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. H. Aung, G. J. Flick, G. R. Buss, H. S. Aycock, R. F. Keefer,
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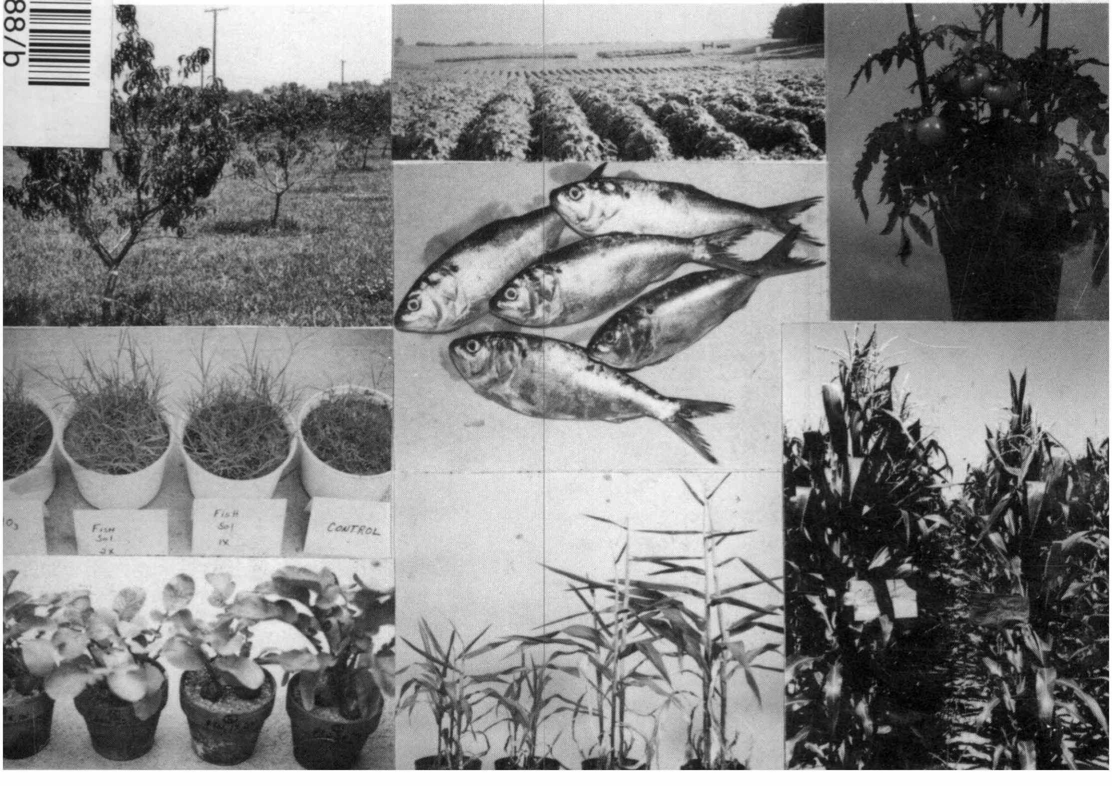

James R. Nichols, Dean and Director
College of Agriculture and Life Sciences
Virginia Agricultural Experiment Station
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

The Virginia Agricultural and Mechanical College came into being in 1872 upon acceptance by the Commonwealth of the provisions of the Morrill Act of 1862 "to promote the liberal and practical education of the industrial classes in the several pursuits and professions of life." Research and investigations were first authorized at Virginia's land-grant college when the Virginia Agricultural Experiment Station was established by the Virginia General Assembly in 1886.

The Virginia Agricultural Experiment Station received its first allotment upon passage of the Hatch Act by the United States Congress in 1887. Other related Acts followed, and all were consolidated in 1955 under the Amended Hatch Act which states "It shall be the object and duty of the State agricultural experiment stations . . . to conduct original and other researches, investigations and experiments bearing directly on and contributing to the establishment and maintenance of a permanent and effective agricultural industry of the United States, including the researches basic to the problems of agriculture and its broadest aspects and such investigations as have for their purpose the development and improvement of the rural home and rural life and the maximum contributions by agriculture to the welfare of the consumer . . . "

In 1962, Congress passed the McIntire-Stennis Cooperative Forestry Research Act to encourage and assist the states in carrying on a program of forestry research, including reforestation, land management, watershed management, rangeland management, wildlife habitat improvement, outdoor recreation, harvesting and marketing of forest products, and "such other studies as may be necessary to obtain the fullest and most effective use of forest resources."

In 1966, the Virginia General Assembly "established within the Virginia Polytechnic Institute a division to be known as the Research Division . . . which shall encompass the now existing Virginia Agricultural Experiment Station . . . "

GROWTH RESPONSES OF CROP PLANTS TO FISH SOLUBLE NUTRIENTS FERTILIZATION

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R.F. Keefer, R. Singh, D.M. Brandon, J.L. Griffin,
C.H. Hovermale and C.A. Stutte

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Abstract

The utilization of fish wastes in the form of fish soluble nutrients (FSN) for agricultural crop plants fertilization was investigated over the past 7 years as an aid to the Virginia seafood industry threatened by the waste disposal problem. Controlled greenhouse and field experiments involving a broad selection of both food and nonfood crops have substantiated the ancient belief that fish and its byproducts have beneficial effects on plant growth. The investigations showed that FSN contains all the inorganic and organic substances needed for plant growth but does not provide a balanced source of nutrients for all crop species. By a proper selection of crop plant and fertilization with moderately dilute (4.0 to 16.0 ml FSN concentrate l^{-1} water) solutions, FSN have proven to be of benefit for the growing of several plants. Indoor crops grown in pots benefited more from FSN fertilization than did field-grown crops.

FSN were found to retard reproductive development of plants and to delay plant aging. How FSN cause these growth processes is unknown and merit additional study.

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Chapter 1
INTRODUCTION

The problems of the disposal of solid and liquid wastes from seafood processing plants are threatening the survival of the seafood industry. Seafood companies must either reduce the levels of liquid and solid wastes produced by their plants or find alternative uses for the wastes. In 1977, the tuna, anchovie and menhaden fisheries produced 978,288 short tons of stick and unloading water. Approximately 699,120 tons were from the menhaden fishery alone; on a percentage basis, the menhaden industry accounted for 71% of the total waste effluent (Aung *et al.*, 1981). The National Pollution Discharge Elimination System has prohibited overboard discharge of the wastes (Champ *et al.*, 1981); and the wastes cannot go into most municipal sewage plants due to requirements under the Solid Waste Management Act. While physical treatment systems may provide an alternative means for handling the wastes of the seafood industry, the cost of such systems is prohibitive. At the request of the Virginia seafood industry for assistance with the disposal problems of seafood processing wastes and by-products, investigations were initiated at Virginia Tech in the fall of 1977. The Virginia Tech proposal involved converting the fish wastes and their by-products into liquid fish or fish soluble nutrients for use directly as a fertilizer or as components in commercial fertilizer formulations for growing agricultural crops.

Purpose and Scope

The primary research objective with fish soluble nutrients (FSN) was to ascertain the general efficacy of the fish by-products as a nutrient source for growing commercial horticultural and agronomic crops. The experiments were conducted under greenhouse and field-growing environments. A number of scientists of various disciplines participated in the investigations, and their contributions are separately recorded in the appropriate chapters of this bulletin. However, to provide some cohesiveness to the broad scope of these investigations under diverse growing conditions, a general discussion and summary are included. It is hoped that the record of the results of fish soluble nutrients fertilization on the growth responses of agricultural crops will serve the following purposes: (a) to aggregate the known information on fish soluble nutrients under a single title, (b) to focus on the beneficial effects of using fish soluble nutrients for crop growing, and (c) to direct attention to certain aspects of the completed work for further investigation.

Chapter 2
REVIEW OF LITERATURE

Historical Perspective

The belief that fish and fish by-products may have nutritional qualities beneficial for plant growth is an ancient one, although the origin of the idea is uncertain. However, fish have been used as fertilizer for many centuries. In France, oil was made from a fish called marlan, *Gadus marlangus,* and the scrap was dried, ground, and packed in airtight casks for sale as a manure. In the 16th and 17th centuries Basque, Breton, and English fishermen caught pilchards, *Chupea pilchardus,* for oil and sold the residual scrap for fertilizer (Aung and Flick, 1980). A popular Thanksgiving story has it, according to the record of the *Mayflower's* Pilgrims, that the New England Abnaki and Wampanoag Indians put a fish in each "hill of corne" and saved the Plymouth Colony from starvation by teaching the Pilgrims to do likewise. However, recently an anthropologist has suggested that the Indian practice of manuring corn with fish was acquired from the early Europeans (Ceci, 1975). Nonetheless, the Indian name for today's principal industrial menhaden (*Brevoortia tyrannus* on the Atlantic Coast, *Brevoortia patronus* on the Gulf of Mexico) was *munnawhatteaug* which meant "fertilizer, or that which manures" (Turrentine, 1913). Despite the ancient practice of using fish for crop growing, a proper scientific understanding of the real value and biochemical properties of fish as fertilizer is still to be sought.

Past and Present Outlook

Fish Fertilizer Industry: An active fish-scrap fertilizer industry existed along the Atlantic seaboard from Maine to North Carolina during the early part of the twentieth century. Then, Virginia ranked first among the states and was the principal producer of fish fertilizer (Turrentine, 1913). But the industry began to decline with the advent and availability of petroleum-based chemical fertilizers and the wartime demand for the protein content of fish scrap for stock and broiler feed supplements. Now, forty years after this wartime use, and because of the increased cost and unsure supply of petroleum, fish fertilizer for growing crops is again becoming environmentally desirable and cost competitive (Stuiber *et al.*, 1977).

Chemical Composition of Fish Soluble Nutrients: The bulk (>80%) of fish soluble nutrients (FSN) are produced from menhaden; a lesser amount comes from other fish species (Van Breedveld, 1969; Stuiber *et al.*, 1977). Fish soluble nutrients are a by-product of the manufacturing of fish meal. FSN contain largely the soluble gelatinous and blood protein of menhaden. In the processing of menhaden, stick or press water is the liquid obtained after steam extraction of oil from the fish, and bilge water is water rich with fish blood, residual oil, and small fragments of fish. The stick and bilge waters are mixed, processed, and condensed to about 50% solids to make FSN. The source of ingredients and the condensation process greatly affect the highly complex composition of FSN. The proportions of amino acids, proteins, lipids, vitamins, and inorganic elements vary according to the fish source and processing method (Soares *et al.*, 1970, 1973). Further elemental composition of Gulf and Atlantic menhaden solubles determined by neutron activation analysis is shown in Table 2-1.

Uses of Fish Soluble Nutrients for Crop Fertilization: FSN, used as a nitrogenous source to promote microbial growth of mushroom compost, resulted in larger mushroom growth and yield (Green, 1974). In a non-replicated trial plot, Van Breedveld (1969) observed that liquid Florida trashfish, fish meal, and freshly-ground-fish fertilization of Homestead tomato and bush bean produced relatively good growth and yield of fruits compared to a 4-8-8 (NPK) commercial fertilizer. On the other hand, Senn and Kingman (1978) reported yield reduction of 'Walters' tomato, 'Cangreen' lima beans, and 'Silver Queen' sweet corn with foliar application of fish emulsion in field trials in South Carolina. However, they noted that the nitrogen content of the fish fertilizer was valuable and could be useful as a soil-applied fertilizer. Risk and Chaster (1960) found FSN to be an excellent aid in the establishment of a grass and legume ground cover for erosion control of highway embankments. The FSN produced desirable binding quality and contributed nutrients for seedling growth. While the odor of FSN was objectionable during handling and application, it dissipated after 2 to 3 days following application. More recently, Aung and Flick (1980) demonstrated that a tomato crop could be grown to fruition in sand culture supplied only with nutrients derived from FSN. They indicated FSN to be a valuable nutrient source. Subsequent studies (Emino, 1981; Aung *et al.*, 1981; Logendra, 1984; Snyder, 1982) involving a range of plant species under different growing conditions have authenticated the belief that FSN is a useful fertilizer for growing crops.

Table 2-1. Elemental Composition of Menhaden Fish Solubles of Different Origin by Neutron Activation Analysis

Element	Eastern Gulf Coast	Central Gulf Coast	Western Gulf Coast	Atlantic
	Macronutrient Concentration (%)[1]			
Potassium (K)	2.6	3.1	3.7	3.5
Magnesium (Mg)	†	†	†	†
Calcium (Ca)	†	†	†	†
Sodium (Na)	1.6	1.9	2.1	2.3
	Micronutrient Concentration (ppm)[2]			
Molybdenum (Mo)	<4	<5	<5	<6
Zinc (Zn)	†	67	†	109
Copper (Cu)	†	†	†	†
Manganese (Mn)	45	11	15	21
Nickel (Ni)				
	Trace Element Concentration (ppm)[3]			
Silver (Ag)	<4	<3	<5	<5
Arsenic (As)	8	14	9	14
Gold (Au)	<0.02	<0.02	<0.03	<0.03
Barium (Ba)	†	†	†	†
Bromine (Br)	100	91	131	130
Cadmium (Cd)	†	†	†	†
Cerium (Ce)	<4	<4	<9	<6
Chlorine (Cl)	40,700	25,450	34,550	36,900

Cobalt (Co)	2	3	†	4
Chromium (Cr)	<6	<5	<2	<8
Cesium (Cs)	<0.9	<0.7	<1.3	<1.0
Dysprosium (Dy)	<0.5	<0.2	<0.2	<0.2
Europium (Eu)	<2.1	<1.5	<0.8	<1.2
Hafnium (Hf)	<0.7	<0.6	<1.8	<0.8
Mercury (Hg)	<0.8	<1.1	<1.1	<1.3
Iodine (I)	<5	<12	10	22
Lanthanum (La)	<1.2	<0.8	<0.9	<1.0
Lutetium (Lu)	<0.1	<0.2	<0.2	<0.2
Lead (Pb)	<10	<10	<9	<10
Rubidium (Rb)	†	†	†	†
Ruthenium (Ru)	†	†	†	†
Antimony (Sb)	<0.8	<1.8	<0.4	<1.1
Scandium (Sc)	0.1	<0.1	0.3	0.1
Selenium (Se)	<5	<2	<6	<5
Samarium (Sm)	0.5	0.3	<0.8	0.8
Tin (Sn)	<98	442	310	<96
Strontium (Sr)	†	†	†	†
Tantalum (Ta)	<0.4	<0.4	<0.6	<0.6
Tellurium (Te)	†	†	†	†
Thorium (Th)	<1.9	<1.5	<2.7	<2.5
Titanium (Ti)	†	†	†	†
Uranium (U)	<0.9	<1.2	<1.3	<1.5
Vanadium (V)	<2.5	1.9	3.0	3.3
Tungsten (W)	<2	<2	<10	<3
Ytterbium (Yb)	<0.9	<1.3	<1.4	<1.6
Zirconium (Zr)	†	†	†	†

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[1] "†" indicates element concentration could not be determined by NAA due to background interferences.

[2] "<" indicates concentration below given value. Background interferences prevented actual determination.

[3] Lead (Pb) was determined by atomic absorption spectroscopy (AAS). Concentration was below the 0.02 ppm limit detected by AAS.

Chapter 3
EXPERIMENTAL RESULTS IN VIRGINIA

Purpose

To determine the efficacy of FSN on several popular decorative plant species.†

Procedures

Philodendron oxycardium Schott and *Epipremnum aureum* Bunt. (pothos) were started from leaf cuttings. The cuttings were planted in a medium of peatmoss, pinebark, and coarse sand (4:2:1 v/v/v) contained in 9-cm plastic pots. Each pot was planted with 4 cuttings, and the cuttings were placed under mist to root. A green and a variegated *Peperomia obtusifolia* A. Dietr. were started as stem cuttings. The stem cuttings were 12-14 cm long with 3 leaves at planting. Lengths of 4-5 cm of the stem cuttings were planted in the peatmoss, pinebark, and coarse sand medium. A single stem cutting was planted per 13-cm clay pot. The cuttings were kept under mist to root. *Brassaia actinophylla* Endl. (schefflera) and *Ardisia crispa* (Thunb.) A.DC. (coral berry) plants were started as seedlings. They were grown in 9-cm plastic pots. *Brassaia* plants were planted 3 per pot, and *Ardisia* planted singly in 13 cm clay pots using the same medium noted. The five plant

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†L. H. Aung and G. J. Flick, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061

species were grown under polypropylene shade in a greenhouse at 27°C day and 20°C night temperatures. The photosynthetically active radiation under the shade measured 112 $\mu E\ m^{-2}\ s^{-1}$ in natural daylight. After 12 weeks of growth, *P. oxycardium, E. aureum,* and *B. actinophylla* plants were transplanted into 18-cm plastic pots for further observations.

FSN (Zapata Haynie Corporation, Reedville, Virginia 22539) were prepared fresh for plant fertilization. FSN were used at 4.0 ml and 8.0 ml concentrate per liter of water. These concentrations contained an equivalent of 240 mg and 480 mg of nitrogen per liter, respectively. Plants were fertilized initially with 100 ml of diluted FSN solution at weekly or biweekly intervals. Similarly, an inorganic 25-10-10 (N-P_2O_5-K_2O; or 25N-4.4P-8.3K) commercial grade fertilizer was prepared using one fifth the recommended rate and supplemented with soluble trace element mix (R. B. Peters Co., Inc., 2833 Pennsylvania St., Allentown, Pennsylvania) for plant fertilization. When plants were larger, the volume of fertilizing nutrient solution was increased to 200 ml per pot. A randomized complete block design of 8-10 replicates was used.

Results

Growth of *Ardisia* plants fertilized weekly with low concentration of FSN (X FSN, 1W) compared favorably with plants fertilized with Hoagland's nutrient solution or a 1/5 rate 25-10-10 fertilizer (Fig. 1). At a higher concentration (2X FSN, 1W) of FSN or a frequent (2W) fertilization schedule, shoot dry weight, leaf number, and plant height were significantly greater than for plants fertilized with Hoagland's nutrient solution (Table 3-1). The philodendron and pothos plants fertilized with FSN and commercial fertilizer grew well and attained marketable size in 10-12 weeks. The height, vigor, and color of the plants grown with FSN compared favorably with plants fertilized with inorganic commercial fertilizer (Tables 3-2 and 3-3, Fig. 2).

The peperomia plants fertilized with FSN showed healthy growth (Fig. 3, middle and lower photographs). The plants fertilized with FSN, as indexed by plant height and leaf number, were almost as good as the plants fertilized with the inorganic commercial fertilizer (Tables 3-4 and 3-5).

Brassaia seedlings fertilized with FSN and inorganic fertilizer attained marketable size in 10-12 weeks. The plants grown with FSN showed a dark-green coloration and a bright sheen foliage and attained size similar to plants fertilized with inorganic fertilizer (Table 3-6; Fig. 3, upper photograph).

Conclusions

FSN promoted growth of the five plant species. FSN at the concentrations and frequency used were as effective as commercial fertilizer for growing the selected crops. The general growth and appearance of the plants fertilized with FSN were excellent. The diluted FSN solution gave minimal odor, and odor should not be an impediment to its use as a nutrient source for house plant fertilization.

Table 3-1. Growth responses of *Ardisia crispa* fertilized weekly (1W) and biweekly (2W) with Hoagland's nutrient solution, soluble commercial fertilizer 25-10-10 (N-P_2O_5-K_2O; 1/5 rate) and FSN*

Treatment	Leaf number	Plant height (cm)	Shoot dry wt (g)
Hoagland's nutrient solution, 1W	29.5	9.0	3.2
25-10-10 fertilizer, 1W	39.8	9.9	4.3
4.0 ml FSN l^{-1} water 1W	37.4	10.0	4.0
8.0 ml FSN l^{-1} water 1W	39.3	10.2	4.2
12.0 ml FSN l^{-1} water 1W	38.0	10.2	3.8
8.0 ml FSN l^{-1} water 2W	44.5	10.6	4.6
12.0 ml FSN l^{-1} water 2W	36.2	10.9	3.6
Lsd 5%	9.5	1.2	0.9

*Values are means of 5 replicates (6 plants replicate^{-1}); Lsd denotes least significant difference at the 5% level of probability. Five months old plants were treated, and grown for 8 more months.

Table 3-2. Growth responses of *Epipremnum aureum* (pothos) fertilized with FSN and 1/5 rate of commercial fertilizer 25-10-10*

Treatment	Stem length (cm)	Leaf number	Total plant dry wt (g)
4.0 ml FSN l^{-1} water, 1W	22.7	11.0	3.7
8.0 ml FSN l^{-1} water, 1W	25.9	11.6	3.6
4.0 ml FSN l^{-1} water, 2W	29.0	12.2	3.4
25-10-10, 1W	27.2	10.5	3.8
25-10-10, 2W	37.4	12.2	4.0
Lsd 5%	6.4	1.3	0.4

*Values are means of 8 replicates of 2 plants replicate^{-1}; plants for dry weight were 12 weeks old, and for stem length and leaf number 6 months old. Lsd denotes least significant difference at the 5% level of probability.

Table 3-3. Growth responses of *Philodendron oxycardium* fertilized weekly (1W) and biweekly (2W) with FSN and 1/5 rate commercial fertilizer 25-10-10*

Treatment	Stem length (cm)	Leaf number	Total plant dry wt (g)
4.0 ml FSN l^{-1} water, 1W	26.5	6.6	3.1
8.0 ml FSN l^{-1} water, 1W	24.6	6.7	3.2
4.0 ml FSN l^{-1} water, 2W	22.9	6.9	3.7
25-10-10, 1W	29.4	7.1	3.3
25-10-10, 2W	33.4	8.2	3.8
Lsd 5%	9.0	1.5	1.0

*Values are means of 8 replicates of 2 plants replicate^{-1}. Plants for dry wt measurement were 12-weeks old, and plants for stem length and leaf count were 6.5 months old.

Table 3-4. Growth responses of *Peperomia obtusifolia* (variegata) fertilized weekly (1W) and biweekly (2W) with FSN and 1/5 rate commercial fertilizer 25-10-10*

Treatment	Stem length (cm)	Leaf number	Total plant dry wt (g)
4.0 ml FSN l^{-1} water, 1W	11.1	12.0	1.5
8.0 ml FSN l^{-1} water, 1W	11.4	14.3	1.5
4.0 ml FSN l^{-1} water, 2W	11.3	12.5	1.8
25-10-10, 1W	9.2	11.9	1.4
25-10-10, 2W	12.4	16.4	1.6
Lsd 5%	2.9	3.2	0.8

*Values are means of 8 single plant replicates. Plants for dry wt were 10 weeks old, and plants for stem length and leaf number were 5 months old.

Table 3-5. Growth responses of *Peperomia obtusifolia* (green variety) fertilized with FSN and 1/5 rate commercial fertilizer 25-10-10*

Treatment	Stem length (cm)	Leaf number	Total plant dry wt (g)
4.0 ml FSN l^{-1} water, 1W	14.5	16.8	2.3
8.0 ml FSN l^{-1} water, 1W	14.9	17.1	2.4
4.0 ml FSN l^{-1} water, 2W	16.1	15.6	2.6
25-10-10, 1W	14.4	15.3	1.9
25-10-10, 2W	15.4	18.6	2.7
Lsd 5%	2.6	4.6	0.9

*Values are means of 8 single plant replicates.

Table 3-6. Growth responses of *Brassaia actinophylla* fertilized with FSN and 1/5 rate commercial fertilizer 25-10-10*

Treatment	Leaf number	Total plant dry wt (g)
4.0 ml FSN l^{-1} water, 1W	9.5	6.6
8.0 ml FSN l^{-1} water, 1W	9.2	4.5
4.0 ml FSN l^{-1} water, 2W	10.5	4.6
25-10-10, 1W	8.5	5.3
25-10-10, 1W	9.7	7.1
Lsd 5%	0.8	2.4

*Values are means of 8 single plant replicates. Plants for leaf number were 5 months old and for dry weights 6 months old; 1W denotes weekly and 2W denotes biweekly fertilization.

Figure 1. Growth of *Ardisia crispa* plants fertilized with fish soluble nutrients (FSN); *Upper photograph from left to right:* 1X FSN, 1W; 1/5 rate 25-10-10, 1W; and Hoagland's nutrient solution (HNS), 1W; *lower photograph from left to right:* 3X FSN, 2W; 2X FSN, 2W; 3X FSN, 1W and 2X FSN, 1W. Designations: X = 4.0 ml FSN l^{-1} water, 1W = weekly and 2W = biweekly fertilization.

Figure 2. The growth of *Epipremnum aureum (upper photograph)* and *Philodendron oxycardium (lower photograph)* fertilized with fish soluble nutrients (FSN) and 1/5 rate 25-10-10 fertilizer.

Figure 3. The growth of *Brassaia actinophylla (upper photograph)*, *Peperomia obtusifolia*, green type *(middle photograph)* and *Peperomia obtusifolia*, variegated type *(lower photograph)* fertilized with fish soluble nutrients (FSN) and 1/5 rate 25-10-10 fertilizer.

Purpose

To determine the efficacy of FSN on the growth of selected vegetable crops.†

Procedures

Seeds of pea (*Pisum sativum* L. cv. Little Marvel), tomato (*Lycopersicon esculentum* Mill. cv. Fireball), lettuce (*Lactuca sativa* L. cv. Buttercrunch), and radish (*Raphanus sativus* L. cv. Cherry Belle) were sown in a sand medium contained in pots under greenhouse conditions. The sand medium used had the following properties: pH 8.1; NO_3-N, 5 ppm; P_2O_5, 4 ppm; K_2O, 11.5 ppm; CaO, 571 ppm; MgO, 30 ppm; 0.1% organic matter; 230 ppm of soluble salts (1:2 soil to water extract). Pea, lettuce, and radish were grown during the spring with 18°C night and 24°C day temperatures. Tomato was grown in late spring and early summer months at 21°C night and 28°C day. Pea was grown in 9 cm diameter plastic pots, radish in 13 cm diameter clay pots, and tomato and lettuce in 18 cm diameter clay pots. The plants were fertilized at designated intervals with various concentrations of FSN, casein hydrolysate (1 g l^{-1} water) and nutrient solution 1 of Hoagland and Arnon (1950). A randomized complete block design of 8-10 replicates was used. The crops were recorded when mature.

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†L. H. Aung and G. J. Flick, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061

Results:

The growth of peas fertilized with FSN was comparable to that of plants fertilized with Hoagland nutrient solution (HNS). The pea plants fertilized with FSN were darker-green and senesced later than plants fertilized with HNS (Fig. 4). The weights of fruits and seeds from plants fertilized with FSN and HNS were similar (Table 3-7).

Lower FSN (X FSN) fertilization of radish gave growth comparable to HNS fertilization. At higher concentration (2X) or frequency (2W) of FSN, radish growth was significantly greater than HNS fertilization (Table 3-8 and Fig. 5).

Leaf size (length and area) of lettuce fertilized with dilute FSN was significantly smaller than that of plants fertilized with inorganic fertilizer or Hoagland nutrient solution. Yield of lettuce tops of FSN-fertilized plants was similarly lower than inorganic fertilizer or HNS fertilized plants. However, leaf production rate and NAR were similar between the FSN, inorganic fertilizer, and HNS treatments (Table 3-9). FSN fertilization, in contrast to inorganic and HNS fertilization, delayed senescence and abscission of lettuce cotyledons (Table 3-10).

FSN fertilization gave growth and fruit yield of greenhouse-grown Fireball tomato comparable to that of plants fertilized with full strength HNS. Vegetative growth was stimulated by FSN fertilization, but flowering and fruiting were delayed by FSN (Aung and Flick, 1980).

Conclusions:

Vegetable crops can benefit from FSN fertilization, but the benefits will differ depending upon the kinds of crops grown for consumption. Thus, the concentrations and frequencies need to be selected to suit the crops being grown. In general, FSN has been shown to be a useful nutrient source for vegetable fertilization.

Table 3-7. Effects of Hoagland nutrient solution (HNS), casein hydrolysate (CH) and fish soluble nutrients (FSN) on reproductive development of peas, *Pisum sativum* L. cv. Little Marvel*

Treatments	Seed number per plant	Fresh wt., g plant^{-1}	
		Fruits	Seeds
Water	1.9	0.8	0.5
HNS, 1W	4.9	3.9	2.6
CH, (1 g l^{-1}) 1W	2.4	1.7	1.0
4.0 ml FSN l^{-1} water, 1W	4.2	3.5	2.2
8.0 ml FSN l^{-1} water, 1W	4.2	4.3	2.4
4.0 ml FSN l^{-1} water, 2W	4.8	5.0	3.1
8.0 ml FSN l^{-1} water, 2W	6.0	5.4	3.5
Lsd 1%	1.6	1.9	1.2

*Values are means of 9 replicates; 1W and 2W indicate weekly and twice weekly fertilization.

Table 3-8. Effects of Hoagland nutrient solution (HNS), casein hydrolysate (CH) and FSN on growth of radish, *Raphanus sativus* L. cv. Cherry Belle*

Treatments	Leaf number per plant	Fresh wt., g $plant^{-1}$ Tops	Fresh wt., g $plant^{-1}$ Storage roots
Water	12.5	2.3	8.0
HSN, 1W	15.8	4.3	16.9
CH, (1 g l^{-1}) 1W	14.3	3.7	13.8
4.0 ml FSN l^{-1} water, 1W	17.4	5.5	18.9
8.0 ml FSN l^{-1} water, 1W	20.0	7.8	25.0
4.0 ml FSN l^{-1} water, 2W	18.4	7.1	24.0
8.0 ml FSN l^{-1} water, 2W	21.6	11.6	31.8
Lsd 1%	2.2	1.6	8.0

*Values are means of 8 replicates; 1W and 2W indicate weekly and twice weekly fertilization.

Table 3-9. Fish soluble and inorganic nutrients fertilization on the growth of leaf lettuce, *Lactuca sativa* L. cv. Buttercrunch grown in sand culture under greenhouse conditions, Feb.-April, 1979*

Treatments	3rd leaf length (cm)	Leaf area plant^{-1} (cm^2)	Fresh wt. (g plant^{-1})	NAR (mg cm^{-1} day^{-1})
1/6 FSN, 6W	8.9	117	34.1	1.34
1/3 FSN, 3W	9.1	121	36.7	1.30
1/3 (15-30-15), 3W	11.1	234	67.8	1.14
1/4 HNS, 3W	11.2	194	64.5	1.50
Lsd 1%	1.6	26	7.8	-

*Values are means of 20 plants. 1/6 FSN, 6W denotes fertilization of plants daily with 1/6 strength of 4.0 ml FSN concentrate 1^{-1} water; 1/3 FSN, 3W = 1/3 strength of 4.0 ml FSN 1^{-1} water every alternate day fertilization; 1/3 (15-30-15), 3W = 1/3 strength of 250 mg 1^{-1} water of a soluble commercial fertilizer every alternate day fertilization, and 1/4 HNS, 3W = 1/4 strength of Hoagland nutrient solution fertilization on alternate days.

Table 3-10. Effect of FSN and inorganic nutrients fertilization on abscission and senescence of *Lactuca sativa* L. cv. Buttercrunch cotyledons*

Treatments	% plants with cotyledons Intact	% plants with cotyledons Abscised	Remarks
1/6 FSN, 6W	100	0	Dark, healthy green
1/3 FSN, 3W	100	0	Dark, healthy green
1/3 (15-30-15), 3W	20	80	Yellow color
1/4 (HNS, 3W	40	60	Yellowish-green

*Values are means of 20 plants; see Table 3-9 for explanation of treatment designations.

Figure 4. The growth and senescence of pea, *Pisum sativum* L. cv. Little Marvel fertilized with Hoagland nutrient solution (HNS) and FSN. *From left to right:* tap water, X FSN, 2X FSN and HNS.

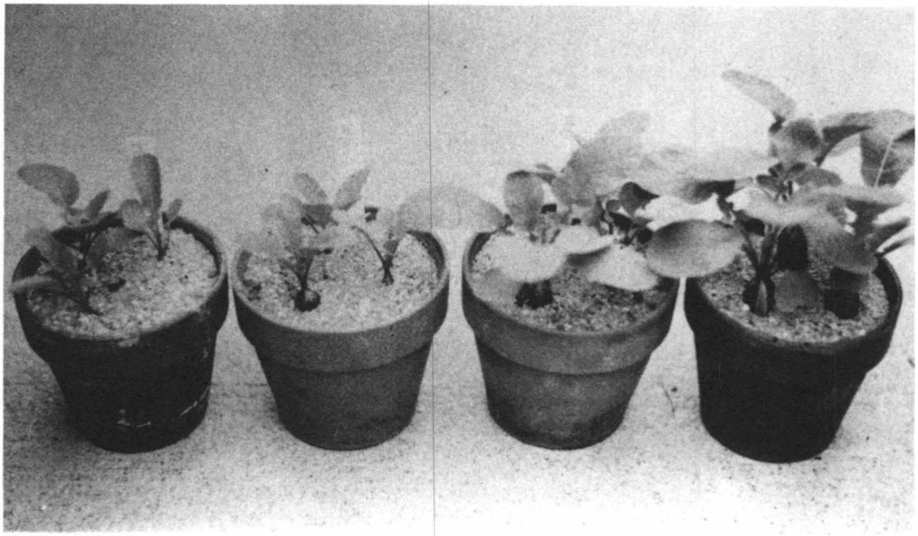

Figure 5. The growth of radish, *Raphanus sativus* L. cv. Cherry Belle fertilized with casein hydrolysate (CH), Hoagland nutrient solution (HNS) and FSN. *From left to right:* tap water, CH, HNS and FSN.

Purpose

To determine the effects of FSN on the growth of soybeans and corn.†

Procedures:

Soybeans, *Glycine max* (L.) Merr. cv. Essex, Ware and Williams were grown at the Virginia Polytechnic Institute and State University Horticulture Research Farm at Blacksburg, Virginia, and at the Eastern Virginia Research Station, Warsaw, Virginia. Before planting, the areas were fertilized with 90 kg ha^{-1} P_2O_5 and 189 kg ha^{-1} K_2O. Seeds were inoculated with a commercial *Rhizobium japonicum* inoculant, and weeds were controlled with 1.8 liter ha^{-1} of trifluralin. Seeds were planted in the early part of June. Plant rows were 5 m long and spaced 0.9 m apart with 4 cm between plants in the rows. A randomized complete block design was used. FSN treatments were applied as a soil drench at the R_2-R_3 stages of development (Fehr and Caviness, 1977). Seed yield was determined at harvest maturity for each cultivar.

Results:

FSN fertilization of soybeans during 3 growing seasons at Blacksburg and Warsaw did not enhance yield (Tables 3-11 and 3-12). There was a significant yield difference between locations and between growing seasons for the cultivars. The yield of soybeans was significantly greater at Warsaw than at

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†L. H. Aung, G. R. Buss and H. S. Aycock, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061

Blacksburg, and the 1982 growing season was more favorable than the 1981 or 1983 seasons.

Conclusions:

The rates of 4.0 ml, 8.0 ml, and 16.0 ml FSN concentrate l^{-1} water applied to field-grown soybeans as a soil drench at the beginning of early fruit-set and seed-fill did not increase seed yield.

Table 3-11. Fish soluble nutrients fertilization on yield of 3 soybean cultivars over 3 growing seasons under field-growing conditions at Blacksburg, Virginia*

Cultivars	Treatments	Yield (kg/ha^{-1})			
		1981	1982	1983	Average
'Essex'	Control	1448	1710	1046	1401
	X FSN	1556	1643	1113	1437
	2X FSN	1536	1690	1053	1426
	4X FSN	1442	1482	993	1306
'Williams'	Control	1858	1918	2354	2043
	X FSN	1958	2045	2381	2128
	2X FSN	1871	1958	2320	2050
	4X FSN	1911	1884	2461	2085
'Ware'	Control	1945	2065	1931	1980
	X FSN	1972	2294	1858	2041
	2X FSN	1878	1978	1958	1938
	4X FSN	1683	2065	2025	1932

*X FSN denotes 4.0 ml fish soluble nutrients concentrate l^{-1} of water.

Table 3-12. Effect of FSN fertilization on yield of 3 soybean cultivars grown for 2 seasons at Warsaw, Virginia*

Cultivars	Treatments	Yield ($kg\ ha^{-1}$)		
		1981	1982	Average
'Essex'	Control	3413	2716	3065
	X FSN	3259	2649	2954
	2X FSN	3393	2461	2927
	4X FSN	3159	2870	3014
'Williams'	Control	3353	2703	3028
	X FSN	3252	2709	2981
	2X FSN	3326	2595	2961
	4X FSN	3118	2501	2810
'Ware'	Control	2535	2287	2411
	X FSN	2729	2186	2458
	2X FSN	2790	2421	2606
	4X FSN	2649	2347	2498

*X FSN = 4.0 ml FSN concentrate l^{-1} of water.

Procedures:

Seeds of *Zea mays* cv. Blitz were grown in sand culture under greenhouse conditions in the Fall of 1979. The seeds were planted in sand contained in 18-cm plastic pots. The plants were grown at 28°C day and 21°C night temperatures. The chemical treatments are noted in Table 3-13. A randomized complete block design of 5 replicates was used.

For field study, two varieties of hybrid corn, *Zea mays* L. cv. DeKalb XL32AA and Beck's 60X, were grown at the Virginia Polytechnic Institute and State University Horticulture Research Farm, Blacksburg, Virginia. The plot area was fertilized before planting with 84 kg ha^{-1} KCl and 56 kg ha^{-1} P_2O_5. Corn was planted during the last week in May or early part of June. Plant rows were 8.0 m long and spaced 1 m apart with 0.3 m between plants in the rows. A split-plot design of 4 replicates with cultivars as main-plots and treatments as sub-plots was used. The treatments and developmental stages are indicated in Table 3-14.

Results:

Growth, as indexed by leaf sheath length and stem diameter, of corn seedlings fertilized with relatively high concentrations of FSN was similar to HNS fertilization. However, leaf number and dry matter production were significantly greater in FSN-fertilized plants than in HNS-fertilized plants (Table 3-13). Casein hydrolysate fertilization resulted in poor plant growth compared to FSN and HNS fertilization.

Field fertilization of corn plants with FSN during the 7-8 leaf, and early tasseling and silking stages did not increase grain yield (Table 3-14).

Conclusions:

Frequent FSN fertilization of corn under controlled conditions enhanced plant growth, but FSN fertilization under field conditions was ineffective in promoting higher grain yield.

Table 3-13. Effect of FSN, casein hydrolysate (CH), and full strength Hoagland nutrient solution (HNS) fertilization on growth of corn, *Zea mays* L. cv. Blitz in sand culture under greenhouse conditions*

Treatments	Leaf sheath length (mm)	Stem diameter (mm)	Leaf number	Dry matter (g plant^{-1})
Foliar application				
HNS, 3W	12.4	4.6	5.1	0.71
CH (1 g l^{-1}), 3W	7.6	3.9	5.0	0.49
12.0 ml FSN l^{-1} water, 3W	13.0	4.9	6.3	1.40
24.0 ml FSN 1^{-1} water, 3W	12.3	4.9	6.2	1.05
Soil application				
HNS, 1W	11.5	4.4	6.1	0.97
CH (1 g l^{-1}), 1W	6.9	3.6	5.4	0.51
4.0 ml FSN l^{-1} water, 1W	9.4	4.1	6.9	1.29
12.0 ml FSN 1^{-1} water, 1W	13.8	5.1	7.2	2.26
24.0 ml FSN 1^{-1} water, 1W	14.4	5.6	7.5	2.24
Lsd 1%	3.5	1.0	0.9	0.89

*Means are values of 5 replications; probability. 1W = fertilization once-a-week and 3W = fertilization thrice-a-week.

Table 3-14. Effect of FSN fertilization on yield of 2 corn hybrids grown under field conditions (1983, Blacksburg, Virginia)*

Treatments	Yield (kg ha^{-1})	
	Becks 60X	DeKalb XL32AA
Conventional	5413	5451
8.0 ml FSN l^{-1} water, seedling	5596	5049
16.0 ml FSN l^{-1} water, seedling	5577	5621
8.0 ml FSN l^{-1} water, seedling & tasseling	4936	5206
16.0 ml FSN l^{-1} water, seedling & tasseling	5162	5847
8.0 ml FSN l^{-1} water, tasseling	5256	5533
16.0 ml FSN l^{-1} water, tasseling	5432	4999
Lsd 1%	829	1269

*Means of 4 replications. Conventional denotes fertilization with 168 kg ha^{-1} of NH_4NO_3; seedling denotes FSN fertilization at the 5-6 leaf stage, and tasseling denotes FSN fertilization when tassels are visible within the 'crown' of the plants before emergence.

Chapter 4

USE OF FISH SOLUBLE NUTRIENTS FOR SOYBEAN FERTILIZATION†

Materials and Methods

Four rates of FSN, 0, 1X, 2X, and 4X (X = 4.0 ml FSN concentrate l^{-1} water) were applied to soybeans at early pod set (R_3 stage of development) to evaluate potential use as a fertilizer. Folian, a liquid fertilizer 12-4.4-0.5 (N-P_2O_5-K_2O-S), was also applied at R_2 stage for comparison. Soybeans were planted in plots of four rows 81 cm wide and 6.1 m in length; the two inside rows were treated. The FSN material was applied in 11.4 l of water per row. Folian was applied at 94 l ha^{-1}. Two popular soybean varieties in Louisiana, 'Dare' (Group V) and 'Bragg' (Group VII), were seeded at a rate of 67 kg ha^{-1} on May 26. Fertilizer at the rate of 0-80-80 was banded 5 cm on each side of the row at planting. Alachlor (Lasso) at 6 l ha^{-1} and linuron (Lorox) at 1.7 kg ha^{-1} were surface-applied after planting. Soybeans were combined-harvested and yields adjusted to 13% moisture.

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†J. L. Griffin and R. J. Habetz, Rice Experiment Station, Crowley, Louisiana 70526

Results and Discussion

Soybean yields were not significantly different for any of the fertilizer treatments applied (Table 4-1). The average yields obtained for Dare and Bragg were 2830 and 2267 kg ha^{-1} respectively. Plant heights and pod heights for the varieties were not influenced by the fertilizer treatments. Field observations indicated that several days after application of the FSN, foliar diseases developed on the upper leaves of both varieties, particularly at the higher rates. The lower yields for the 4X FSN treatment compared to the control for both varieties indicated that disease development may have had an adverse effect on yield.

Conclusion

No advantage for using FSN or Folian was noted.

Table 4-1. Growth and yield of 'Dare' and 'Bragg' soybeans as influenced by foliar-applied FSN and liquid fertililzer at Crowley, Louisiana*

Fertilizer treatment	Plant height (cm)	Pod ht. (cm)	Yield (kg ha^{-1})
	-----------------Dare-----------------		
4.0 ml FSN l^{-1} water	65.5	11.4	2656
8.0 ml FSN l^{-1} water	63.5	9.7	2857
16.0 ml FSN l^{-1} water	64.8	10.9	2736
Folian	66.8	10.2	2977
Control	66.0	12.2	2931
Average	65.3	10.9	2830
	-----------------Bragg----------------		
4.0 ml FSN l^{-1} water	98.6	16.5	2374
8.0 ml FSN l^{-1} water	102.9	17.3	2213
16.0 ml FSN l^{-1} water	96.5	15.2	2072
Folian	99.8	16.0	2186
Control	102.9	17.8	2488
Average	100.0	16.5	2267

*All treatments applied at R_3 stage of development.

Chapter 5

EVALUATION OF FISH SOLUBLE NUTRIENTS AS A POTENTIAL NITROGEN SOURCE FOR RICE†

Introduction

Nitrogen is required more frequently and in larger amounts than are other plant nutrients for rice production in Louisiana. Ammonium sulfate has been the primary N source for rice in the past because of its slightly greater efficiency in lowland rice culture (Mikkelsen *et al.*, 1967). Urea-N is rapidly gaining in use, however, because of its lower cost per unit of N and its availability. Organic N sources are not currently used in U.S. rice production, but interest in them is increasing because of rising costs of synthetic N sources. Patnaik and Rao (1979) showed that organic N sources are suitable for rice in Asia.

FSN have not been evaluated, however, as a N source for rice or other agronomic crop species under field conditions. The objectives of this 2-year study were to determine the relative efficiency of FSN in relation to ammonium sulfate and urea and to determine the feasibility of using FSN as a N source for rice. Evaluation of N sources for rice is needed because of the importance of N fertilizers in maximizing rice productivity and of the cost of N in relation to other cultural inputs.

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†D. M. Brandon, F. E. Wilson, Jr. and W. J. Leonards, Jr., Rice Experiment Station, Crowley, Louisiana 70526

Materials and Methods

Two field experiments were conducted in 1980 and 1981 in a Crowley silt loam soil (a thermic Typic Albaqualf) at the Rice Experiment Station. Selected soil chemical properties of the 0 to 10.2 cm soil profile depth in the experimental area are shown in Table 5-1.

Table 5-1. Chemical properties of the Crowley slit loam soil within experimental urea*

pH	% Organic matter	Extractable nutrients - ppm				
		P	K	Ca	Mg	Na
6.2	1.12	12	70	938	239	67

*Specific analytical methods reference: R.H. Brupbachler, W.P. Bonner, and J.E. Sedberry, Jr. 1968. Analytical methods and procedures used in the soil testing laboratory. La. Agric. Exp. Stn. Bull. 632.

Nitrogen sources used in the experiments were ammonium sulfate (21% N), urea (45% N), and fish soluble nutrients (5.3% N). The FSN contained other plant nutrients, but to prevent deficiency of P and K in the experiment, 67.3 kg P_2O_5 ha^{-1} and 67.3 kg K_2O ha^{-1} were applied.

Nitrogen rates of 0, 33.6, and 67.3 kg ha^{-1} of the N sources were surface applied and soil-incorporated by harrowing prior to planting. A 67.3 kg N ha^{-1} rate was also split to provide 44.9 kg N ha^{-1} preplant and 22.4 kg N ha^{-1} at the panicle initiation growth stage. The N sources and rates were factorially arranged in a randomized complete block experimental design with four replications.

The rice varieties 'Saturn' and 'Leah' were drill-seeded May 30, 1980, and May 28, 1981, respectively. Cultural practices other than N fertilization that favor maximum growth and productivity in the drill-seeded systems were used in these experiments.

Results and Discussion

The effect of ammonium sulfate, urea, and FSN on rice plant height and grain yields are shown in Tables 5-2 and 5-3.

Table 5-2. Influence of synthetic nitrogen sources and FSN on the performance of drill-seeded 'Saturn' rice at the Louisiana State University Rice Experiment Station in 1980

N rate, kg/ha	Plant height, cm				Grain yield @ 12% moisture, kg/ha			
	Ammonium sulfate	Urea	FSN	N rate mean	Ammonium sulfate	Urea	FSN	N rate mean
0	89	90	89	89	4372	4047	4193	4204
33.6	96	92	94	94	4966	4776	4865	4876
67.3	98	101	98	99	5336	5246	5336	5302
44.9 pre + 22.4 post	100	96	97	98	5325	5213	5112	5213
Source mean	96	95	95		5000	4820	4876	
Lsd 5%: N source		6.0				258		
Lsd 5%: N rate		5.0				471		
Lsd 5%: Source × rate		N.S.				N.S.		

Table 5-3. Influence of synthetic nitrogen sources and FSN on the performance of drill-seeded 'Leah' rice at the Louisiana State University Rice Experiment Station in 1981

N rate, kg/ha	Plant height, cm				Grain yield @ 12% moisture, kg/ha			
	Ammonium sulfate	Urea	FSN	N rate mean	Ammonium sulfate	Urea	FSN	N rate mean
0	63	65	62	63	3352	3453	3116	3307
33.6	71	70	66	69	4002	4080	3509	3868
67.3	75	73	71	73	4932	4675	4013	4540
44.9 pre + 22.4 post	73	73	68	71	4585	4641	3744	4327
Source mean	70	70	67					
Lsd 5%: N source		4				605		
Lsd 5%: N rate		5				157		
Lsd 5%: Source × rate		N.S.				N.S.		

The three N sources equally increased plant height of 'Saturn' as the N rate was increased from 0 to 67.3 kg N ha^{-1} in 1980 (Table 5-2), but ammonium sulfate and urea increased the height of 'Leah' significantly above that of the FSN source in 1981 (Table 5-3). Significant plant height increases with increasing N rates within N sources occurred both years as expected. The relative shortness of 'Saturn' and 'Leah' varieties in these experiments was caused by N deficiency because of the suboptimum total N rates of 33.6 and 67.3 kg ha^{-1}. Suboptimum N rates were used in these experiments because it was assumed that differential N efficiency between sources would be maximized at suboptimum N rates.

Grain yields of 'Saturn' increased with increasing N rates in 1981, and there was no significant difference among the three N sources (Table 5-2). Grain yields of 'Leah' increased with increasing N rates in 1981, but ammonium sulfate and urea produced significantly greater rice yields than did FSN (Table 5-3). A split application of the N sources did not improve grain yields over those of a single preplant application of the total N fertilizer. Nitrogen source by rate interaction was not observed either year. The grain yields in both years were relatively low because of insufficient N for maximum yields. Yield differences between 'Saturn' and 'Leah' may be explained by the differential sensitivity of the two varieties to N deficiency. Saturn is a tall, medium-grain variety that requires much less N than the short-stature long-grain 'Leah' for maximum yield. Consequently, the low fertilizer N rates used in these experiments probably limited the performance of 'Leah' more than that of 'Saturn'.

These data indicate that FSN may be an acceptable, but not superior, N source for rice. FSN produced plant growth and grain yields comparable to those of ammonium sulfate and urea in 1980 but not in 1981. The test form of the FSN obviously would not be acceptable for commercial application because of its unpleasant odor and lack of uniformity.

Summary and Conclusions

Two field experiments were conducted to determine the relative efficiency of FSN in relation to ammonium sulfate and urea. There was no significant difference among the three N sources in 1980 based upon yield, but ammonium sulfate and urea were more effectively utilized than FSN by rice in the 1981 experiment. Grain yields were increased linearly with the three N sources as N rates increased from 0 to 67.3 kg N ha^{-1}. The FSN product appeared equal, but not superior, to ammonium sulfate and urea as a N source in these limited studies. Disadvantages of the tested FSN included unpleasant odor and nonuniform concentrate.

Chapter 6

FIELD TESTING OF FISH SOLUBLE NUTRIENTS FOR CROP PRODUCTION IN WEST VIRGINIA†

A summary of results of experiments conducted in West Virginia is given as follows:

Field Corn

FSN applied annually for three years at the rates of 0, 0.5, 1, 2, and 3 times the recommended rates to a Wheeling sandy loam soil for field corn production generally showed improved yields (Table 6-1). During the first year, two times the recommended rate yielded considerably more corn than all other treatments. On the other hand, in the second and third year, one half of the recommended rate of FSN produced highest yields. Corn yields were slightly reduced by applying three times the recommended rate. At this same location, FSN applied at one or two times the recommended rate to plots which had received chicken manure in 1974 also showed high yield. The result could have been due to the FSN reacting with the organic matter residual from the manure, releasing nutrients for improved crop growth. Further experimentation is needed to confirm these conclusions.

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†R. F. Keefer and R. Singh, Division of Plant and Soil Sciences, West Virginia University, Morgantown, West Virginia 26506

Sorghum and Sweet Corn

At a second location near Frankford, West Virginia, plots were also established on a Clymer silt loam soil fertilized with 0, 0.5, 1, 2 and 3 times the recommended rates of FSN. These plots had been limed to two levels (approximately pH 5.6 and 6.5). Sorghum for molasses was grown in 1980 and 1982 and sweet corn in 1981. On the low-lime plots for both crops it appears that the recommended rate of FSN gave the best yield (Table 6-2). However, on the high lime plots, applying double the recommended rate of FSN produced the greatest yield of both crops. Three times the recommended rate of FSN appeared to give lower yields. Additional data are needed for sweet corn to verify the conclusions.

Strawberries

Two years ago we tried a demonstration using FSN sprayed on top of strawberry plants early in the spring. That was a dry year and the farmer indicated that berries seemed to last longer where FSN were applied. Frost in 1981 killed most berries, but in 1982, a "normal" year, our data from a replicated experiment (Table 6-3) shows improved P and K nutrition with a slight reduction in yield where FSN were applied. Thus it appears that strawberries benefit from FSN mainly during dry years.

Conclusions:

FSN applied to soil at one location for field corn over three years showed average yield increases of 20 to 24 percent above the control. Up to 38 percent yield increase was found where FSN were applied at two times the recommended rate on plots which had received chicken manure in 1974.

Sorghum (2 years) and sweet corn (1 year) at a second location were grown on a soil that received up to three times the recommended rate of FSN. Generally, on the low-lime plots (pH 5.6) the recommended rate of FSN (328 l ha^{-1}) gave the best yield. Yield was increased above the check by 50 percent for sorghum and by 5 percent for sweet corn. On high-lime plots (pH 6.5), best yields were obtained using double the recommended rate of FSN (655 l Ha^{-1}). Yield was increased above the check by 18 percent for sorghum and by 8 percent for sweet corn.

Strawberries seemed to benefit from FSN only in a dry year. Yields were actually reduced some by application of FSN in a "normal" year; however, strawberry fruit did have improved P, K and Mn nutrition.

Table 6-1. Yield of field corn from a Wheeling sandy loam soil at Point Pleasant, West Virginia, fertilized with fish soluble nutrients

Fish Solubles Nutrients Rate	Year			3 year average
	1980	1981	1982	
(l/ha)	--------------------(kg/ha)--------------------			
0	3136	6186	6271	5198
164	5000	6780	7375	6385
328	5680	6033	6966	6226
655	6544	6195	6771	6470
983	5328	6033	6640	6000
Applied onto plots receiving chicken manure in 1974				
328	5836	6679	7263	6593
655	7216	7153	7243	7204

Table 6-2. Yield of sorghum and sweet corn grown on a Clymer silt loam soil near Frankford, West Virginia, fertilized with fish soluble nutrients

Fish Soluble Nutrients Rate	Low Lime						High Lime					
	Sorghum			Sweet Corn (1981)			Sorghum			Sweet Corn (1981)		
	1980	1982	2 yr ave.	Grain	Fodder	Total	1980	1982	2 yr ave.	Grain	Fodder	Total
(l/ha)	---(T/ha)---											
0	14.55*	13.94	14.24	8.26	8.10	16.36	21.79	14.65	18.22	8.33	10.37	18.70
164	11.77	15.78	13.78	6.92	6.49	13.41	19.21	15.23	17.22	8.22	11.54	19.76
328	27.72	14.86	21.29	8.62	8.59	17.21	20.24	15.78	18.01	8.08	9.72	17.80
655	16.31	17.62	16.96	8.33	5.44	13.77	25.37	17.72	21.54	9.25	10.98	20.23
983	12.63	16.75	14.69	7.42	6.84	14.26	22.30	15.30	18.80	8.10	9.30	17.40

Table 6-3. Strawberry yield and chemical analysis of berries grown on a Clymer silt loam soil near Frankford, West Virginia, fertilized with fish soluble nutrients (1982)*

Fish Soluble Nutrients Rate	Total Yield	Elemental Analysis									
		N	P	K	Ca	Mg	Fe	Cu	Mn	Zn	Cr
(l/ha)	(T/ha)			-------------(%)--------------					------(ppm)-------		
0	35.05	.15	.24	.49	.19	.13	62	6	73	25	2.3
328	30.22	.14	.22	.52	.15	.13	66	7	79	24	2.6
655	29.57	.16	.29	.62	.15	.13	88	6	95	27	2.5

*Analysis of Cd, Ni and Pb were less than 0.5 ppm for all plots.

Table 6-4. Chemical analysis of Concord grapes and 'Red Haven' peaches fertilized with fish soluble nutrients (1983; farm of Ellis Smith, Frankford, West Virginia)

Fish Soluble Nutrients Rate	Elemental Analysis								
	N	P	K	Ca	Mg	Fe	Cu	Mn	Zn
(l/ha)	(%)					(ppm)			
					Grapes				
0	2.77	0.12	1.04	1.41	0.22	219	18.4	260	47.1
328	2.69	0.12	1.12	1.37	0.22	285	20.9	270	48.3
655	2.72	0.11	0.87	1.60	0.24	275	21.5	281	35.0
					Peaches				
0	3.25	0.15	1.95	1.30	0.30	128	14	58	30
164	3.39	0.11	1.73	1.05	0.27	149	13	51	38
328	3.64	0.13	1.80	1.13	0.29	149	11	70	47
655	3.75	0.15	1.89	1.05	0.30	143	13	104	34

Chapter 7

FIELD EVALUATION OF THE YIELD ENHANCEMENT POTENTIAL OF FISH SOLUBLE NUTRIENTS FERTILIZATION ON SOYBEANS IN ARKANSAS†

The period of reproductive soybean growth is one of high nutrient demand. The pods eventually became such large 'sinks' for nutrients and carbohydrates that the demand exceeds the assimilation capacity. Nutrients and carbohydrates are then mobilized from the vegetative portions of the plant to the reproductive 'sinks.' Subsequently, senescence and eventual death are triggered. An increase in the availability of nutrients during early reproductive growth has been observed to contribute to the delay of senescence and the enhancement of harvestable soybean yield (Brevedan *et al.*, 1977, 1978; Streeter, 1978).

Procedures

Two soybeans, *Glycine max* (L.) Merr. cv. Forrest and Davis, were grown on a silt loam soil at the Rice Branch Experiment Station, Stultgart, Arkansas. Soybeans were planted in 4-row plots of 6 m length, and rows were spaced 80 cm apart. The spacings gave a plant population of 226,417 plants ha^{-1}. Soybean seeds were inoculated with a commercial *Rhizobium japonicum* inoculant. The herbicide Treflan was used at 0.56 kg ha^{-1}. The

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†C. A. Stutte, Agronomy Department, University of Arkansas, Fayetteville, Arkansas 72701

plots were fertilized with a preplanting application of 225 kg ha^{-1} of a 10-20-10 fertilizer and 79 kg ha^{-1} of KCl. A randomized complete block design of 4 replicates was used. Irrigation was provided by furrow irrigation.

Results

Foliar fertilization of FSN at the rates used did not give yield enhancement of irrigated Forrest and Davis soybeans (Tables 7-1 and 7-2). The lower yield of soybean in 1980 was due to the unseasonably hot and dry conditions during the 1980 growing season. The 1983 season resulted in the best yield of soybean. It should be noted that the foliage of soybean plants treated with FSN remained green for a week longer than untreated plants.

Conclusions

Foliar FSN fertilization of soybeans affected a delay of foliage senescence, but the effect was not translated into higher grain yield.

Table 7-1. Effects of foliar application of FSN on irrigated 'Forrest' soybeans at Stuttgart, Arkansas, during 3 growing seasons

Treatments	Yield (Kg ha^{-1})		
	1980	1982	1983
Control (untreated)	2406	3113	3648
0.62 l FSN ha^{-1}	2207	2875	3681
1.24 l FSN ha^{-1}	2275	2811	3900
1.85 l FSN ha^{-1}	2361	2923	3662
Lsd 5%	292	555	288

Table 7-2. Effects of foliar application of FSN on irrigated 'Davis' soybeans at Stuttgart, Arkansas, during 2 growing seasons

Treatments	Yield (Kg ha^{-1}) 1980	Yield (Kg ha^{-1}) 1983
Control (untreated)	2368	4168
0.62 l FSN ha^{-1}	2482	3809
1.24 l FSN ha^{-1}	2495	3897
1.85 l FSN ha^{-1}	2446	3481
Lsd 5%	416	553

Chapter 8

EVALUATION OF FOLIAR FERTILIZATION WITH FISH SOLUBLE NUTRIENTS ON SOYBEAN YIELD IN MISSISSIPPI†

Purpose

To determine the yield potential of foliar FSN fertilization on field-grown soybeans in Mississippi.

Procedures

Soybeans cv. Tracy and Bragg were grown on a fine sandy loam soil with a pH of 6.1 in 1980 and 1981. The area was fertilized with 336 kg ha^{-1} of a 5-15-30 fertilizer. Plant rows of 15 m length were spaced 0.75 m apart. The plants were sprayed with 243 l ha^{-1} of diluted FSN at the R_2-R_3 developmental stage. Benlate was applied at the rate of 0.6 kg ha^{-1}. A randomized complete block design of 3-4 replications was used.

Results

Foliar fertilization of Tracy and Bragg soybeans did not enhance yield (Tables 8-1 and 8-2). In the 1980 growing season, soybean foliage suffered burn injury because of the unseasonal heat waves in Mississippi. Seed size (g 100^{-1} seed) was also unaffected by FSN fertilization. The average seed size value was 14.1±0.6 for Tracy and 14.5±0.6 for Bragg.

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†C. H. Hovermale, South Mississippi Branch Experiment Station, Poplarville, Mississippi 39470

Conclusions

No seed yield enhancement was obtained using foliar FSN fertilization. Under adverse high temperature growing conditions, foliar applications caused foliage injury.

Table 8-1. Effect of foliar application of FSN on yield of soybean cv. Tracy at Poplarville, Mississippi (1980 season)*

Treatments	Yield (kg ha^{-1}) Expt. I	Yield (kg ha^{-1}) Expt. II
Control	2166	1677
4.0 ml FSN l^{-1} water	2012	1395
8.0 ml FSN l^{-1} water	2193	1462
4.0 ml FSN l^{-1} + Benlate	-	1576
Benlate (0.6 kg ha^{-1})	2146	1576
Lsd 1%	1299	402

*Means of 3 replications for Experiment I, and 4 replications for Experiment II.

Table 8-2. Effect of foliar application of FSN on yield of soybean cv. Bragg at Poplarville, Mississippi (1981 season)

Treatments	Yield (kg ha^{-1})
Control	1992
4.0 ml FSN l^{-1} water	2072
8.0 ml FSN l^{-1} water	2039
16.0 ml FSN l^{-1} water	1978
Lsd 1%	463

*Means of 4 replications.

Chapter 9
GENERAL DISCUSSION

The growth and nurture of plants require a great variety of inorganic and organic substances (Steward, 1968). It is therefore, not surprising that crop plants benefited from FSN fertilization since FSN possess all the inorganic and organic substances (Soares *et al.* 1973). However, while FSN supply *all* the chemical substances for growth, they *do not provide a balanced amount* of substances essential for the growth of all crop plants. For example, FSN are low in calcium, and for the proper growth of high calcium requiring crops like lettuce and tomato, calcium must be added to supplement the low level in FSN. Nevertheless, it is quite apparent from the recorded experiments conducted with a wide array of crops that FSN are capable of promoting plant growth and are a valuable source of nutrients for crop fertilization. Furthermore, these investigations reaffirm the validity of the ancient belief and practice regarding the nutritive value of fish for plant fertilization. With proper formulations (Stuiber *et al.,* 1977) and judicious use (Aung and Flick, 1982), FSN can be a valuable source of nutrients for crop growth.

The persistent question since the inception of our investigations with FSN fertilization of crops is: *how do FSN* *promote plant growth?* Empirically, the answer is relatively simple. FSN promote plant growth by supplying large quantities of chemical substances for incorporation into plant protoplasm. Theoretically, however, the question remains difficult and unanswered. Because FSN are a complex mixture of numerous amino acids, vitamins, lipids, and inorganic substances derived from the protoplasmic constituents of fish (Soares *et al.,* 1973), and because our biochemical and physiological understanding of the single and combined effects of the FSN compounds on metabolic processes is incomplete, we can offer at this time only some observations, reflections, and insights.

Although the primary objective of the FSN projects was to determine the general efficacy of FSN for growing crops, certain experimental observations were made on the fractional effects of FSN on plant growth. The mineral residual fraction ('ash' fraction) obtained after ashing the FSN at 450°C for 2 h was capable of enabling tomato to complete its life cycle although plant growth was drastically curtailed (Fig. 6). The inference from this observation was that the 'ash' fraction of FSN contained a portion of the growth-promoting substances. When the 'ash' fraction of FSN was supplemented with an organic amino acid source like casein hydrolysate, tomato growth was improved over the growth obtained with 'ash' alone. However, the growth of the combined (inorganic plus organic) treatment was not as vigorous as that of plants fertilized with non-ashed FSN. Two inferences were drawn from this experimental observation: (a) both minerals ('ash') and organic compounds (amino acids and other organic substances) are essential ingredients of growth, and (b) casein hydrolysate was not supplying certain factors present in the raw FSN for plant growth. Knowledge of the nature of what these 'certain factors' are is lacking. A possible class of compounds, the cytokinins, have been implicated since the compounds are associated with causing a delay of plant senescence (Thimann, 1980; Guern and Peaud-Lenoel, 1981). The inference is that because FSN fertilization also causes delay of plant senescence (Table 3-10; Fig. 4) it may contain cytokinins. At present, there is no chemical proof for the occurrence of cytokinins in FSN.

Alternatively, the FSN-induced delay of plant senescence may be attributed to its content of amino acids. The supply of amino acids of FSN may prolong the period of protein synthesis of plants fertilized with FSN and thereby delay senescence. This suggestion remains a distinct possibility since the cytokinin-induced delay of plant senescence was mediated by amino acid accumulation and protein synthesis. Investigations along these directions may be fruitful. It is important to investigate the growth effects of FSN fractions for gaining understanding of how FSN affect plant growth, but it is equally important to recognize and utilize the agricultural and economic potential of FSN as a complete gross product or byproduct of the seafood industry.

Another approach for gaining insight into the plant growth-regulating substances of FSN may be to formulate mixtures of components known to be present in FSN for testing and comparing to unfractionated complete FSN. Such an approach may have the additional value of discovering certain formulations which may be better suited for growing plants and for providing a basis for reformulating or refining FSN for cropping and marketing.

Investigations with FSN to date have been concerned predominantly with annual and certain perennial indoor crops like *Brassaia.* Except for some preliminary and limited study with FSN on grapes and peaches (Table 6-4), little attention has been directed at other perennials like fruit and forest species. It would be beneficial to ascertain the influence of FSN fertilization on additional perennial crops and to determine the long-term effects of FSN on plant and soil composition following frequent FSN fertilization.

The nutrient compositional changes of crops from FSN fertilization indicated that with judicious use edible plant parts were not adversely affected by excessive undesirable minerals (Aung *et al.*, 1983). Furthermore, the studies revealed that the nutrients of FSN were readily absorbed by various crops. While it may be presumed that the organic substances of FSN would be degraded and transformed by microorganisms, a proportion of these organic substances appear to be available for direct uptake. The apparent uptake of these organic substances is evidenced by the rapid growth responses of crops following brief periods after FSN fertilization. Also, when pea was grown under germ-free (gnotobiotic) conditions, FSN fertilization resulted in striking growth responses (Hale and Aung, 1981). The FSN under the germ-free conditions would not be degraded by microbial action since microorganisms were excluded. On the other hand, when diluted FSN was prepared and allowed to stand at 26°C for 12-36 hours, the FSN solution rapidly spoiled and gave off an unpleasant odor. The identity of the microorganisms causing spoilage of FSN is unknown, but presumably both aerobic and anaerobic microorganisms are involved. However, freshly prepared, diluted FSN used for crop fertilization pose no unpleasantry to users even under protected greenhouse conditions. Commercially, when FSN are formulated and used as a liquid fertilizer, they have only a minimal odor and pose no problem in marketing or utilization. Alternatively, odor may be masked with deodorants like citronella oil (Stuiber *et al.,* 1977).

FSN-fertilized plants grown under greenhouse conditions gave significant growth responses. In contrast, field fertilization of crops like soybean and corn has shown erratic or no enhanced grain yield. The discrepancy in growth responses and yield of these crops may be attributed to the nature of the crops, to different growing climates and soils, and to the more frequent repeated application of FSN in confined containers under controlled growing conditions. FSN application in the field was less frequent, more diffused in terms of the soil mass, and subjected to greater microbial degradation or transformation. Frequent FSN fertilization of field crops would entail more labor and material cost. Even under field conditions, some growth responses were observed under FSN fertilization, but the responses failed to be translated into consistent higher grain yield. Thus, it would be important to determine what crops to fertilize with FSN, based upon the purpose(s) for which the crops are grown and under which conditions they will be grown.

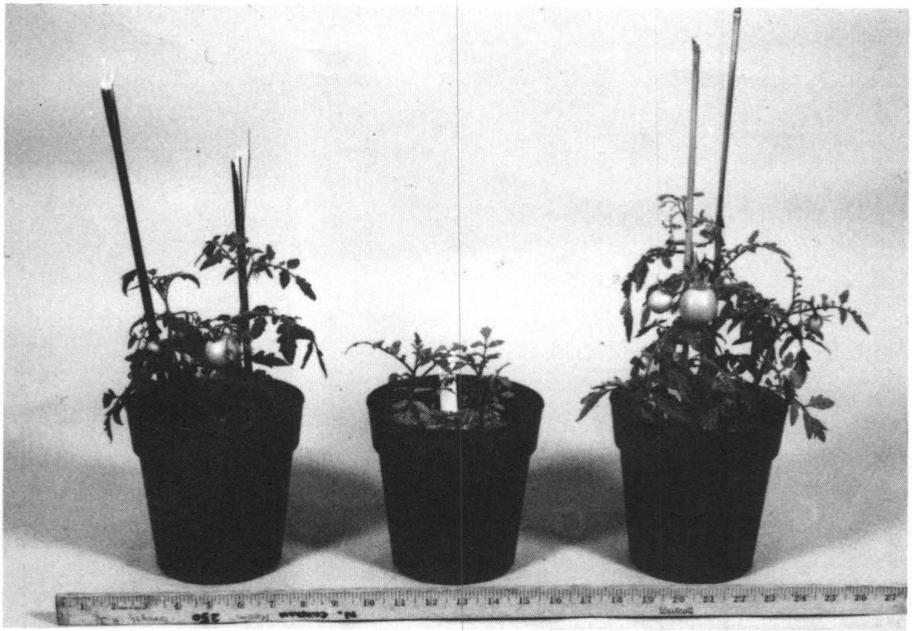

Figure 6. Differential growth of tomato, *Lycopersicon esculentum* Mill. cv. Fireball fertilized with casein hydrolysate *(left photograph)*, 'ashed' FSN *(center photograph)* and 'ashed' FSN plus casein hydrolysate *(right photograph)*.

Chapter 10
SUMMARY

- FSN are a useful source of nutrients for plant growth.

- FSN contain all the inorganic and organic substances needed for plant growth but do not provide a *balanced* source of nutrients for all crop plants.

- For specialty crops with known requirements for certain nutrients, FSN must be supplemented with additional nutrients to provide the desired crop growth.

- With proper formulations and judicious use at relatively dilute solutions, FSN have proven to be effective for growing plants.

- FSN fertilization promoted plant growth in general without an excessive accumulation of undesirable elements in edible plant parts of crops grown for food.

- Diluted FSN spoil rapidly and must be prepared fresh before use. The spoilage microorganisms need study.

- The odor of diluted FSN is minimal and is not unduly objectionable. The odor of FSN may be masked or deodorized by using citronella oil.

- FSN retard flowering and fruiting and delays senescence. The causal mechanism of how FSN affect these growth processes is unknown. The roles of cytokinins, amino acids, and protein synthesis merit additional study.
- FSN are apparently absorbed rapidly under natural and germ-free conditions.
- FSN utilization under greenhouse conditions for fertilization of indoor crops was more effective than field crop fertilization.
- Additional FSN investigations on certain perennial fruit and tree species may be beneficial.
- A careful selection of crops and growing conditions is a prerequisite for profitable use of FSN for plant fertilization.

Chapter 11
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Virginia's Agricultural Experiment Stations

1—Blacksburg
Virginia Tech

2—Steeles Tavern
Shenandoah Valley Research Station

3—Orange
Piedmont Research Station

4—Winchester
Winchester Fruit Research Laboratory

5—Middleburg
Virginia Forage Research Station

6—Warsaw
Eastern Virginia Research Station

7—Suffolk
Tidewater Research and Continuing Education Center

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9—Critz
Reynolds Homestead Research Center

10—Glade Spring
Southwest Virginia Research Station

11—Hampton
Seafood Processing Research and Extension Unit