High P or low P? The mystery of phosphorus in hydroponic culture

If you searched for the optimal P concentration for plant growth in hydroponics you will likely find very different results, ranging from low values to very high values. This is inherently contradictory and difficult to understand, why don’t we have a smaller range for optimal P conditions? Why has it been so hard to describe what the best P levels are? Today we will talk about P nutrition and why there has been so much confusion regarding optimal P levels in hydroponic culture.

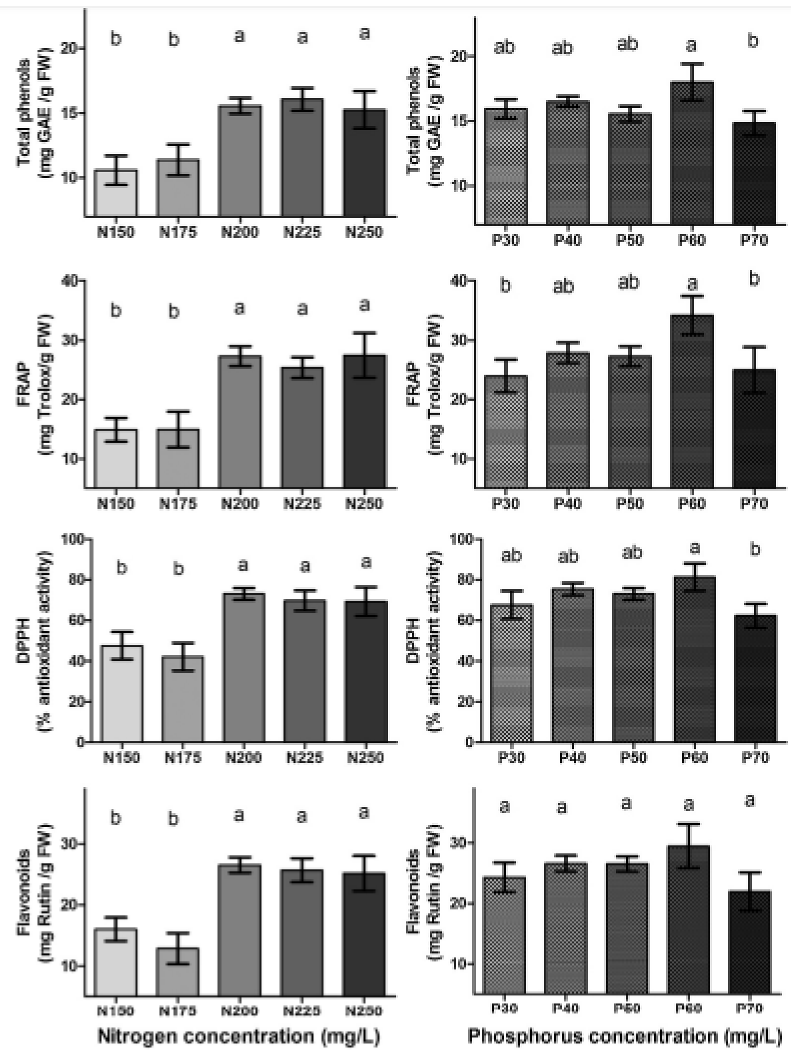

Fig. 1. Effects of nitrogen (N) and phosphorous (P) concentrations on total phenol mg GAE/g fresh weight. antioxidant activity (DPPH, FRAP, in mg Trolox/g fresh weight) and flavonoids (mg Rutin/g fresh weight) of lavender plants grown hydroponically in perlite.

Effects of P and N concentration on lavender plants (taken from this article)

Almost all books about hydroponics and flowering plants will put optimal P concentrations in solution between 20 and 50 ppm, rarely will you find any book recommending P levels outside of these values in general, since these are recognized to be safe and they play well with standard nutrient concentrations used for other elements. However you will find articles for different plants recommending P levels that can be as high as 200 ppm to as low as 10 ppm. Take for example this article on Calendula, which recommend a P application of 10ppm, while this article on Lavender suggests 60ppm. Note that optimal P might also depend on the desired result as this article on *Origanum dictamnus* shows that there is a movements of essential oils from leaves to bracts at higher P concentrations in these plants.

Not only is there confusion about optimal P levels, but even the effects of P and the interaction of P with micronutrients are not very well understood. There is evidence (see here) that P promotes Mn uptake in tomatoes while it suppresses Fe and Zn uptake, while we have entirely different results in barley, where P is found to actually impede manganese acquisition. The above two articles also give a lot of references to P uptake literature, which I suggest you checkout if you would like to learn more.

Table 1. Yield % (w/w) of the Essential Oils of Leaves and Bracts of Cultivated *Origanum dictamnus*

phosphorus concentration mg/L	leaves	bracts
5	3.1	3.8
30	2.7	4.0
60	2.8	4.3

Table taken from this article

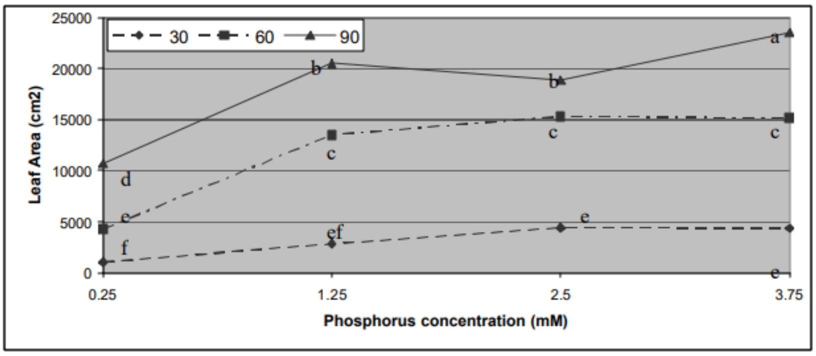

Figure 3.1 Effect of phosphorus concentration on leaf area of tabasco pepper plants grown in hydroponic greenhouse culture at 30, 60, and 90 DAT. Observations with the same letter are not significantly different, means separation by Tukey Kramer method (P<0.05).

Taken from this thesis.

The P literature is quite extensive (I suggest you read this thesis and its references if you would like to get a deeper dive), but overall we know that concentrations below 20ppm are rarely optimal and we do know that levels above 60ppm can be optimal for some plants under some conditions. In the thesis mentioned above we can see that tabasco pepper plants have the highest leaf area after 90 days in a P solution at almost 120 ppm.

Optimal P levels are perhaps harder to evaluate because they depend substantially on the concentration of other elements in solution as well as solution pH and root zone temperatures. We know that lower P stimulates root growth and reduces shoot growth while higher P levels have the exact opposite effect. Therefore variations in the ratio of P to other nutrients might be the optimal path for many crops but this is very hard to generalize as it depends on the particular growing conditions of each particular crop being grown.

Sadly the answer is that we don’t have an “optimal P” that will match all growing conditions and plants. We know that growing with a P value between 30-50ppm will give you decent results on almost all crops, but we also know that there are substantial gains to be made by optimizing P under your particular growing conditions (plant, media, tempeatures, etc). In some cases 50%+ increases in yields might be possible if P is properly tuned to the exact growing conditions used.

Your optimal P might be way lower or higher than what's recommended in the literature, so start with the ballpark literature recommendation and make experiments from there to properly adjust P to maximize yields in your crop. Also make sure you carry out leaf-tissue, media and run-off analysis while you do this to ensure you get the best possible results.

The NPK Mystery – What Do These Numbers Mean and How are they Calculated ?

When you go into a forum about hobby hydroponic or soil growing one of the first things you will notice is that there is a big confusion regarding the meaning of the traditional NPK notation and the way these values are actually calculated. Some people believe this is supposed to be merely an N to P to K ratio measurement while others erroneously use ppm information directly to get their NPK fertilizer information. On today's post I want to talk about the real meaning and nature of the NPK measurement as it is used in traditional agriculture, how it is calculated and what it tells us about a fertilizer. (below a fertilizer made with pelletized nutrients in clay, traditionally described using the NPK ratio, this ratio is important because it is necessary to know how much is clay and how much is fertilizer)

The NPK measurement was invented as a way to gauge the quality and concentration of the 3 most important nutrients relevant in agriculture within a particular solid or liquid fertilizer. These three numbers represent the percentage composition by

weight of any given fertilizer, telling us its percentage composition of N as nitrogen, K as K2O and P as P2O5. The reasons why K2O and P2O5 were used to represent potassium and phosphorous instead of referring to the simple quantities of these elements are that, first of all, the traditional analysis methods used to determine K and P give the values of the oxides in a more straightforward manner and second, the actual percentages of K and P when expressed as the oxides give “good ratios for the plants in soil” when the values are close to the value of N (making comparisons easier).
It is now important to note that the NPK reading must be calculated taking into account the weight of the given nutrient within the solution and the WHOLE weight of the fertilizer used. For example if you have a liquid concentrated fertilizer that has a composition of N = 12000 ppm, K = 20000 ppm and P = 4000 ppm which was prepared with 200g of added salts. The NPK ratio of this solution would be :

Total Solution Weight = 1000g (1L of water) + 200g (added salts)

N = 12000 ppm = 12000 mg/L = 12 g/L
K = 20000 ppm = 20000 mg/L = 20 g/L
P = 4000 ppm = 4000 mg/L = 4 g/L

Percentage of Nitrogen = (12g/1200g)*100 = 1%
Percentage of K as K2O5 = (20g/1200g)*1.2046 (K to K2O conversion factor)*100 = 2%
Percentage of P as P2O5 = (4g/1200g)*2.2914 (P to P2O5 conversion factor)*100 = 0.76%

The final NPK ratio is therefore 1-0.76-2. As you see you need to know the total weight of the solution and the elemental composition in order to be able to obtain this number. It should also be clear that the traditional NPK ratio is a PERCENTAGE COMPOSITION measurement and NOT a mere comparison of the ppm concentration ratios of N, P and K. Knowing a fertilizer’s NPK not only allows you to know the ratio between these three elements but it also allows you to know how much of each one is contained within the solution so that the relative strength of different fertilizers can be calculated.

The traditional NPK ratio however has very limited use in hydroponic cultivation since it was invented to gauge the quality of soil intended fertilizers. Nonetheless it can be used to compare the relative strengths of different fertilizers and the ratio of the three main nutrients within them. However it should be clear that if you want to communicate a measurement that compares ppm concentration ratios you should not refer to this as an NPK measurement since this will cause confusion against the “traditional NPK” which was explained above. In hydroponics it would be easier to talk about ratios of ppm which should be expressed as N/K-P/K-1 for example which would give us the ratio of N to K and P to K without giving information about the percentage composition of the solution.