002	0.61	0.4396	24	ns
PC 3	SS	7.5833 ± 2.1853	8.1667 ± 2.3157	0.81	0.3741	24	ns
	EVG	8.5000 ± 2.1669	9.7083 ± 2.2357	3.61	0.0635	24	ns
	LVG	12.0000 ± 1.8415	11.7917 ± 2.8127	0.09	0.7628	24	ns
	HS	11.9167 ± 2.7174	11.7917 ± 3.1894	0.02	0.8844	24	ns
PC 4	SS	5.5000 ± 1.3513	5.9583 ± 2.0104	0.86	0.3588	24	ns
	EVG	7.2917 ± 1.6280	7.8333 ± 2.1602	0.96	0.3317	24	ns
	LVG	8.3333 ± 2.5820	8.6667 ± 2.9291	0.17	0.6777	24	ns
	HS	9.3333 ± 2.6320	8.7083 ± 2.4931	0.71	0.4027	24	ns
PC 5	SS	6.4167 ± 1.4421	6.0000 ± 2.0000	0.69	0.4120	24	ns
	EVG	9.7083 ± 1.7315	9.0000 ± 2.3956	1.38	0.2465	24	ns
	LVG	11.6667 ± 2.8993	9.9167 ± 3.0633	4.13	0.0479	24	*
	HS	12.0833 ± 2.8117	11.1250 ± 1.9850	1.86	0.1792	24	ns
PC 6	SS	8.8750 ± 2.8332	9.4167 ± 2.9476	0.42	0.5195	24	ns
	EVG	10.2083 ± 2.8889	11.9167 ± 2.5007	4.80	0.0336	24	*
	LVG	12.7500 ± 3.2067	12.0000 ± 2.4672	0.82	0.3685	24	ns
	HS	13.1667 ± 3.5834	12.5417 ± 3.2434	0.40	0.5295	24	ns

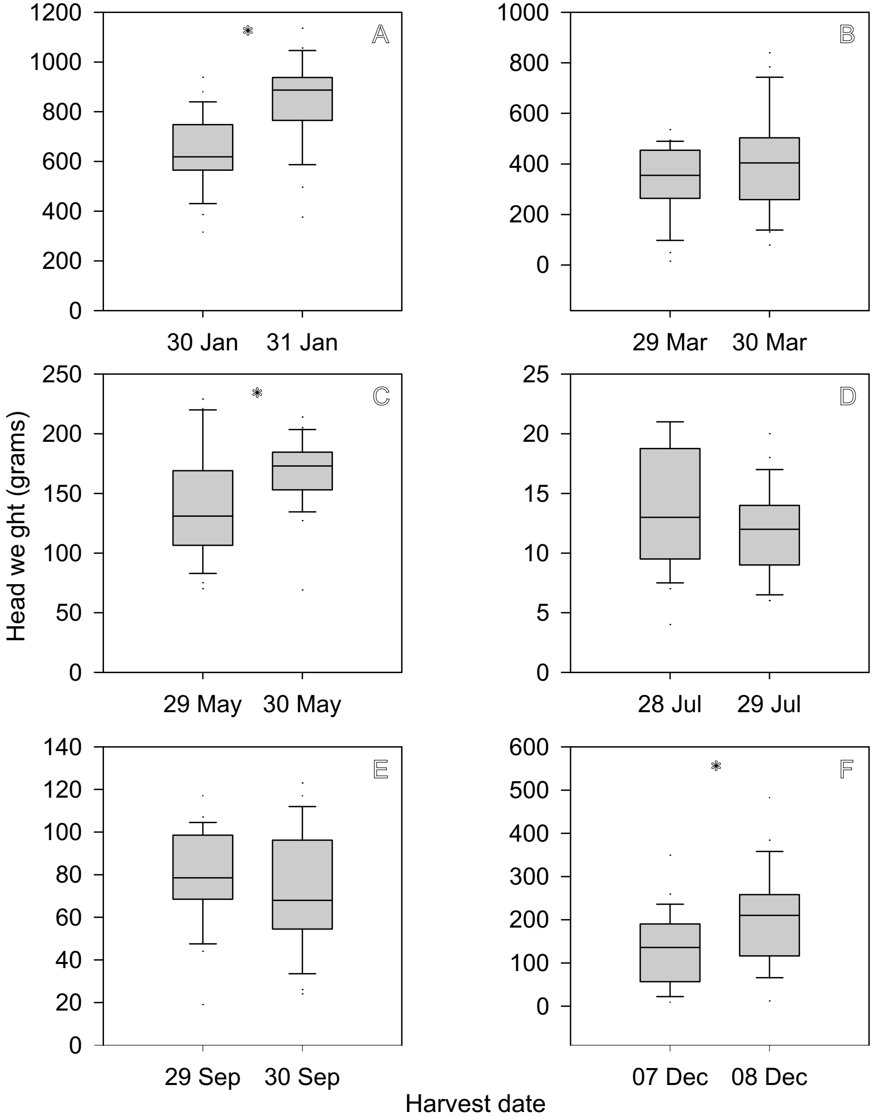
PC = Planting Cycle, GS = Growth Stage, FCS = Fully Covered Structure, PCS = Partially Covered Structure, SL = Significance Level, SS = Seedling Stage, EVG = Early Vegetative Growth, LVG = Late Vegetative Growth, HS = Heading Stage, * = Significant Difference

Table 3: Number (mean ± SD) of aphid-infested lettuce leaves counted in each structure per growth stage (sample occasion) of the crop during each planting cycle.

PC	GS	Structure type					
		FCS	PCS	*F* value *P*	value	*n*	SL
PC 1	SS	0.6667 ± 1.0901	0.6250 ± 0.6469	0.03	0.8728	24	ns
	EVG	4.5833 ± 4.5389	1.5833 ± 2.1247	8.60	0.0052	24	**
	LVG	11.5000 ± 3.4891	1.0417 ± 1.2676	190.49	<0.0001	24	***
	HS	9.3333 ± 2.7452	0.5417 ± 0.7790	227.80	<0.0001	24	***
PC 2	SS	0.0417 ± 0.2041	0.1250 ± 0.3378	1.07	0.3064	24	ns
	EVG	0.1250 ± 0.4484	0.4167 ± 1.0598	1.54	0.2207	24	ns
	LVG	0.5833 ± 1.1389	0.7917 ± 1.4440	0.31	0.5816	24	ns
	HS	1.5833 ± 3.5621	0.6250 ± 0.8242	1.65	0.2055	24	ns
PC 3	SS	0.5417 ± 0.7790	0.2500 ± 0.4423	2.54	0.1176	24	ns
	EVG	0.0833 ± 0.4082	0.3750 ± 0.6469	3.49	0.0681	24	ns
	LVG	1.2083 ± 1.7189	1.7500 ± 1.4521	1.39	0.2444	24	ns
	HS	2.4583 ± 2.7972	1.7500 ± 1.1516	1.32	0.2572	24	ns
PC 4	SS	0.0417 ± 0.2041	0.0417 ± 0.2041	0.00	1.0000	24	ns
	EVG	0.3750 ± 1.0959	0.7083 ± 0.8065	1.44	0.2362	24	ns
	LVG	0.3750 ± 0.7697	1.0417 ± 1.2329	5.05	0.0295	24	*
	HS	1.6250 ± 1.4982	1.0833 ± 0.9743	2.20	0.1444	24	ns
PC 5	SS	0.2917 ± 0.5500	0.9583 ± 1.0826	7.23	0.0099	24	**
	EVG	2.2500 ± 1.2938	3.4583 ± 1.9106	6.58	0.0136	24	*
	LVG	8.7500 ± 3.5047	9.4583 ± 3.5260	0.49	0.4887	24	ns
	HS	11.3333 ± 2.4964	10.1667 ± 2.3713	2.76	0.1037	24	ns
PC 6	SS	2.1250 ± 2.5760	0.0417 ± 0.2041	15.6	0.0003	24	***
	EVG	9.7500 ± 3.3133	1.3750 ± 2.0602	110.58	<0.0001	24	***
	LVG	12.1667 ± 3.6792	0.0833 ± 0.2823	257.36	<0.0001	24	***
	HS	0.0000 ± 0.0000	0.0000 ± 0.0000	0.00	1.0000	24	ns

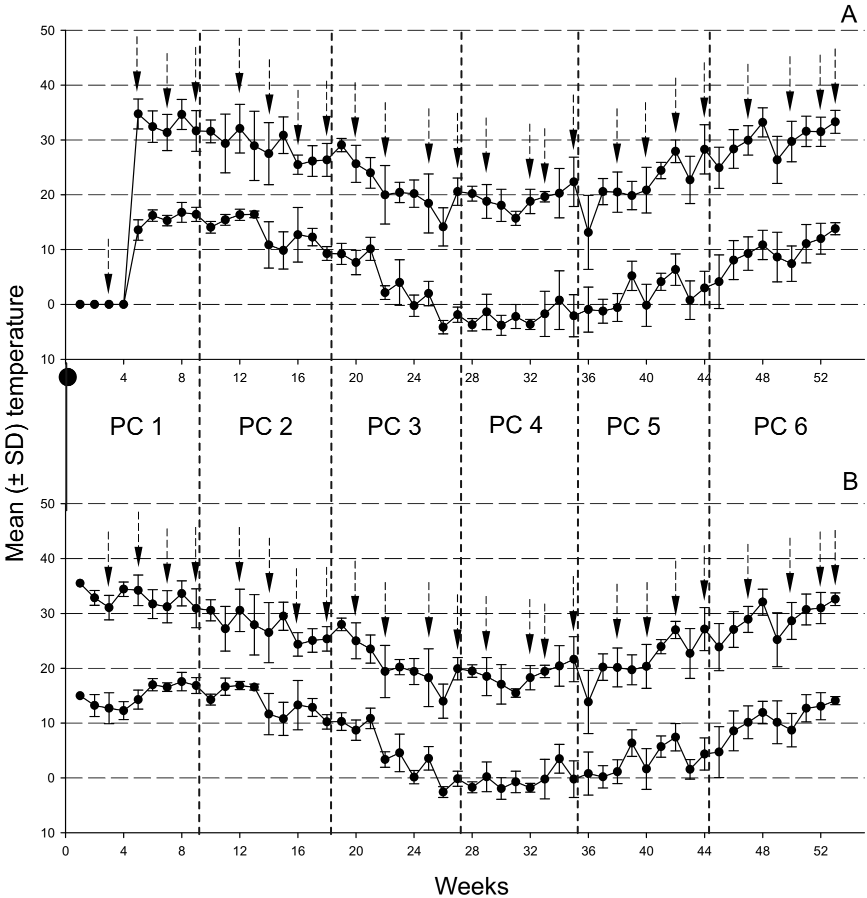
PC = Planting Cycle, GS = Growth Stage, FCS = Fully Covered Structure, PCS = Partially Covered Structure, SL = Significance Level, SS = Seedling Stage, EVG = Early Vegetative Growth, LVG = Late Vegetative Growth, HS = Heading Stage, * = Significant Difference, ** = Highly Significant Difference,

*** = Extremely Significant Difference



* = Significantly different at $P < 0.05$

Figure 1: Fresh lettuce head weight (mean ± SD) measured in the fully covered structure (left-side box in each diagram) and partially covered structure (right-side box in each diagram) during each planting cycle.



Solid circles = maximum temperatures. Open circles = minimum temperatures, PC = Planting Cycle

Figure 2: Weekly mean (± SD) maximum and minimum temperatures recorded from fully covered shadehouse structure (A) and partially covered shadehouse structure (B). Arrows indicate weeks in which sampling were conducted.