Evaluating costs and benefits of organic-approved liquid injectable fertilizers to improve nutrient uptake and yields in tomato

Oren Hoffman, Nicole Tautges and Kate Scow

Final report

July 2021

Rationale and literature review

Organic tomatoes rank among the top 10 organic commodities sold in the U.S., accounting for over $180 million in sales in 2016 (USDA-NASS 2017). California is the country's center of tomato production, responsible for growing over 95% of tomatoes consumed in the U.S. (CTRI 2019). However, many organic growers relying on cover crops and/or compost for fertility report problems achieving sufficient soil nutrient availability during the period of rapid growth, which limits tomato nutrient uptake, yields, and fruit quality. Data from previous UC-Davis research trials found that nitrogen (N) uptake limitations resulted in 15% lower yields in organic than conventional tomatoes, with estimated losses of $500 to $1000 in revenue per acre (Castro Bustamante & Hartz, 2015). Other studies comparing compost fertilizer to conventional chemical fertilizer have identified similar difficulties with nitrate release from compost. Herencia et al. (2007) observed higher total N in organic compost-amended soils, but lower nitrate uptake by the vegetable crop compared to conventional fertilizer. Murmu et al. (2013) also observed lower N uptake and fruit yields in processing tomatoes when amended with three different types of organic amendments compared to synthetic fertilizer. Similarly, Ferris et al. (1996) observed levels of soil nitrate at tomato planting insufficient to support high yields following compost addition in an organic system compared to a conventional system with chemical fertilizer. This gap was observed despite the fact that the total N applied in compost exceeded that applied in the conventional system. Feris also reported tomato plants displaying N deficiency symptoms early in the growing season.

Liquid "fertigation-friendly" OMRI-approved fertilizer products are increasingly being marketed to organic tomato growers, who are looking for supplemental in-season sources of N but are often unable to achieve the benefits of these products despite their high cost. In-season organic-approved products are needed for organic tomato production, given previous consistent observations of N deficiencies when producers rely only on compost incorporated in the fall before planting. However, growers need to have confidence in the benefit of these liquid fertilizer products, before incurring their high cost of application. **The goal of this study was to evaluate the impact of four different types of organic fertigation products on soil N levels, plant N concentrations, fruit yields, and the economics of the system.**

Experimental plan and implementation

The plan was to evaluate three distinctly different organic amendment types (fish extract, compost "tea", and microbial/amino acid). Compost "tea" (or liquid compost) was not used, as those products usually have far lower (<1%) nitrogen content, and we aimed to use amendments with similar nitrogen content. Accordingly, the three amendments used included a fish emulsion (Phytamin Fish 3-2-0, California Organic Fertilizers INC., Hanford, CA) grain fermentation and soy hydrolysis product (Converted Organics 4-2-2, Converted Organics, Gonzales, CA), and a combination fish and corn steep product (Phytamin Special 4-1-1, California Organic Fertilizers). Another product, based only on corn steep (Phytamin Express 4-1-1, California Organic Fertilizers) was not used in the field, but was included in lab analysis and incubation experiments. While the N content was very similar among the products (3-4%), the molecular make-up of N-carrying molecules can be very different (see Appendix). All products are OMRI approved and are appropriate for use in drip irrigation. Table 1 specifies their macronutrient content and price, normalized for N rate; more info on them can be found in the appendix.

Table 1. Product name (abbreviation in figures), macronutrient content, and price (per lb N), of amendments used in study. The application cost refers only to product price, without labor and equipment costs.

Product	**N-P-K (%)**	**Price ($/lbN)**	**Application cost ($/ac)**		
			20 lb/ac	40 lb/ac	60 lb/ac
Phytamin Fish (Fish)	3-2-0	16.8	336	672	1008
Phytamin Express (Exp)	4-1-1	17.8	356	712	1068
Phytamin Special (Special)	4-1-1	15.8	316	632	948
Converted Organics (CO)	4-2-2	21	420	840	1260

The field protocol was slightly amended from the original plan, mostly due to constraints on use of field equipment and field work under COVID-19 restrictions. The original plan to fertigate three times was reduced to 2 times, spaced 10-14 days apart. The combined nitrogen rate of the two applications was ca. 18 Lbs/Ac, applied during the stage with highest nitrogen uptake by tomato plants (Hartz & Bottoms, 2009).

Methods

Field experiment

The organic liquid amendments were applied through the drip-tape system by connecting a ditch pump (Figure 1) to the end of each treated row while closing the drip-tape at the top of the row with a valve. The products were diluted in water as recommended by the manufacturers. The drip lines and pump were immediately flushed with clean water after each application.

Soils were sampled every two weeks, starting one week before the first application, and ending four weeks after the second application. Fresh samples were sent for nutrient analysis (Soiltest Labs, Moses lake, WA). Tomato leaves were sampled 10 days after the first application and 16 days after the second application, and analyzed for NPK content after drying.

Machine harvest took place on September 9, 2020. Each treatment row was harvested individually and row yield was measured; Yield data was transformed to Lbs/ac. Control rows were selected from the center of the field, and yields were measured and transformed similarly.

Figure 1. Fertigation system consisting of a pump and buckets filled with the amendments diluted in water. Photo taken June 8, 2020.

Results

The treatment effects for yield, soil N and leaf N were analyzed using within-block response-ratio, to eliminate differences between blocks that were driven by large-scale soil variability. One of the blocks had an especially problematic weed infestation in the treatment rows, most likely masking any potential yield benefits of the amendments. Two of the treatments did in fact produce yields almost 50% lower than the average control. Accordingly, this block was removed from analysis of yield, limiting the confidence and interpretability of those results.

Soil nitrogen concentrations: response to treatments

Amendment treatments failed to show any increase in field soil mineral N – as nitrate, ammonia, or total N. This result either reflects low levels of fertilization, or high variability in that parameter across all treatments (coefficient of variation for TIN was 25%). The application rate used (~18 lbs-N/ac) was higher than the rate suggested by the manufacturer per application, but applied only twice during the season, compared to a suggested 5-7 applications.

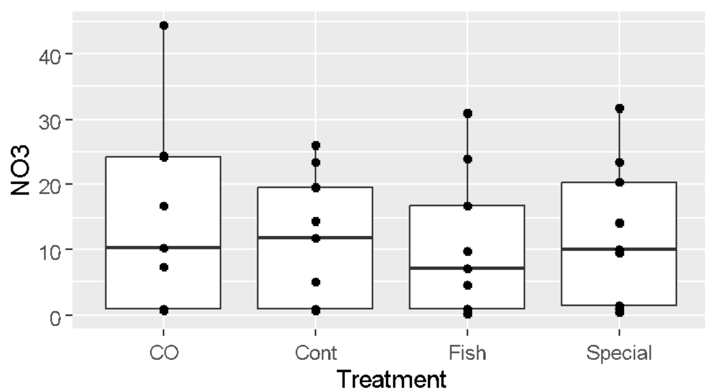

Figure 2. Nitrate concentration (ppm) in field soil 4 weeks after the last amendment application. No significant differences were found among treatments in any of the dates sampled.

Soil N mineralization experiment

The incubation experiment included the three fertilizers applied in the field (Phytamin Fish, Phytamin Special, Converted Organics) and another fertilizer (Phytamin Express). Incubation of fertilized soil samples, using an N application rate of ~50 lbs /ac (triple the rate used in the field trial) did result in significant increases in soil inorganic N immediately after application, nor throughout the incubation duration (Figure 1). While all liquid amendments resulted in higher soil inorganic N compared to the control, no significant differences were found among the different fertilizer types at any point during the incubation. The proportional rate of increase in mineral N (i.e. standardized by $TIN_{day\ 0}$) was similar among all treatments, except for the Special amendment, which appears to mineralize slightly slower (though not statistically significant). A methodological issue during the incubation, most likely due to low soil water content, resulted in no net mineralization during the last 14 days of the trial. Regardless, the majority of N added as fertilizer was mineralized within the first 14 days (Figure 5). This metric was calculated as $\left(N_{fert} - N_{cont}\right)/0.02$, where N represents the soil N content (g/kg) at day 14 for each treatment, and 0.02 g/kg was the initial N application rate.

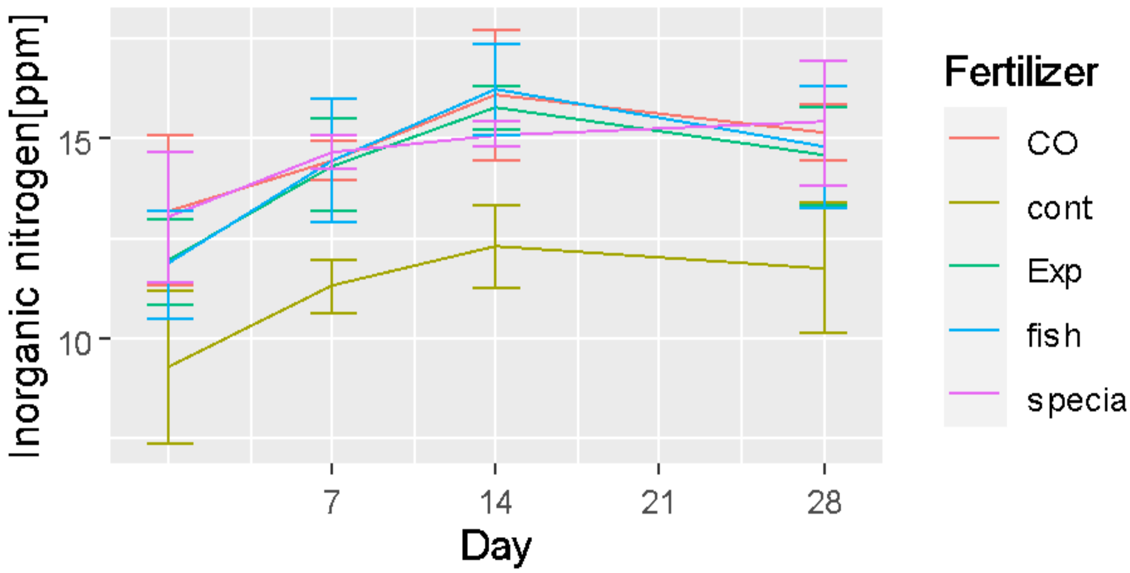

Figure 3. Inorganic nitrogen concentration (ammonia + nitrate) from soil solution extract (5:1) throughout 28 days of incubation following organic liquid fertilizer application. CO – Converted Organics, Cont – control, Exp -Phytamin Express, Fish – Phytamin Fish, Special – Phytamin Special.

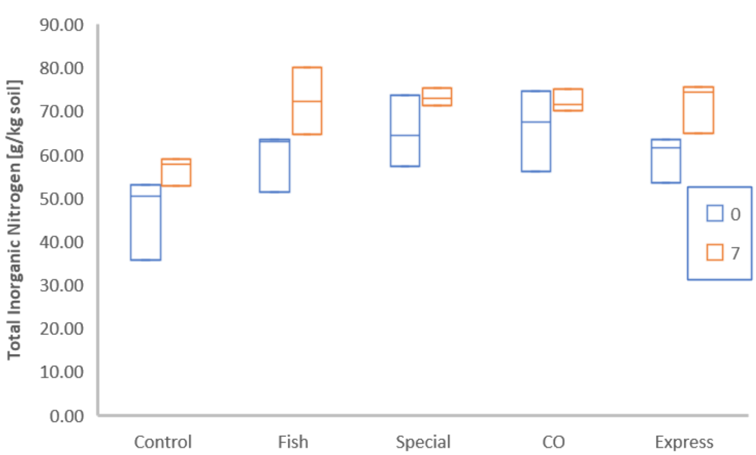

Figure 4. Concentration of inorganic nitrogen in incubated soil extracted ~2 hours after fertilization (0), and a week later (7). CO – Converted Organics, Cont – control, Exp -Phytamin Express, Fish – Phytamin Fish, Special – Phytamin Special.

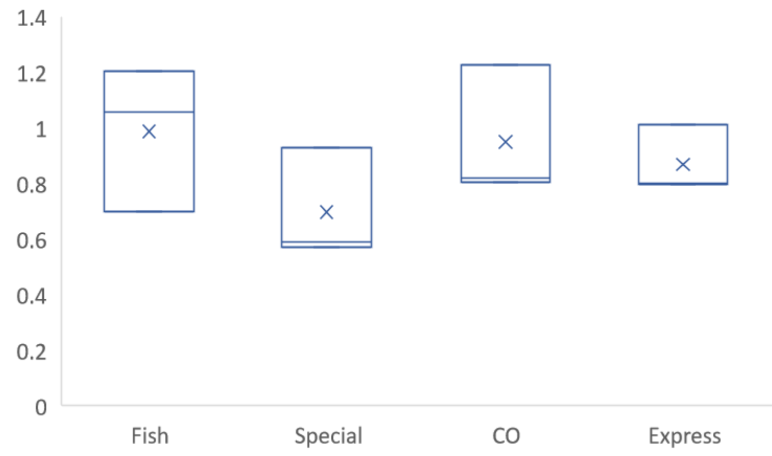

Figure 5. Boxplot (mean, median, quartiles) showing proportion of fertilizer nitrogen mineralized during 14 days of incubation. Values can exceed 1 if nitrogen mineralization was larger than the amount added (0.02 g/kg)). CO – Converted Organics, Cont – control, Exp -Phytamin Express, Fish – Phytamin Fish, Special – Phytamin Special.

Leaf N – response to treatments

Tomato yield response

Yield effects of all treatments were small, ranging between 12% below and 3% above control values, and low number of repetitions limits interpretation. The fish emulsion product (Phytamin Fish) had a consistent,albeit minimal, positive effect on yield, while the corn/amino-acid (Converted Organics) product showed a consistent yield loss, compared to the control.

Soil mineral N (nitrate, ammonia, or combined) content had no predictive ability of yield for any date measured. We found that leaf N was a better predictor of tomato yield, especially later in the season (~70 DAT). The variability in leaf N - yield relationship precludes accurate prediction, but can give a rough estimate of a predictive threshold for yield loss (1.75-1.8%).

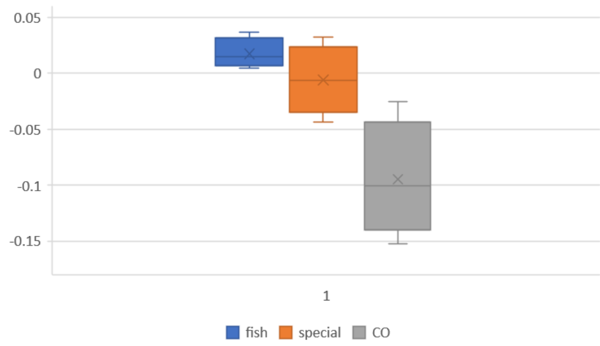

Figure 6. Response-ratio (ratio of treated to control, 0 representing equal level) of tomato fruit yield by treatment, assessed within plo.t CO – Converted Organics, Cont – control, Fish – Phytamin Fish, Special – Phytamin Special.

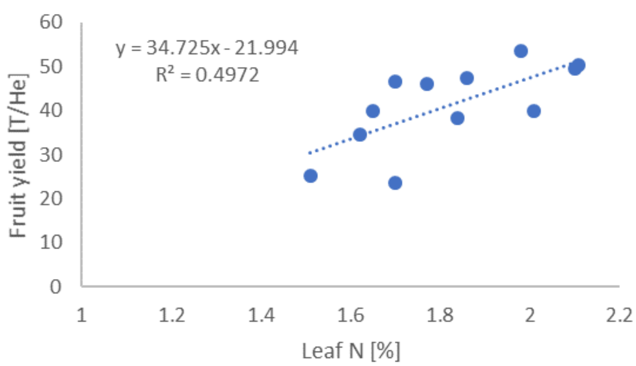

Figure 7. Relationship between tomato yield (taken September 9) and leaf nitrogen content (sampled on July 10)

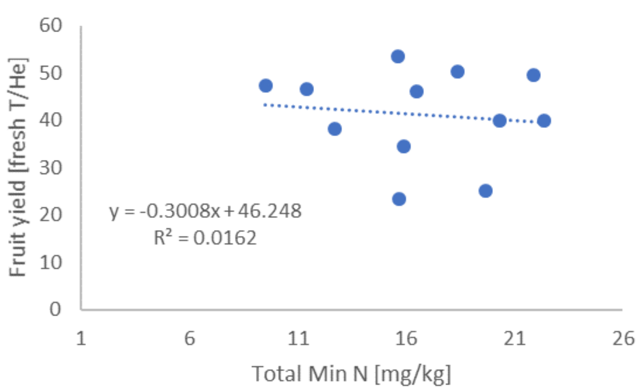

Figure 8. Relationship between yield and soil mineral nitrogen content (sampled July 10)

Cost – benefit of liquid organic nitrogen sources

It is important to note that our experiment resulted in very slight yield increases only in the presence of one out of the three amendments o (Phytamin Fish). This might be attributable to other stressors – rather than N deficiency – limiting fruit yield in our experimental organic system. As stated in the results, leaf N content did predict yield to some extent, but neither variables were consistently affected by the treatments. Other factors might include the relatively low seasonal application rate used, less than 20 lb/Ac of nitrogen, or strong weed pressure. In comparison, a conventional grower would apply 180-280 lb/Ac over the season (though likely resulting in significant nitrate leaching) (Hartz & Bottoms, 2009), and would have far less weed pressure. With regard to application rates, the results from the amended soil incubation suggest that increasing the mass added per application (perhaps reducing application frequency) could deliver substantial plant available N, if delivered during peak N demand.

The prices of the products we used are presented in Table 1, along with the estimated cost per acre of applying them at different rates. Importantly, these numbers represent only the cost of the material, and not labor or equipment costs, which can vary from farm to farm depending on available resources, but can be significant. It is worth noting that bulk prices would be significantly lower than the prices presented here (about 25% discount).

Conclusions

We tested 3 organic liquid fertilizer products containing 3-4% N in fertigated organic processing tomato plots. There was little difference among the products in their impact on any of the parameters measured, including soil and plant N and yield. We were not able to detect any impacts on tomato fruit yield due to High variability and a problematic plot. The same products, and an additional one, were also tested under controlled conditions in the lab to estimate nitrogen mineralization rates. The fish-based product gave the best results in the field, as well as showed the highest mineralization rate in incubation, but more data are needed to make any robust conclusions.

Liquid organic fertilizers show promise for organic vegetable production. Recent studies have demonstrated similarly high mineralization rates of N from liquid compared to solid organic amendments (Lazicki et al., 2020). Given that in-season tomato leaf analyses did not show significant nitrogen deficiencies in the control plants, it is possible that tomato yields were not limited due to nitrogen availability. To the extent that nitrogen did limit fruit yield in our experimental plots, we could not ascertain a significant treatment effect of any of the products tested at the application rate we used.

With regard to tracking nitrogen levels and potential limitations in-season, we found that soil testing was not as accurate as leaf testing for yield predictions. Mineral N values in our soil are all in a problematic range in terms of plant availability (Tautges et al. 2019), but did not predict plant N status or yield. Previous studies have found a combination of early-season (3-5 WAT) plant and soil N testing to be the best predictor of late-season N deficiency, but that plant N status is not enough to predict yield (Castro Bustamante & Hartz, 2015).

Another important aspect, which was not possible to evaluate in this study, is the other effects of these amendments aside from nitrogen supply to the crop. The products used here, and especially those containing hydrolyzed protein, are also expected to benefit the crop because they also provide plant growth factors that promote tomato fruit quality and yield(Drobek et al., 2019). The use of these organic biostimulants is being investigated in many agricultural systems, but generalizations so far are hard to make. Their effects depend on crop species and variety, as well as the type and severity of stresses the plant is experiencing (Francesca et al., 2020; Hodge et al., 2021).

Literature cited

Castro Bustamante, S., & Hartz, T. K. (2015). Nitrogen management in organic processing tomato production: Nitrogen sufficiency prediction through early-season soil and plant monitoring. *HortScience*, *50*(7), 1055–1063. https://doi.org/10.21273/hortsci.50.7.1055

California Tomato Research Institute. 2019. Tomato Net: the definitive website for research information on California processing tomatoes. Available at: https://tomatonet.org/

Drobek, M., Frąc, M., & Cybulska, J. (2019). Plant biostimulants: Importance of the quality and yield of horticultural crops and the improvement of plant tolerance to abiotic stress-a review. *Agronomy*, *9*(6), 335. https://doi.org/10.3390/agronomy9060335

Ferris, H., Venette, R.C., and Lau, S.S. 1996. Dynamics of nematode communities in tomatoes grown in conventional and organic farming systems, and their impact on soil fertility. Applied Soil Ecology 3:161-175.

Francesca, S., Arena, C., Hay Mele, B., Schettini, C., Ambrosino, P., Barone, A., & Rigano, M. M. (2020). The use of a plant-based biostimulant improves plant performances and fruit quality in tomato plants grown at elevated temperatures. *Agronomy*, *10*(3), 363. https://doi.org/10.3390/agronomy10030363

Hartz, T. K., & Bottoms, T. G. (2009). Nitrogen requirements of Drip-irrigated processing tomatoes. *HortScience*, *44*(7), 1988–1993. https://doi.org/10.21273/hortsci.44.7.1988

Herencia, J., Ruiz-Porras, J.C., Melero, S., Garcia-Galavis, P.A., Morillo, E., and Maqueda, C. 2007. Comparison between organic and mineral fertilization for soil fertility levels, crop macronutrient concentrations, and yield. Agronomy Journal 99:973-983.

Hodge, S., Merfield, C. N., Liu, W. Y. Y., & Tan, H. W. (2021). Seedling responses to organically-derived plant growth promoters: An effects-based approach. *Plants*, *10*(4), 660. https://doi.org/10.3390/plants10040660

Lazicki, P., Geisseler, D., & Lloyd, M. (2020). Nitrogen mineralization from organic amendments is variable but predictable. *Journal of Environmental Quality*, *49*(2), 483–495. https://doi.org/10.1002/jeq2.20030

Murmu, K., Swain, D.K., and Ghosh, B.C. 2013. Comparative assessment of conventional and organic nutrient management on crop growth and yield and soil fertility in tomato-sweet corn production system. Australian Journal of Crop Science 7:1617-1626.

Tautges, N., Woodward, E., and Scow, K. 2019. Effects of irrigation and management practices on soil health and crop properties of processing tomatoes. California Tomato Research Institute project final report.

USDA-National Agricultural Statistics Service. 2017. 2016 certified organic survey. Available at: https://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Organic_Production/

Appendix

Labels of the four amendments used in this study.

CALIFORNIA ORGANIC FERTILIZERS INC.

PHYTAMIN® FISH

Liquid Fertilizer

3-2-0

Guaranteed Analysis

Total Nitrogen (N) 3.0%
- 1.0% Ammoniacal Nitrogen
- 1.0% Water Soluble Organic Nitrogen
- 1.0% Water Insoluble Organic Nitrogen

Available Phosphoric Acid (P_2O_5) 2.0%

Derived from fish solubles. (Fish solubles are pH stabilized with phosphoric acid.)

NON-PHYTOTOXIC:
To date, all crops tested have not shown any negative effects to treatments of **Phytamin® Fish** at labeled rates. Mixes with other products require compatibility and phytotoxic testing by user. Call manufacturer if in doubt!

Fertigation
Application of **Phytamin® Fish** is safe through most types of irrigation equipment including drip tape and aluminum pipe. **Phytamin® Fish** may not pass through some drip type irrigation systems. Always flush irrigation lines after **Phytamin®** treatment to prevent possible clogging or corrosion. Always inject **Phytamin®** products in front of any filter system. **Phytamin® Fish** is mildly corrosive to aluminum in a concentrated form.

Not recommended for use in hydroponics. Please contact the manufacturer for information on special formulations.

Commercial Fertilizer

Information regarding the contents and levels of metals in this product is available on the Internet at http://www.aapfco.org/metals.htm, or by calling (800) 269-5690.

CONDITIONS OF SALE: 1. Seller warrants that this product consists of the ingredients specified and is reasonably fit for the purpose stated on this label when used in accordance with directions under normal conditions of use. No one, other than an officer of seller, is authorized to make any warranty, guarantee, or direction concerning this product. 2. Because the time, place, and rate of application are beyond seller's control, seller's liability from handling, storage, and use of this product is limited to replacement of product or refund of purchase price.

CALIFORNIA ORGANIC FERTILIZERS, INC.™

10585 Industry Ave.
Hanford, California 93230
(800) 269-5690 · Fax: (559) 582-2011
www.organicag.com

Rev. 10-1-14

Lot #: ____________________

DIRECTIONS FOR USE

Mix well before use.

Cotton
To improve production, **Phytamin® Fish** should be applied as a foliar spray during the early bloom stages of growth.
Application Rates: ½ - 2 gallons per acre in sufficient water to assure thorough coverage. Begin treatments at first bloom up to 3 weeks after first bloom. Treatments may be made up to three times at 10 day intervals.

Trees, Fruit & Nuts
Application Rate: ½ - 1 gallon per acre applied in ample water to provide for thorough coverage. Begin treatments between first bloom and full bloom. Repeat treatments as necessary.

Grapes
Application Rate: ½ - 1 gallons per acre applied at 7 to 14 day intervals starting when spring cane growth reaches 12 inches in length.

Tomatoes
Phytamin® Fish may be applied at any time throughout the bloom period.
Application Rate: ½ - 1 gallon per acre at 10 to 14 day intervals throughout the bloom period.

Peppers
Phytamin® Fish should be applied during the early bloom period.
Application Rate: ½ - 1 gallon per acre applied in sufficient water for thorough coverage. Two to three treatments should be made at 10 day intervals beginning at first flower bud.

Vegetables
Do not apply as a foliar fertilizer to lettuce or other leaf crops.
Sprinkler irrigation is not considered to be foliar application.
Yield and quality may be improved by regular treatments of **Phytamin® Fish** throughout the growing period.
Application Rates: ½ - 1 gallon per acre in sufficient water for thorough coverage. Treatments should be made after thinning at 10 to 14 day intervals.

Other Crops
Application Rates: Phytamin® Fish may be used successfully on most crops. Please consult your dealer for rates and timing of applications.

SOIL APPLICATION
Side-dress: Apply 5 to 50 gallons per acre.
Drip Systems: Apply 1 to 5 gallons per acre per week.
Water-run: Apply 3 to 30 gallons per acre.
Pre-plant: Apply 2 to 50 gallons per acre.
Sprinkler Irrigation: Apply 2 to 20 gallons per acre.

Package Size:
- ☐ 5 gal. / 18.9 L
- ☐ 55 gal. / 208.2 L
- ☐ 275 gal. / 1041 L
- ☐ Bulk
- ☐ Sample

Density: 9.5 lbs. per gallon at 68° F

CALIFORNIA ORGANIC FERTILIZERS INC.™

PHYTAMIN® EXPRESS

Liquid Fertilizer

4-1-1

Guaranteed Analysis

Total Nitrogen (N)	4.0%
3.5% Water Soluble Nitrogen	
0.5% Water Insoluble Nitrogen	
Available Phosphoric Acid (P_2O_5)	1.0%
Soluble Potash (K_2O)	1.0%

Derived from corn steep liquor, soy protein hydrolysate.

NON-PHYTOTOXIC:

To date, all crops tested have not shown any negative effects to treatments of **Phytamin® Express** at labeled rates. Mixes with other products require compatibility and phytotoxic testing by user.

Call manufacturer if in doubt!

Fertigation

Application of **Phytamin® Express** is safe through most types of irrigation equipment including drip tape and aluminum pipe. **Phytamin® Express** may not pass through some drip type irrigation systems. Always flush irrigation lines after **Phytamin®** treatment to prevent possible clogging or corrosion. Always inject **Phytamin®** products in front of any filter system. **Phytamin® Express** is mildly corrosive to aluminum in a concentrated form.

Purpose of Product

To provide nitrogen, phosphorous and potassium as fertilizer.

Information regarding the contents and levels of metals in this product is available on the Internet at http://www.aapfco.org/metals.htm

CONDITIONS OF SALE: 1. Seller warrants that this product consists of the ingredients specified and is reasonably fit for the purpose stated on this label when used in accordance with directions under normal conditions of use. No one, other than an officer of seller, is authorized to make any warranty, guarantee, or direction concerning this product. 2. Because the time, place, and rate of application are beyond seller's control, seller's liability from handling, storage, and use of this product is limited to replacement of product or refund of purchase price.

CALIFORNIA ORGANIC FERTILIZERS, INC.™

10585 Industry Ave.

Hanford, California 93230

(800) 269-5690 · Fax: (559) 582-2011

www.organicag.com

Rev. 3-7-17

DIRECTIONS FOR USE

Mix well before use.

Cotton

To improve production, **Phytamin® Express** should be applied as a foliar spray during the early bloom stages of growth.

Application Rates: ½ - 2 gallons per acre in sufficient water to assure thorough coverage. Begin treatments at first bloom up to 3 weeks after first bloom. Treatments may be made up to three times at 10 day intervals.

Trees, Fruit & Nuts

Application Rate: ½ - 1 gallon per acre applied in ample water to provide for thorough coverage. Begin treatments between first bloom and full bloom. Repeat treatments as necessary. Recommendations are for almonds, walnuts, stone fruits, apples, pears and pomegranates.

Grapes

Application Rate: ½ - 2 gallons per acre applied at 7 to 14 day intervals starting when spring cane growth reaches 12 inches in length.

Tomatoes

Phytamin® Express may be applied at any time throughout the bloom period.

Application Rate: ½ - 2 gallons per acre at 10 to 14 day intervals throughout the bloom period.

Peppers

Phytamin® Express should be applied during the early bloom period.

Application Rate: ½ - 2 gallons per acre applied in sufficient water for thorough coverage. Two to three treatments should be made at 10 day intervals beginning at first flower bud.

Vegetables

Do not apply as a foliar fertilizer to lettuce or other leaf crops.

Yield and quality may be improved by regular treatments of **Phytamin® Express** throughout the growing period.

Application Rates: ½ - 2 gallons per acre in sufficient water for thorough coverage. Treatments should be made after thinning at 10 to 14 day intervals.

Other Crops

Application Rates: Phytamin® Express may be used successfully on most crops. Please consult your dealer for rates and timing of applications.

SOIL APPLICATION

Side-dress: Apply 5 to 100 gallons per acre.

Drip Systems: Apply 1 to 30 gallons per acre per week. Flush system with clean water after treatment.

Sprinklers: Apply 3 to 40 gallons per acre per week. Flush system with clean water after treatment.

Water-run: Apply 3 to 50 gallons per acre.

Pre-plant: Apply 10 to 200 gallons per acre.

Density: 10.2 lbs. per gallon at 68° F