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Fisheries Series: No. 3

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By

Yun-an Tang and Tung-Pai Chen

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CONVERSION OF METRIC TO U. S. AND BRITISH MEASURES

LENGTH

1 meter	= 3.28 feet
1 centimeter	= 0.39 inch
1 foot	=30.48 centimeter
1 inch	= 2.54 centimeter=2.54 millimeter

AREA

1 hectare (ha.)	= 2.47 acres
1 square meter	=10.76 square feet
1 acre	= 0.405 hectare
1 square foot	= 0.0929 square meter.

WEIGHT

1 kilogram (kg.)	= 2.204 pounds
1 pound (lb.)	= 0.454 kilogram
1 metric ton	= 1,000 kilograms=2,204 pounds
1 short ton	= 0.907 metric ton=2,000 pounds
1 long ton	= 1.016 metric ton=2,240 pounds

WEIGHT PER AREA

1 kilogram per hectare (kg./ha.)	= 0.892 pound per acre (lb./acre)
1 pound per acre	= 1.12 kilogram per hectare

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INTRODUCTION

The fish culturists who are familair with the conditions and management of milkfish ponds in Taiwan are generally aware of three major problems: (1) the tremendous expenditures that go into enrichment of the ponds by fertilization with organic manures to promote the growth of benthonic algae to feed the fish, (2) the efforts that have been made in management of the milkfish population in ponds by stocking and recovering so that the food organisms produced by manuring can be efficiently utilized and the production of harvestable size fish from a body of water can be maintained year after year, and (3) the occurence in the pond bottom of tremendous number of ***Chironomus*** larvae that compete with the milkfish for food and destroy the "algal beds"—a layer of jelly-like mud at the top of bottom soils on which the colonial microscopic algae grow. These three problems are most important in the improvement of the management of milkfish ponds in Taiwan.

This report deals with the first problem and presents the results of a series of experiments in the enrichment of ponds by fertilization with chemical fertilizers. This type of work is necessarily of long-term nature and requires large-scale experimentation. This report is intended as a progress report on the findings of the past four years on this subject.

Although a number of workers have done intensive work to demonstrate the feasibility of the use of chemical fertilizers in the freshwater ponds of Germany (Demoll, 1925; Schäperclaus, 1933; Krügell and Heinrich, 1939; and Wunder, 1949) for rearing the common carp, ***Cyprinus carpio,*** and in the southern states of the U. S. A. (Swingle, 1947) for rearing the major species of the sunfishes, ***Centrachidae,*** fertilizer requirements of fish pond should be expected to vary with different pond conditions and different species of fish. The water, soil and climatic conditions of the milkfish ponds of Taiwan are basically different from those in the carp ponds of Germany and the warm-water fish ponds of the southern states of the U. S. A. In order to use chemical fertilizers successfully and economically in the milkfish ponds of Taiwan, it is necessary to know the environmental conditions of the ponds first, and then make suitable modifications of the methods and materials.

To meet this need, a co-operative program was set up in 1952 to experiment on the use of chemical fertilizers in milkfish ponds, under which the Taiwan Fisheries Research Institute furnished the experimental ponds and personnel and the Chinese-American Joint Commission on Rural Reconstruction gave financial assistance for reparing the ponds, dykes, and sluce gates, as well as technical advice in planning the experiments.

DESCRIPTION OF THE PONDS

A series of 15 ponds with an area of 1/6 hectare each were used in the first three years, and 18 ponds of 1/6 hectare and 6 of 1 hectare were added in the fourth year. In the fifth year, 1957, a total of 42 hectares of ponds are used for this experiment. These ponds are experimental ponds of the Fish Culture Station of the Taiwan Fisheries Research Institute located at Tainan, which is the centre of the milkfish industry of Taiwan. Before these ponds were constructed, the site was an unused pond which had not received fertilization for more than ten years. The water supply of these ponds is from a canal connected with the sea.

The water in these ponds was kept constant at a level of 25 to 35 cm. in depth, which is the common practice of fish farmers. Experiments have shown that this depth range is the maximum for the growth of benthonic algae and, at the same time, the minimum for fish growth (Yamamura, 1942). During the dry season from April to June, sea water was sometimes admitted to the ponds to make up the loss by natural evaporation. On the other hand, the water of these ponds was partially drained from time to time during the period from June to September when there was too much rain.

The average water temperature of these ponds ranged from 9° C to 34° C throughout the year (Figure 1). The rearing season of milkfish, however, is the period from April to November when the minimnm water temperature is above 20° C, which is perhaps optimum for the growth of the benthonic algae as well as the milkfish.

The salinity of the pond water fluctuated from 0.5 to 7.0%, being determined by rainfall and natural evaporation. In the early part of the fish rearing season, when the ponds were freshly filled with water from the water supply canals, its salinity was almost the same as the sea water. With the rise of temperature and the continuance of dry weather following the coming of spring, the salinity of the water increased day by day, often reaching 7.0 per cent, and the total salt content of the water might be as much as double the amount in the sea water. When the wet season came, the salinity fell rapidly, sometimes reaching a minimum of less than 0.5 per cent. This lowering of salinity came to an end at the latter part of September with the passing of the rainy season (Figure 2).

The pH of the pond water varied from 7.8 to 9.2 throughout the fish rearing season from April to November 1956. When the ponds were filled with fresh sea-watar through the water supply canal, its pH generally ranged from 8.2 to 8.4. It often reached 9.2

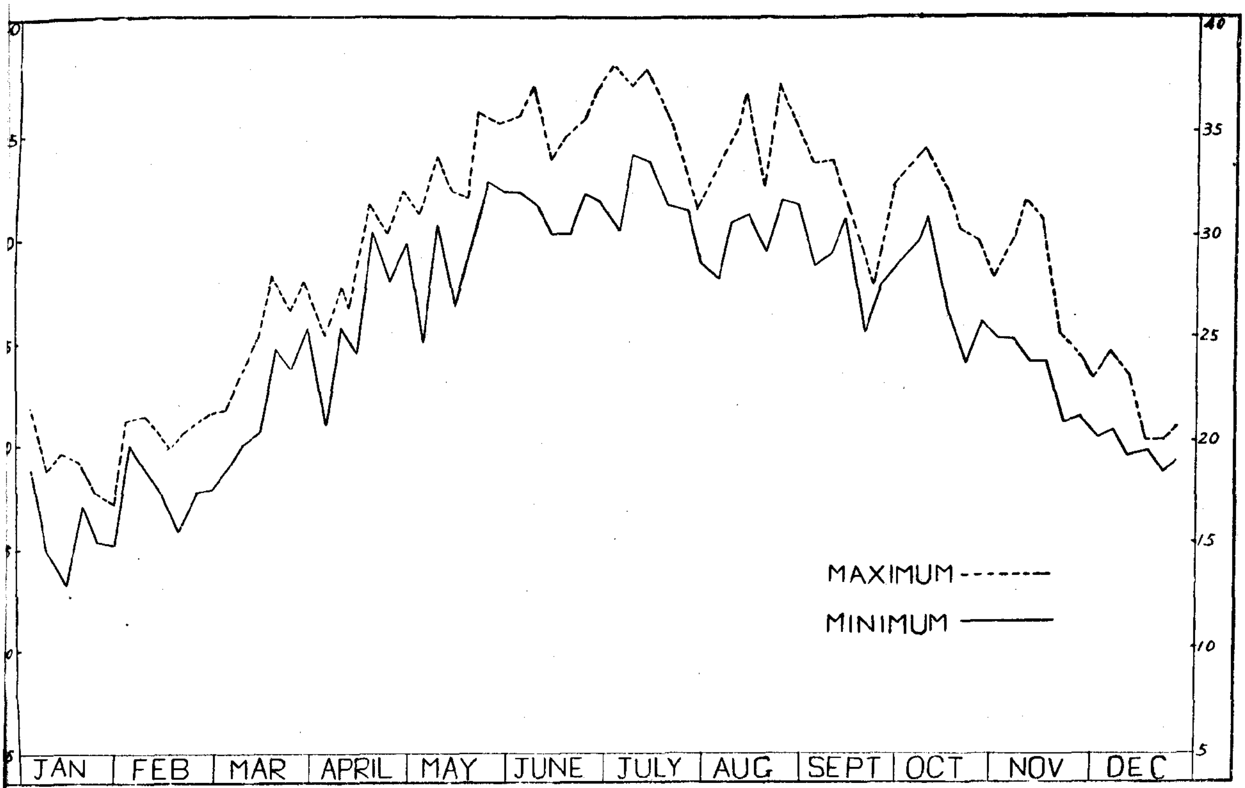

Fig. 1. Annual water temperature (5-day average) in the milkfish ponds of Tainan. Records of the period from December to March were taken from the wintering pond.

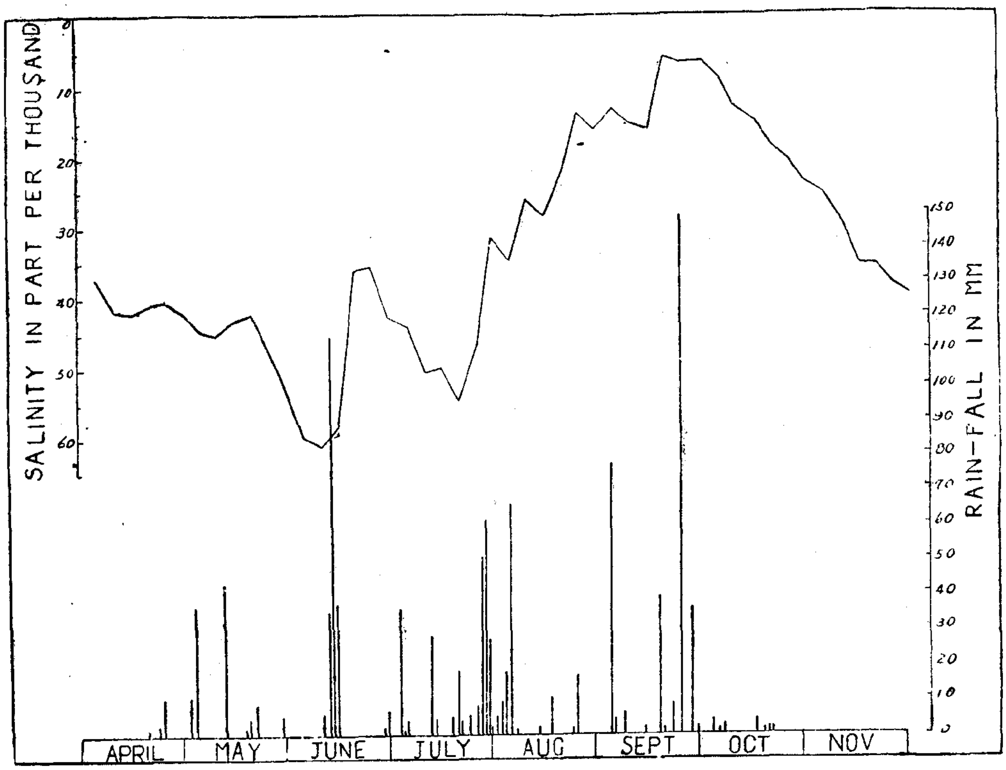

Fig. 2. Changes of salinity in milkfish ponds in Tainan and their relation to rainfall during the fish rearing season of 1956.

when the water salinity rose above 6.0 per cent. During the wet season, it usually ranged from 7.8 to 8.2. With abundant rainfall, it sometimes dropped to 7.5.

The soils of the pond bottom were grayish black in color and composed of 81.51 per cent of fine grains of less than 0.1 mm. in diameter.

The organic matter content of the bottom soil (5 cm. from the surfaee of the bottom) in these ponds was 3.64 per cent at the end of the first year's experiment, but at the end of the fourth year, it increased to 4.90 per cent. This percentage of organic matter content is much lower than those ponds in long use, where the organic matter content is generally 7.55 per cent or more.

The benthonic algae found in these ponds consisted of a mixture of ***Oscillatoria, Spirulina, Phormidium, Micocoleus, Lyngbya, Anabaena*** and possibly other genera of the order ***Oscillatoriales*** and various diatoms. The higher aquatic plants of the genus ***Ruppia*** were also present in small quantity during the wet season.

The most important orders or families of the bottom fauna found in these ponds were the following: ***Polychaeta, Oligochaeta, Hydrophilidae, Chironomidae*** and ***Cerithidae.*** Most of these organisms disappeared entirely from the ponds after the tea-seed cakes (the residue after expressing the oil from the seeds of ***Camellia sinensis*** containing 9 to 11 per cent of saponin) were applied in the early part of March. This scarcity of bottom fauna continued until the beginning of the wet season. During this period the water salinity ranged from 4.0 to 7.0 per cent. Chironomus larvae were the predominant organisms on the surface of the pond bottom and sometimes occured in great concentration. Over 40.000 individuals weighing more than 60 grams have been found on one square metre of bottom when the salinity of pond water was less than 3.0 per cent during the rainy season.

OPERATION

The operation of these ponds in this experiment was based on the principles of the established practice developed by generations of fish farmers. A general description of the system of management of mikfish ponds in Taiwan has been given by Chen in 1952. The following is an explanation of the operation concerning particularly the procedures of fertilization and the management of fish population by stocking and recovering that were adopted in this experiment.

Application of fertilizer—It should be remembered that the application of fertilizers to milkfish pond is for the purpose of increasing the benthonic algae which serve as feeds. According to the water, soil and climatic conditions of the pond, the fertilization of milkfish ponds in Taiwan is made in the following four periods:

1. The first fertilization period or the period of fertilization for the algal beds: This period is from December to early March. The minimum water temperature during this period is usually less than 20°C. The fish in the ponds below marketable size are removed to the wintering ponds because of the lower water temperature. At the be-

ginning of this period, the mud on the surface of the pond bottom is usually in colloidal condition. In order to effect the caking of this colloidal mud and the subsequent formation of the "algal beds", drying of the bottom at intervals during this period is necessary. After the "algal beds" are formed and stiffened by repeated drying, fertilizers are required to enrich the "algal beds" to meet the nutritional need ef the benthonic algae at the end of this period.

2. The second fertilization period or the period of fertilization for stimulating the growth of benthonic algae: This period is from March to the beginning of the rainy season, in June. During the period the water temperature rises with the coming of spring and the salinity of the pond water is incrased by natural evaporation. The "algal beds" in the pond bottom have already received fertilizer at the end of the first fertilization period. For hastening the growth of the benthonic algae to supply food to the newly planted yearlings from the wintering ponds, two kinds of fertilizer, tea-seed cake and manure, both acting as stimulating agents should be applied. The former material has a powerful effect in speeding up the decomposition of the organic matter in the bottom soil with the rise of the water temperature, so that the plant nutrients compounded in the organic matter can be released in soluble form. The latter material, especially the night soil and cattle manure, is very valuable for stimulating the growth of benthonic algae in the early part of this period when the water temperature is relatively low.*

3. Third fertilization period or the period of fertilization for turbid water: This period is from June to Septmber, throughout the wet season. The salinity durıng this period is less than 3.0 per cent, and the water temperature rises aboue 30°C. Under ordinary conditions, when the benthonic algae grow vigorously in the pond bottom, the water in the pond is clear and deep green in color. During this period, however, due to unfavorable weather, two types of turbid water, one caused by the bloom of plankton algae and the other by the suspension of muddy particles, often appear in the ponds, especially in the latter part of this period when the "algal beds" have been destroyed. Turbidity is undesirable in the milkfish pond, because the suspended matters shut out the sunlight and prevent the growth of benthonic algae. The techniques employed for fertilization of the ponds during this period are complicated, and the results obtained usually show variation according to the complex conditions of the soil, water, and climate. In many cases, when the water is turbid with dominance of plankton algae, the feeds which are specially prefered by the milkfish and have less fertilizer effect on the water such as peanut cakes should be applied in comparatively large pieces. Then the water will clear in a few days. But when the water is turbid with dominance of muddy particles, a heavy application of organic fertilizer, specially the soaked rice bran, wheat bran or Leucaena-seed meal, which causes less organic suspension after

* Similar results were obtained by Swingle in the freshwater ponds of Alabama, U.S.A., and both Demoll and Krugel and Heinrich mentioned that liquid manure sttmulates the plankton growth in freshwater ponds of Germany (Swingle, 1947, Demoll, 1925 and Krugel and Heinrich 1939).

application will usually bring round the condition.* After the turbid water has cleared, the benthonic algae would grow again provided the plant nutrients are available. Otherwise adequate application of fertilizers is required under fine weather and with higher salinity of the water.

4. The fourth fertilization period or the period of fertilization for the colloidal bottom: This period is from the end of the rainy season to the end of the fish rearing season. The salinity of the pond water rises rapidly after the passing of the rainy season and the water temperature lowers gradually following the coming of fall. The "algal beds" on the bottom are usually destroyed by the frequent attacks of typhoon and freshet in the latter part of the rainy season, and the upper layer mud on the bottom usually becomes colloidal. To fertilize the ponds under this condition, two types of treatments are generally employed. One is to drain the pond and dry the bottom under the sun for several days in order to re-establish the "algal beds". After a thin layer of "algal beds" is formed, application of fertilizer to the bottom before the pond is refilled with water is necessary. Following the lowering of water temperature at the approach of the end of the fish rearing season, liquid manures are required to stimulate the growth of the benthonic algae in the relatively cold water. Another treatment is the same as the method of fertilization for tubid water caused by muddy suspensions.

Management of fish Population: The fish population in a milkfish pond is completely under control by stocking and recovering. A general schedule for stocking the pond and recovering the fish in the ponds at Taiwan is given in Table 1.

EXPERIMENTS AND RESULT

In the experiments various chemical fertilizers were used alone and in combination with organic materials. The common organic fertilizers for fish pond were also tested for the purpose of comparsion. It was first intended in the 1953 experiment to measure the benthonic algae periodically in the experimental ponds in addition to measuring the fish. But, since no satisfactory and convenient method has been developed for this purpose, the idea was abandoned. The results obtained from these experiments, therefore, were based entirely on the weight of the fish produced per unit area, supplemented by observation on the conditions of the ponds, such as water color and growth of benthonic algae. Unfortunately it was not possible to carry out any of the experiments during the last 4 years for the entire duration of the fish rearing season, as they were all interrupted by typhoons in the latter part of the wet season. The residual effect of each treatment in the following years is not considered significant because of the long period of fallowing after the fish were harvested each year. But it was recognized that the organic matter in the bottom soils increased with the increase of tillage in each pond.

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* Similar results were obtained by Irwin and Swingle in the freshwater ponds and impoundments of the southern states of the U.S.A. (Irwin 1945 and Swingle 1947)

Table 1. Stocking of the Ponds and Recovering of the Fish during the Fish Rearing Season, Rate per Hectare

Stocking				Recovering					
Time	Stage	Av. number per kg.	Number	Days after Stocking	Numbers of harvests[5] (by gilling)	Mesh size of gillnet in cm.	Av. number per kg.	Survival %	Approximate total wt. in kgs.
Early part of April	Large yearling[1]	15-20	1500	45-70	1-1.5	6.5-7.0	3.5	95	400
Early part of April	Small yearling[2]	200-300	1500	70-100	1-1.5	6.5-7.0	3.5	95	400
Early part of April	1st planting[3] of fry		3000	120-150	1.5-2	5.5-6.0	5.0	85	500
Latter part of May	2nd planting of fry		3000	120-150	1.5-2	5.5-6.0	5.0	85	500
Latter part of June	3rd planting[4] of fry		4000	120-150	1-1.5	5.0-5.5	6.5	80	200

1. Taken from wintering ponds.
2. Bought from farmers who raise small yearlings.
3. 16 mm. in total length and 0.08 gram in body weight.
4. About 1/2 are harvested at the end of the fish rearing season and the remaining 1/2 removed to the wintering pond for next year's stocking.
5. Fish are caught by gill-net at 3 to 4 week intervals from the early part of June to the latter part of November. Total number of harests 6 to 9.

Experiment in 1953—The experiments in this year were conducted with the primary aim to determine the feasibility of the use of chemical fertilizers instead of organic manures in the first fertilization period. A 4-month test from the beginning of the fish rearing season was conducted with 5 treatments of 3 replicates each in the 15 1/6-hectare ponds. The mixture recommended by Swingle (1950) for use in freshwater ponds in the U. S. A. was adopted, i. e. 100 pounds of 6-8-4 plus 10 pounds of soda, with the ratio of N-P_2O_5-K_2O approximately at 8-8-4. This 8-84 chemical fertilizer contained ammonium sulphate, superphosphate and potassium chloride. It was considered that the development of acidity in pond water by the application of ammonium sulphate wuld not have effect on this type of water, especially when used during this period. The action of chemical fertilizer upon the growth of either free-floating form or bottom filamentous form of algae in freshwater ponds has been reported in detail by Swingle (1947). In this experiment, the chemical fertilizer was to furnish the plant nutrients in soluble form and to encourage the growth of microscopic algae in the bottom.

The results of this experiments are shown in Table 2. From this table it will be observed that when 1400 kg./ha. of 8-8-4 chemical fertilizer was applied to the bottom before the ponds were refilled with water at the end of the first fertilization period, the average fish production was 838 kg./ha. for the four months from April to August. This yield was approximately the same as the average fish production from the ponds which received approximately twice the amount of rice bran or 30 times the amount of night soil.

The rice bran (containing 2.08 per cent nitrogen and 2.78 per cent P_2O_5) is a very common organic manure used in the milkfish ponds of Taiwan. When rice bran was used in the first fertiiization period, it acted readily in promoting the growth of benthonic algae because of its rapid decomposition after it was applied. When it was used in the rainy season of the third fertilization period, the turbid water caused by muddy particles was usually cleared by the application. It served as food for the milkfish when the natural food in the ponds was exhausted or insufficient.

The use of night soil (containing more than 90 per cent water) in the milkfish pond is usually limited to the time during the second or fourth fertilization period when the pond water is clear and relatively cold. But the use of it in the first period in this case undoubtedly increased the depth of the "algal beds" in these newly constructed ponds and was beneficial to the growth of benthonic algae.

Emphasis on the importance of phosphatic acid as the limiting factor of organic production in freshwater ponds is to be found in numerous European works (Stepan, 1928; Brüning, 1930; Rossler, 1931; Krügell and Heinrich, 1939; Weimann, 1939; and Wunder, 1949). Experiments in German ponds have shown that, even in the use of superphosphate alone, the average increase of yield in the pond was 90 per cent, with maximum increase up to 158 per cent per annum. Consequently, it was thought that phosphatic acid might play an important role in the growth of microscopic algae on the bottom and possibly in the building up of bacterial flora in or under the "algal

Table 2. Production of Milkfish from Various Fertilizer Treatments in a 4-Month Experiment from April to August 1953.

Pond No.	Fertilizer treatment, kg./ha.			Fish proeuction, kg./ha.			
	1st Fertilization period[1]	2nd Fertilization preiod	3rd Fertilization period[2]	2-year milkfish	1-year milkfish	Other species of fish[3]	Total[4]
11	1400—8-8-4	90—Tea-seed cake	350—Rice bran	564	254	65	883
31	1400—8-8-4	90—Tea-seed cake	350—Rice bran	570	234	4	808
53	1400—8-8-4	90—Tea-seed cake	350—Rice bran	534	190	99	823
Av.	1400—8-8-4	90—Tea-seed cake	350—Rice bran	556	226	56	838
12	2100—S.P.	90—Tea-seed cake	350—Rice bran	504	186	32	·722
32	2100—S.P.	90—Tea-seed cake	350—Rice bran	510	66	41	617
56	2100—S.P.	90—Tea-seed cake	350—Rice bran	480	138	70	688
Av.	2100—S.P.	90—Tea-seed cake	350—Rice bran	498	130	48	676
13	2700—Rice bran	90—Tea-seed cake	350—Rice bran	606	126	64	796
33	2700—Rice bran	90—Tea-seed cake	350—Rice bran	576	320	29	925
55	2700—Rice bran	90—Tea-seed cake	350—Rice bran	528	194	69	793
Av.	2700—Rice bran	90—Tea-seed cake	350—Rice bran	570	214	54	838
34	1200—Peanut cake	90—Tea-seed cake	350—Rice bran	504	108	44	656
36	1200—Peanut cake	90—Tea-seed cake	350—Rice bran	540	162	4	706
52	1200—Peanut cake	90—Tea-seed cake	350—Rice bran	570	78	48	696
Av.	1200—Peanut cake	90—Tea-seed cake	350—Rice bran	538	116	32	686
35	36000—Night soil	90—Tea-seed cake	350—Rice bran	546	324	2	872
51	36000—Night soil	90—Tea-seek cake	350—Rice bran	570	270	45	885
54	36000—Night soil	90—Tea-seed cake	350—Rice bran	594	114	11	719
Av.	36000—Night soil	90—Tea-seed cake	350—Rice bran	570	236	19	825

1. Divided into two equal applications.
2. Three applications 114 kg./ha. added 7/9, 164 kg./ha. added 7/22, and 30 kg./ha. added 7/30/'53.
3. Mostly *Tilapia mossambica.*
4. The fish were harvested by gilling on 6/16, 7/17 8/15 and finally by draining the pond on 8/26/'53.
5. S.P.=Superphosphate.

beds" in these ponds under certain conditions.

In this experiment, when 2100 kg./ha. of superphosphate was added in two equal applications at the end of the first fertilization period, the average fish production was 676 kg./ha. for a 4-month period of rearing. This yield was approximately 20 per cent less than that from treatment with 8-8-4 chemical fertilizer alone, but approximately the same as the average yield from ponds receiving 1200 kg./ha. of peanut cakes.

Peanut cake (containing 6.5 per cent nitrogen and 1.3 per cent P_2O_5) is too expensive for commercial use in the first fertilization period. However, when pieces of peanut cakes were added to the turbid water with bloom of plankton algae during the wet season, fish would gather to feed on them and leave the pond bottom comparatively undisturbed. Then, plankton algae would precipitate under intensive sunlight and calm weather. The use of peanut-cakes in the first fertilization period in this case was relatively ineffective in establishment of the algal mat on the bottom and resulted in low fish production. This probably was due in part to the fact that the release of plant nutrients from the decomposition of this material was too slow to meet the need of the benthonic algae.

Experiment in 1954—In order to determine the suitable quantity of chemical fertilizers for application to the milkfish ponds in the first fertilization period and the effect of the mixture of inorganic and organic fertilizers, experiments were conducted in the same ponds as in the preceeding year and carried out for six months from the beginning of the fish rearing season. In each treatment, one application was made in the first fertilization period and another in the third period. The quantity of fertilizer used in the third fertilization period was one-half that used in the first period. The N-P_2O_5-K_2O ratio used in this year was 8-4-2, since it was thought that the growth of this type of colonial blue-green algae required high nitrogen supply, and a mixture of lower percentage of phosphorus might be equally effective.

The results obtained by the 1954 experiment are given in Table 3. One can see from this table that the fish production from the ponds treated with chemical fertilizers increased with the increase of the amount of nitrogen and nitrogen-phosphorus fertilizers applied. When 200 and 100 kg./ha. of ammonium sulphate alone were applied in the first and third fertilization periods respectively, a total fish production of 954 kg./ha., or 232 kg./ha. more than that produced by the application of 120 kg./ha. of tea-seed cakes, was obtained. But the application of 450 kg./ha. of 8-4-0 mixture raised the production to 1116 kg./ha, which was 394 kg./ha. more than from the pond treated with tea-seed cakes, and 162 kg./ha. more than from the pond without addition of superphosphate.

Although considerable inconsistency was found in the relationship between fish production and the amount of 8-4-2 chemical fertilizer applied, it seems that the most suitable amount of this mixture of chemical fertilizer in the fist fertilization period, under the conditions of these ponds, ranges somewhat from 300 to 500 kg./ha. It is

Table 3. Production of Milkfish from Various Fertilizer Treatments in a 6-month Experiment from April to October 1954

Pond No.	Fertilizer treatment, kg./ha.			Fish production, kg./ha.		
	1st Fertilization period	2nd Fertilization period	3rd Fertilization period[1]	2-year milkfish	1-year milkfish	Total[2]
51		120—Tea-seed cake		380	342	722
52	200—Ammonium sulphate	120—Tea-seed cake	100—Ammonium sulphate	534	420	954
53	300—8-4-0	120—Tea-seed cake	150—8-4-0	579	537	1116
54	350—8-4-2	120—Tea-seed cake	175—8-4-2	498	552	1050
55	400—8-4-2	120—Tea-seed cake	200—8-4-2	456	673	1129
56	450—8-4-2	120—Tea-seed cake	225—8-4-2	342	906	1248
31	500 | 8-4-2	210—Tea-seed cake	250—8-4-2	588	516	1104
32	400—1-to-1 mixture of 8-4-2 and rice bran	120—Tea-seed cake 6000—Night soil	200—1-to-1 mixture of 8-4-2 and rice bran	636	1002	1638
33	300—Rice bran	120—Tea-seed cake 8000—Night soil	300—8-4-2	516	444	960
34	300—8-4-2	120—Tea-seed cake 8000—Night soil	300—Rice bran	624	462	1086
11&12	400—Rice bran	120—Tea-seed cake 12000—Night soil	200—Rice bran 6000—Night soil	564	435	999
13&36	1200—Rice bran	120—Tea-seed cake 8000—Night soil	600—Rice bran 4000—Night soil	642	750	1392
35	14000—Rice bran	120—Tea-seed cake	7000—Night soil	504	610	1116

1. One application made 6/12/'54.
2. The fish were harvested by gilling on 6/8 and 10/2/'54.

possible that the omission of potash from the mixture may be equally effective, since the potash is not considered an important factor in this type of water.

When treated with 600 kg./ha. of 8-4-2 chemical fertilizer, the pond produced 1,129 kg,/ha. of fish during six months of rearing. This was 130 kg./ha. more than the pond fertilized with 600 kg./ha. of rice bran plus 18,000 kg./ha. of night soil, but 263 kg./ha. less than the pond fertilized with 1800 kg./ha. of rice bran plus 12,000 kg./ha. of night soil. Apparently, this higher production from the last mentioned pond treatment was due in part to the large amount of rice bran used in the third fertilization period, i.e. during the rainy season.

When 300 kg./ha. of 8-4-2 chemical fertilizer in mixture with equal amount of rice bran was applied with 2/3 in the first fertilization period and the remaining 1/3 in the third fertilization period, the fish production was 1638 kg./ha. for tne 6-month period. This is an increase of 509 and 639 kg./ha. over the ponds receiving the equal amounts of 8-4-2 chemical fertilizer and rice bran respectively. However, when 300 kg./ha. of 8-4-2 chemical fertilizer and 300 kg/ha of rice bran were given separately to two ponds in different fertilization periods, only 1086 and 960 kg./ha. of fish respectively was produced (Table 3) . The explanation for this is given in the discussion section of this report.

Experiment of 1955—The experiment of this year was conducted in an attempt to determine the correct mixture of 8-4-2 chemical fertilizer and rice bran and the amount of these various mixtures that would be suitable for application in the first fertilization period. This experiment was carried out for only a 3-month period, from April to July. The results are shown in Table 4.

As it was thought that the amount of organic matter rich in nitrogen in the bottom soils might influence the results of this experiment, an analysis of the total nitrogen content in the upper layer of the bottom soils (5 cm. from the surface) was made before the experiment began. Its results showed that the total nitrogen content in the bottom soils of these ponds ranged from 0.430 to 0.474 per cent (Table 4). This difference was considered too small to significantly influence the results of this experiment.

In Table 4, it will be observed that the results from various ratios of mixture of 8-4-2 chemical fertilizer and rice bran have failed to show highly significant difference. This was probable due in part to the neglect to reduce the fish population by gilling with the result that the fish in each of these ponds reached approximately the carrying capacity of such body of water. There was some evidence, however, that the application of more than 1000 kg./ha. of any of these mixtures did not give better result than when 1/2 of that amount was applied. Apparently, the excess of either of these two materials would not be completely utilized by the benthonic algae. These figures also indicate that the application of less than 500 kg./ha. of a 1-to-1 mixture of these two materials would be insufficient.

Table 4. Production of Milkfish from Various Fertilizer Treatments in a 3-month Experiment from April to July 1955.

Pond No.	Total nitorgen[1] content in bottom soil %	Fertilizer treatment, kg./ha.		Fish production, kg./ha.		
		1st Fertilization period	2nd Fertilization period	2-year[2] milkfish	Other speies of fish	Total[3]
11	0.464	350—1-to-1 mixture of 8-4-2 and rice bran	120—Tea-seed cake 8000—Night soil	696	3	699
12,34 &51	0.442	500—1-to-1 mixture of 8-4-2 and rice bran	120—Tea-seed cake 8000—Night soil	778	2	780
13&54	0.459	600—1-to-1 mixture of 8-4-2 and rice bran	120—Tea-seed cake 8000—Night soil	834	—	834
31	0.439	1000—1-to-1 mixture of 8-4-2 and rice bran	120—Tea-seed cake 8000—Night soil	798	4	802
56	0.474	800—2-to-1 mixture of 8-4-2 and rice bran	120—Tea-seed cake 8000—Night soil	792	2	794
33	—	1000—2-to-1 mixture of 8-4-2 and rice bran	120—Tea-seed cake 8000—Night soil	782	—	782
53	0.446	500—3-to-1 mixture of 8-4-2 and rice bran	120—Tea-seed cake 8000—Night soil	756	—	756
52	0.448	500—1-to-2 mixture of 8-4-2 and rice bran	120—Tea-seed cake 8000—Night soil	798	1	799
55	0.440	800—1-to-2 mixture of 8-4-2 and rice bran	120—Tea-seed cake 8000—Night soil	834	1	835
32	0.430	1000—1-to-2 mixture of 8-4-2 and rice bran	120—Tea-seed cake 8000—Night soil	786	2	788
36	0.459	1300—1-to-2 mixture of 8-4-2 and rice bran	120—Tea-seed cake 8000—Night soil	792	1	793
35	0.454	1300—1-to-3 mixture of 8-4-2 and rice bran	120—Tea-seed cake 8000—Night soil	780	—	780

1. The content of total nitrogen was determined by the common Kjeldahl method.
2. Ponds were stocked with small yearlings only.
3. The fish were harvested by draining the ponds on 7/28/'55.

Experiment of 1956—An experiment of larger scale was conducted in 1956 to determine the practical and economical value of the use of chemical fertilizers in milkfish ponds. Ponds used for each treatment in this experiment had an area of at least one hectare. Unfortunately, this experiment came to a sudden end on September 18 due to attack of strong typhoon. The fish production shown in Table 5 represents the catch from three gillings made on June 24, July 19, and August 28.

When 8-9-2 chemical fertilizer was applied to the pond water in this experiment, considerable attention was paid to the prevention of the bloom of plankton algae. During the second fertilization period when there was a bloom of the benthonic algae and the salinity of the water was 3.5 per cent or more, the application of 100 kg./ha. of 8-9-2 chemical fertilizer usually brought the algae to more vigorous growth on the bottom. While in the early part of the rainy season, when the pond water was still clear and its salinity not lower than 1.5 per cent, the application of chemical fertilizer generally resulted in success provided there was enough sunlight penetration to the bottom surface. The experience gained is that, during the summer season, chemical fertilizer alone should not be applied to the pond water when: (1) the water is turbid or semi-turbid, (2) when the salinity of the water is less than 1.5 per cent, and (3) when the weather is cloudy.

From Table 5, it will be observed that the application of 1300 kg./ha. of 8-9-2 chemical fertilizer produced 1051 kg./ha. of fish from five months of rearing. This is an increase of 123 kg./ha. over the quanity produced by application of 2500 kg./ha. of rice bran plus 2000 kg./ha. of hog manure (roughly the established fertilization practice). It is apparent that careful application of chemical fertilizer would give satisfactory result that compares well with organic materials even during the third fertilization period. One should bear in mind, however, that the results obtained by using chemical fertilizer in the third fertilization period would vary with the amount of rain fall and the intensity of sunlight during that period.

Ponds treated with 8-9-2 chemical fertilizer in mixture with rice bran or hog manure in the first and third fertilization periods should increase fish production, especially when a 1-to-1 mixture of 8-9-2 chemical fertilizer and rice bran was used during the third fertilization period,

When 900 kg./ha. of 8-9-2 chemical fertilizer plus 400 kg./ha. of either Leucaena-seed meal or soy-been cake were used, the fish production was approximately equal to the amount of fish produced by application of 2500 kg./ha. of rice bran plus 2000 kg./ha. of hog manure. Apparently, the results obtained by the experiment of this year correspond somewhat to the findings from the experiments made in the previous three years.

The addition of 3 per cent of superphosphate to night soil used in the second fertilization period resulted in a fish production of 24 kg./ha. more than that without the addition. Although this figure could not be considered as significant, the difference in effect was quite apparent from field observation.

Table 5. Production of Milkfish from Various Fertilizer Treatments in a 5-month Experiment from April to September 1956.

Fertilizer Treatment, kg./ha.			Fish production, kg./ha.		
1st Fertilization period	2nd Fertilization period	3rd Fertilization period[1]	2-year milkfish	1-year milkfish	Total[2]
500 8-9-2	150 Tea-seed cake 200 8-9-2	600 8-9-2	783	313	1051
500 8-9-2	150 Tea-seed cake 100 8-9-2 6000 Night soil+200 S.P.[3]	300 8-9-2 400 Leucaena-seed meal	791	132	923
500 8-9-2	120 Tea-seed cake 100 8-9-2 6000 Night soil	300 8-9-2 400 Soy-bean cake	605	294	899
500 8-9-2+1000 hog manure	120 Tea-seed cake 100 8-9-2 6000 Night soil+200 S.P.	300 8-9-2+300 rice bran 400 Rice bran	796	360	1156
200 8-9-2+600 rice bran	120 Tea-seed cake 100 8-9-2 6000 Night soil+200 S.P.	1500 Rice bran	646	375	1021
1000 Rice bran 2000 hog manure	120 Tea-seed cake 6000 Night soil	1500 Rice bran	678	250	928

1. For each application, 100 kg./ha. of chemical fertilizer was used.
2. Three harvests by gilling were made on 6/24, 7/19 and 8/28/'56.
3. S.P.=Superphosphate

DISCUSSION

The importance of benthonic algae as food for milkfish in brackishwater ponds has been recognized by a number of workers in various countries (Yamamura, 1942 in Taiwan; Schuster, 1949 in Indonesia; and Rabanal, 1949 in the Philippines). Markus (1941) further states that there is a marked relationship between the production of fish and the growth of benthonic algae in the milkfish ponds of Indonesia. Fertilization of milkfish pond, therefore, is undoubtedly for the purpose of increasing the benthonic algae, especially the colonial blue-green algae of the order ***Oscillatoriales***, which seems to be most important to the milkfish under harvestable size (see also Schuster, 1949,).. The effect of fertilizer on the growth of this type of algae has been found to vary according to soil, water, and climatic conditions of the pond· In Taiwan, it has been found that temperature, salinity, turbidity, sunlight, and the propreties of bottom soil are the most important factors, and, under certain conditions, each is possible of becoming a limiting factor for the growth of this type of algae in in fertilized ponds.

As to the bottom soil, Markus (1941) states that the capability of production of benthonic algae always coincides with the occurence of a highly hydrophile mud covering the pond bottom. Apparently, the properties of the bottom soil should have important relationship to the action of the fertilizer. Therefore, a critical study of the physical, chemical and microbiological characters of the bottom soil is needed for determining the most desirable kinds and amounts of fertilizer under various condition of the pond.

In the milkfish ponds of Taiwan, environmental conditions are favorable in the early part of spring for the application of chemiaal fertilizer to the pond bottom to establish colonial blue-green algae in the bottom. But, with the coming of the rainy season during the summer, conditions turn to favor the bloom of plankton algae in the water. These plankton algae are undesirable in the milkfish pond because they prevent the growth of benthonic algae by shutting out the sunlight. The effect and technique of the application of chemical fertilizer to the turbid water and colloidal bottom during the latter part of the fish rearing season (from the middle of summer to the end of fall) need further study.

The nitrogen and phosphorus from the chemical fertilizers were both found to have good and rapid response after they were applied under favorable environmental conditions. Either of these two elements increased fish production when applied separately. But the combination of nitrogen and phosphorus in the ratio of about 2:1 or 1:1 seemed more effective. The application of inorgainic potash fertilizer seemed unnecessary to this type of pond, because large amount of this element is contained in both the water and the bottom soils.

Although our present knowledge of the nutritional requirments of the colonial blue-green algae on the bottom of milkfish pond is very meagre, observations made by Swingle (1947) on the fresh waters of Albama, U.S.A., showed that where the organic matter rich in nitrogen is decaying colonial green and blue-green algae often become dominant. A parallel is found in the bloom of benthonic algae resulting from heavy manuring with organic materials in the first fertilization period followed by the application of tea-seed cakes (broken into small pieces) to speed up the decay of the organic matters in pond bottom. The present experiments also showed that the application of chemical fertilizer in mixture with certain organic materials produced more fish than when the same amounts of the two materials were applied separately. It is possible that the decomposition of these organic materials in the ponds fertilized with inorganic fertilizers supplied, under favorable conditions, a substance or substances, possibly carbon dioxide (Swingle 1947), which might play the part of a limiting factor for the bloom of the colonial blue-green algae on the bottom.

SUMMARY

Experiments on the use of chemical fertilizer in rearing milkfish in the brackish-water ponds of Taiwan were conducted from 1953 to 1956. The results obtained from the experiments during the four years are summarized as follows:

1. Chemical fertilizer could be successfully used in the milkfish ponds of Taiwan in the early part of the fish rearing season to promote the growth of benthonic algae, which serve as feed of the milkfish.

2. The application of 300 to 500 kg./ha. of 8-9-2 or 8-4-2 chemical fertilizer on the pond bottom in the early part of spring gave satisfactory result.

3. The effective use of chemical fertilizer in the pond water during the rainy season of summer was limited to the prevalence of the following conditions: (1) when the pond water was clear, (2) when the salinity of the pond water was above 1.5 per cent, and (3) when sufficient sunlight was capable of reaching the pond bottom.

4. The average fish production from ponds treated with chemical fertilizer was approximately equal to that produced by treatment with double the amount of rice bran (the most important fertilizer used in the milkfish ponds of Taiwan) or 30 times the amount of night soil (pond fertilizer next in importance to rice bran) during the four to six months at the beginning of the fish rearing season. The local cost of the 8-9-2 chemical fertilizer (containing ammonium sulphate, superphosphate and potassium chloride), rice bran and night soil are NT$1,585.00, NT$1,783.00 and NT$65 per metric ton respactively at the time of writing.

5. The application of chemical fertilizer in mixture with certain organic fertilizer to milkfish ponds resulted in increased fish production as compared with the ponds receiving chemical fertilizer or organic manure in the same amount separately.

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