Phosphorus Requirements by Garlic under Fertigation

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Fertigation is becoming a very popular practice in irrigated vegetable production. Apart from conserving water, a vital resource, it allows nutrients to be applied with irrigation water where the crop needs it, at the required rate, and at the correct time.

Farmers have increased vegetable crop yields by the effective use of fertigation (Papadopoulos, 1987; Hartz, 1994) mainly developed as micro-irrigation systems. Phosphorus (P) is an important nutrient for successful garlic production. As garlic yield increases, P requirement also increases along with most other nutrients. Application of P to garlic commonly ranges from 50 to 120 kg P_2O_5/ha (Ruiz, 1985), depending on soil P level, crop yield target, and soil characteristics.

There are three basic requirements for maximizing garlic yields under fertigation:

- Soil analysis to define the physical and chemical conditions of the soil and establish the fertilizer and irrigation program.
- Crop nutrient demand data for the growing season.
- Most recently mature leaf (MRML) nutrient concentrations references to correctly interpret the tissue analysis and fine-tune the fertigation program.

Of these three factors, the last two are not adequately defined.

Phosphorus demand by garlic has been reported to range from 50 to 65 kg P_2O_5/ha (Bertoni et al., 1988; Ruiz, 1985). Results of studies have been published in which tissue analysis was used to diagnose P status in this crop. However, they only report P demand for limited stages of the crop's development. They do indicate that the correct P content in the MRML ranges from 0.3 to 0.6 percent P (Jones et al., 1991; Ruíz, 1985; Tyler et al., 1988). Given that garlic is a long season crop (up to seven months), good leaf P status references for the whole season are required. Knowing this information, farmers will have the opportunity to correctly identify deficiencies and, through fertigation, promptly correct them during any growth stage.

Garlic grown under fertigation has a higher yield potential and P uptake.

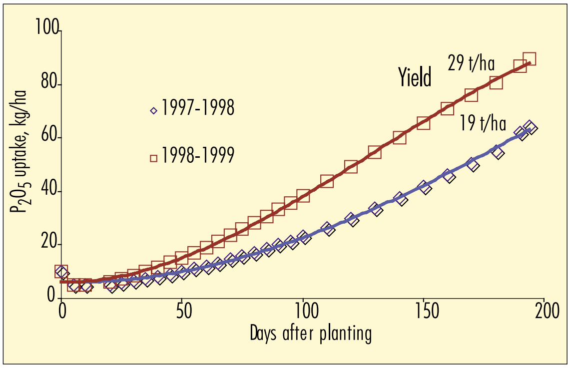


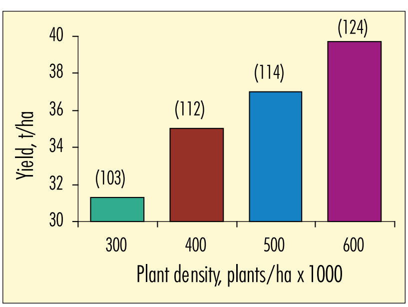
Figure 1. Phosphorus uptake by garlic under furrow irrigation (1997-98) and fertigation (1998-99) in a Vertisol (central Mexico).

Experimental Conditions

The study was conducted on a Vertisol with a pH of 7.8, 2.1 percent organic matter, 14 parts per million (ppm) Olsen P, 18.1 $cmol_c$/kg calcium (Ca), 5 $cmol_c$/kg magnesium (Mg), 2.8 $cmol_c$/kg potassium (K), 5.7 ppm DTPA iron (Fe), 0.8 ppm DTPA copper (Cu), 1.2 ppm of DTPA zinc (Zn), and 12 ppm DTPA manganese (Mn). Work was conducted at the Celaya Agricultural Research Station of the National Institute of Agricultural Research (INIFAP). The station is located in central Mexico at 20º 15´ N latitude, 101º 39´ W longitude, and 1,650 m above sea level, with an annual average temperature of 19ºC.

The study used furrow irrigation in 1997 and 1998 and fertigation in 1998 and 1999. Phosphorus uptake curves were obtained for these two experiments. Another fertigation experiment was established in 1999 and 2000 to explore the effect of plant density on yield and crop P uptake. Garlic received 80 kg of P_2O_5/ha at planting in all experiments and 240 and 285 kg of nitrogen (N)/ha in 1996 and 1997, respectively. The plant density experiment in 1999 and 2000 used 405 kg N/ha. In 1997 and 1998, N was split using three applications during the season. In both fertigation experiments, N fertilizer was applied as demanded by the crop via irrigation water. All three experiments received 100 kg K_2O/ha. Plant density was 300,000 plants/ha for the furrow-irrigated experiment and 380,000 plants/ha for the fertigated experiment in 1998 and 1999. Four plant densities of 300,000, 400,000, 500,000, and 600,000 plants/ha were studied in 1999 and 2000. In all cases, the cultivar was *cv.* Tacascuaro.

Figure 2. Yield of bulb and P uptake (kg P_2O_5/ha) by garlic under fertigation and grown at four different population densities (central Mexico).



Phosphorus Extraction Data for Garlic

Figure 1 shows season-long P uptake data by garlic for different experimental irrigation schemes. The garlic crop takes up very little P during the first 50 days after planting, but uptake greatly increases after that date. Garlic grown under furrow irrigation took up 64 kg P_2O_5/ha, while under fertigation the crop took up 89 kg P_2O_5/ha. The respective crop yields were 19.1 and 29 t/ha. Thus, higher yield potential of the crop under fertigation increased P demand by the plant by almost 50 percent. These data show that each tonne of garlic removes as much as 3.1 to 3.6 kg P_2O_5.

As shown in **Figure 2**, garlic yield increased as plant density increased. Yield increased from 31 t/ha with 300,000 plants/ha to 39.7 t/ha with 600,000 plants/ha. Planting density is an important factor when considering P uptake. Based on these data, P uptake increased from 103 to 124 kg of P_2O_5/ha for the respective yields. These outstanding yields are not reported in the literature.

Unfortunately, bulb size was reduced as yield increased, a quality factor that negatively affects fresh market value. For industrial purposes, small bulb size is not critical, but a plant density of 300,000 plants/ha would be better for garlic grown for fresh markets.

Table 1. Phosphorus content in the most recently mature leaves for different growth stages of garlic (Celaya, Gto., Mexico).

Days after planting	Growth stage	Leaf P, %
22	V-3	0.40-0.50
29	V-4	0.30-0.40
35	V-5	0.30-0.35
49	V-7	0.25-0.35
63	V-9	0.25-0.35
78	V-11	0.25-0.35
94	V-13	0.25-0.35
107	IBG	0.25-0.35
122	IBS	0.25-0.30
147	BG	0.20-0.30

V=vegetative stage (number of leaves);
IBG=initiation of bulb growth;
IBS=initiation of bulb splitting;
BG=bulb growth

Proper Sampling of the MRML for P Content

Table 1 shows adequate P content ranges for MRML of garlic for several stages of the growing season. It is common that adequate P levels for the MRML decline as the plant ages. It should also be noted that leaf position on the plant also affects P content measurements. Hence, it is important to use the MRML for tissue P analysis. As shown for the two sampling dates presented in **Figure 3**, regardless of crop age, the younger leaf will have higher P concentrations. In **Table 1**, the MRML corresponds approximately to leaf number 4 (**Figure 3**), which is found by counting back from the most immature leaf to the most recently mature leaf. The correct MRML is commonly identified as having formed a ring around the base of its stem. **BCI**

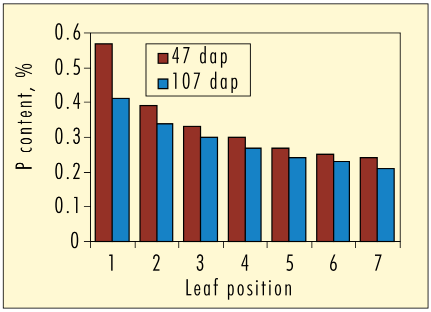


Figure 3. Effect of leaf position on P content in the MRML of garlic crop at 47 and 107 days after planting (dap); central Mexico.

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