VORTEX GENERATOR WATER STUDY

EFFICACY OF VORTEX GENERATOR WATER TREATMENT ON BUTTER LETTUCE

NEW AGE LABORATORIES

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INTRODUCTION

New Age Laboratories and Johnson AG & Marine Consultants were contracted by Pacific AG in Raymond, Washington to evaluate the effectiveness of VORTEX GENERATED irrigation on Butter Lettuce. Growth, nutrient uptake and aphid pressure on lettuce were evaluated. The replicated trial was run outdoors using plug plants irrigated with VORTEX GENERATOR treated water or Santa Cruz County, California city water.

This report summarizes the methods, results and conclusions of a single, VORTEX GENERATOR, irrigated trial on lettuce in Santa Cruz County, California. The Vortex Generator used in this study affects the functionality of water which includes its multiple states of motion such as velocity, spin and unity of direction within the volume. These factors affect the physical, chemical and electrical properties of water and the behavior. The vectors of water motion flows are created by the

vortex velocity and pressure differentials. When water passes through the Vortex Generator, the spin state is greatly accelerated resulting in smaller molecular cluster sizes which can result in rapid water changes of greater density, penetrability and infiltration (President Water Company, 2021). Examples of natural vortex generated water are: waterfalls flowing over rocks, whirlpools, cyclones, hurricanes and surf waves in the ocean.

MATERIAL AND METHODS

Experimental Design: The trial was conducted at Johnson Ag & Marine Consultants research facilities in Santa Cruz County, California. The VORTEX GENERATOR (VG) water treatment equipment was manufactured by The President Water Company, LLC, Raymond, WA with manufacturing in Western Australia and USA, and provided by J. Brackins of Pacific Ag, in Raymond, Washington.

The VG Model was PW75HF ¾"-20mm, 15.5” in length.

To conduct this test we placed a “Y” connector at the spigot and attached a second hose, to which the PW75HF Vortex Generator was connected. “Control” or “Vortex Treatment” was facilitated with the twist of a valve. Santa Cruz County water was the same source water for both groups.

The equipment was attached to a hose bib and water was passed through the VG for irrigating treated plots. The lettuce cultivar (REX) used in the study was purchased as plug plants from Headstart Wholesale Nurseries (Gilroy, California). Planting medium used was Whitney Farms Organic. Plug plants were grown in 4” plastic pots. Prior to planting, the 4” pots were filled with potting medium and irrigated daily for two days in the greenhouse with either VG treated or Control city water.

All plug plants in the trial were pre-treated prior to planting with a nutrient root dip prepared in VG or Control water dipped for 3 seconds/plug and planted directly into pre-irrigated 4" pots in the greenhouse to acclimate for twenty-four hours prior to establishing the outdoor trial. Plots were separated by at least 20 ft. A randomized, complete block design with three replicates per treatment was utilized at the test site. Each replicate plot consisted of 3 rows of 5 plants each per VG treatment and Control.

TREATMENT	**TYPE**	**SCHEDULE**
VORTEX	Irrigation	Preplant Plug Dip, 9 irrigations
CONTROL, city water	Irrigation	Preplant Plug Dip, 9 irrigations

Fertilizers and Nutrient Applications: All plants were treated as follows:

DATE	APPLICATION	RATE	TYPE
2/5/2021	MicroPak AEA Holo Calcium AEA Sea Phosphorus Pacific Gro SeaStim AEA HUMA Charb AEA MicroPak Iron	7g/gal 30g/gal 118g/gal 30g/gal 50g/gal 2 tbsp 1 teaspoon	Pre Plant Root Dip for 3sec/plant in CONTROL or VORTEX treated water
3/6/2021	Iron + MicroPak AEA	½ quart/Acre	Foliar
3/13/2021	Miracle Grow 18-18-21	80% 20g/gal	Soil applied 20ml/plant
3/30/2021	Miracle Grow 18-18-21	80% 20g/gal	Soil applied 20ml/plant

Weather Data: Data were collected from California Irrigation Management Information System (CIMIS) Station 104, De Laveaga-Monterey Bay, CA located approximately 10 miles north of the outdoor trial study site.

Cumulative Rainfall and Average Daily Solar Radiation

DATE	**Cumulative Rainfal**l inches	**Average Solar Radiation** ly/day
Feb 2021	1.43 “	316 langleys/day
March 2021	2.74 “	434 langleys/day
April 2021	0.0	565 langleys/day

Air Temperature (Maximum/Minimum F) on fertilization dates:

2/5/2021	Root Dip	62.9/36.7 F
3/6/2021	Foliar	62.7/42.2 F
3/13/2021	Soil Application	60.9/38.7 F
3/30/2021	Soil Application	77.7/39.2 F

Air Temperature (Maximum/Minimum F) on Irrigation dates:

2/22/21	74.4/41.9 F
2/25/21	67.9/41.0 F
2/28/21	65.8/40.2 F
3/7/21	63.3/34.1 F
3/19/21	59.6/40.3 F
3/23/21	67.2/44.3 F
3/26/21	65.4/37.5 F
3/30/21	77.7/39.2 F
4/1/21	81.1/47.2 F

Lettuce Crop Sap Sampling and Evaluations: Lettuce leaf samples of Control and VG treated crops were sampled on the following schedule and analyzed at New Age Laboratories in Michigan for twenty-four factors (Appendix 1).

3/1/2021 sampled at 0730	29 days after planting
3/8/2021 sampled at 0730	36 days after planting
3/16/2021 sampled at 0800	44 days after planting
4/5/2021 sampled at 0800	54 days after planting; harvest date

To provide the required leaf biomass for sap analyses, equal amounts of leaf biomass were sampled from each plant for Control and VG replicate plots on the noted dates.

Final Lettuce Harvest was done 54 days after planting. Ten plants were harvested from the middle of each of three replicate Control and VG plots. The head portion of each lettuce plant was harvested using shears and weighed fresh on an OHAUS

Balance (grams). During harvest for fresh weights, lettuce heads were individually evaluated for pests.

Lettuce Aphid (*Nasonovia ribis-nigri*) evaluations were done on: 3/1/2021, 3/16/2021 and at harvest on 4/5/21. Ten plants in each of 3 replicate Control and VG treated plots were evaluated; a total of 30 plants in each treatment. Lettuce plants were evaluated by counts and scored to the following ranges (aphids/plant): 1= 0 aphids/plant, 2=2-5, 3=6-100, 4=101-500, 5=501 to 1000+. All life stages were combined in the scoring.

Statistical Analyses: Lettuce harvest weights, select sap analyses and aphid scoring data were analyzed using standard statistical parametrics ,T Test and Chi Square inferences (Rolf, F. & Sokal, 1981, Stapplet, 2021).

RESULTS

The lettuce plug plants in this study were cultivated for 55 days (February 5 to April 6, 2021) using the same horticultural parameters of fertilizers and irrigation timing from planting to harvest. No pesticides were used on the outdoor trial plots and plants received natural rainwater in addition to scheduled irrigations. The Treated replicate plots received scheduled irrigations using the VG treated Santa Cruz City water throughout the study. The Control lettuce plots received untreated Santa Cruz City water. Treated and Control plots were separated by at least 20 feet and CIMIS weather data characterize the typical Central California, maritime, climatic conditions throughout the duration of this outdoor study.

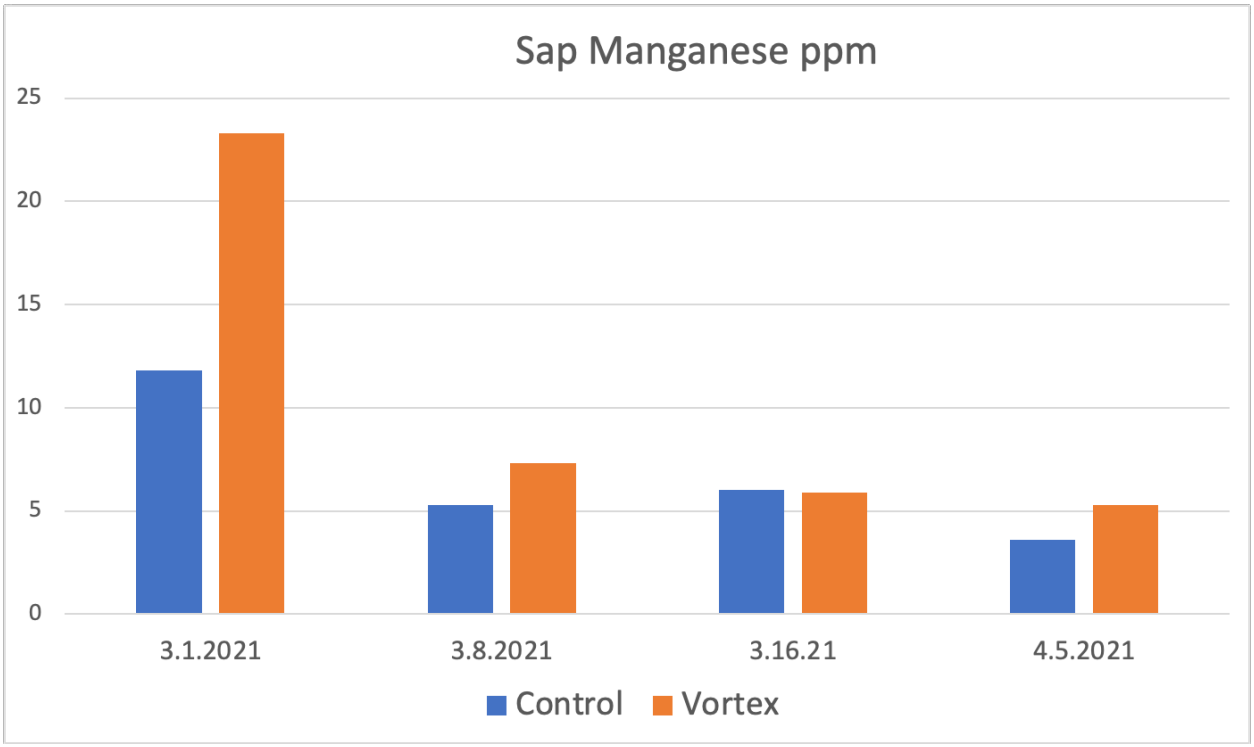
An analysis of the final lettuce harvest fresh weights showed no significant difference (T(29)=1.05=30.24%) between VG Treated and Control irrigated plots.

Average grams/plant	Replicate A	Replicate B	Replicate C
Control N=30	59.3	69.9	67.1
VG Treated N=30	67.5	65.7	72.8

Lettuce sap samples comparing Control and VG irrigated plots were analyzed: 29, 36, 44 and 54 days after planting. The results were similar or variable in their ranges; with the exception of the 29-day post plant data, which were notable. Sap analyses of old and new leaves following subsequent foliar and soil fertilizer applications, were similar (Appendix 1).

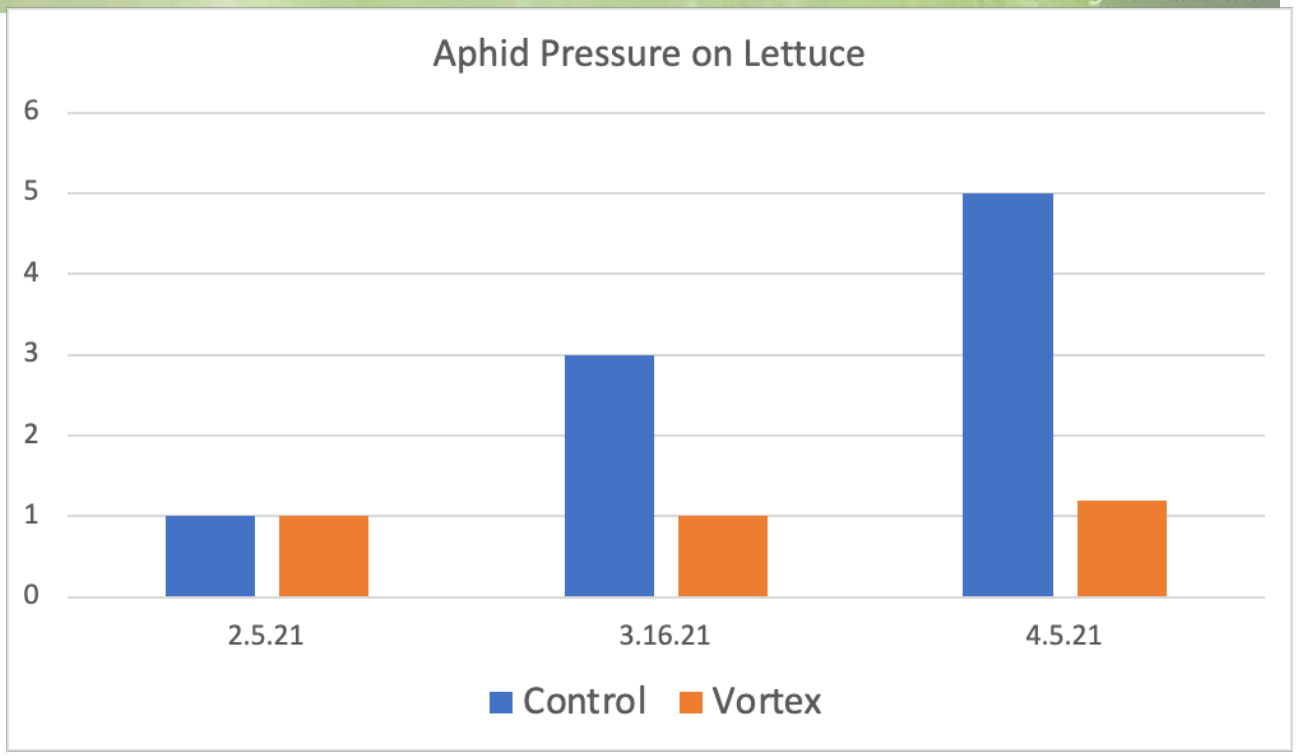
However, the sap Manganese for emerging new leaves at 29 days after planting was significantly higher (P<.01%) in the VG plots (mean=23.3ppm SD 2.9) than in the Control plots (mean 11.8ppm SD=4.8). This result followed the preplant root dip which contained micronutrients. As noted by Huber, D. (2007), manganese is only semi-mobile and is taken up in its reduced form by the roots; especially in

the presence of adequate chloride which was high (Sap=2000 ppm to 3,500 ppm in both new and old leaves). It was noted that VG plants had a slight tip burn which is consistent with a higher uptake of salts using VG irrigation. This has also been noted in strawberry (Johnson, J. et. al., 2011).



Lettuce plug plants were inspected upon arrival, at planting and on 3/1/2021; 29 days after planting and no pests were observed. Aphid counts on 3/16/21 and at harvest on 4/5/2021 were notable. The aphid populations in the Control Plots steadily increased during the trial and in contrast remained at near zero in the VG Plot throughout the trial.

Due to the high numbers of aphids on the control lettuce plants, counts were scored in ranges. These categorical data were analyzed using a Chi Square test which showed that the Control plots had significantly more aphids than the VG treated plots (P>.001). It is of significance that at harvest less than 5 aphids were found on only 3 VG treated lettuce plants whereas 100% of Control plants were infected in the range of 500 to 1000+ aphids per plant when trial plots were separated by only 20 feet.



Legend of Range Categories: 1 = 0 aphids/plant, 2 = 1-5 aphids/plant, 3 = 6 –100 aphids/plant, 4 = 101 – 500 aphids/plant, 5 = 501 – 1000+ aphids/plant.

CONCLUSIONS

It is concluded from this trial that Vortex Generated (VG) irrigation of replicate Lettuce plots resulted in significantly greater Manganese uptake by roots following a preplant micronutrient dip than plants in Control plots. It is also concluded that VG irrigated plants showed a notable and significant resistance to aphid pressure. There was not however, a significant difference between Control and Treated lettuce biomass at harvest.

One mode of action of Vortex Generated water is to increase the ionization and permeability of nutrients through changes in physics and electrochemistry of the resultant water (President Water Co., 2021).It is suggested that the Preplant micronutrient dip of lettuce plants in VG water facilitated the high manganese uptake measured in the 29 day Sap analyses.

It has also been demonstrated that Manganese uptake is facilitated by an adequate presence of chloride ions (Burnell, J. 1988) and this was shown in the lettuce sap data for both the Control and VG plants. However, *Manganese was significantly higher in VG plant sap*. Numerous studies have shown the importance of manganese in plants as a cofactor active in enzyme activity, lipid and fatty acid metabolism and photosynthesis (Marschner, H. 2002, Marschner,

P., 2012, Hamilton, K., 2020). Manganese also contributes to the production of secondary metabolites such as phenols which may induce resistance of plants to aphids (Hughes & Williams, 1988). Huber (2007) also notes that manganese in its reduced form predisposes plants to resist diseases when the nutrient balance and reduced sugars are correct and available.

It has been shown that plants can show resistance to disease and pests when sap sugars and manganese are not oxidized but in the reduced forms (Alizamani, T. et. al., 2020, DeGeyter, E. et.al., 2011). Further, sap analyses of reduced sugars would be important to include in future studies (Douglas, A. et. al., 2006).

In summary, nutrient uptake in Vortex Generated water through lettuce roots resulted in high sap manganese levels, a balanced nutrient profile and notable aphid resistance compared to the untreated Control in this replicated study. Pest control and balanced nutrition in the commercial farming of organic crops has significant challenges. The use of novel and creative methods such as Vortex Generated irrigation could prove to be a valuable agronomic tool in these two critical arenas.

SUGGESTIONS FOR FURTHER STUDY:

It is suggested that further studies dive deeper into: Vortex Generated irrigation to roots and soil with micronutrient treatments; specifically Manganese coupled with soil analyses. It would also be valuable to explore VG irrigation and resultant profile analyses of individual sap nitrogen components, sugars (reduced and oxidized) and Molybdenum. A comparison of foliar versus soil fertigation may also shed light on the most effective modes of nutrition balance using Vortex Generated water.

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