Development of Starter Solution Technology as a Balanced Fertilization Practice in Vegetable Production

C.H. Ma and T. Kalb
Crop and Ecosystem Management Unit
AVRDC – The World Vegetable Center
Shanhua, Tainan
Taiwan

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Abstract

Supplying essential nutrients to plants during active growing periods is crucial for increasing crop productivity. Studies were conducted at AVRDC to evaluate the effects of starter solutions in combination with inorganic and organic fertilizers on the initial growth and overall yield of cabbage, cherry tomato, sweet pepper and chili pepper. Small amounts of inorganic fertilizer were prepared as a liquid fertilizer and applied immediately after transplanting and/or at critical periods during crop growth. These applications significantly boosted early growth and overall yields of all vegetables tested. It also enhanced the release of nutrients from organic composts. An application of 7.2N–6.2P–6K kg ha^{-1} starter solution could substitute for 30-50% of inorganic fertilizer and 50% of organic fertilizer used during the cropping season. It also reduced residual mineral N in soil, which might easily cause environmental pollution after cultivation. Maximum yields of cabbage, cherry tomato and chili pepper were obtained using a basal application of chicken manure compost, an application of a starter solution at transplanting, and then followed by various sidedressings of supplemental fertilizers, depending on crop and season. Maximum yield of sweet pepper was obtained using a basal application of standard inorganic fertilizer and a starter solution at transplanting. Balanced fertilization practices based on starter solution technology in combination with organic and inorganic nutrient sources were found to increase fertilizer efficiency, increase farmer profits, and reduce risks of environmental pollution. This technology was very easy to apply and modify for different vegetables.

INTRODUCTION

Improper fertilizer management and the depletion of nutrients in soils have limited yields and created land degradation in developing countries. Excessive applications of chemical fertilizers in vegetable production systems also cause environmental pollution and human health hazards. Improving the efficiency of nutrient uptake by plants and minimizing environmental risks through judicious fertilization practices are needed. Promotion of balanced fertilization using a combination of organic and inorganic sources may improve crop production in terms of both sustainability and profitability (Pinstrup-Andersen and Rajul, 1998; Steen, 1995).

Many vegetables require high amounts of nutrients in a relatively short growth period. Sustaining adequate NPK concentrations in the soil solution from sowing to harvesting is crucial for increasing productivity. Previous studies at AVRDC have shown that a small amount of concentrated liquid NPK supplement applied as a starter solution and/or a well-timed sidedressing can boost early growth and overall yields of vegetables. The starter solution provides vital nutrients to young plants before their root systems are well established and helps plants to meet their immediate nutrient needs during active growing periods, resulting in higher yields (AVRDC, 1999-2004).

On the other hand, vegetable crops grown using organic fertilizer alone on an N equivalent basis to inorganic fertilizer may show reduced plant growth and yields. Slow mineralization rates of nutrients, particularly the available N from the organic composts have been attributed to be the cause (AVRDC, 2002). The application of starter solution may enhance nutrient release from organic composts; hence, it may help plants to overcome the shortage of nutrients released by organic fertilizers at the beginning of growing periods (AVRDC, 2002).

The application of starter fertilizer has been a common practice worldwide (Rhoads and Wright, 1998; Stone, 2000). The objective of this study was to develop starter solution technology as a component to balanced and judicious fertilization practices for selected vegetables. An incubation study was also set out to clarify the enhanced effects of starter solution on nutrient availability of organic composts.

MATERIALS AND METHODS

Starter solution and fertilizer effects on heading cabbage (*Brassica oleracea* L., *capitata* group, 'Tropical Delight'), cherry tomato (*Lycopersicon esculentum* Mill. 'Tainan ASVEG No. 6'), sweet pepper (*Capsicum annuum* L. 'Veltor') and chili pepper (*Capsicum annuum* L. 'Jin's Joy Selex') were evaluated in the years 2000 to 2003. The experiments used randomized complete block design with four replications.

Organic fertilizers were banded at 0.10-0.15 m below the surface of raised beds before transplanting. Small amounts of concentrated liquid fertilizer were then applied near the root immediately after transplanting and/or at critical times. The starter solution No. 4 (St_4) was prepared by dilution of inorganic liquid compound fertilizer No. 4 (6% N – 5.2% P – 5% K) and applied at a rate of 240N–210P–200K mg in 50 ml water per plant (equivalent to 7.2N–6.2P–6K kg ha^{-1}) after transplanting ($St4_0$) and at 12 days after transplanting (DAT) for cabbage; at 12, 25, 36 and 88 DAT for sweet pepper; at 12, 25, 36 and 72 DAT for chili pepper, respectively. The starter solution No. 5 (St_5) was prepared by dilution of inorganic liquid compound fertilizer No. 5 (4.5% N – 4% P – 7.5% K) and applied at a rate of 160N–140P–266K mg in 50 ml water per plant (equivalent to 4.7N–4.2P–7.9K kg ha^{-1}) after transplanting ($St5_0$) and at 21 and 63 DAT for cherry tomato. In liquid No. 4 fertilizer, only 50% of N is in ammonium form, but in liquid No. 5 fertilizer almost 95% of N is in ammonium form. The liquid fertilizer solution was applied in a volume less than 1% of soil maximum water holding capacity and was absorbed by the soil surface near plant roots. Additional details of treatments for each trial are listed in Tables 1 and 2. Treatments in each trial included a wide range of fertilizer regimes, and only a representative choice of results is presented herein. Additional results from these and related trials are available (AVRDC, 1999-2004).

Twin rows were planted on 1.5-m-wide raised beds with in-row spacing of 0.45 m. Cultural practices followed standard open field production practices, which included using silver plastic mulch covered with rice straw, supporting plants with stakes, and following integrated pest management practices. Initial growth responses were measured using dry weights of tops (leaf and stem) and roots at 2-3 weeks after transplanting (WAT). Head or fruit weights were measured at each harvest.

The effects of starter solution technology in combination with organic or inorganic fertilizer on the soil residual mineral N were investigated in a recent tomato trial (Table 2). The starter solution (St) was an inorganic liquid compound fertilizer No. 5 (4.5% N – 4% P – 7.5% K), diluted and applied at a rate of 240N–210P–400K mg in 50 ml water per plant (equivalent to 7.2N–6.2P–12K kg ha^{-1}) after transplanting and at 3, 6, 9, and 12 WAT. The standard inorganic (SI) fertilizer treatment consisted of a basal application of 90N–39P–75K kg ha^{-1} and sidedressings of 60N–13P–50K kg ha^{-1} at 3 and 9 WAT and 60 kg N ha^{-1} at 6 and 12 WAT.

The soils originally contained 24 kg ha^{-1} of inorganic N before transplanting. The net residual mineral N was inorganic N measured after final harvest minus the original inorganic N content, and then converted to kg N ha^{-1} based on soil weight of 2.000.000 kg ha^{-1}.

In the incubation study, surface soils were amended with locally supplied pig manure (PM) and chicken manure (CM) composts at a rate equal to 330 kg N ha^{-1}, adjusted to 0.033 MPa soil moisture and incubated at a constant temperature of 25°C.

Total inorganic N and available P and K in soils were analyzed at different incubation times by using 2M KCl, 0.5 M $NaHCO_3$ and Morgan's solution (NaOAc-HOAc) as extractant of soils, respectively.

RESULTS AND DISCUSSION

Initial Growth

The initial growth of the all four tested vegetables was all significantly enhanced by one or two starter solution applications compared to those crops grown using either inorganic or organic fertilization practices alone (Table 1). Small amounts of concentrated liquid fertilizer applied near the root immediately after transplanting and/or at critical times, resulted in improved nutrient concentrations in the soil solution and provided plants with readily available nutrients. The apparent root development enhanced by starter solutions resulted in vigorous and healthy plant growth.

All of the vegetables in this study require large amounts of nutrients, particularly N, in a relatively short time period. The initial N availability in soil may influence much of the early growth, which subsequently affects the yield. Results from this study show the importance of keeping nutrient concentrations high in the soil solution to boost early growth of plants. The beneficial effects of the starter solution application indicated that an application of 7.2N–6.2P–6K kg ha^{-1} starter solution could substitute for about 50% of CM compost applied or 30-50% of inorganic fertilizers applied as basal in the standard inorganic treatment.

Yield Responses

Maximum yields in cabbage were obtained using organic fertilizers supplemented with starter solution at transplanting and one application after 12 days (Table 1). The highest yields for cherry tomato were in plots fertilized with CM and either supplemented with one starter and two later applications of concentrated liquid inorganic fertilizer or one starter solution supplemented with one solid inorganic sidedressing at 9 WAT. For sweet pepper, the yield was highest in the standard inorganic fertilizer treatment supplemented with one starter application after transplanting. Chili pepper yields were highest in treatments with CM and one starter supplemented with four additional applications of liquid fertilizers at 12, 25, 36 and 72 DAT.

Although the boosting effects of starter solution on initial growth were extremely significant, their influences on yield varied with crop and season. These facts indicate that the starter solution technology can be a good practice to substitute for conventional basal fertilization practices. However, the proper amount and timing of sidedressings used in combination with starter solutions must be developed according to the crop and local conditions.

Nutrient Released from Organic Manures

Fig. 1 illustrates the release patterns of available N from PM and CM composts during the incubation period. The application of a starter solution at a rate equivalent to 14N–12P–12K kg ha^{-1} enhanced nutrient release from PM- and CM-amended soils. The starter solution increased inorganic N levels from 19 to 50 kg ha^{-1}, which became critical for the initial establishment of plants.

This study provides evidence for the enhancing effect on nutrient releases from manure composts by starter application. Although the increment of NPK covers only 3-4% of total amounts released, it is critical to improve plant establishment in the first week after transplanting. These results also indicate that soil N management during the initial 30 days after application of CM is important to sustain high yields.

Residual Mineral N in Soil after Harvest

A recent study on the residual mineral N in the soils after harvest of tomatoes is presented in Table 2. At the same rate of N application, the mineral N remaining in soils from standard inorganic plots was 3.5 times higher than in plots applied with CM alone. Since almost 90% of the residual mineral N is in nitrate form, it is very susceptible to leaching by rain or irrigation and may cause ground water pollution. Application of starter solution with CM could lower the net leftover mineral N in soil while sustaining higher yield levels.

CONCLUSIONS

The positive effects of starter solution application on initial plant growth were evident, the starter could substitute for 30-50% of inorganic fertilizer and 50% of organic fertilizer used during the cropping season. Later in the cropping season, the effects of starter solution technology used as a sidedressing on yield varied depending on the vegetable, timing of the sidedressing, and other supplemental fertilizers.

Thus, efficient fertilization practices based on the results can be used in developing countries, where fertilizers are rather costly, moreover, leaching can be reduced. The technology is a low input, soil-based approach, which may also be applicable to situations wherever excessive fertilizer use prevails. Balanced fertilization practices based on starter solution technology in combination with organic and inorganic nutrient sources can become a technology leading to increase fertilizer efficiency, profits of farmers, and reduce risks of environmental pollution. This technology is very easy to apply and modify for different vegetables.

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Tables

Table 1. The effects of starter solution applied with organic manures or inorganic fertilizers on the growth and yields of selected vegetables.

Fertilizer treatment	Crop	Initial growth[1]		Head or fruit yields ($t\ ha^{-1}$)
		Top dry weight ($g\ plant^{-1}$)	Root dry weight ($g\ plant^{-1}$)	
CM*2[2]	Cabbage	2.4 c[5]	0.21 b	30.1 b
CM+$St4_0$+St-12 DAT		3.9 a	0.29 a	34.4 a
CM+1/2 SI		3.1 b	0.24 b	27.2 b
Standard inorganic(SI)[3]		3.2 b	0.26 ab	26.3 b
CM[2]	Cherry tomato	11.1 b	0.67 b	38.6 b
CM+$St5_0$+Side[4] 63 DAT		17.1 a	0.85 a	48.1 a
CM+$St5_0$+St-21,63 DAT		15.6 a	0.82 a	47.7 a
Standard inorganic (SI)[3]		10.7 b	0.58 b	40.1 b
CM[2]	Sweet pepper	1.6 b	0.30 bc	32.6 b
CM+$St4_0$+St-12,25,36,88 DAT		3.2 a	0.38 ab	35.5 ab
SI + $St4_0$		3.5 a	0.40 a	43.6 a
Standard inorganic (SI)[3]		1.7 b	0.28 c	33.9 b
CM[2]	Chili pepper	7.2 b	0.73 c	13.8 ab
CM+$St4_0$+St-12,25,36,72 DAT		11.3 a	1.03 b	16.6 a
SI+$St4_0$		14.2 a	1.29 a	14.7 ab
Standard inorganic (SI)[3]		7.2 b	0.74 c	13.4 b

[1] Surveys were made 12 DAT for cabbage, 21 DAT for tomato, and 16 and 25 DAT for sweet and chili peppers. DAT = days after transplanting.

[2] Chicken manure composts (CM) applied were equivalent to 2 and 1 times the rate of N applied as inorganic solid fertilizer (i.e. 22.3 and 11.2 $t\ ha^{-1}$ of CM*2 and CM for cabbage, 14 $t\ ha^{-1}$ CM for cherry tomato and sweet pepper and 10.4 $t\ ha^{-1}$ for chili pepper, respectively)

[3] Standard inorganic fertilizer (SI) consisted of a basal application of 60 N – 39 P – 50 K $kg\ ha^{-1}$ and sidedressings of 60 N – 0 P – 33 K $kg\ ha^{-1}$ at 12, 25 and 36 DAT for cabbage; basal application of 90 N – 39 P – 75 K $kg\ ha^{-1}$, sidedressings of 60 N – 26 P – 50 K $kg\ ha^{-1}$ at 21 and 63 DAT; and 60N $kg\ ha^{-1}$ at 42 and 84 DAT for cherry tomato; basal application of 80 N – 41 P – 75 K $kg\ ha^{-1}$ and 40 N – 4 P – 17 K $kg\ ha^{-1}$ at 12, 25, 36 and 50 DAT; 30 N – 3 P – 13 K $kg\ ha^{-1}$ at 72 and 96 DAT for sweet pepper and chili pepper, respectively.

[4] Side = sidedressing ; applied as 60 N – 26 P – 50 K $kg\ ha^{-1}$ solid inorganic fertilizer at 63 DAT.

[5] Mean separation within columns by Duncan's multiple range test, P = 0.05.

Table 2. Total nitrogen applied through different sources and net residual mineral N in soil after harvest of tomato.

Fertilizer treatment	Total N applied (kg ha^{-1}) From CM	From SI fertilizer	From St	Total	Net residual mineral N in soil after harvest (ppm)	(kg ha^{-1})	Residual mineral N/ Total N applied (%)
CM*2[1]	660	0	0	660	33.2 bc[4]	66.4	10
CM	330	0	0	330	20.8 c	41.6	13
CM+St_0	323	0	7	330	19.1 c	38.1	12
CM+St_0+St 3,6,9,12 WAT[2]	295	0	36	330	16.5 c	33.0	10
CM+St_0+Side 3 WAT[3]	323	60	7	390	37.9 bc	75.9	19
CM+St_0+Side 3,9 WAT	323	120	7	450	43.5 abc	86.9	19
CM+1/2 SI	330	165	0	495	57.4 ab	114.8	23
SI+St_0	0	323	7	330	69.5 a	139.0	41
Standard inorganic (SI)	0	330	0	330	69.8 a	139.7	42

[1] CM = chicken manure composts applications were equivalent to 2x and 1x the rate of N applied as inorganic solid fertilizer (32.4 and 16.2 t ha^{-1} of CM).
[2] St = starter solution; applied after transplanting (St_0) and at 3, 6, 9, 12 WAT.
[3] Side = sidedressing; applied as 60 N – 13 P – 50 K kg ha^{-1} solid inorganic fertilizer at 3 or 3, 9 WAT.
[4] Mean separation within columns by Duncan's multiple range test, P = 0.05.

Figures

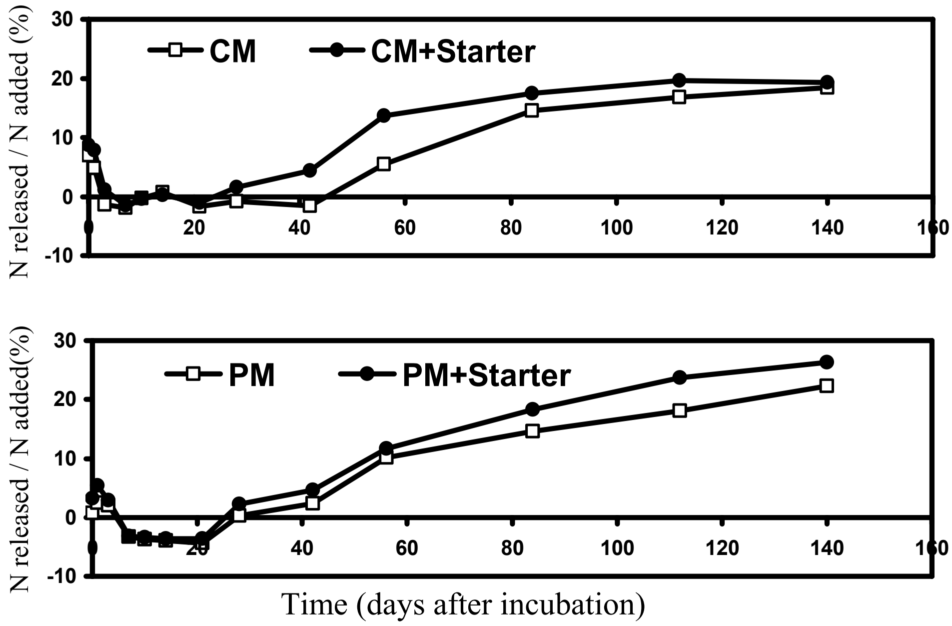

Fig. 1. N released from chicken manure compost (CM) and pig manure compost (PM) amended soil as affected by starter application (expressed as percentage of total application).