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MULTI-ADVERSITY RESISTANCE BREEDING PROCEDURE IN COTTON IN THE PHILIPPINES

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ABSTRACT

The rapid accumulation of genes that condition multi-adversity resistance is made possible through sequential selection pressures exerted in several stages of the crop from seed to maturity and retaining only the superior individuals in each stage.

The selection criteria for seeds are size and density while deterioration and velocity are used in the germination stage. For seedlings, the criteria are damping-off and nematode resistance. On the other hand, aphid and leafhopper tolerance are selected for in the vegetative stage and bollworm and flowerweevil tolerance at flowering and bolling stages. Hairiness and nectariless characteristics are also selected for including high number and weight of bolls per plant and high lint recovery.

Introduction

Improved crop varieties are a key to progressive agriculture. Substantial improvements in seedcotton yield, resistance to pests, fiber quality and utilization of the cotton seed for animal feed and human consumption can be attained through skillful manipulation of cotton genotypes.

The Philippines benefits from the experiences of cotton-producing countries especially on insect and disease control researches. The unfortunate consequence of depending almost entirely to chemical pest control prior to the 70's has spurred new research directions in cotton pest control. Host-plant resistance to cotton insects and diseases is now in advanced stages of development in some countries. The following characters are important in pest control and can be incorporated in our varieties:

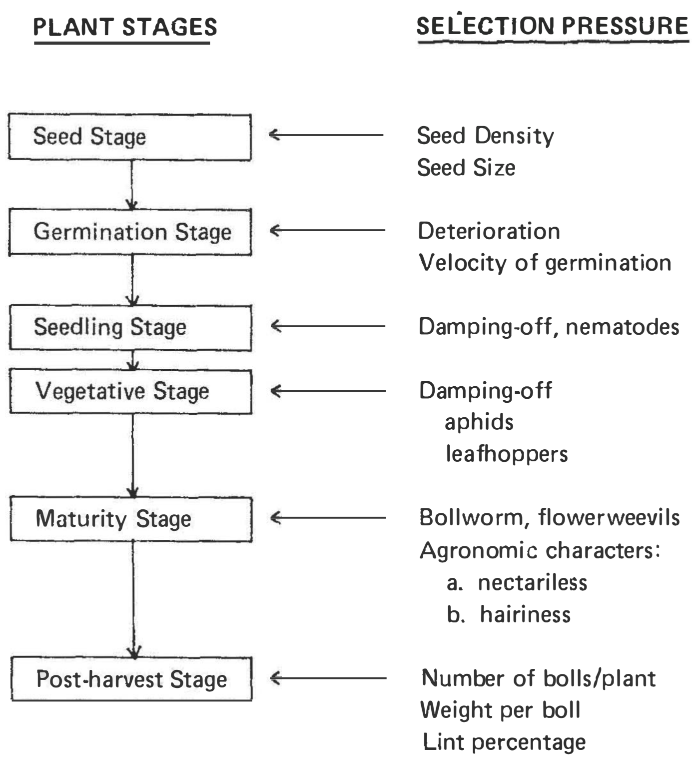
1. Nectariless (absence of nectar-producing glands). In Mississippi, this character was found to account for about 60% reduction of plant bugs and *Heliothis* sp. in cotton.
2. Hairiness – a coat of long hairs on the surface of the leaves prevents damage due to leafhoppers (Hautea, 1980; Toledo, 1980).
3. Deciduous bract (bract falls off after boll formation). This character

appears important in controlling boll rot and more importantly helps in controlling the lung disease (byssinosis) of cotton mill workers.

Procedure in Breeding for Multi-Adversity Resistance (MAR)

The main objective of the technique is to select cotton genotypes that possess multi-adversity resistance by exposing the selection population to a series of selection pressures throughout the growing cycle of the plant. The procedure is effective and efficient in screening large number of genotypes in a short time to be of good value to cotton plant breeding. The procedure involves exerting selection pressures on the different stages of the crop (from seed germination to maturity) and retaining only those superior individuals which give resistance and escape from adversities.

Advanced generation crosses either heterozygous-heterogenous (F_2, F_3, etc.) and heterogenous-heterozygous population as well as established cultivars are subjected to the program. The following diagram briefly illustrates the multi-adversity breeding procedure:



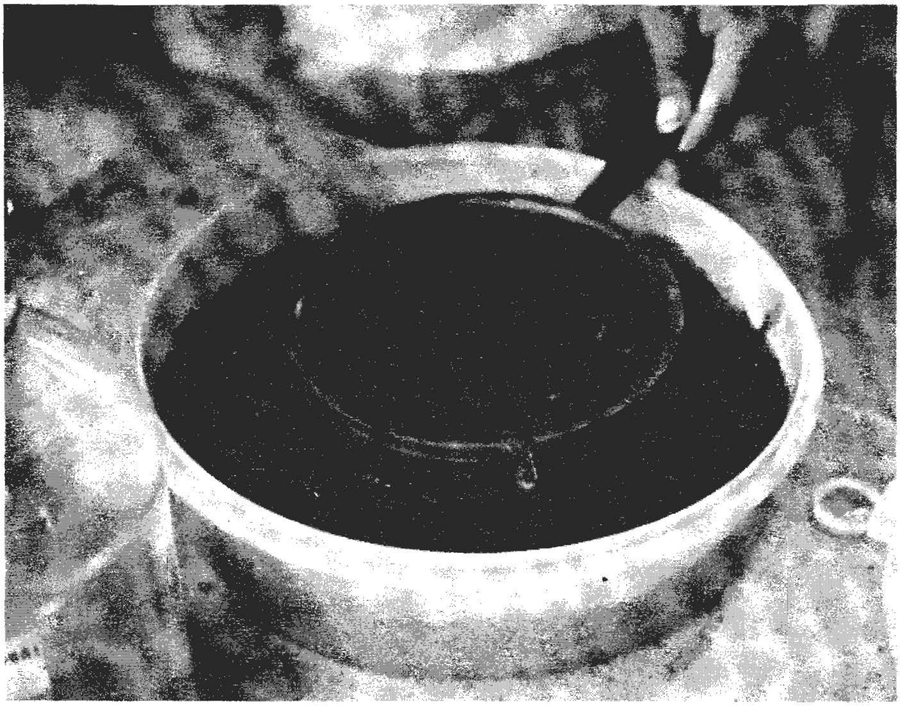


Figure 1. Cotton seeds are delinted in sulfuric acid solution before they are sorted wherein only large, dense and fully-developed seeds are selected.

Each stage of plant growth is subjected to adversities from the seed stage to the post-harvest stage.

Seed Stage

At this stage, seeds are bulked resulting to a mixture of mature, immature and insect-infested seeds. However, a simple selection based on seed density and seed size is made. These are indices of survivability and field performance of plants. Cotton seeds are delinted in sulfuric acid solution, washed thoroughly in running water and then dried. Delinted seeds are sorted, selecting only large, dense and fully developed seeds. Sorting of seeds could either be done manually or by using the flotation method.

Large, dense and fully developed seeds have been shown to be able to tolerate seedrot and damping-off, tend to grow faster and become more vigorous and early maturing (Cabangbang, 1978). Dense or heavy seeds are believed to be of high quality since the cotyledons that constitute the large position of the seed is responsible for their being heavy or light. Seeds that do not reach full development before harvest are immature, hence cotyledons that do not reach full development, when

Table 1. Comparative performance of seeds at different germination velocities (UPLB-PCARR Project 147, 1975-79).

Germination velocity (Days after germination)	*Seed-rot and mold infection (%)*	*Damping-off infection (%)*	*Abnormal plants (%)*	*Discarded plants (%)*	*Plants selected (%)*	*Early maturing plants (%)*	*Plant height (%)*	*Boll diameter (cm)*	*Lint (%)*
2	10.4	4.2	22.1	44.9	35.0	55. 0	79.58	3.27	36.16
3	4.7	3.8	31.9	40.7	60.5	41.10	83.37	3.31	33.95
4	10.5	3.7	41.3	50.3	49.7	45.83	83.32	3.30	35.75
5	8.9	4.5	35.3	47.4	52.5	33.26	79.65	3.30	36.02
6	15.1	3.2	26.1	42.4	57.4	22.03	77.60	3.18	36.41
7	34.1	4.1	20.5	56.1	43.8	22.03	72.89	3.11	34.85
8	54.0	3.5	23.13	79.13	20.3	–	74.58	3.31	25.75
MEAN	19.67	3.8	28.6	51.6	45.6	36.5	78.7	3.25	35.55

Figure 2. Seedlings from rapidly germinating seeds are selected and transplanted in plastic cups.

dried, shrink. The air spaces in the seeds are believed to be responsible for the floating of seeds when put in water separating them from "full" seeds that sink to the bottom. The seeds that float are categorized as light seeds and are discarded.

Germination Stage

Selection at this stage is based on deterioration resistance and fast germinability. At this stage, selected seeds from the different entries are germinated in flat trays moistened with pond water covered with moistened materials, e.g. newspaper, provided with an aerobic condition. Pond water encourages seed rot and mold infection. Seeds that do not deteriorate and those that germinate faster are selected. On the other hand, seeds that deteriorate or those that are slow to germinate prolong the period at which they are attacked by microorganisms thus killing them before they can establish themselves into full seedlings. Consequently, those seeds that germinate earlier can benefit from the moisture available in the field at planting time. Studies at UPLB-CA (Cabangbang *et al.*, 1978; Mateo, 1981), on the correlation of resistance to deterioration and germination velocity of seeds to some agronomic features gave evidence to support the soundness of the selection criteria (Table 1).

Table 2. Summary of performance of cotton strains subjected to MAR procedure (1979).

Set No.	*Weight of seeds selected (g)*	*Number of plants transferred to cups*	*Number of plants transformed to pots/seed flats*
1	260	818	–
2	348	891	129
3	360	1,178	12
4	245	1,076	133
5	193	387	51
Total	1,406	4,350	325

Only those seeds which germinated rapidly within 3-4 days from sowing and without mold infection are selected and consequently transplanted in plastic cups.

Seedling Stage

In many cases, seeds may have a germination percentage of 90% and above. However, actual emergence in the field with normal planting conditions will sometimes be 50% or less. Almost always, the seeds germinate but fail to emerge or develop into healthy seedlings. It is the purpose of selecting genotypes that can tolerate seedling diseases to correct this anomaly.

Aside from the effects of extreme fluctuation of moisture supply at planting time, seedling diseases such as seed rot, pre-and post-emergence damping-off and root rot result in reduced field stand. These diseases are caused by a number of fungal and nematode species. The screening procedure against the two pests could be carried out most conveniently and effectively by combining the two organisms in the same media. Seeds are sown in plastic cups infected with *Sclerotium rolfsii* and *Potylenohulus reniformis.* The interaction between nematode and damping-off organisms is a significant phenomenon in this procedure. The presence of nematodes increases the susceptibility of cotton plants to fungal infections by providing infection points for the fungi.

After a period of approximately one month on this selection pressure, five individuals with vigorous and disease-free seedlings or genotypes that are resistant to or can tolerate infection are selected for the next stage of selection pressure.

Vegetative Stage

The selection pressure applied at this stage is confined to sucking insects that greatly affect plant performance. Among the common insects found at this stage are aphids, leafhoppers, thrips and defoliators. The screening consists of rearing

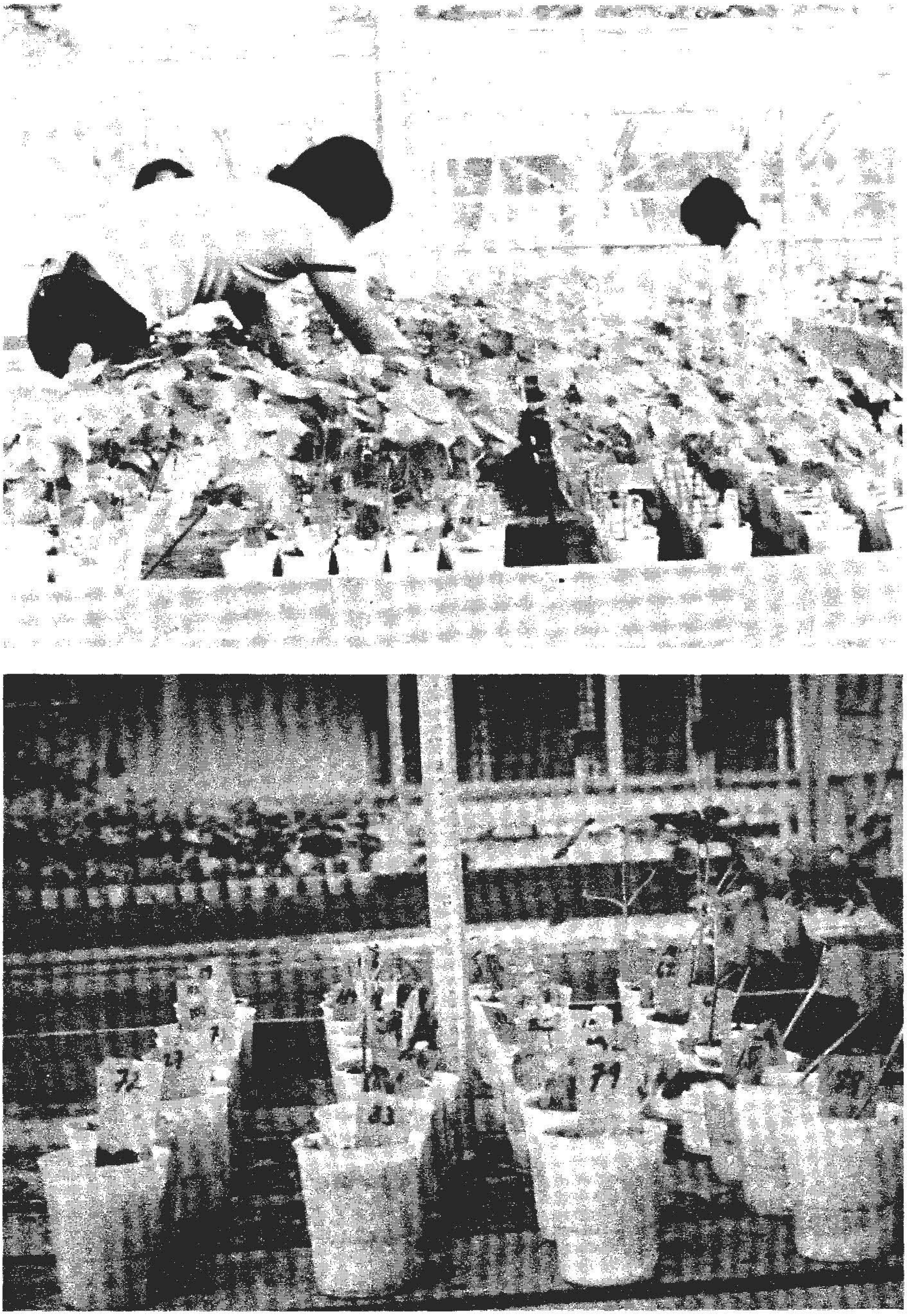


Figure 3. Genotypes that can tolerate seedling diseases like seed-rot, damping-off and root-rot, are selected for at the seedling stage.

Table 3. Performance of MAR selections tested in 2 locations (1979).

Entry	*College, Laguna*				*San Juan, Ilocos Sur*			
	Plant height (cm)	*Weight per boll (cm)*	*Seedcotton yield (kg/ha)*	*Lint recovery (%)*	*Plant height (cm)*	*Weight per boll (cm)*	*Seedcotton yield (kg/ha)*	*Lint recovery (%)*
MAR-67	103.5^{ab}	5.07^{a}	2124.24^{a}	33.97^{a}	64.9^{b}	4.64^{b}	1372.75^{a}	36.53^{a}
MAR-68	133.7^{a}	5.37^{ab}	1740.65^{a}	35.99^{a}	73.0^{ab}	5.43^{a}	1290.96^{a}	38.92^{ab}
MAR-72	98.5^{b}	5.39^{ab}	2368.11^{ab}	34.62^{a}	66.9^{b}	4.79^{a}	1490.74^{a}	35.72^{b}
MAR-82	104.0^{ab}	5.65^{a}	2229.26^{a}	36.02^{a}	79.0^{a}	5.02^{a}	1468.35^{a}	40.55^{a}

Means followed by the same letter(s) are not significantly different from each other.

Figure 4. Disease-free seedlings are selected and transferred to pots for the next stage of selection pressure.

a large number of the three insect species and infesting the seedlings one after the other. When natural infestation of any one of the three insect species is heavy, artificial infestation is discontinued.

Maturity Stage

Selection for morphological features as well as resistance to insects attacking the flower, squares, bolls and other parts is accomplished at this stage. These agronomic characters include nectariless, and hairiness.

The nectariless character of the plant refers to the absence of gland which produces the nectar that serves as an attractant. Nectaries are also major sources of food, primarily sucrose, for several types of moths.

This character has been reported to provide beneficial levels of resistance to plant bugs (*Lygus lineolaris*), cotton leafhopper (*Predatomoscelis sireatus*) and pink bollworm (*Pectinophora gossypiella*). Boll rot organism has been reported to enter through extrafloral flower and boll nectaries; thus, nectariless cotton has reduced boll rotting (Shepherd, 1982).

The screening procedure for bollworm and flowerweevil resistance is quite flexible since a number of techniques could be employed. These include mass rearing and artificially infesting the insect pests and/or subjecting the plants to

Table 4. Mean performance of different cotton varieties in Manaoag, Pangasinan and College, Laguna (Advanced Trial, 1982-81).

Entry	*Plant height (cm)*	*Weight per boll (g)*	*Seedcotton yield (kg/ha.)*	*Lint percentage*
Deltapine 16 (L)	76.9	4.41	994.2	37.5
Acc. 005	72.0	4.43	877.6	37.7
085	78.0	4.07	961.0	36.6
111	75.4	4.38	1020.0	37.2
142	82.2	3.64	907.1	33.1
161	73.4	4.56	994.3	39.1
162	79.2	4.43	948.9	38.2
164	79.3	4.42	958.9	35.4
385	76.7	4.61	956.7	35.8
MAR-67	92.0	4.69	898.3	35.3
MAR-72	93.0	4.43	916.8	33.9
MAR-82	91.2	4.74	780.9	37.7

Table 5. Mean performance of cotton varieties in College, Laguna: Victoria, Tarlac and Polomolok, South Cotabato (Advanced Trial, 1981-82).

Entry	*Plant height (cm)*	*Average weight per boll (g)*	*Seedcotton yield (kg/ha.)*	*Lint percentage*
Batac 1	80.8	4.3	1580.2	37.9
Deltapine 16(L)	83.6	4.4	1379.5	39.0
Acc. 001	80.2	4.5	1404.1	36.7
MAR-67	92.2	4.5	1170.9	33.8
MAR-72	103.2	4.6	1395.9	35.5
Acc. 157	90.8	4.3	1412.0	38.6
394	87.9	5.1	1619.2	36.6
396	71.1	4.2	1659.7	38.8

natural infestation. Growing alternate hosts including susceptible cotton varieties earlier to increase insect population level in time for the selection population is also a convenient method. The problem with this procedure, however, is the complication brought about by the infestation of other insect pests which could not be controlled without killing bollworm or flowerweevil.

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Figure 5. The selection pressure applied at the vegetative stage is confined to sucking insects that greatly affect plant performance.

Table 6. Performance of cotton accessions in the 1982-83 preliminary trial at College, Laguna.

Entry	*Plant height (cm)*	*Number of bolls per plant*	*Seedcotton yield (kg&ha.)*	*Lint recovery (!)*
UPL-C1	124.09	5.29	1490.8	39.20
UPL-C2	107.00	5.42	1693.4	38.54
Deltapine 16(A)	120.33	6.36	1862.5	39.28
Acc. 431	140.67	9.25	1882.2	39.66
432	131.33	7.81	1829.7	41.97
436	118.67	7.79	1807.8	40.16
437	100.50	7.19	2135.7	40.63
438	110.00	6.65	1984.1	39.90
439	135.80	5.11	1514.6	39.57
454	154.00	8.97	1641.0	34.03
459	131.00	6.95	1876.4	36.71
MAR-5	117.00	5.09	1234.6	36.72
6	111.67	6.66	1472.1	39.22
7	100.33	6.33	1517.9	38.28
8	105.33	7.73	1505.1	33.74
9	112.00	7.30	1715.3	37.86
10	120.33	6.73	1679.0	34.24
11	122.33	9.40	2380.5	39.51
12	132.33	5.82	1585.9	35.60

Table 7. Fiber properties of cotton accessions in College, Laguna (Preliminary Trial, 1982-83).

Entry	*Staple length (mm)*	*Fineness (ug/in)*	*Tensile strength (psi)*	*Fiber maturity (%)*
UPL-C1	29.0	4.3	77,528	85.0
UPL-C2	29.0	4.4	81,871	88.0
Deltapine 16(A)	29.5	4.1	73,657	86.5
Acc. 431	27.5	3.9	70,577	79.0
432	26.6	4.4	74,941	88.0
436	29.1	4.1	73,277	84.0
437	29.2	4.2	72,669	86.0
438	29.2	3.4	73,123	77.0
439	29.3	4.1	83,342	87.0
454	28.3	4.3	78,848	88.5
459	29.0	4.2	82,364	86.5

Table 7 continued

Entry	*Staple length (mm)*	*Fineness (ug/in)*	*Tensile strength (psi)*	*Fiber maturity (%)*
MAR-5	27.3	4.3	84,620	92.5
6	28.7	4.1	74,789	80.0
7	28.8	4.3	74,864	85.0
8	26.3	4.7	72,467	81.5
9	28.6	4.3	74,701	82.5
10	26.7	4.5	70,597	85.0
11	25.3	4.8	76,785	87.0
12	27.5	4.2	74,277	87.5

Table 8. Performance of cotton varieties entered into the Advanced Trial in three locations (1982-83).

Location	*Entry*	*Plant height (cm)*	*Number of bolls per plant*	*Seedcotton yield (kg/ha.)*	*Lint recovery (%)*
College, Laguna	UPL-C1	93.46	7.29	2021.8	41.30
	UPL-C2	89.60	6.05	1902.7	38.45
	Deltapine 16(A)	106.53	7.22	2016.4	38.62
	Acc. 043	96.13	6.04	2133.0	36.35
	184	94.67	5.09	1754.6	36.90
	MAR-1	109.14	4.36	1669.9	36.63
	MAR-3	125.78	4.21	1529.3	34.39
San Juan, Ilocos Sur	UPL-C1	88.20	6.70	2481.0	40.90
	UPL-C2	88.40	7.80	3014.0	37.20
	Deltapine 16(A)	102.20	6.70	2926.0	33.30
	Acc. 043	94.50	6.80	3061.0	35.50
	184	78.10	5.90	2220.0	36.40
	MAR-1	118.80	4.90	2252.0	40.50
	MAR-3	127.00	4.40	1911.0	36.30
Polomolok, South Cotobato	UPL-C1	102.00	9.50	1900.0	41.10
	UPL-C2	79.90	8.60	2020.0	41.50
	Deltapine 16(A)	107.00	8.60	2320.0	41.60
	Acc. 043	101.20	8.90	2110.0	39.60
	184	93.80	7.40	2060.0	37.80
	MAR-1	109.10	6.40	2220.0	41.00
	MAR-3	120.10	7.70	1750.0	39.20

Table 9. Fiber properties of cotton accessions tested in 3 locations (Advanced Trial, 1982-83).

Location	*Entry*	*Staple length (mm)*	*Fineness (ug/in)*	*Tensile strength (psi)*	*Fiber maturity (%)*
College, Laguna	UPL-C1	28.6	4.10	75,378	85
	UPL-C2	28.7	4.60	84,713	91
	Deltapine 16(A)	28.9	4.00	74,154	83
	Acc. 043	28.1	4.00	81,603	84
	184	26.5	4.20	65,883	79
	MAR-1	26.3	4.00	78,258	85
	MAR-3	28.2	3.90	78,999	85
San Juan, Ilocos Sur	UPL-C1	25.6	5.05	80,305	89
	UPL-C2	28.4	4.36	88,069	87
	Deltapine 16(A)	25.1	5.07	76.939	94
	Acc. 043	25.4	4.56	84,639	88
	184	24.3	4.29	69,249	78
	MAR-1	25.3	4.28	81,361	86
	MAR-3	25.5	4.47	86.014	89
Polomolok, South Cotobato	UPL-C1	26.6	3.16	74,498	67
	UPL-C2	27.8	3.94	81,041	78
	Deltapine 16(A)	27.5	4.40	69,421	78
	Acc. 043	26.0	3.21	74,324	67
	184	26.1	2.90	68,661	54
	MAR-1	27.3	4.12	84.452	80
	MAR-3	26.4	3.68	76,177	77

Post-Harvest Stage

Seeds of plants possessing desirable characters are collected for the preliminary trial. Yield components such as number of bolls per plant, weight of bolls per plant, lint percentage and other necessary components are determined and serve as bases for selection.

a. Number of bolls per plant. Inasmuch as the plant had been subjected to similar stress condition, it is assumed that individual plants with more bolls have higher yield potentials than those with lesser number of bolls.

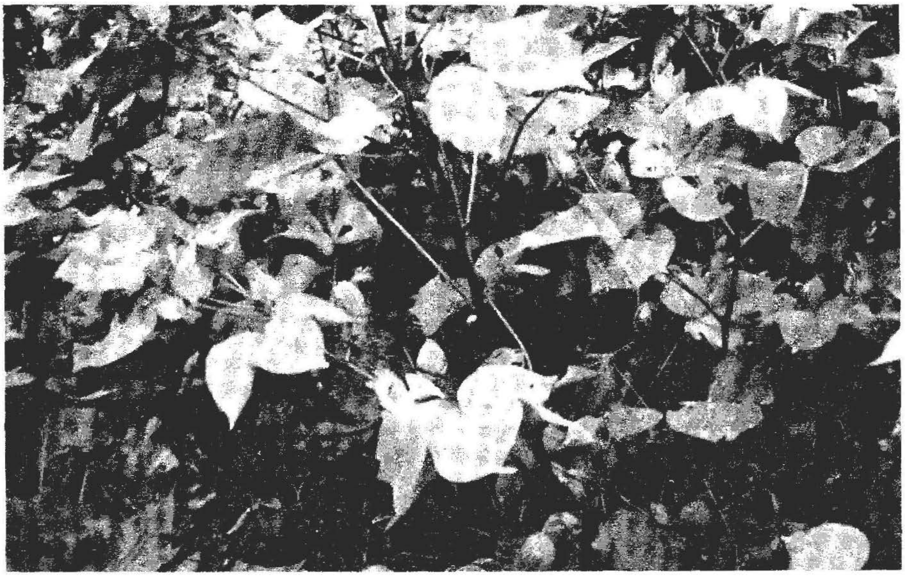

Figure 6. At the maturity stage, selection for morphological features as well as resistance to insects attacking the flower, squares, bolls and other parts is done.

Figure 7. Selected strains are entered into variety trials in different locations to obtain additional information on their resistance and agronomic characteristics.

b. Average weight per boll. Assuming the same number of bolls, plants with heavier boll will have higher yield potential than those with lighter bolls.

c. Lint percentage. Cultivars with high lint percentage is highly desired since quality and quantity of lint harvested determine varietal potential. Usually, lint recovery from the farm is about one-third of seedcotton harvested.

Varietal Trials

The performance of four (4) cotton strains subjected to the MAR procedure in 1979 is indicated in Table 2. In the same year four (4) selections from a previous MAR test were entered into the preliminary test in College, Laguna and San Juan, Ilocos Sur. Table 3 indicates the results of the test. Three of these varieties were carried on to the Advanced Trial at Manaoag, Pangasinan and College, Laguna in 1980 (Table 4). The Advanced Trial of 1981-82 again included two MAR selections (Table 5). This was conducted in three (3) locations: College, Laguna; Victoria, Tarlac and Polomolok, South Cotobato. During the 1982-83 cropping season, other MAR selections were entered into the preliminary (Tables 6 and 7) and advanced (Table 8 and 9) tests. These include the fiber properties of the cotton strains tested.

Conclusion

The MAR procedure should be a standard breeding technique for multi-adversity resistance. Subjecting the plants to a succession of pressure from seed stage to harvest stage should yield an improved population. The replicated yield trials are expected to give additional information for a more reliable index of resistance and agronomic characteristics.

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M.M. Lantin, Discussant

A crop breeding program is usually aimed at improving not only one but several traits that determine the total worth of a cultivar. In addition to yield and quality, traits being improved include production stabilizing attributes such as resistance to insect pests, diseases and environmental conditions that adversely affect crop productivity. Cotton is a host to a variety of pathogens and insect pests. It is one of the world's important crops that is grown under the protection of large amounts of pesticides. Genetic resistance to pests is obviously desirable and it is always a major objective of the total breeding effort for this crop.

Multi-adversity resistance (MAR) is a common goal of most crop breeding programs. Differences, however, exist in the basic strategies used in accomplishing this objective. The cotton breeding program at the Institute of Plant Breeding adopts a scheme wherein sequential selection pressures are imposed at various stages of the crop (during which the different adversities occur) from seed to maturity. It is an integrated and fairly comprehensive procedure that systematically combines screening for resistance to insect pests and diseases with selection for good seedling vigor and high yield. However, this same feature basically characterizes all multiple-trait selection schemes. So how does the MAR breeding procedure as described in the paper differ from the other schemes? What are the limitations of such a selection system? Under what conditions could we expect it to be successful?

The MAR breeding procedure is what one may call an "all-or-nothing" kind of selection system. If a particular genotype fails to pass the seed or seedling stage screenings then it is discarded and not exposed anymore to other adversities in later stages of growth. The high selection pressure imposed in the early stages usually results in the elimination of large fraction of the population being screened. The number is further reduced in subsequent stages and oftentimes, the breeder is left with very few genotypes even before the maturity stage. It may then turn out that the surviving few would not be acceptable because of low yield rating as indicated by the different yield components. This tandem method of improvement differs from the more common independent culling scheme where each genotype being evaluated has complete data on the traits which are being improved simultaneously. The breeder discards or retains a genotype on the basis of minimum scores set for the different traits. Such breeding procedure recognizes the possible inverse relationships that may exist among traits. In such cases, the breeder may choose to give higher weights to more important traits. For example, the breeder would probably save a genotype that yields 4 tons per hectare even if it has a relatively lower level of resistance to a disease. Combining the traits in an index which becomes the sole selection criterion could even lead to faster progress.

Progress in plant breeding, however, is not solely dependent on the selection procedures or the means through which the desired genotype is isolated from the source population. The nature of the breeding population itself plays an equally important, if not a more dominant, role. No amount of selection effort would result to the desired type if, to start with, the genes are not present in the source population. The key to the successful development of the target genotype through MAR breeding procedure or any multiple-trait selection scheme is the creation of a broad-based gene pool which has all the genes controlling the desired traits. This is developed out of germplasms previously screened or evaluated for the different traits. Such assemblage of genes should be allowed to undergo as many generations of recombination as possible in order to generate new genic combinations involving as many resistance genes and yield genes as required. Selection can then proceed with higher probability of isolating the desired high-yielding and multi-adversity resistant cultivar.

Gregorio B. Begonia, Discussant

By exposing the selection population to a battery of selection pressures throughout the growing cycle of the plant, we can select cotton genotypes possessing multi-adversity resistance in a relatively short time. The above features of the MAR breeding technique as excellently described by Dr. Cabangbang make the method a very efficient and effective tool in plant breeding – especially in cotton where it was first tested way back in the early 60's.

However, despite the merits and simplicity of the breeding procedure, there are some points that need further clarification.

a. *Definition of the parental generation:*
The characteristics/attributes of the parents involved in the crosses must be clearly defined. It is very unlikely that we can find all the necessary attributes in a few parents. In other words, we need a substantial number of parents to create a wide germplasm pool that contain all the attributes mentioned in the MAR procedure. If we have already created a wide germplasm pool, I think that is the appropriate time to tinker with MAR.

b. *Population Size:*
If we commence the MAR procedure using F_2, F_3, etc. materials, how big is the population to start with? The basic question here is: How many genes control each of the characters involved in the MAR procedure? We must note that as the number of genes determining a certain character is increased, a corresponding increase in the population is needed in order to obtain the desirable recombinations. Also, the question of population size is further complicated if there is *linkage*. The closer the genes are, the lesser the chance to break that linkage. In order to observe the desirable recombination, you need a large

population. Furthermore, we still need to know the linkage relationship between characters.

c. *What is the most effective generation for selection?*
Is it the F_2, the F_3, or what?
We must remember that not all characters can be effectively evaluated at an early generation of the segregating population (F_2, F_3). For example, if we use F_2, this may be effective for qualitative characters (e.g. petal colors, etc.) but not for quantitative characters (e.g. yield).

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MUTAGENIC RESPONSE OF PEANUT (*ARACHIS HYPOGAEA* L.) TO FAST NEUTRONS

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ABSTRACT

Dormant seeds of peanut were treated with varying doses of fast neutrons employing efficient pre- and post-irradiation techniques for determination of various plant responses useful in a long range program of mutation breeding. Mean reductions in seedling height and frequency of M_1 somatic mutations increased with increasing radiation dose. No reductions in M_1 seedset was obtained even in the dose above the LD_{50} of 1600 rads. The frequency of M_2 macromutations ranged from only 3.60-5.65 per 100 M_2 plants. The genetic basis of each of these radiation responses is briefly discussed.

The high sensitivity of M_1 peanut seedlings and growing plants to fast neutrons is probably due to the highly differentiated seed embryo at the time of irradiation while the radio-resistance exhibited by the matured plant appears to be related to the polyploid genome of the species.

Introduction

The more widely known human achievements in the utilization of the energy of the atom lies ironically in the field of weaponry for mass destruction. Relatively unknown to the bigger portion of the human population is the use of this energy for the improvement of crops which are of benefit to man. For instance in 1974, about a hundred new crop varieties were listed as having been improved through mutation breeding and officially released by various governments for widescale cultivation. Not a few plant radiation investigators, however, attach greater significance to this human effort than even the socio-economic impact of the improved crop types on the lives of millions of people in the food-hungry world. The emergence of a new technology for inducing hereditary change has revived interest in some of the age-old problems concerning the origin and future of the species, topics that have challenged the minds of thinkers since olden times.

As the pioneering studies of scores of plant radiation workers during the past four decades have not fully explored the intricate problems related to the control and direction of the induced mutation process, there is a need for further investigation for gaining a better mutagenic treatment. Moreover, most of the work in mutation induction through seed irradiation have made use mainly of sparsely-ionizing radiations, such as X-rays and gamma rays, and only a few studies have

Table 1. M_1 seedling height response of peanut to fast neutrons.

Fast neutron dose	*Total seedlings*	*Seedling height (cm.)* Range	Mean	% Control
0 (Control)	150	14.5–17.8	15.62	100.00
500 rads	150	13.4–15.7	14.55	93.15
1000 "	150	10.2–13.4	11.36	79.13
1500 "	150	6.7–11.6	8.14	58.52
2000 "	150	3.7– 7.9	5.98	36.28

Table 2. Frequency of M_1 peanut plants bearing somatic mutations after fast neutron seed irradiation.

Fast neutron dose	*Total M_1 Plants*	*Plants with somatic mutations* No.	Frequency per 100 plants
0 (Control)	1416	0	–
500 rads	1405	19	13.52
1000 "	1372	144	104.80
1500 "	1398	302	216.02
2000 "	1053	487	462.49

1978). Oxygen contamination during irradiation could result in an interaction between oxygen and radiation-induced oxygen-reactive sites prior to the initiation of soaking (Conger and Constantin, 1979). The advantage of employing neutrons in practical mutation breeding, i.e., reduced oxygen effect, is now widely recognized (Ramulus and Ranjasumy, 1972). Neutrons have been reported to be up to 40 times more effective than sparsely-ionizing radiations on dormant seeds at the D_{50} level of damage but only 6-8 times more effective on germinating seeds (Conger *et al.*, 1973).

The frequency of M_1 plants with somatic mutations which consisted mainly of leaf flecking on seedlings and leaf sectoring (Table 2) increased with increasing fast neutron dose. The formation of somatic mutation in plants growing from mutagen-treated seeds is believed due mainly to chromosomal change. Breakage of chromosomes accompanied by genetic deletion has been found to be the most probable mechanism for the formation of chimeral sectors (Mericle and Mericle, 1967). The high frequency of somatic mutations in M_1 plants after fast neutron seed-irradiation is probably an indication of the effectivity of densely ionizing radiations on biological material when their effects are not altered or modified by

Table 3. Mean M_1 seedset in peanut after fast neutron seed irradiation.

Fast neutron dose	*Total M_1 plants*	*Range (%)*	*Mean (%)*	*% control*
0 (Control)	25	85.76–97.36	91.46	100.00
500 rads	25	73.82–94.14	84.22	92.08
1000 "	25	69.67–88.39	79.65	87.09
1500 "	25	64.85–81.76	72.84	79.64
2000 "	25	51.08–82.35	68.07	74.43

conditions in the cellular environment. Of interest is the suggestion that chimerism often results from a mutation in a few apical cells and will likely become perpetuated in the meristem cells bearing chromosomal aberrations (Conger *et al.*, (1973). Compared with the seedling growth response of barley *(Hordeum vulgare* L.), a species widely used as the standard test material in seed irradiation with an LD_{50} at a dose of 1120 rads (Soriano *et al.*, 1971), peanut is much more radioresistant due invariably to its being a polyploid with a chromosome number of 2N=40 (Ashri, 1982; Kirti *et al.*, 1982). With mungbean (*Vigna radiata*), LD_{50} for seedling height was found close to a thermal neutron dose of 30 x 10^{12th} N/Cm^2/sec (Kwon and Oh, 1983).

In the present study, pre- and post-irradiation conditions known to influence seed response to densely-ionizing radiations (Conger and Constantin, 1979) were largely minimized. Previous studies on peanut even with sparsely-ionizing radiations appear to have failed to consider this aspect of the work except a report (Gregory, 1968) dealing with gamma ray treatment of seeds with only 8% moisture content.

Modification of the effects of fast neutrons with seed moisture content and oxygen have definitely been achieved (Angstrom, 1968) contrary to a previous idea that only those of sparsely ionizing radiations could be so modified. However, seed moisture content has been reported to be the most important factor modifying fast neutron effects (Conger and Carabia, 1972). Post-irradiation storage likewise has been found to enhance fast neutron damage (Gopal-Ayengar *et al.*, 1977). Lower reductions in OER were reportedly obtained with increasing ionization density for as long as such mutated cells retain their apical position (Balkenia, 1972). Chimerism in plants with irradiated origin has been specifically associated with persistent dicentric chromosomes (Contant *et al.*, 1971). Furthermore, leaf sectoring after exposure to radiation was reported to be due to chromosomal aberrations which increase exponentially with dose (Kaplan, 1977).

The data on M_1 seedset are shown in Table 3. No significant reduction in ovule fertility after fast neutron seed irradiation was found even in the dose higher than LD_{50}. This radioresistance may be due to the polyploid nature of the peanut

Table 4. Frequency of macromutations in some M_2 lines of peanut after fast neutron seed irradiation.

M_2 line	*Total plants*	*No. of macromutants*	*Frequency of macromutants per 100 M_2 plants*
8446– 1	194	11	5.65
8446– 2	250	9	3.60
8446– 3	197	8	4.06
8446– 4	236	10	4.24
8446– 8	608	23	3.78
8446–14	243	12	4.94

genome (Ashri, 1983). While the M_1 seedlings and growing M_1 plants showed high sensitivity to radiation, the mature plant failed to manifest a similar degree of response. Polyploids are known to be quite resistant to mutagenic treatments due probably to their having more than a duplicate set of chromosomes. At the molecular level, polyploids have been reported to contain more DNA per cell than their diploid counterparts (Sparrow *et al.*, 1971) and are thus able to overcome the effects of genetic damage effectively.

Table 4 shows the frequency of macromutants in the M_2 generation. These consist mainly of dwarf plants, plants with five-leaflet leaves, odd-pinnate leaves, variegations, dark-green plants and early flowering, characters previously found to be inherited in the selfed progeny of the M_2 variants. The frequencies of macromutants of 3.60-5.65 per 100 M_2 plants in the six M_2 lines are rather low compared with mutation frequencies in diploid species after seed treatment with either sparsely- or densely-ionizing radiations. Both types of radiation reportedly induce the same types of genetic changes (Borojevic, 1975). Compared with neutron-irradiated material, the germinal mutation frequencies obtained in peanut are rather low. For instance in soybean, an M_2 mutation frequency of 24 per 1000 M_2 plants was obtained after irradiation of seeds with a dose of only 1000 rads fast neutrons (Hendratno *et al.*, 1982) and in mungbean, mutation frequencies of 8.43% and 10.76% were obtained after seed treatment with thermal neutrons (Kwon and Oh, 1983).

Most of the mutant types were, however, partially sterile due probably to chromosomal damage possibly of the exchange type which reportedly could get transmitted to the succeeding generations (Schori and Ashri, 1970). The association between a mutant character and chromosomal aberration may explain the low mutagenic specificity commonly obtained after seed irradiation (Smith, 1972). Fast neutrons have been reported to be more effective than sparsely ionizing radiations for inducing genetic variations which may, however, be mostly quantitatively inherited, an indication that those mutations are due to chromosomal alterations rather than "point" mutations (Daly, 1973).

Finally, the genetic response of peanut at the mature stage appears typical of polyploids characterized by low response to treatment. This is evidenced by the relatively small reductions in seedset and low frequency of M_2 mutations. This low response of peanut to fast neutrons is most probably due to the tetraploid genome and the somatic competition that invariably occurs between normal and mutated cells during the growth stages of the M_1 plant. The chromosome number of peanut of 2N=40 may have originated either through polyploidization of a wild species (*Arachis monticola*) with 2N=20 or through fusion of the diploid genomes of *A. villosa* which is believed to have contributed the A-genome of cultivated peanut and *A. baticoci*, the B-genome (Kirti *et al.*, 1982). On the other hand, the high sensitivity of peanut seedlings and growing plants may have been brought about by its well-differentiated seed embryo (Emery, 1972) with an extremely large plumule which consists of 10 leaves and four axillary buds. As the epicotyl does not produce new parts during the first three weeks of growth, radiation damage in the treated seed embryo is reflected by the high response of the M_1 seedlings of that age.

Summary and Conclusion

1. In general, a linear dose-response relationship was obtained for seedling growth reductions and frequency of M_1 plants with somatic mutations. LD_{50} was found at a dose of approximately 1600 rads.

2. The high sensitivity of peanut seedlings and growing M_1 plants to fast neutrons after seed irradiation may have been due to the highly differentiated embryo at the time of treatment.

3. Radioresistance of peanut to the treatment, shown by low M_1 seedset reductions and low frequency of M_2 mutations, appears to be associated with its polyploid genome.

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Adoracion T. Arañez, Discussant

The study of Dr. Joventino D. Soriano on mutagenic response of peanut to fast neutrons may pave the way for the improvement of peanut varieties in the Philippines. According to Sigurbjornsson and Micke (1974), the technique of mutation breeding can be recommended to plant breeders as a practical tool with a reasonable guarantee of success. However, it appears that many plant breeders are unaware that the use of this technique has resulted in noteworthy plant breeding advances. They attributed this partly to the publication of works on induced mutations and mutation breeding in proceedings with distribution that is limited beyond their own circles. Mutation breeding may be done by direct multiplication of mutants or mutants may be used in cross breeding. The estimated value of induced mutant crop varieties now grown by farmers, shows that the net value of these crops outshines any cost that have gone into mutation breeding research. Around 145 mutant varieties are developed through the use of induced mutations as early as 1974. The mutagens used which have led to the development of superior varieties are X-rays, gamma rays, neutrons and chemical mutagens. Among the improved characters of crop varieties developed through induced mutations are higher yield, lodging resistance, disease resistance, early maturity, short stem, quality, winter hardiness, higher protein, shattering resistance, improved plant type and easier harvesting. Released varieties developed through induced mutations are cereals, legumes, fruit trees, ornamentals and other crops (Sigurbjornsson and Micke, 1974).

Researchers at the Philippine Atomic Energy Commission (PAEC) have produced through mutation breeding four new high yielding varieties of rice, four improved varieties of mungbean and a compact soybean mutant (PAEC Accomplishment Report, 1972-80).

A change in only one or few bases of the DNA may give rise to a mutant allele. A base substitution in the polynucleotide alters a codon. A different amino acid may be coded for by the new codon. The tertiary and quaternary configuration of a protein may be changed due to an alternation in the sequence of amino acids in the polypeptide. A change in the configuration of a protein may change its activity or property.

A study on human sickle-cell anemia showed that a change in one amino acid of a polypeptide chain is enough to produce an abnormal hemoglobin. The chemical abnormality of the sickle-cell hemoglobin resides in a change of a single amino acid. The 6th amino acid from the N-terminus of the β-peptide chain which is glutamic acid is replaced by valine. The triplet code for glutamic acid is GAA or GAG while that for valine is GUA or GUG (Goodenough and Levine, 1974). In either case, replacement of adenine by thymine will change the amino acid coded for by the triplet from glutamic acid to valine.

Gaul (1964) is of the opinion that plant breeding is controlled evolution and that in breeding, full use is made of two of the three main factors of evolution, that is recombination and selection. He added that mutation, which is the third factor and a primary evolution factor can be used for breeding. The variations produced by mutagens are not essentially different from those caused by spontaneous mutation during evolution (Sigurbjornsson, 1970).

It is hoped that in the future, more researchers will go into the use of mutagens in producing genetic variations especially for plants that are usually propagated by asexual methods, those with long vegetative phase prior to sexual reproduction and in lower forms which are usually haploid and of which the only way to change the genetic material is through the use of agents that are capable of modifying the DNA.

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Prescillano M. Zamora, Discussant

In the work just presented by Dr. J.D. Soriano, which he undertook vis-a-vis a long-range program of mutation breeding, the application of fast neutrons (in varying doses) on dormant seeds of peanut has elicited the following responses: (1) seedling height was reduced with increasing radiation doses, (2) frequency of M_1 somatic mutations was increased with increasing radiation doses, (3) M_1 seedset was not reduced even in the dose above LD_{50} of 1600 rads, and (4) frequency of M_2 macro-mutations ranged from only 3.60 to 5.65/100 M_2 plants vis-a-vis the control plants.

In discussing the genetic basis of each of the foregoing radiation responses of the experimental material, Dr. Soriano stated that the high sensitivity of the M_1 seedlings and of the growing plants is probably due to the highly differentiated state of the embryo at the time of irradiation, while the radioresistance exhibited by the mature plants appears to be related to the polyploid genome of the experimental material.

With the foregoing remarks as term of reference, I now would like to focus my comments on the probable developmental anatomic basis for that mutagenic response relating to the increased frequency of M_1 somatic mutations with increasing radiation doses and the proposed explanation that said response is probably due to the highly differentiated state of the embryo at the time of the treatment.

Depending upon the variety, the fruit of peanut generally contains 2-4 seeds placed in tandem within a single locule. The seed of peanut (in the mature fruit) consists of a large embryo (ca 1.0 cm long x 0.7 cm wide) and a seed coat. Structurally, the peanut embryo is very similar to that of other species of legumes (Reed, 1924; Yarbrough, 1949; Smith, 1956). It consists of an axis, the hypocotyl-root axis bearing, at one end, the root apical meristem and, at the other, the two cotyledons and the apical meristem of the first shoot, the epicotyl. According to one report (Yarbrough, 1957), the peanut embryo has not only a leafy epicotyl but also two lateral shoot primordia arising at the cotyledonary axis in the mature seed.

Developmentally, the peanut embryo follows a pattern that resembles closely that of a dicotyledonous species (Smith, 1956). Although it develops a multicellular suspensor, the type of embryo which forms may be categorized as a common angiosperm type. Four or five days after pollination, the embryo consists of about 5 to 13 cells. Eight to ten days after pollination, it still has only about 5 to 15 cells. But it grows rapidly on about the 11th day after pollination, so that on about the 30th day after pollination, the embryo is, as described above, large with a short hypocotyl-root axis, bearing a well-organized apical meristem, a small epicotyl (plumule) also bearing a well-organized apical meristem and two large fleshy cotyledons.

The highly organized epicotylar apical meristem is interpretable according to the tunica-corpus concept of shoot apex (shoot apical meristem) organization. Accordingly, two tissue zones occur in the epicotylar apical meristem, namely, the tunica, consisting of two peripheral layers of cells, and the corpus, a mass of cells overarched by the tunica. The demarcation between these two zones results from the contrasting modes of cell division of the tunica and the corpus. The layers of the tunica show predominantly anticlinal divisions; that is, they undergo surface growth. The corpus cells divide in various planes, and the whole mass grows in volume. Each layer of the tunica arises from a small group of separate initials, and the corpus has its own group of initials located beneath those of the tunica. In other words, the number of tiers of initials is equal to the number of tunica layers plus one, the tier of corpus initials. The epidermis usually arises from the outermost tunica layer, while the underlying tissues may arise from the tunica or the corpus or both. Thus, the tunica-corpus concept is useful in relating the effects of irradiation treatments on the experimental material, in this case, the epicotylar apical meristem of the peanut embryo.

By the results of Dr. Soriano's treatments, somatic mutations consist mainly of leaf flecking and leaf sectoring in seedlings. Said forms of chimerism could result from the mutation of some of the initial cells at the apical meristem of the epicotyl that had been affected by the treatments applied, in this case fast neutrons. Said effects are then perpetuated with the subsequent division of the affected initial cells and these are expressed phenotypical as leaf flecking and leaf sectoring.

The foregoing is paralleled by induced cytochimeras produced with the use of colchicine (Satina *et al.*, 1940; Dermen, 1953, 1960; Clowes, 1961; others). Treatment of shoot and floral apices with colchicine, has resulted in the change of the number of chromosomes in individual cells as in the case of *Datura*, peach and cranberry from 2N to 4N and 8N. When cells occupying the position of initials in the shoot apex are thus affected the change becomes detectable and is perpetuated developmentally in more or less extended parts of the plant body that develop after the treatment, and the alterations had been traced directly to the initial cells in the apical meristems.

It is thus possible by these examples to support the view with high degree of confidence from the ontogenetic standpoint that the observed chimeric phenomenon brought about by fast neutron treatments is due to the activity of the affected initial cells in the apical meristem of the epicotyl of the peanut embryo.

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STUDIES ON THE CULTURE OF THE EARTHWORM, *EUDRILUS EUGINAE*, AND ITS USE AS FEED FOR *MACROBRACHIUM IDELLA* AND FERTILIZER SOURCE FOR *BRASSICA COMPENSIS*

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ABSTRACT

Studies on the culture of *Eudrilus euginae* in boxes with different levels of pig manure, feeding of dried *E. euginae* to the freshwater shrimp, *Macrobrachium idella*, and the application of earthworm castings (vermicompost) as fertilizer for pechay (*Brassica compensis*) were conducted.

The best production of *E. euginae* was obtained with 75% manure and 25% sawdust as bedding. Earthworm castings from the treatment had the lowest nitrogen, potassium and organic matter contents. Results indicated that nutrient content of vermicompost decreases with increase in earthworm production.

M. idella fed with the earthworm had higher total weight gain, lower feed conversion ratio and greater production of juveniles compared with those of the shrimp fed with the dried freshwater fish, *Therapon plumbeus*. *E. euginae* had greater values of crude protein and fat on a moisture-free basis basis compared with *T. plumbeus*.

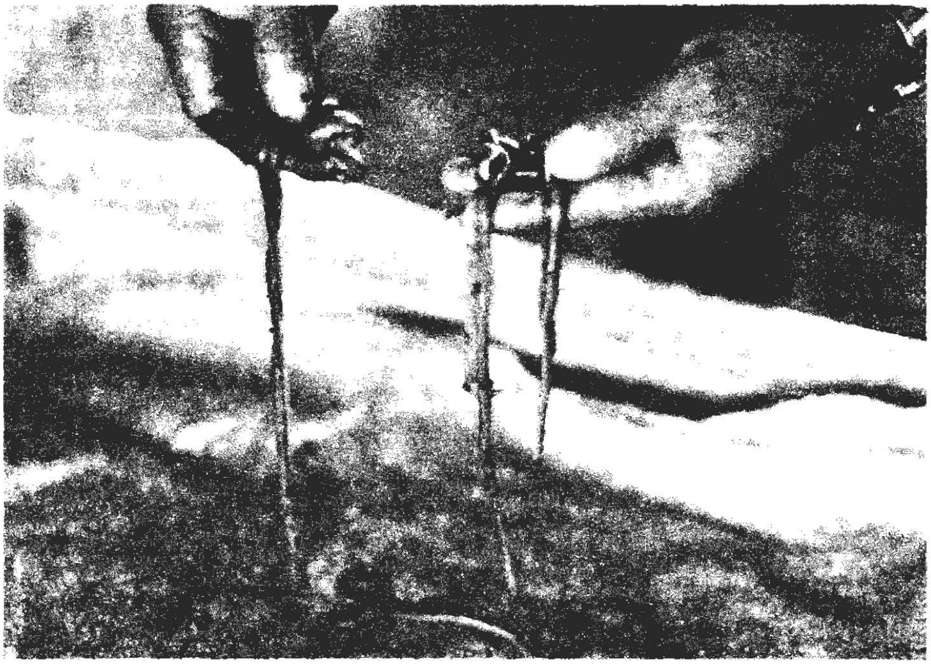
The highest yield of *pechay* was achieved with fertilization using 50% vermicompost and 50% complete fertilizer. Yields of *pechay* with partial vermicompost fertilization were significantly greater compared with that using 100% complete fertilizer. Fertilization cost with 100% vermicompost was lowest.

Introduction

The present foreign exchange crisis of the Philippines is expected to reduce the importation of animal feed ingredients and chemical fertilizers. There is an urgent need for the development of import substitutes using local and available resources.

Earthworms have been identified as potential sources of animal protein for poultry, livestock and fish feeds (Ulep, 1982; Sabine, 1978; Guerrero, 1983). Earthworm meal has been analyzed to have high quality protein (67-70% crude protein) comparable with that of imported fish meal. It also has higher metabolizable energy than fish meal (Ulep, 1982).

In studies conducted by Guerrero (1983), weight gain, survival rate and feed conversion of *Tilapia nilotica* fed with a diet containing 15% earthworm meal (*Perionyx excavatus*) were significantly better than those of *T. nilotica* fed with



African nightcrawler *(Eudrilus euginae)* breeders

a standard diet containing fish meal. According to Pascual (personal communication), addition of 5% earthworm meal in the feed of *Penseus monodon* improved attractability of pellets and significantly increases weight gain of the prawn compared with the fish meal-diet.

Earthworm castings (vermicompost) have value as soil amendments or as organic fertilizer. The castings have a high cation-exchange rate with a carbon to nitrogen ratio under 20:1 which is suitable for plant assimilation. Castings produced from animal waste contain 3.0% nitrogen (dry weight), 0.32% phosphorous and 0.4% potassium (Dacayo, 1981).

In pot experiments, Dacayo (1981) found the positive response of lettuce, ginger, *Portulaca oleracea*, African daisy and *pechay* to varying proportions of soil and vermicompost. Significantly higher yields were obtained with 50% soil and 50% vermicompost with lettuce, 100% vermicompost for ginger, and 25% soil + 75% vermicompost for *P. oleracea* and *pechay* over the control (soil).

The earthworm *Eudrilus euginae* is an introduced species in the Philippines. Egg capsules of the earthworm were received by the senior author from Dr. Otto Graff of West Germany in 1982. The species originates from West Africa and is widely distributed in tropical and subtropical countries. *E. euginae* is fast-growing and recommended for vermicomposting in the tropics (Graff, 1981).

We conducted three studies. Study I was to determine the effect of different

Culture boxes of *Eudrilus euginae*

pig manure levels on the growth of *E. euginae* cultured in boxes. Study II was on the feeding of dried *E. euginae* to the freshwater shrimp *Macrobrachium idella* in outdoor pools. The use of vermicompost for fertilizing *pechay* (*Brassica compensis*) in field plots was evaluated in Study III.

Materials and Methods

Study I was conducted at the Technology Resource Center's Vermiculture Project in San Ildefonso, Bulacan. Wooden boxes measuring 61 x 46 x 20 cm each and lined with polyethylene sheets were used as culture units. Three levels of pig manure were tested for growth of *E. euginae.* The treatments were: I – 100% manure, II – 75% manure + 25% sawdust, and III – 50% manure + 50% sawdust. Eight kilograms of the dried bedding were placed in each box. Water was mixed with the bedding to maintain a moisture content of 60-80%. The bedding was allowed to ferment for one week before stocking of the earthworm.

Juvenile *E. euginae* was stocked at 200 g per box. Four replicates (boxes) were used for each treatment. The boxes were kept under a shed and watered regularly to maintain moisture. Total fresh weight of the earthworm in each box was weighed after 30 days of culture. Samples of the castings were analyzed for NPK, organic matter and pH.

Study II was conducted at the Bureau of Fisheries and Aquatic Resources

Adult male (left) and female *Macrobrachium idella*

Fisheries Station in Los Baños, Laguna. Four 36-m^2 concrete pools with earth bottoms and maximum depth of 1m were used. The pools were filled with water from a shallow well to a depth ranging from 0.4 to 0.6 m. Dried chicken manure was applied at 1 ton/ha in the pools as basal fertilizer.

Live adults of the freshwater shrimp *Macrobrachium idella* were collected from Laguna Lake. Each pool was stocked with 96 g of *M. idella* with average individual weights of 5.6 to 5.8 g.

Two feeding regimes were tested. Dried *Therapon plumbeus*, a freshwater fish, was fed to the shrimp in two pools. Dried *E. euginae* was fed to the shrimp in the other two pools. Feeding was done daily for 60 days at the rate of 20% of shrimp biomass.

The total weight gain (adults and juveniles), feed conversion and juvenile production of the shrimp were evaluated after the two-month culture period. Proximate analyses of *T, plumbeus* and *E. euginae* samples were done.

Study III was also conducted in San Ildefonso, Bulacan. The soil in the experimental area was light-textured. Soil analysis showed it to have 1.8% organic matter, 47 ppm phosphorus, 8 ppm potassium and pH of 4.9.

Twelve plots measuring 5 x 1 m each were used. *Pechay* seedlings were planted 30 cm apart in three rows with 15 plants per row in each plot. Four fertilizer treatments were tested, namely: I -- vermicompost only, II – 50% vermi-

Pechay (*Brassica compensis*) fertilized with vermicompost

compost + 50% complete fertilizer (14-14-14). III – 25% vermicompost + 75% complete fertilizer, and IV – 100% complete fertilizer. Each treatment had three plots.

The fertilizers were applied at the rate of 25 g per plant for each application. One fertilizer application was done at planting and another after two weeks. The plots were watered regularly as needed.

The plants were harvested after 30 days from planting. Total yield of *pechay* and cost of fertilizer per plot were determined.

Results and Discussion

The results on the production of *E. euginae* with different levels of pig manure are presented in Table 1. Analyses of the data showed that the highest production of the earthworm was obtained with 75% manure + 25% sawdust (Treatment II) followed by Treatment III. Treatments II and III were significantly different from Treatment I ($P<0.05$).

Analyses of the vermicompost samples produced in Study I (Table 2) showed that the sample from Treatment II had the lowest nitrogen, potassium and organic matter contents. This is to be expected because of the bioconversion of the nutrients into earthworm flesh. The results also indicate that the nutrient content of vermicompost decreases with increase in earthworm production.

Table 1. Production of *E. euginae* in boxes with different levels of pig manure after 30 days.

Treatment	*Weight Gain*[a] *(kg)*	*% Weight Increase*
I	0.94	470
II	1.83*	915
III	1.57*	785

[a]Mean of four replicates
*Means are not significantly different.

Table 2. Analyses of vermicompost samples (oven-dry) from Study I.

Treatment	*Nitrogen (%)*	*Phosphorous (%)*	*Potassium (%)*	*Organic Matter (%)*	*pH*
I	2.85	0.12	0.48	45	5.8
II	1.75	0.15	0.28	35	6.0
III	2.0	0.13	0.30	40	6.2

Table 3. Average total weight gains, feed conversion ratios and average number of juveniles of *M. idella* fed with *T. plumbeus* and *E. euginae* for 60 days.

Feed	*Ave. Total Wt. Gain (g)*	*Feed Conversion Ratio*[a]	*Ave. No. of Juveniles*
T. plumbeus	375	1.82	448
E. euginae	407	1.67	674

[a]Feed Conversion Ratio = $\frac{\text{Total feed given}}{\text{Total weight gain}}$

Table 4. Proximate analyses of *T. plumbeus* and *E. euginae*.

Nutrient (%)	*T. plumbeus*	*E. euginae*
Crude Protein	65.88	68.0
Fat	3.88	9.57
Nitrogen-Free Extract	22.35	11.05
Ash	7.29	9.07

Table 5. Average yield of pechay with different fertilizers and cost of fertilizer per plot after 30 days.

Treatment	Ave. Yield/Plot (kg)	Cost of Fertilizer/Plot (₱)
I	4.11*	2.25
II	4.66*	3.93
III	4.62*	4.78
IV	3.67	5.62

*Means are not significantly different.

All the samples were found to be slightly acidic. Of the three, however, the sample from Treatment I had the lowest pH. This may be attributed to its high organic matter content. Sawdust is believed to have benefited earthworm growth by improving texture and porosity of the bedding.

M. idella fed with the earthworm had higher average total weight gain, lower feed conversion ratio and greater average number of juveniles than with the fish feed (Table 3).

Proximate analyses of dried *T. plumbeus* and *E. euginae* (Table 4) showed that the latter had higher crude protein, fat, ash and crude fiber but lower nitrogen-free extract than the former on a moisture-free basis.

Our findings corroborate those of Pascual (personal communication) on the superiority of earthworm over fish as a feed for crustaceans. The amino acid profile of earthworm meal is comparable with that of imported fish meal and meat meal (Sabine, 1978). Lipids are known to be essential for the reproduction of animals.

The results of Study III show the advantages of the use of vermicompost (75% manure + 25% sawdust) over that of complete fertilizer for *pechay* in the study area (Table 5). The highest yield of *pechay* was achieved with Treatment II (50% vermicompost + 50% complete fertilizer). However, the lowest cost for fertilization was with Treatment I (vermicompost only). Treatments II and III were significantly different from Treatment IV ($P<0.05$).

The use of vermicompost is appropriate for light soils low in organic matter. With its high cation-exchange capacity, vermicompost provides cultured plants with more available nutrients in acidic soils (Dacayo, 1981). In general, the response of a plant to vermicompost will depend on soil conditions and the plant's nutritional requirements.

Acknowledgment

We wish to thank the Technology Resource Center and Philippine Council for Agriculture and Resources Research and Development for funding the studies.

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Juliana B. Dacayo, Discussant

The use of vermicompost (VC) in agriculture as alternative/supplement to commercial fertilizer is timely during this period of energy crisis. Its relatively lower nitrogen content than most farmyard wastes like chicken manure thereby reducing its burning effect makes vermicompost safer to use in most crops.

Dr. and Mrs. Guerrero and myself started to work cooperatively on the earthworm and its castings at the Central Luzon State University in Nueva Ecija about five years ago. They concentrated their interest on the earthworm as protein source for feeds while I focused my attention on the utilization of the castings as nutrient source for agricultural crops.

The response of lettuce, pechay, ginger, green onions, *P. oleracea*, carrot, sweet corn and rice to added vermicompost is encouraging. Using vermicompost from a substrate consisting of cow manure, ipil-ipil and sawdust at equal proportion (1:1:1) in pot experiments, a mixture of 80% soil + 20% VC by volume proved best for lettuce, pechay, ginger, green onions and *P. oleracea* while in carrot 10% VC + 90% soil increased tuber yield by 29% over the control.

Field experiments on rice and sweet corn show that in corn an increment of 114% in ear yield was realized by the application of 5 tons VC. This was comparable to plants which received the recommended rate of inorganic fertilizer (60-40-0/ha.). Grain yield in rice was not affected up to an increment of 4 tons VC per hectare, however, 2 tons VC in addition to the recommended rate of inorganic fertilizer had 40% more grain yield than the control.

The residual effect of vermicompost had been tested on green onion in the greenhouse. The above-ground plant parts were cut every 30 days for 3 years. After the third year, plants in 20% vermicompost + 80% soil growth medium had total leaf yield comparable to those which received annually the recommended rate of inorganic fertilizer.

It is believed that the beneficial effect of vermicompost is a combination of its chemical, biological and physical properties which improve soil conditions making it more suitable for plant growth. The presence of enzymes beneficial to plants had been reported in the literature.

Aside from its favorable effect on plant growth, future studies should be geared on other aspects such as handling, storage as well as packaging in order to insure minimal nutrient losses prior to usage.

DeDatta, 1974). Moreover, it is compounded by the difficulty of distinguishing between young grasses and rice seedlings due to similarities in some morphological features.

Currently, butachlor, a selective pre-emergence herbicide that controls most

Table 1. Timing of application, mean yield, toxicity rating and % weed control of butachlor (Machete EC) on direct-seeded rice during the 1981 dry season.

Location	*Rep.*	*Treatment*	*Rate* *kg. a.i./ha.*	*Time* *Time* *Application*	*Mean* *Yield* *MT/Ha.*	*MEAN CROP INJURY*				*MEAN % WEED CONTROL RATING*					
						20 DAS%		*40 DAS%*		*20 DAS*			*40 DAS*		
						SR	*GR*	*SR*	*GR*	*EC*	*MV*	*CD/SS*	*EC*	*MV*	*CD/SS*
BEST	3	Machete EC	1.0	4 DBS	3.87	11	11	5	5	91	88	94	85	83	89
MRRTC	3	Machete EC	1.0	2 DBS	4.24	12	12	8	6	85	89	97	84	83	91
VRES	3														
&		Machete EC	1.0	6 DAS	2.95	20	12	7	4	85	80	87	83	78	80
UPLB	3														
		Handweeded	2 x	20 + 40 days	4.46	0	0	0	0	94	92	96	93	90	93
		Untreated	--	–	2.37	0	0	0	0	0	0	0	0	0	0

*EC = *Echinochloa crus-galli*
MV = *Monochoria vaginalis*
CD/SS = *Cyperus difformis/Scirpus supinos*

Table 2. Timing of application, toxicity rating and % weed control of butachlor and 2,4-D mixture (Rogue) on direct-seeded rice during the 1983 dry season in Nueva Ecija

				Mean	*Mean Phytotoxicity Rating*				*Mean % Weed Control Rating**					
	Treatment	*Rate*		*Yield*	*20 DAS %*		*40 DAS %*		*20 DAS*			*40 DAS*		
Rep.	*(Form)*	*(kg. a.i./ha.)*	*Time*	*MT/Ha.*	*SR*	*GR*	*SR*	*GR*	*EC*	*MV*	*CD*	*EC*	*MV*	*CD*
6	Rogue EC	.75 + .5	6 DBS	4.41	0	0	0	0	100	100	100	99	98	99
	Rogue EC	.75 + .5	8 DBS	4.51	3	1	1	0	100	100	100	100	100	100
	Rogue EC	.75 + .5	6 DAS	1.06	92	91	67	12	93	96	97	93	100	95
	Rogue EC	.75 + .5	9 DAS	3.20	53	51	19	12	100	100	100	98	97	93
	Rogue 6G	.75 + .5	9 DAS	3.15	32	30	11	4	100	99	98	99	98	96
	Untreated	–	–	2.21	0	0	0	0	0	0	0	0	0	0

*EC = *Echinochloa crus-galli*
MV = *Monochoria vaginalis*
CD = *Cyperus difformis*

Table 3. Safening effect of Screen(R) on pre-germinated direct sown rice in field plots treated with high doses of butachlor (Machete) and butachlor + 2, 4-D (Rogue) at 2 days before seeding.

Location & Season	*Rep*	*Treatment*	*Rate (kg. a.i./ha.)*	*Screen Rate ml/kg. seed*	*AVERAGE PHYTOTOXICITY* 10 DAS %		20 DAS %		40 DAS %	
					SR	*GR*	*SR*	*GR*	*SR*	*GR*
CLSU	3	Machete	2		22	0	17	2	0	0
(1983 Dry Season)		Machete	2	1.3	1	0	6	0	0	0
&		Machete	2	2.6	1	1	1	0	0	0
HCF	3	Machete	2	5.2	0	0	0	0	0	0
(1983 Wet Season)		Machete	2	10.4	0	0	0	0	0	0
		Rogue	1 + 0.67		44	4	41	3	20	0
		Rogue	1 + 0.67	1.3	17	4	15	1	11	0
		Rogue	1 + 0.67	2.6	1	1	1	0	0	0
		Rogue	1 + 0.67	5.2	0	0	0	0	0	0
		Rogue	1 + 0.67	10.4	0	0	0	0	0	0

derably recovering at 40 DAS. Grain yield was highest from 8 DBS Rogue treatment (4.51 MT/Ha.) followed by 6 DBS (4.41 MT/Ha.), 9 DAS (3.20 MT/Ha.), 9 DAS (3.15 MT/Ha.), untreated (2.21 MT/Ha.) and the least from 6 DAS (1.06 MT/Ha.). Therefore, with proper rate and timing, the butachlor + 2,4-D mixture can be safely used on direct wet-seeded rice to realize excellent weed control and high rice yields. However, rice seedlings in treated fields should never be submerged in water.

Due to phytotoxicity problems associated with herbicide treatments on direct wet-seeded rice, the use of antidotes gained increased attention recently. At IRRI, Mabbayad and Moody (1982) found that treatment with naphthalic anhydride (NA) improved rice stand and grain yield even when butachlor was applied at planting time or 3 DAS. Without NA, butachlor application at 3 DAS resulted in the shortest plants. In the United States, Screen has been demonstrated to be an effective safener in sorghum from herbicide injury due to alachlor. Results of studies demonstrated that Screen protects sorghum from alachlor at rates of 0.06% to 0.125% a.i. w/w. Without Screen, there would be complete loss of sorghum stand due to alachlor (Schumacher, pers. commun.). Since butachlor is also an acetanilide herbicide, the efficacy of Screen in reducing its phytotoxicity on puddle sown rice was also tested at 1.3, 2.6, 5.2 and 10.4 ml./kg. seed correspondingly equivalent to 0.06%, 0.125%, 0.25%, and 0.5% a.i. (w/w). However, the concentrations of herbicides used were twice that recommended for butachlor and 33% higher for the butachlor + 2,4-D mixture and they were applied at 2 DBS. As revealed by the 10, 20 and 40 DAS evaluation of herbicide phytotoxicity (Table 3), just like in alachlor used on sorghum, Screen can act as safener for butachlor and its 2,4-D mixture on direct seeded rice under Philippine situations at concentrations 0.06 to 0.125% a.i. (w/w). Pre-germinated seeds sown on butachlor-treated plots have fully recovered at 40 DAS even without Screen. However, for the simultaneous evaluation on butachlor + 2,4-D treated plots, 0.125% of the antidote was needed to nullify phytotoxicity. Screen can therefore be applied on butachlor and butachlor + 2,4-D-sensitive DS rice varieties to minimize the stand and growth reductions resulting from herbicide exposure of seedlings.

Increased weed control efficacy and improved crop safety resulting in higher grain yields in direct puddle-sown rice is possible by 2-4 DBS application of butachlor, 6-8 DBS application of butachlor + 2,4-D mixture and the use of Screen as seed safener. This weed control technology should facilitate 2 cropping seasons with high yielding and short maturing variety like IR-36 and realize 7-10 MT/Ha. grain yield per year as opposed to the 1.5-2 MT/Ha. from single cropping of the traditional variety.

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Keith Moody, Discussant

Wet-seeding (sowing of pregerminated seed on to puddled soil) is increasing in importance as a method of growing rice in the Philippines. Herbicides are often recommended for weed control in wet-seeded rice because of the difficulties encountered with hand weeding when rice seeds are broadcast onto the soil surface. However, selectivity is often marginal because the rice and weeds are at the same stage of development. Consequently, the rice plant and the weeds may show the same degree of susceptibility to the applied herbicide.

There are many ways that herbicide selectivity in wet-seeded rice can be improved. The authors describe two. One of these, which involves no monetary outlay on the part of the farmer, is altering the time of application of the herbicide. By applying butachlor and the proprietary mixture of butachlor + 2,4-D before seeding the authors obtained less crop injury, better weed control, and higher yields compared with the conventional application time of 6 days after seeding.

Herbicide application before seeding did not completely eliminate herbicide phytotoxicity because stand reduction and growth reduction was observed with both herbicides. When water control is poor and the field is flooded at or soon after planting severe stand reduction might occur even though the herbicide is applied before seeding. To minimize stand and growth reductions resulting from exposure of the seedlings to herbicides the authors have used a crop safener, MON 4601.

Without a doubt, MON 4601 does fulfill its purpose but the farmer may be reluctant to use such a compound because of the expense involved and having to soak seeds in the safener adds one more step to the production process. Combining the herbicide with the safener as has been done for other products is an alternative that should be considered.

Another method of reducing herbicide toxicity is to reduce the rate of herbicide applied. This may result in less crop damage and less monetary input without loss of weed control. The farmer may even be willing to accept some loss of weed control if he can be guaranteed a good stand at less cost. Weeds which escape the herbicide treatment can then be removed by hand.

Wet-seeding of rice will continue to increase in importance in the Philippines if the problems of controlling weeds and damage due to herbicides can be solved. The type of research that the authors describe needs to be continued and other approaches for reducing herbicide damage should also be considered. With the concerted effort of everyone concerned, the farmer in the not-too-distant future, will be guaranteed that every time he plants wet-seeded rice and applies a herbicide he will not have to worry about herbicide damage.

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COLLECTION AND TAXONOMIC STUDIES OF THE BLUEGREEN ALGAE AND NATURAL POLLUTION

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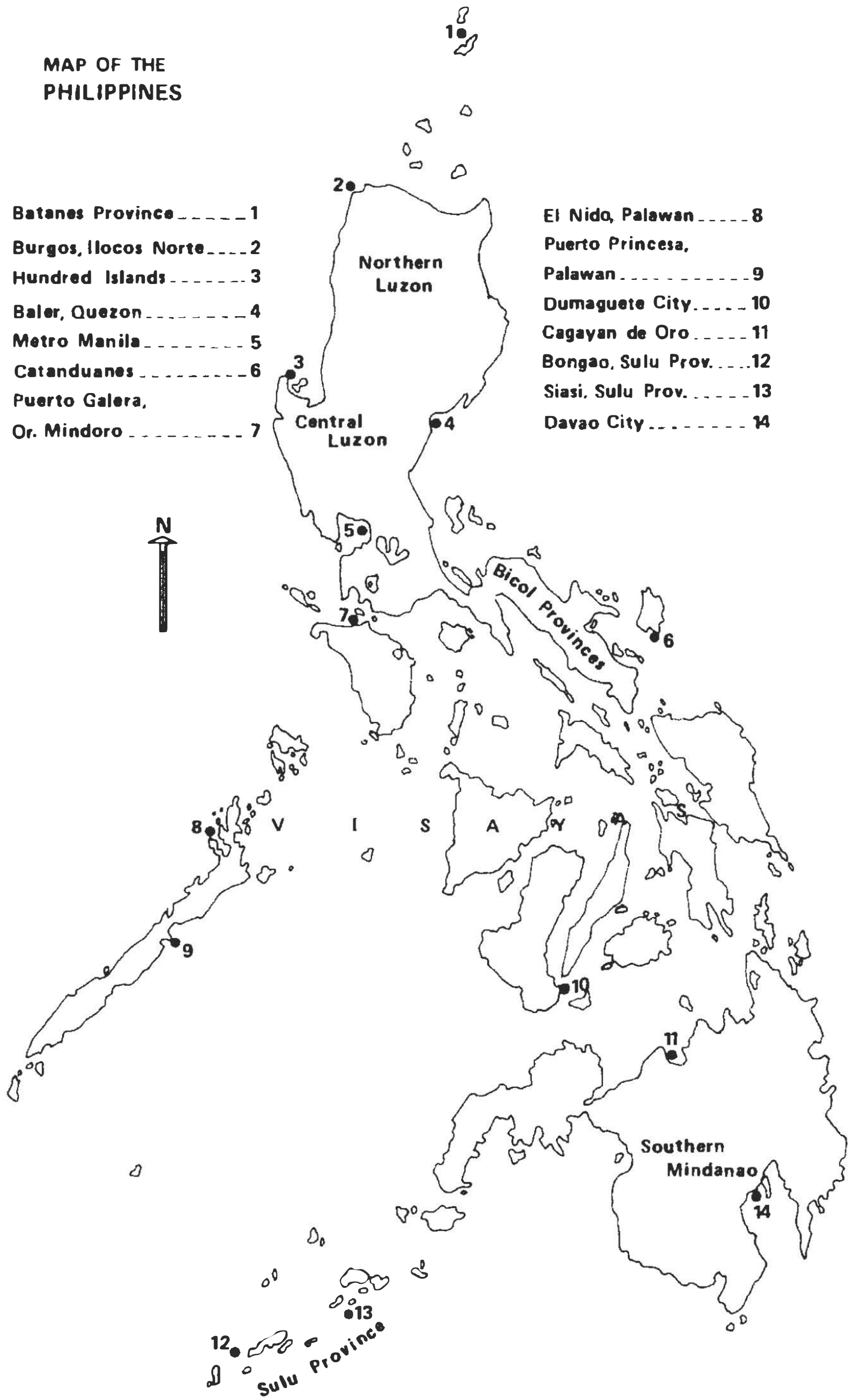
Introduction

I pursued as much as possible in about 30 years the various habitats of the bluegreen algae in the Philippines. In 1962, there was published in the Philippine Journal of Science Vol. 91, No. 3, a monographic treatment of these algae which gives a complete record of 162 species and 3 forms. The ecology of the distribution of the algae was supplemented by a close observation and record of habitats where the materials were collected. See map on page 54.

Research Procedure and Observation

The Philippines as a tropical country has generally uniform climate with the annual average temperature of 24° to 31°C except in some isolated places like the Mountain Provinces in Northern Luzon and Mt. Apo in Southern Mindanao. Both are characterized with much higher elevation and consequently exhibiting very much lower temperature. As a whole the country has many inland waters of various sizes in the form of lakes, rivers, ponds, canals and stagnant pools. There are also many low areas oftentimes occupied by squatters while others are waste lands with generally sunken rolling topography. The former are usually moist if not submerged in shallow water almost throughout the year including several premises around many open markets where small private business shops were established permanently. The areas constitute very fertile collecting grounds for the bluegreen algae. It is a perennial sight of natural pollution in very much less developed parts of the Philippines. Undoubtedly this is equally true in other developing countries of the Southeast Asia including the Pacific regions.

On the other hand, in many fishponds generally stocked with milkfish, *Chanos chanos* and tilapia, *Tilapia mosambica* are developed frequently waterblooms of *Microcystis aeruginosa, Oscillatoria tenuis, O. chalybea, O. princeps*, and *Phormidium tenue* during the warm summer months. *Lyngbya aestuarii* oftentimes with some Oscillatoria species grow extensively and develop blanket algae in some fishponds of rice paddies and inland estuaries. Fourteen species generally produce toxicity during the warm summer months (Table page 3). In some rice



Map shows the fourteen stations (solid circles) where collection and study of the benthic marine algae were made. One collection was done in every visit.

paddies are also usually developed abundant growth of *Tolypothrix tenuis* which form algal bloom during some hot weather. Where *Spirogyra* and other green algae such as *Cladophora* and *Rhizoclonium* species grow abundantly, the young rice plants generally become affected with the fast growing green algal filaments. As a result, unusually the rice plants undergo slower growth due to the green algae. Several obiquitous bluegreen algae now start to grow which add to the algal pollution.

In Laguna de Bay, *M. aeruginosa* is an annual waterbloom which usually develop during the late summer months. Oftentimes the bloom is immediately followed with the death of milkfish and other less resistant organisms present in several food chains. The death of the fish sometimes gives a national problem: the bloom which causes adverse effects to the growth of several aquatic organisms add to the sources of natural pollution. This causes inevitably the death of thousands of milkfish due to the complicated nature of pollution accompanied by the slow process of asphyxiation of usually the less resistant organisms. Accordingly, similar phenomenon happens also in other ponds in the country which unfortunately have not been regularly reported.

Records of canals and stagnant pools generally promote growth of *Spirulina subsalsa, S. major, Oscillatoria tenuis, O. chalybea* and *O. princeps*. The majority of collecting grounds visited during the dry season give the prevalence of higher summer temperature from the second half of February to June. Rain is generally least observed during these months. The temperature, however remains almost constant during the rest of the year covered by the rainy season from July to part of September. Repeated observations show that the twenty species reported in this paper are mostly species of natural pollution (See Table). Most of them belong to the family Oscillatoriaceae. There are many other bluegreen algae which are also studied but did not have their habitats classified with those of the polluting species. They may be mentioned as *Aphanothece stagnina, Phormidium papyraceum, Symploca muscorum* and *Fisherella ambigua*.

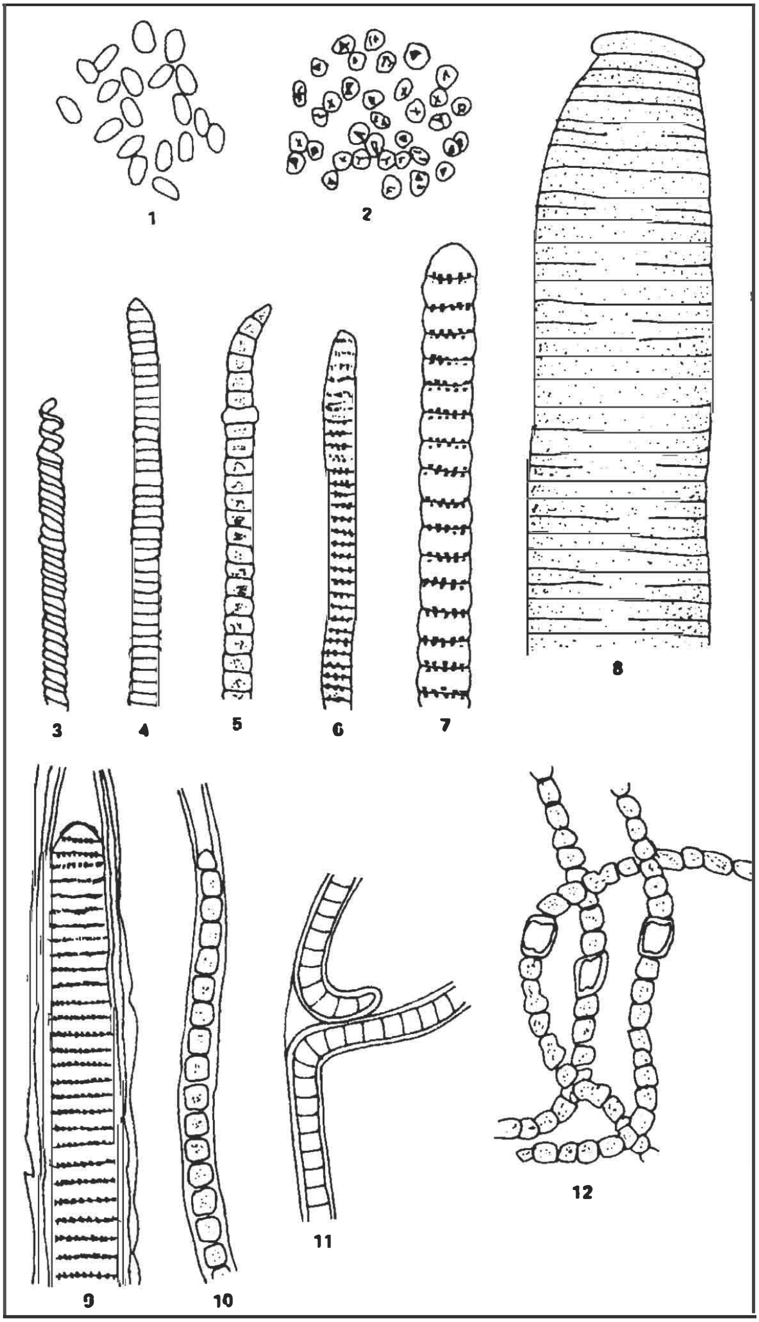
The species of the genera *Oscillatoria* and *Spirulina* have apparently very thin sheaths which could obstruct or slow down infrequently the flow of the cell nourishments and wastes of metabolism. The easy passage of raw materials needed in food synthesis and the release of wastes due to cell activities are in the maximum. As a result, the cells in the filaments in immensely increased proportion multiply faster than those of the other organisms in the same habitat.

In the phenomenon especially of excess population of many bluegreen algae, there is inevitably the accompaniment of excess toxicity. The reserved food of the algae being proteinaceous, when they die produce a toxicity which generally inhibits the growth if not kill other organisms in the immediate vicinity. This is one source of excessive pollution commonly happening in many canals including the indefinitely stagnant waters and other places mentioned elsewhere. The atmosphere gives an obnoxious odor which is a nuisance to the immediate vicinities. On the other hand, the great majority of species with generally prominent sheaths fail to

Table. Representative species of the collection to show the nature of the habitat from where many bluegreen specimens are generally available

Species	*Permanent Water*		*Usually Wet*		*Usually Dry*	*Remark*
	Much Pollution	*Less Pollution*	*Mostly Wet*	*Moist or Dry*		
1. *Microcystis aeruginosa*	xx					*Spirulina subsalsa*, *S. major*, *Oscillatoria prolifica*, *O. tenuis*, *O princeps* and *O. chalybea* were collected dominant in permanent canals with much pollution. They do not have conspicuous sheaths. *Lyngbya martensiana* is an exception. Usually dry habitat did not yield much specimens except some Scytonema species.
2. *Spirulina subsalsa*	xx					
3. *Spirulina major*	xx		x			
4. *Oscillatoria prolifica*	xx					
5. *Oscillatoria tenuis* ,	xx	x	x			
6. *Oscillatoria princeps*	xx	x	x			
7. *Oscillatoria chalybea*	xx	x				
8. *Phormidium inundatum*		x	xx			
9. *Phormidium retzii*		x	x			
10. *Symploca muscorum*			xx			
11. *Lyngbya major*		xx	xx			
12. *Lyngbya martensiana*	xx					
13. *Porphyrosiphon fuscus*				x		
14. *Microcoleus vaginatus*		x	xx			
15. *Nostoc communutun*		x	x			
16. *Desmonema wrangelii*			x			
17. *Tolypothrix tenuis*		xx				
18. *Scytonema hoffmannii*				xx	x	
19. *Scytonema guyanense*				xx	x	
20. *Calothrix braunii*				x		

Note: Species 1 to 14 are major sources of pollution, the rest of the species up to 20 do not contribute much.



One plate: 1. *Coccochloris stagnina*, 2. *Microcystis aeruginosa*, 3. *Spirulina subsalsa*, 4. *Phormidium autumnale*, 5. *Oscillatoria brevis*, 6. *O.*, *granulata*, 7. *O. tenuis*, 8. *O. princeps*, 9. *Lyngbya aestuarii*, 10. *Symploca muscorum*, 11. *Scytonema guyanense*, and 12. *Nostoc muscorum*. All x 810 except *S. guyanense* x 355.

grow as fast and therefore the increase in pollution is very much less during the year.

There are additional characteristics in the bluegreen algae which may be differrently developed aside the presence of very thin sheaths, which should influence easily the permeability of some structure of the cell wall together with the membrane. Others are subsequently inherent in the growth and development of the species. Unfortunately, they are not within the scope of investigation and therefore should need another study and discussion.

Additional bluegreen algae of wide distribution and where they grow in abundance should be studied further. A biochemist must be available to study the relative potency of toxicity which these algae produce in many habitats. He should be able to suggest controlled measures after consultation with the researcher. When the necessary data is completed, one very practical way to eradicate, if not control the growth of the bluegreen algae, is to introduce currents which accelerate the aeriation of the locality concerned. What presently appear to be clear like several standing waters can be colonized later by the fast growth of ubiquitous bluegreen algae (see plate again with first 12 figures).

KEY TO FAMILIES

1. Unicellular to colonial forms . . . . Chroococcaceae
1. Always filamentous forms 2
    2. Cells of trichomes uniform, heterocysts absent . Oscillatoriaceae
    2. Cells of trichomes not uniform, heterocysts present 3
3. Trichomes generally narrower within the sheath . . . . Nostocaceae
3. Trichomes generally much wider within the thicker gelatinous sheath . . . . Scytonemataceae

Family CHROOCOCCACEAE

1. Cells less in diameter, contents finely granular . . . . . *Aphanothece stagnina*
1. Cells larger in diameter, contents coarser with psuedovacuoles . . . . *Microcystis aeruginosa*

Family OSCILLATORIACEAE

1. Trichomes filamentous and spiral 2
1. Trichomes also filamentous but not spiral 3
    2. Spirals of trichomes apparently attached to each other . . . . *Spirulina subsalsa*
    2. Spirals of trichomes far apart . . . . *S. major*
3. Trichomes aggregated in a common gelatinous sheath 4

3. Trichomes free from the gelatinous sheath 5
   4. Apical cell of individual trichome capitate . . . . *Microcoleus vaginatus*
   4. Apical cell of individual trichome rotund not capitate . . . . *M. paludosus*
5. Sheaths of trichomes hardly visible 6
5. Sheaths of trichomes conspicuous, thick and striated . . . . *Lyngbya aestuarii*
   6. Trichomes up to 10u in width 7
   6. Trichomes more than 10u in width 8
7. End of trichomes rounded . . . . *Oscillatoria amphibia*
7. End of trichomes sharply tapering . . . . *O. animalis*
   8. Width of trichomes much wider up to 60u . . . . *O. priceps*
   8. Width of trichomes much narrower 9
9. Cells of trichomes not constricted at joints towards apex 10
9. Cells of trichomes constricted at joints and bent towards apex . . . . *O. chalybea*
   10. End cell shaped like proboscis . . . . *O. proboscidea*
   10. End cell rotund . . . . *O. limosa*

Family NOSTOCACEAE

1. Thallus irregularly expanded, filaments free, regularly or spirally coiled . . . . *Anabaena spiroides*
1. Thallus irregularly expanded, filamen'ts entangled, not regularly and spirally coiled 2
   2. Trichomes narrow, 3-5u wide . . . . *Nostoc muscorum*
   2. Trichomes narrow, 4.5-6u wide . . . . *N. communi*

Family SCYTONEMATACEAE

1. Filaments floating usually colonial, cushion-shaped, sheaths very conspicuous . . . . *Tolypotrix tenuis*
1. Filaments growing mostly in moist rocks and soil, sheaths conspicuous and not striated, false branching present . . . . *Scytonema guyanense*

Remarks: The manuscript attempts to enumerate as much as possible the blue-green algae which were observed to be the sources of major pollution so far studied in the Philippines. Collections were made in Luzon and partly in the Visayas and Mindanao areas.

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Joventino D. Soriano, Discussant

The lifelong and painstaking work of Dr. Gregorio T. Velasquez on the blue-greens will stand out as an example of a basic research with great significance for a long time. As his former masteral thesis student some thirty years back, I have always admired his undying enthusiasm and interest in his studies. I do not know of any word in any language that would best describe his love for his work and, except his wife, Dr. Carmen C. Velasquez, who is likewise a fiercely research-oriented professor, I have yet to see another Filipino scientist who has been gifted with the strong determination and persistence to work, with or without honorarium, on his research project everyday be it on weekdays, week-ends or holidays. Dr. Velasquez has indeed shown us how to do research well and may his life serve as an example to our young and promising scientists that indeed the proverbial pot of gold literally awaits at the end of the rainbow for those who will take the so-called rocky and rugged path of dedicated research. The government is supporting financially the national scientists of our country through an adequate monthly pension when they are already too old to earn a living. This is our nation's way of showing its appreciation and gratitude to these scientists for work well done far beyond the call of duty. It is not too late for anybody in the academic or technical professions to begin *today* a new life – a quite fruitful life fully dedicated to productive research the Velasquezés way.

To evoke further interest in the blue-green algae and to enable us understand some of the biological processes in the cell, it has been known for a long time that the cells of Myxophyceae are structurally different from those of green algae and other higher plants. A review of recent electron microscopic studies appear to support this view.

With regard to the cell wall and cell sheath, the cells are attached to each other by a wall often forming a bead-like trichome. Each cell is surrounded by a mucilaginous sheath with many short fibrils. These fibrils extend from the outer wall outward through the mucilaginous sheath. The sheath surrounding an akinete or heterocyst appears to be a compact fibrous material. This may explain the resistance of these reproductive bodies to conditions of dessication and pollution commonly observed in population centers.

Concerning cytoplasmic particles, the lamellae which probably correspond to the photosynthetic apparatus of higher plant cells divide the cytoplasm into several layers of varying widths. The lamellae appear to be concentrated at the peripheral region of the cell probably for maximum light reception.

Dense granular bodies measuring about 300-350 Å in diameter are distributed all over the cytoplasm. Small ribosome-like particles are densely distributed toward the central region of the cell. Another kind of particles which measures about .4-.8 micro in diameter show a dense matrix made up of particles as "dense structured granule" and are thought to be mitochondria-like bodies in the blue-green algal cell.

One or more vacuoles of varying sizes have been observed throughout the cell. They lack of definite membrane.

Regarding the nucleoplasm, a network of fine fibrils has been commonly observed more or less toward the center of the cell. The nucleoplasm lacks of membrane and assumes an irregular form. It gives a positive reaction to the Fuelgen test and is thought by many workers to be an "incipient nucleus."

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Macrina T. Zafaralla, Discussant

It is indeed very timely that no less than Dr. Velasquez, father of Philippine phycology, chose to focus the subject of his paper on the most important group of freshwater algae in the Philippines today.

The Cyanophyta is the most important because presently, the biggest bulk of research money ever put into a particular algal group is being funneled into blue-green algal studies. These studies include nitrogen fixation by free-living bluegreens, N_2-fixation by the Anabaena-Azolla symbiosis and lately, single-cell protein production from *Spirulina*. Count among these the funds that are now being siphoned to ecological studies involving the aquatic environment where the blue-greens, cosmopolitan and perennial as they are, always capture the attention of those who search for biological indicators of water quality.

Dr. Velasquez, the grand old man of Philippine phycology, is the incontestable Filipino botanist of world-wide renown in as far as blue-green algal taxonomy is concerned. He pioneered the field of science which he represents in this country, therefore, to hear him stress the importance of systematic studies is a salute to the few of us phycologists who devote the most productive part of their lives to this painstaking scientific endeavor.

The importance of taxonomy cannot be overemphasized. The strides achieved in phycology are founded on the strength of floristic investigations.

Dr. Velasquez made references on the population down to the cellular level of organization. Algal associations with certain environmental conditions and situations were cited by him like the algal blooms or water blooms particularly those of *Microcystis* in Laguna de Bay which are frequently followed by the now-famous fish kill phenomenon. Population studies involving phytoplankton like *Microcystis* are vital in the determination of the carrying capacity of a body of water. At the cellular level, the professor made mention of the cellular characteristics of species which necessitate the formation of control measures so that these organisms would not pose aesthetic problems in the environment. Another facet of research identified was that on algal toxins.

In addition to what the professor has underscored in his paper, and to backup his foresight, I would like to add that today, there stands the challenge for researchers of algae and of other organisms as well, to identify where they should begin and participate in the task of environmental protection/conservation and food production.

The professor made mention of algal species of natural pollution. Algal indicators of environmental change need further refinement for these to be of greater reliability and applicability. We look forward to the day when the structural and functional features of algal communities can be used to predict occurences of dreaded environmental phenomena such as that of a fish kill. Algal assays to reflect the extent of environmental contamination by heavy metals, agricultural pollutants, enriching nutrients and the like are basically at the infancy of experimentation under local conditions. We need to develop algal assays that are adapted to local conditions.

There is a need for us to be able to relate with resource managers and decision makers so that what appears to be purely academic stuff does not only go beyond the shelves of our offices but also land on the decision maker's table. This end can be achieved by participation in the design and implementation of environmental impact assessment and evaluation systems for development projects.

Dr. Velasquez's paper strikes me as a valuable endorsement of the long-held view that there is more to the science of phycology than what we algologists are presently doing. The professor has stressed some of the research gaps. Every researcher on algae should perhaps join the professor in his commitment to timely directions for algal research in the Philippines today.

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SEAWEED HUSBANDRY: A SOCIO-ECONOMIC ISSUE

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Introduction

This paper attempts to present data obtained from completed and on-going researches on Philippine marine macro-algae and to trace its possible linkage with the issue on socio-economics.

Overview

Archipelagic countries like the Philippines confine most of their rich harvest from the sea to animal materials like fin-fish, shell-fish and sea mammals. The marine plant materials, predominantly seaweeds, compose only a small fraction of the resource gathered from the marine habitat. This, despite the fact that most of these marine macro-algae have varied uses ranging from food staples, industrial, biomedical, and agricultural needs, to a more revolutionary use, stemmed from the concept of 'biomass energy'. These remarkable uses of seaweeds if seriously tapped in the less developed or developing countries, specifically those within the periphery of the Pacific Basin, is expected to favor the balance of their economy and improve the social status of the populace. More than just being contented with harvested seaweeds feral in nature, there is no assurance in any manner of predictable commodity. There is, therefore, a need to introduce seaweed husbandry imbued with the idea of judiciously utilizing specific seaweed species herein termed as *crop*, conservation of resources, propagation of superior species, and an assurance of continuously renewable supply of the crop.

The elements of husbandry adopted for terrestrially-produced agricultural crops are also applicable to edible seaweeds or sea vegetable algae, thus:

1. Identification of the seaweed species with emphasis on the physiology and morphology of the economically useful part of the crop. In the case of seaweeds such as *Eucheuma*, *Gracilaria*, and *Porphyra*, the entire thallus is the economic organ.
2. Characterization of the eco-niche of each species as a guide to plot their distribution as well as determine the optional population density for maximized production output.

3. Introduction of structural and nutritional technologies designed to ensure dominance of the crop over wild stock herein considered weeds.
4. Ensuring effective growth control techniques upon the crop with the end in view of determining the approximate regularity of harvest season.

Husbandry, more associated with the domestication of crops, when applied to seaweeds may cover its sustained production as well as the regulated foraging of economically useful species. Briefly, husbandry may fall within the context of managed cultivation and harvest of marine plants/seaweeds. Successful husbandry necessitates healthy research and development (R and D) activities on the crop to be domesticated. R and D as precursory step to seaweed husbandry once applied in the Philippines may be determined by some factors:

1. The necessity to meet market demand.
2. The need to operate profitably within the sphere of legal and ethical constraints.

As in any business the acceptance of seaweed husbandry through the medium of mariculture practice of economically viable species is geared at maximizing production to meet market demand. Thus, the goal of most businessmen in order to keep alive their industry is to bloat the return of investments (ROI) of the stockholders, corporate partners or government funding agencies acting as investors and/or owners. This is done by getting involved in sound investments in profitable ventures. Definitely R and D programs, in any language, are among the most speculative of investments. Sad to say, that the atmosphere for R and D lending is at its ebb at present in the Philippines. This bleak picture is attributable to the following reasons:

1. Insufficiency and diverting of money available for innovative R and D projects to tasks way down the ladder of priorities.
2. Disenchantment among technically trained personnel/researchers to get involved on R and D activities, a repercussion of the aforementioned factors.
3. Absence of an integrated seaweed research center where R and D programs may be initiated.
4. The issue on poor money management by lending agencies has led to fears of gross economic collapse. The idea of risk-avoidance mentality simply discourages R and D expenditures.
5. Growing skepticism about the credibility of benefits that science and technology can offer. This is based largely on a poor understanding of what science is and how its results should be handled.
6. The energy crunch in the early 1970's has caused a shift of innovative efforts to energy conservation and disenchantment from product development efforts.

The net result of these factors, unless checked in due time, is a tremendous socio-economic displacement aggravated by reduced financial support for in-house basic research in seaweeds. One of the more timely remedies to this socio-economic upheaval (low production out-put and subsequent dislocation of workers), is emphasis on 'fire-fighting' projects to save our unindustrialized seaweed resources through the introduction of husbandry of seaweeds.

Seaweeds as Export Commodity

Many valuable species of marine macro-algae have never been tested, and many more including some previously mentioned in literature, have still unrealized potential. The results of a completed research, described a total of seventy six (76) species of useful seaweeds gathered from several points in the Philippines (Cordero, 1980).

Also, a progress report covering year one (October 1982-September 1983) of an on-going project based on Panay Island presents significant data on the identification, seasonal occurrence and distribution of forty-two (42) species of sea vegetable algae (Cordero, 1983). Both the 1980 and the 1983 projects, proofs of the richness of our seaweed resources and their potential export capabilities, drew fundings from the National Research Council of the Philippines (NRCP) and the National Museum (NM). Among the potentially economic seaweeds described are *Caulerpa, Eucheuma, Gracilaria, Gelidiella* and *Porphyra* – enjoying extensive distributions in both flanks of the country, but for *Porphyra* which is confined to northern Luzon.

Until the first half of the 1960's the Philippines seaweed export relied mainly on harvesting unmanaged natural/wild stock materials of *Eucheuma* and *Gracilaria.* The pressing needs for higher quality and greater stability and quantities of certain seaweed species, drove the innovative industrialists and farsighted governmental agencies to look toward managed cultivation, or mariculture, as ready answer.

The development of seaweed mariculture has progressed at an imperceptibly snail's pace compared to terrestrial-based agriculture. As expected, crops underwent boom-and-bust cycles dictated with radical price fluctuation in the international markets. Incidentally, in the late 1960's mariculture made its debut in the Philippines using *Eucheuma* as stock material (Doty, 1973). The technology introduced was nonetheless exciting considering that it involves the use of vegetative propagation through cuttings or fragmentation of thalli.

Endowed with favorable ecological parameters, including its geographical location in the tropical region, the Philippines boasts of a rich natural seaweed population. Not only do these crops serve to supplement the harvestable and exportable items, their locations serve also as natural guide for mariculturists where to fix their culture set-ups.

Incorporation of mariculture harvest (*Eucheuma*) with those natural stocks gathered as feral crops (*Gracilaria, Sargassum*), helped improve the Philippine seaweed export as gleaned from the ten-year Bureau of Fisheries and Aquatic Resources (BFAR) report, thus:

Year	*QUANTITY (Kgs.)*	*VALUE (₱)*
1971	473,511	163,979
1972	259,049	237,164
1973	522,649	307,121
1974	2,099,195	4,825,378
1975	3,675,939	10,749,605
1976	5,900,000	13,152,965
1977	8,136,500	15,152,389
1978	85,824,000	18,612,030
1979	106,107,000	58,568,219
1980	115,652,000	63,730,358

Likewise, noteworthy was our 1979 and 1980 seaweed exports to several countries, top five being the following:

COUNTRIES	*QUANTITY (Kgs.)*	*VALUE (₱)*
Denmark	4,878,066 and 4,524,372	13,229,769 and 11,230,920
USA	4,243,116 and 2,285,848	19,551,505 and 21,013,106
Germany	1,535,500 and 914,000	4,070,353 and 93,240
Japan	1,890,811 and 1,678,606	10,073,107 and 12,014,883
Spain	1,196,000 and 1,479,500	3,382,400 and 3,576,745

One should note that the figures presented above are purely results of the introduction of mariculture technology using *Eucheuma* species. Considerably, this red carrageenophytic alga constitutes the bulk of our seaweed export commodity. However, using the 1978 data provided by the BFAR Regional Office in Cebu, the brown *Sargassum* shows the following export statistics, mostly to Japan (c.f. Cordero, 1981):

September 1978 . . . . 97,000 kilos (dry weight)
October 1978 . . . . 214,400 kilos (dry weight)

Another seaweed exported to Japan from Cebu, is *Caulerpa* although figures are not available.

Indeed, mariculture, while this brought about financial benefits to some Filipinos, is one significant facet in seaweed husbandry. If we are to think about the

Japanese experience on their successful *Porphyra* mariculture and its subsequent husbandry, we should be thinking about doubled production for each breakthrough in cultivation methodology adopted by them.

Porphyra, one of the first seaweeds to be industrialized, is largely produced and managed in every suitable bays in Japan. The slow but progressive improvement in the Japanese cultivation technique resulted in an industrial production of about 860 million sheets of the papery, protein-rich red algae per year between 1938 – 1947 and increasing to 6 billion in 1970. Five years later, 7.1 billion sheets (278,127 tons net weight) were produced giving a return of investment of $380 million (Kurogi, 1975).

Incidentally, in the Philippines, where three known species of *Porphyra* grow (*P. crispata, P. marcosii* and *P. suborbiculata*), mariculture of this seaweed promises to be a rewarding venture (Cordero, 1974).

A feasibility study conducted on the sea farming of the genus *Porphyra* (*P. marcosii* Cordero and *P. suborbiculata* Kjellman) in the Philippines (J. M. Cordero, 1982), reveals encouraging results, thus:

I. *Financial Aspects.* The proposed corporation shall have a ₱400,000 shares at ₱100 per share. Of the ₱400,00 authorized, 62.5% or ₱250,000 worth shall be subscribed and paid up by five incorporators/stockholders.

The ₱249,300 required investment will be financed through equity of five incorporators who will each contribute ₱50,000 in order to start the project.

One culture net, measuring 14 meters long and 1.5 meters wide with 12 cm. wide mesh, is expected to yield 20 kilos (net weight) of fresh *Porphyra* for three harvests (800 nets x 20 kilos) = 16,000 kilos = 5,333 dried *Porphyra.* The selling price is ₱180.00 per kilo or ₱30.00 per dried sheet (8-10 inches in diameter), to increase at 10% annually based on an average inflation rate.

B. *Prospected Income:*

The expected sales and net income for five years are shown as follows:

TIME (Year)	*GROSS SALES (Kgs.)*	*NET INCOME (₱)*
Year 01	767,880	160,910
02	929,016	222,832
03	1,125,228	308,543
04	1,362,816	435,561
05	1,649,049	618,435

II. *Demand Forecast.* The demand forecast could be gleaned from viewing the total target and categorizing them into two segments of the market.

1. *Primary Market.* Restaurants and hotels in Metro Manila including those

found in major cities, serving Japanese foods and catering to the middle and upper income groups and the tourists flocking the Philippines, especially the Japanese averaging about 193,465 annually. Per information gathered from 54 big hotels and food establishments, each establishment uses approximately 1,000 kgs of *Porphyra* for regular Filipino customers and about 25,795 kgs annually for tourists coming to the Philippines. Hence, the total demand forecast is about 1,446,948 kgs.

Another primary market for the products are the Japanese residing in the Philippines which number around 3,500 consisting of about 1,500 households. Again, based on interviews, each household consumes about 1 kg of *Porphyra* per month or a total of 18,000 kgs monthly.

The other primary market are the people of the Ilocos Region. The 1,064,0841 potential consumers were determined by assuming that 30% of the total households in the Ilocos Region would consume a modest amount of 1 kg of *Porphyra* a year. The 30% of assumption was based on the economic level of the population who can afford this particular commodity. Hence, considering then that there are 3,543,642 population in the Ilocos Region (Philippine Year Book, 1981), the total demand forecast is about 1,063,089 kgs.

2. *Secondary Market.* The secondary market shall be the Filipinos who have learned to eat and accept the nutritive values of *Porphyra.* Of the total Metro Manila population of 5,843,000 (Philippine Year Book, 1981), the potential market is assumed to be 2% only. The percentage consumption is a conservative one considering that the commodity to be offered is new to most of the populace so much so that it is assumed that each of the 116,872 individuals will consume at least 0.5 kg of *Porphyra* annually.

The total demand forecast for both the primary and secondary markets is 2,586,473 kgs per annum.

It is projected that the corporation will be able to penetrate its target market of 100% after year three of its first five years of operation.

Based on computations, net income is expected to increase by 38% annually.

III. *Socio-Economic Implications.* The proposed project anticipates to bring about several economic benefits to various sectors.

a. *To the Incorporators.* An expected annual income of ₱272,964 or an average of ₱54,592 per incorporator appears highly realistic. This will generate an earning of 109% for each incorporator's investment of ₱50,000. These earnings pooled together could be reinvested to expand the business as to include other commercially important seaweed species.

b. *To the Government.* The Philippine government stands to profit from the proposed project in the form of income taxes paid by the corporation, the individual incorporators as well as by the major employees of the firm.

c. *To the Society.* The project expects to save several establishments, viz., hotels, restaurants, dollars in the importation of dried *Porphyra.* This will help provide the low income Filipinos, specifically, cheap source of protein, iodine, etc., once *Porphyra* becomes acceptable as part of their meals. Additionally, the project expects to help solve partially unemployment by hiring laborers to attend to the maintenance of the seaweed farm, harvesting, drying, packing and handling of the product for marketing and distribution purposes.

Our *Eucheuma* production from feral crops to mariculture through vegetative propagation minus husbandry, shows the following figures; thus, our harvest dwindled from a high of 1,000 tons in 1968 to 318 tons in 1973; export from 805 tons to 264 tons dry weight (Caces-Borja, 1973). In 1974, the production figure improved following limited investment in R and D done by one foreign-financed business outfit. Thus, from the premariculture production figure of 500 tons (dry weight) harvest in 1973, it skyrocketed to over 10,000 tons. One thing is, however, discernible between the *Porphyra* and *Eucheuma* projects of Japan and the Philippines, respectively. The former is owned totally by the Japanese, while the latter is not owned by the Filipinos.

Prospects of Seaweed Husbandry

When referring to whether seaweed husbandry is present or practical to introduce in the Philippines, consideration should be given the following questions:

1. Is there seaweed husbandry in the Philippines?

   As pointed earlier, while mariculture of *Eucheuma* had its foothold in the Philippines during the latter half of the 1960's, no trace of husbandry went with it, technically speaking! Superficially, however, the cultivation of the two genera *Caulerpa* and *Eucheuma* may be considered to have reached the minimal level acceptable under the cropping system standard. Species of green *Caulerpa* (*C. racemosa* and *C. lentillefera*), are cultivated vegetatively through cuttings and are broadcasted in fish ponds of Mactan Island, Cebu. While that of *Eucheuma (E. striatum, E. spinosum,* and *E. cottonii*), the large scale cultivation initially located in Mindanao are now mostly found in select waters in the Visayas and in the South China Sea Coast of the country. Again, while *Caulerpa* cultivation is owned by Filipinos, *Eucheuma* culture activities are run by foreign capitalists. It is evident that the principal concern of the *Eucheuma* capitalists appear more of producing the crops to feed their respective mother/foreign based companies where processing of the raw material into industrial, biomedical and food products take place.

The answer, therefore, to the above question is YES, but only to a limited extent, Also, that elements of husbandry are applicable to both feral crops composed of *Caulerpa, Sargassum, Eucheuma, Garcilaria, Gelideila* and *Porphyra* species as well as the cultivated species of *Caulerpa* and *Eucheuma.*

2. What is the state-of-the-arts of seaweed or sea vegetable algae husbandry obtaining in the Philippines?

The issue raised by this question is whether the current state-of-the-arts of sea vegetable algae husbandry accepts the possibility of its being packaged for future technology transfer.

While it is accepted that experiments have been done to propagate and culture sea-vegetable algae as the green *Caulerpa* and the red *Eucheuma, Gracilaria,* and *Porphyra,* only select species of the first two are presently being cultivated. The cultivation levels of *Caulerpa* and *Eucheuma,* barely quantifiable as crop husbandry, are more appropriately classified as a fishpond and an open ocean practice, respectively.

Acceptably, however, while both *Caulerpa* and *Eucheuma* have reached the commercial stage of production as an evidence of acceptance of husbandry elements, still the agronomic measures needed to package a transferable technology have not been credibly delineated, quantified, and confirmed in field practise to allow large scale promotion of these marine resources. The anemic information on agronomic parameters necessary in the successful husbandry of seaweeds may find remedy through R and D efforts as well as relevant basic researches.

Assessment and Projections

Further refinement of the current mariculture technology is expected to improve the state-of-the-arts of sea vegetable husbandry considered key to the birth of a successful seaweed industry of the country. Somehow, we should try to graduate from too much dependence on the monoculture of *Eucheuma* and *Caulerpa* vegetative propagation often dubbed as a quick-payback investment. Now on its second decade, proponents of seaweeds mariculture have yet to come up with innovative culture methods including studies on the plant's biology or using reproductive characters as guide toward production of better strain or cultivar.

It appears from the foregoing discussion that *Caulerpa* and *Eucheuma* have safely attained the stature of cultivated crops, and that the elements of responsible husbandry are positive for these two sea vegetable species.

It might be worthy of note that in order to attain true commercial successes, following an appropriate management scheme of the seaweed industry, will depend on how fast we could change from monoculture to polyculture practice. In the latter practice several species of seaweeds and/or other crops interact synergistically. By adopting the polyculture system, overhead and operational costs would be spread over two or more commercial operations and would likewise allow extensive recycling of nutrients and water within the culture area.

It is ripe, therefore, that a viable crop production package of technology for both *Caulerpa* and *Eucheuma* be collated taking into account the experiences and observations of mariculture experts in places where these twin marine crops are presently successfully cultured.

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Gregorio T. Velasquez, Discussant

It has been observed that an audience with biological interest like this afternoon is present to listen to the symposium. No other than the President of the University of the Philippines here at Diliman also arranged a series of symposia recently with speakers like our scientific program in the National Academy of Science and Technology. They were drawn from among the faculty of the University, leaders of economics and selected politicians. Several members of the faculty and students attended to participate and discuss with the speakers. The symposia meant to evaluate the exchange of opinions primarily to offer solutions to the present state of the government and economy in the country. We wish then that our exchange of opinions today led by our speaker is equally fruitful.

Dr. Cordero mentioned among others that two species of *Eucheuma, Porphyra* and *Gracilaria* have been known as sources of carrageenan and possibly local sources of agar used by the people especially in the rural districts. Success has been shown in *Eucheuma* as presently a large source of the local dollar-earning towards the nation's economy. *Porphyra* and *Gracilaria* are beginning to attract also similar sources of dollar-earning needed at present.

But if we can suggest other red algal specimens such as *Hypnea musciformis, Laurencia pinnatifida* and *Gracilaria verrucosa,* I believe that these marine benthic algae can be useful as good sources of exportable food like the three genera already mentioned above. The latter genera grow also in abundance in the local seas.

The Philippines is an archipelagic country composed of seven thousand islands where seventy-five percent are marine waters, the rest freshwaters. On top of these records the freshwater in agriculture has most likely reached the maximum development production of our staple food. The fertilizers imported from abroad can not be available these days in agriculture. The prices are prohibitive since we do not have sufficient dollars. Even the saltwater of the sea has diluted our freshwater used in some ricefields. Hence, the nation should keep alert of this slow but destructive change in the local ecology.

But how can our alertness suit to the present national disaster? Below then may be indeed very timely suggestions:

1. That while Dr. Cordero has informed us of the exportable food resources like
2. *Eucheuma*, with the varieties: *E. striatum* (cottonii of commerce), *E. spinosum* and possibly *Porphyra crispata* now included in the present mariculture. *H. musciformis, L. pinnatifida* and *G. verrucosa* can be added.
3. Only with exception that the algae for the selected stocks in propagation be planted to adapt themselves to the ecosystem where they grow best.
4. With time permitting the inclusion of genetic experiments and selection in the processing of better stocks should be done simultaneously.

5. And lastly, it is important that our workers in the field be possessed with interest and dedication to do the follow-up of the experiments in order to realize the excellence of results. The maturation of the mariculture as in *Eucheuma* is needed to realize the objectives.

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QUALITY ASSURANCE IN THE FISH PROCESSING INDUSTRY

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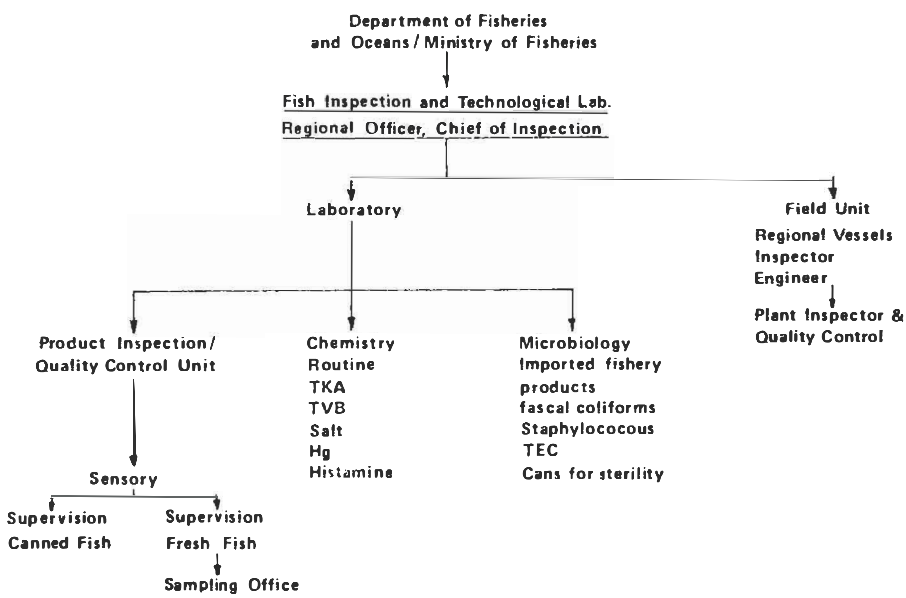
1.0 Quality Assurance vs. Quality Control

The development and expansion of the local export trade of fish and fishery products can be facilitated by instituting a system of quality control measures.

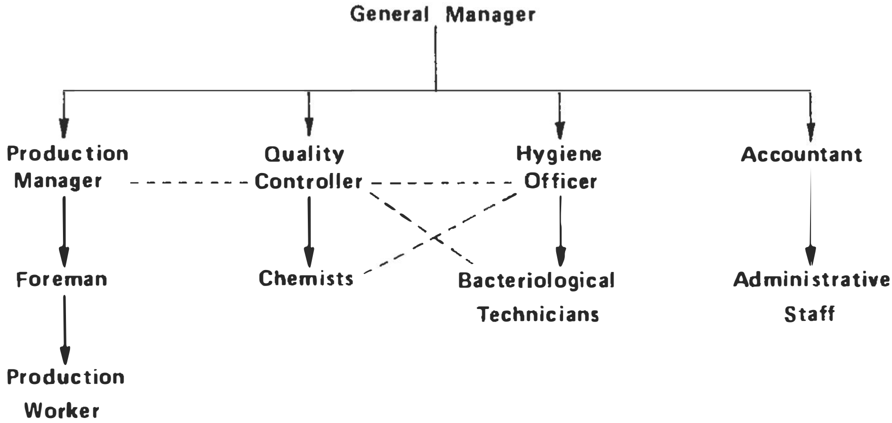
Quality Control is defined as the application of measures that slow the deterioration of quality to its lowest practical rate while *Quality Assurance* is the application of measures that ensure the availability of only high quality seafoods for consumption.

2.0 Schematic Diagram of an Ideal Quality Control Organization

2.1 Government



2.2 Industry/Processing Plant



3.0 Problems in the Local Industry Due to Lack of Quality Assurance Measures

3.1 *Vibrio, Staphylococcus, Salmonella* in exported shrimps and prawns

Tons of frozen shrimps imported from the Philippines were destroyed because of *V. cholerae* contamination by Tokyo quarantine officials of the Health and Welfare Ministry (April 21, Bulletin Today, 1984). It was the first case of cholera germs found in frozen shrimps imported from the Philippines.

Failure to comply with food import regulations has resulted to tremendous losses incurred by exporters of fishery products, these losses can be avoided. Importing countries like West Germany, Denmark and France have strict specifications for food poisoning organisms such as *Staphylococcus* and *Salmonella* in frozen shrimps and prawns. These countries require the absence of *Salmonella* in 25 g sample; *S. aureus* counts must not exceed 10^2/g sample. Mendoza (1981) reported that the counts of *S. aureus* in market samples of frozen shrimps and prawns ranged from $10^1 - 10^3$. Three processing plants were found to be positive for *Salmonella*. Analysis of the possible source of contamination in four shrimp processing plants investigated showed a prevalence of *S. aureus* in the hands of workers ranging from 40 to 77.88%. Moreover, the raw materials were found to be contaminated with *Salmonella*. Observance of proper hygiene by the workers and in all stages of processing of the product must be strictly followed to eliminate the risks of contamination of the shrimps and prawns with pathogenic organisms.

3.2 Histamine in Canned Tuna

Histamine is implicated in scombroid poisoning. Scombroid poisoning is due to microbial enzyme decarboxylation of histidine to histamine. Scombroid toxin is common in frigate mackerel (tulingan) and other species of the family Scombridae such as tuna, tuna-like species and mackerel. Studies on the effects of delay in icing and processing of scombroid fish on the histamine levels have been conducted locally (Orejana *et al.*, 1983).

Canned tuna for export usually contains between 10 mg% and 30 mg% histamine which is above the limit of 10 mg% set by importing countries like West Germany. The BFAD (Bureau of Food and Drug) therefore requires a certificate of histamine analysis before canned tuna can be exported as an assurance of quality.

3.3 Lack of Hygiene in Fish Sauce/Fish Paste Establishments (Processing Plants)

Recently (April 19, 1984; Bulletin Today) shipments of fish sauce and paste for the U.S.A. were rejected and detained by the US Food and Drug Administration due to the presence of insect and rodent filth. The rejection of the contaminated food products was mainly due to lack of hygiene in the processing establishments. The practice of using dirty containers, contaminated salt, contaminated raw materials should be strongly discouraged in the fish sauce/fish paste industry.

3.4 Under-Processing/Over-Processing of Canned Fish Products

Microbial spoilage of canned products may be a consequence of under-processing which may result to health risks with *Clostridium botulinum* contamination and commercial risks with non-pathogenic spoilage. The process must be sufficient to eliminate heat resistant spores of *C. botulinum* or other even more heat resistant spores. The specified process time and temperature for a specific product must be achieved and strictly followed.

The lack of heat penetration data monitoring can result in under-processing or overprocessing. Overprocessing may lead to overcooking and loss of color, flavor, texture, and nutrients. All these are to be avoided with implementation of quality assurance measures.

3.5 *Salmonella* in Fish Meal

The Salmonella outbreaks in U.S.A., U.K., Europe and Israel in the early 1970's resulted to strict regulations for incoming fish meal. Contamination of fish meal with *Salmonella* will likely occur if the meals are not properly handled. Sumner, Quiazon and Nieto (1981) found that fish meal imported from the U.S.A was contaminated with *Salmonella*. The contamination of the meal may have possibly occurred in the Philippines due to improper handling and storage.

3.6 Aflatoxin in Fish Meal and Some Smoked Products

Fish meal and smoked products may harbor aflatoxin producing molds if not properly handled. Prevalence of aflatoxin producing molds in some smoked fish products has been reported by Bulaong (1983). Possible source of these aflatoxin producing molds is the brine used for salting the smoked fish. Trinidad, Espejo-Hermes and Reilly (1983) isolated several species of *Aspergillus* which are potential aflatoxin producers in the brine used in the commercial production of smoked fish. The practice of some local processors of using the brine continuously must be discouraged due to the danger of growth of aflatoxin-producing molds in the product.

3.7 Freezer Burn in Frozen Fish

The rate of deterioration of frozen fish is mainly dependent on its temperature. Variation in temperature may result to freezer-burn (whitened, toughened, and wrinkled appearance of parts of the surface that have been excessively dehydrated). Freezer burn can be reduced by using tight-fitting wrapping impermeable to water vapour, and by glazing the product (dipping the frozen product in water).

3.8 Poor Market Quality of Wet Fish

Wet fish usually command lower prices than processed products due to improper practices of fishermen, wholesalers and retailers. Fish must be maintained at a temperature of as near as $0^{\circ}C$ as possible after catch to assure its good quality. For this purpose adequate amounts of ice must be used. Re-icing, particularly during the hot months, must be done as often as possible.

3.9 Inferior Quality of Local Extracts of Carrageenan

The inferior quality of carrageenan produced locally could be due to lack of quality control of materials. Mixtures of seaweeds for carrageenan extraction are being used in the industry. Proper selection of raw materials must be done to produce good quality carrageenan extracts.

3.10 Inferior Quality of Dried and Smoked Fish

This problem emerged due to the absence of standards for these products. Variability in the processing practices results to inferior quality. The important aspects of quality in dried and smoked fish are concerned with the freshness and manner of preparation of the raw material, the salting process, the smoking process and the post-processing history of the products i.e. its storage, transportation and retailing.

3.11 Melanosis in Shrimp

The development of the black spots or melanosis may begin within a few hours after catch of the shrimps. However, even with continuous icing, blackening may be far advanced before the shrimps can be marketed. Icing of the shrimps immediately after catch should be encouraged to prevent melanosis. Removal of the head of the shrimps and/or the proper use of soluble antioxidants such as ascorbic and citric acid will help prevent blackening. *Calamansi* juice has been reported to be efficient in preventing blackening in shrimps (Bersamin, Legaspi and Macalincag, 1971).

4.0 Quality Standards and Codes of Practice Recommended for Fish and Fishery Products

The regulations on fish and fishery products are intended to ensure that these products conform to the standards of wholesomeness, sanitation and labelling required of domestic and import trade.

All fish and fishery products must comply with the FDA requirement covering the following areas: adulteration, misbranding, labelling, definition and standards for identification, tolerance of poisonous and deterioration substances, pesticide residues, food additives and good manufacturing practices defect action level.

Failure to declare the presence of added salt or the kind of oil used as the packing medium in canned fish has resulted in the detention of fish products. Artificial coloring is not permitted if it conceals damage or inferiority. Use of permitted artificial flavouring, artificial colors or chemical preservation must be conspicuously declared in the labelling. Imitations must be labelled as such.

Particulate and bacterial contamination in the processing, storage, handling, incubation, and operating practices within the plant must be avoided.

4.1 Quality Indices

4.1.1 Physical/Sensory

The sensory evaluation of fish quality has usually been made by methods based on either hedonic scale or on descriptions of the various sensory attributes of the fish: appearance of the eyes, gills and skin; texture of the flesh; odour of the raw and cooked fish and flavour of the product.

Physical evaluation includes TD (thaw drip measurement in frozen fish), Torrymeter (freshness test), texture measurement (by Instron or modified texture meters), odor/pollution levels measurement for fishmeal and others.

4.1.2 Microbiological Tests

Most commonly employed for microbiological analysis are the following:

Standard plate count at 35-37°C
Escherichia coli (Faecal coliform)
Staphylococcus aureus
Salmonella and *Vibrio*

4.1.3 Chemical/Nutritional Methods

Analyses for histamine (TLC, GLC, Fluorimeter) amino acid rancidity (TBA peroxide value), mercury, TMA (trimethylamine) and DMA (dimethylamine), TVB (total volatile base), protein, fat and others are required by some importing countries.

4.2 Specifications and Recommended Codes of Practice of Handling and Transport, Processing, Storage, and Distribution of Fish and Shellfish

4.2.1 ICMSF (International Commission on Microbiological Specifications of Foods). This body reviews and publishes values for SPC (Standard Plate Count) and pathogens, commonly used in different countries for different fishery products.

4.2.2 Codex Alimentarius — Joint FAO/WHO Food Standards Programme

Currently up to 121 (as of Nov. 1, 1981) countries are collaborating in the drafting of comprehensive, minimum standards for a wider range of products moving in international trade. Almost all are for products meant for direct sale to the consumer.

4.2.3 PSA (Philippine Standards Association)

The PSA (NSTA funded) is putting up standards on processed fish and shellfish with the cooperation of various research/government agencies (BFAR, UP, FDA, NIST) and the industry. FTI has also formulated standards for frozen and fresh fish.

5.0 Role of R & D (Research and Development) in Quality Assurance

Research and Development is important in the development of a new product, process or equipment which may elicit a change in quality control procedures. It could also be helpful in the task of translating values obtained from test procedures into meaningful grades and in integrating the various grades into a complete standard of quality. In short, R & D can lead to quality control measures which will upgrade the quality of products thereby improving their competitiveness in the market.

6.0 Conclusions and Recommendations

The emphasis given by developed countries on the quality control and fish inspection of fish and fishery products is quite remarkable. The high quality of fish and fishery products may be attributed to the voluntary and/or mandatory regulations and guidelines issued by government and private agencies. Quality consciousness is inherent in the manufacturer's concept while with the local manufacturers in the Philippines profit seems to be the primary consideration. In the developed countries, improved quality is synonymous with a better price for the product.

In the Philippines, the law of supply and demand and other economic factors as well as psychosocial problems make it quite difficult to enforce standards, if they exist at all for a limited number of products.

The lack of well-equipped centralized and regional quality control laboratories and the lack of qualified manpower mainly account for the poor credibility of government research agencies from the point of view of the industry. As a consequence, the improvement of quality of fishery products through technology transfer or research results is quite difficult to achieve. The traditional products (smoked, dried, and fermented) in the market are of heterogeneous quality. Since no grading of products is made locally, better quality products are not assured of a higher price, as is the case in the U.K. and other countries due to the use of the EEC rating.

As to research priorities, local government agencies emphasize production and give lower priority to processing and quality standardization of products.

It is highly recommended that the organizational scheme of quality control and inspection in the Philippines should be reviewed and bureaucracy reduced accordingly. The overlapping of functions of various agencies which lessens efficiency must be eliminated or well-coordinated. Voluntary rather than mandatory compliance to guidelines (e.g. Codes of Practice by the Codex Alimentarius) should be encouraged. The private sector should be willing to share the task of improving product quality by financing semi-private or cooperative ventures similar to those found in Germany and Norway.

The importers of tuna in Germany and Denmark require histamine data from the exporters. The need for setting up a histamine laboratory for the industry either by the government and/or private sector is a priority that should not be overlooked.

There is a need to establish uniform procedures (microbiological, chemical, and sensory) for all the local agencies and the industry to adopt in the quality assessment of fish and fishery products, particularly for exported products.

The development of standards that are applicable to local products is recommended. For exported products the standards set by the importing country must be fully satisfied in order to create a good image of Philippine fishery products in the international market.

The grading of products as to quality and the corresponding increase in price for products of better grade will help encourage the industry to voluntarily conform to the codes of practice and standards put up by the quality control and fish inspection agencies.

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CHEMISTRY

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SPECTROSCOPIC STUDIES OF THE REACTION OF DICHOLORO-*bis*-N,N' – DIPHENYLTHIOUREACOBALT (II) WITH OXIDIZING AGENTS IN NON-AQUEOUS SOLVENTS

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The spectroscopic properties of solutions of *bis*-N,N'- Diphenylthioureadichlorocobalt in acetone, acetonitrile and ethanol are compared with those in the solid complex. The changes in the electronic spectra upon the addition of oxidizing agents are presented. The formation of a stable intermediate species is discussed based on the shift of the absorption band maxima and the appearance of new absorption bands.

Introduction

In a broader study of comparing selenium and sulfur as donor atoms, complexes of the disubstituted selenourea and thioureas with cobalt (II) and nickel (II) were synthesized (Rivero, 1977). The crystals were characterized through elemental analysis, infrared spectra, the absorption bands in visible region, and the magnetic susceptibilities. Through these measurements, the identity of the complexes as pseudotetrahedral complex with the selenium or sulfur as donor atoms in one pair of ligands, and the corresponding halide as the other pair of ligand was established. One of the complexes studied was dichloro-*bis*-N,N'-diphenylthioureacobalt (II), $Co(Diphentu)_2\ Cl_2$. Some vibrational bands of the complex are shown in Table 1, along with the vibrational bands of the pure ligand. The broad N-H symmetric stretching vibration was not shifted at all in the complex compared to that in the pure ligand. On the other hand, the C=S at 645 cm^{-1} in the pure ligand was shifted to 520 cm^{-1} in the complex, indicating that coordination is at sulfur and not at nitrogen.

The absorption bands in the visible region for the solid $Co(Diphentu)_2Cl_2$ are shown in Figure 1; the absorption maxima with the corresponding assignments are listed in Table 2. The Dq values for $Co(Diphentu)_2\ Cl_2$ is 342 cm^{-1} and the corresponding Racah parameter B for the complex is 731 cm^{-1} (Rivero, 1981). The B value of $Co(Diphentu)_2Cl_2$ indicates a large degree of covalent bonding, since B is a measure of the degree of electron cloud expansion away from the central metal ion.

In solution, some of the complexes studied were relatively stable. *bis*-N,N'-Dibenzylthioureadichlorocobalt, $Co(Dibenztu)_2\ Cl_2$, and *bis*-N,N'-Dibenzylthiourea-

Table 1. The IR vibrational bands of N,N' – Diphenylthiourea and Dichloro-*bis*-diphenylthioureacobalt (II), with the corresponding assignments.

N,N'–Diphenylthiourea	*Dichloro-*bis*-N, N'–dithioureacobalt (II)*	*Assignment*
	275 W	
	295 vs	Co-Cl
	315 m	Co-S
	325 s	
450 w	400 w	
485 m	510 vs	υ (N–C–N), δ (C=S), ρ (NHR)
510 w		
550 w		
630 v s sh	520 vs	υ (C=S)
645 s sh	640 m	δ (N–C–N), υ (C=S) ρ (NHR)
760 v s sh	600 m	δ (N–C–X)
765 s sh		C_6H_5
1315s	1265s	CS NH II: NH wagging, υ_{sym} (N–C–N), υC = C
1345 s br	1290 s	
1340-1350 s br	1310 s	
1590 m sh	1515 vs	CSNH I: NH twisting, υ_{asym} (N–C–N)
1598 m sh	1540 vs	
3000 m	3000 m	C=C–H
3020 m	3025 w	Ar–H
3205 vs br	3205 s	N–H υ_{sym} and υ_{asym}
	3320 s sh	
	3350 s sh	

dichlorocobalt, Co(Dibenztu)$_2$ Cl$_2$, and *bis*-N,N'-Dibenzylthioureadibromocobalt, Co(Dibenztu)$_2$Br$_2$, were shown to retain their pseudo-tetrahedral coordination in nonaqueous solvents (Quimsing and Rivero, 1984). Co(Dibenztu)$_2$Cl$_2$ showed susceptibility to lose or gain electrons, as shown in electrochemical measurement carried out on its solution in acetonitrile (Quimsing, 1983). In this study, the spectroscopic properties of the N,N'-diphenylthiourea complex with cobalt (II) in acetone, acetonitrile and ethanol were measured. The changes of the UV-Vis absorption spectra in the different solvents are discussed. In an attempt to measure the susceptibility of Co(Diphentu)$_2$Cl$_2$ to oxidation, solid oxidizing

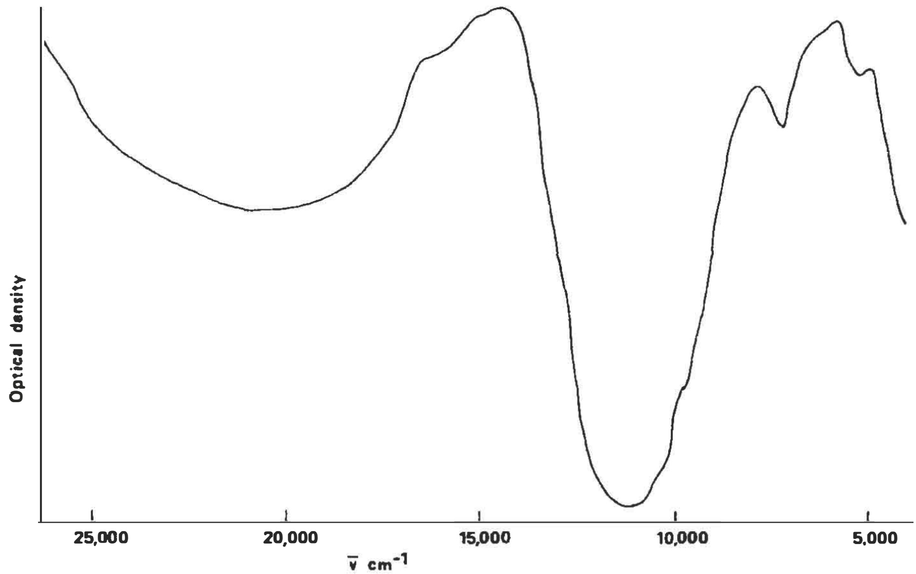


Figure 1. The absorption spectrum of Dichloro-*bis*-N,N' diphenylthioureacobalt (II) in the near IR-Vis region.

complexes were added and the change in the absorption spectra with time was monitored.

Experimental Procedure

N,N'-Diphenylthiourea was prepared from redistilled aniline and carbon disulfide following the procedure reported earlier (Quimsing, 1983). The complex was prepared by dissolving 1 mmole of the ligand in hot anhydrous dichloroethane, then adding 0.5 mmole of cobalt chloride dissolved in hot anhydrous ethanol. Crystals separated out upon gradual evaporation of the solvent; these were re-crystallized in hot anhydrous dicholoroethane.

The melting point was measured using a Buchi melting point apparatus, while the IR spectra were measured in a Perkin-Elmer IR spectrophotometer. The UV-visible absorption spectra of the solution were measured using a digital single beam UV-Visible spectrophotometer.

Results and Discussion

The absorption spectra of $Co(Diphentu)_2Cl_2$ in different solvents are shown in Figure 2. For comparison, the analogous spectra of cobalt chloride in the three solvents were measured and the absorption spectra are shown in Figure 3. For sub-

Table 2. The absorption maxima of Dichloro-*bis*-N, N' – diphenylthioureacobalt (II) solid with the corresponding assignments of the absorption bands.

$\bar{\upsilon}$, *cm−1*	λ, *nm*	*Assignment*
4600	2173	$^4A_2$ (F) → $^4T_1$ (F)
5600	1786	
7300	1370	
11500	869	spin-forbidden band
14000	714	$^4A_2$ (F) → $^4T_1$ (P)
15000	667	
21400	467	spin-forbidden bands
22300	448	
29000	345	charge-transfer band

sequent discussion, the following labels of absorption bands are used:

- ν_1 absorption band at 630-700 nm $^4A_2(F) \rightarrow {}^4T_1(P)$
- ν_2 hump or shoulder at 580-580 nm $^4A_2(F) \rightarrow {}^4T_1(P)$
- ν_3 weaker band at 350 nm
- ν_4 weak to strong band at 300 nm. aromatic, $n \rightarrow \pi^*$

In acetone, the absorption band of $Co(Diphentu)_2Cl_2$ at 678 nm is broad, with a molar extinction of 270. The shoulder at 600 nm, is still part of the $^4A_2(F) \rightarrow {}^4T_1$ (P) transition, which, depending on the solvent used, may become prominent. The maximum of the absorption band at 350 nm decreased in intensity upon coordination, using the solution of the ligand in the same solvent as the standard. The knick at 370 nm is seen in this spectrum. The absorption spectrum of the acetonitrile solution of the complex is different from that of the acetone solution. The molar extinction is lower than the corresponding value of the cobalt chloride solution. The hump or shoulder at 580 nm is very prominent. Furthermore, the aromatic band at 350 nm (ν_3) is weaker than the corresponding band of the pure ligand (Figure 4), but there is a trace of the weak band (ν_3) at 390 nm. When the spectrum is measured against the ligand in acetonitrile as standard, the absorption bands are much weaker. The absorption spectrum in ethanol shows that the aromatic band is shifted to longer wavelength and ν_1 (tetrahedral band) is still weaker than that of the acetone solution. The wavelengths of both peaks however, were not shifted relative to acetone.

A comparison of the spectra of the three solutions of $Co(Diphentu)_2Cl_2$ is shown in Figure 2. These spectra had the solution of ligand as standard. It is seen

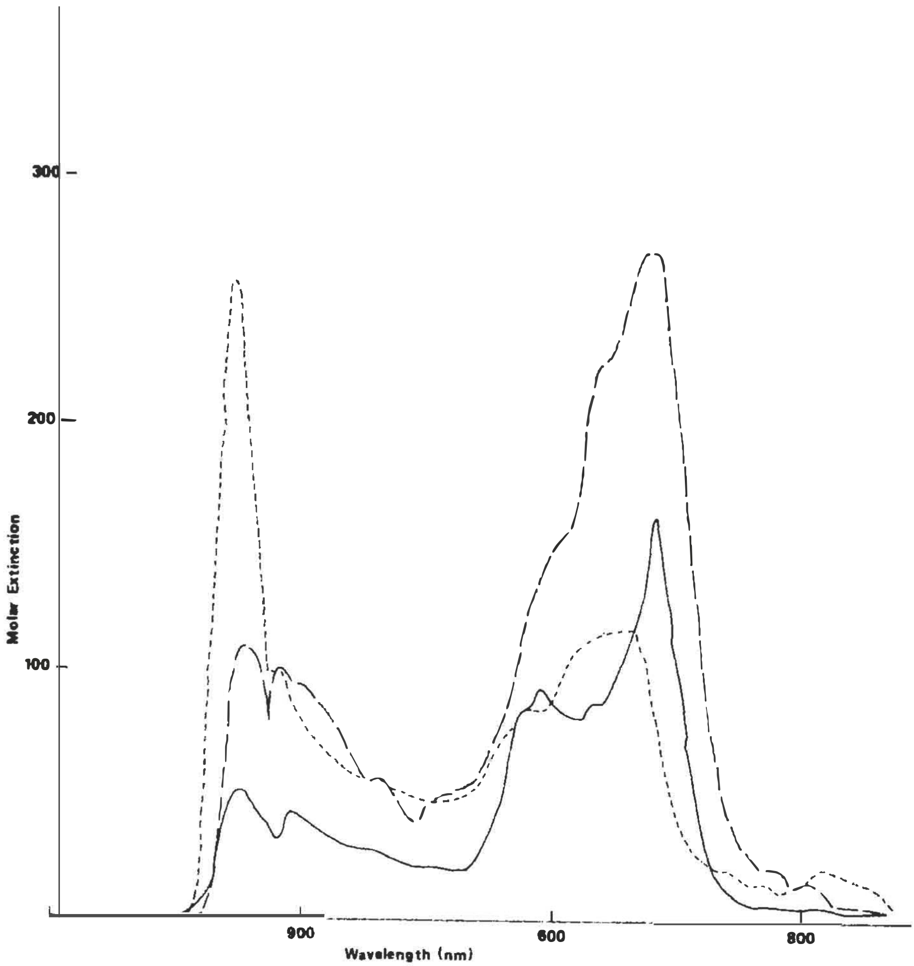


Figure 2. The absorption spectrum of Co (Diphentu) $_2Cl_2$ in acetonitrile in acetone.

that the bands for the ethanol solution were shifted towards shorter wavelength. Acetone appears not to influence the location of ν_1, although in general, these absorption bands are weaker than that expected of tetrahedral complex.

Table 3 compares the absorption bands of $Co(Diphentu)_2Cl_2$ in different solvents with those of cobalt chloride. It is shown that ν_1 is located in the region expected for tetrahedral complex, i.e. between 600 to 700 nm, but closer to 700, as shown in Figure 5 and 6. Figure 5 shows the absorption band of $[CoCl_4]^{2-}$ for the transition $^4A_2(F) \rightarrow {}^4T_1(P)$ (Ballhausen and Jorgensen, 1955). The absorption band has a characteristic splitting into two almost equivalent peaks at 690 nm and 662 nm, and a separate peak or at times, a shoulder at 630, less intense than the

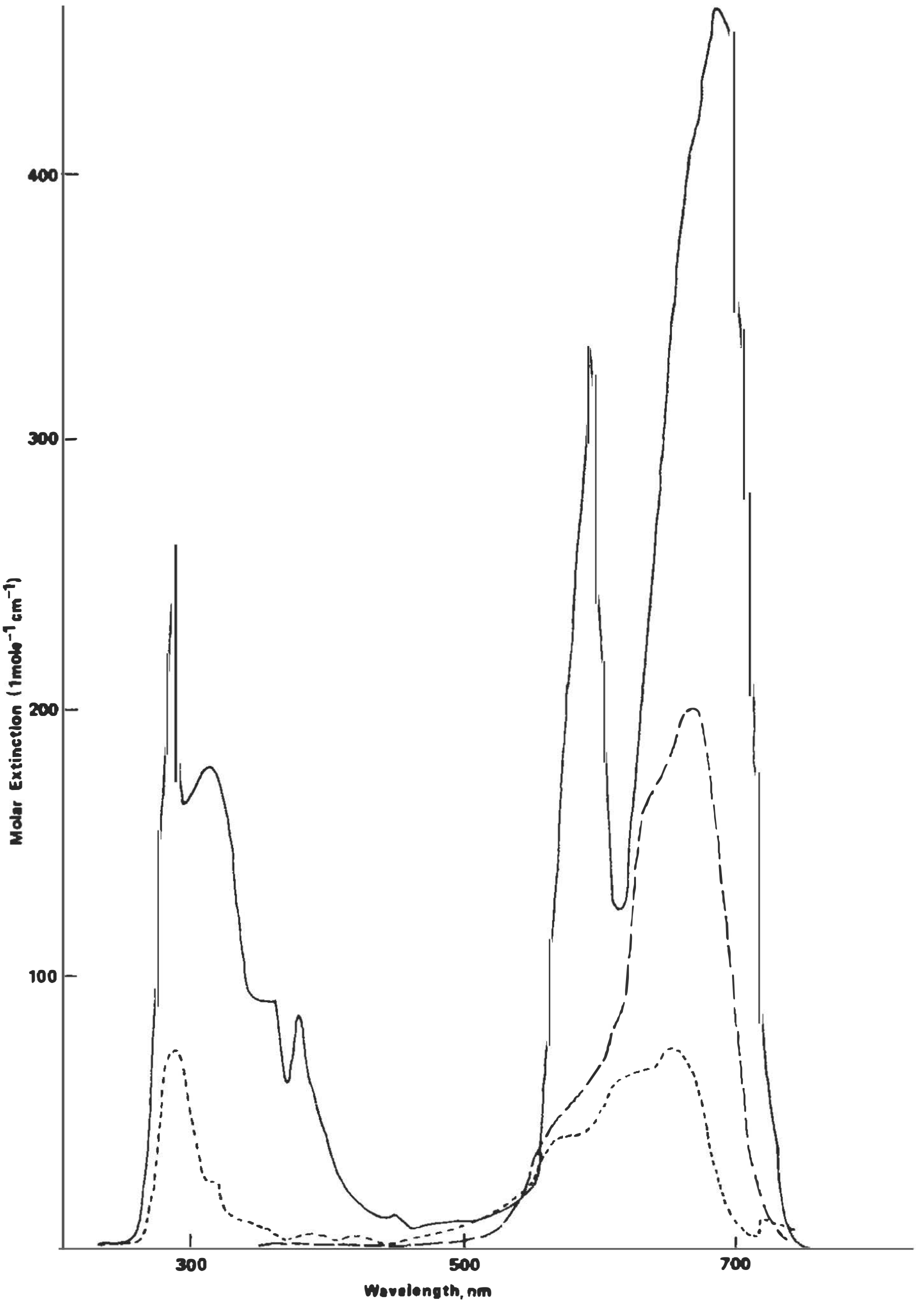


Figure 3. Absorption spectrum of $CoCl_2$ in acetonitrile (——————·—·———) in acetone (— —); in ethanol (— — — — — — — —).

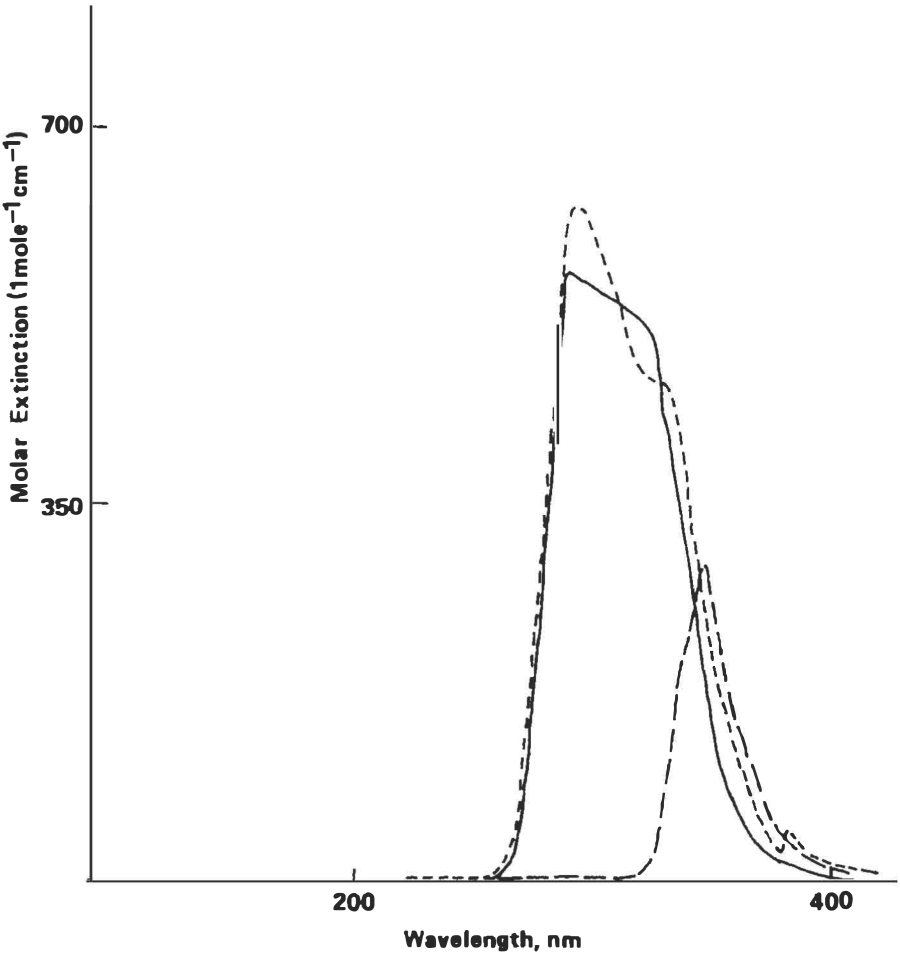


Figure 4. The absorption spectrum of N,N' –Diphenylthiourea in acetonitrile (__________), in acetone (– –) and in ethanol (– – – – – – – – – – –).

other two. The maximum for this band is at 676 nm with a molar extinction of 570 and 540 for the strong double peak, and 350 for the weaker peak or shoulder at 630 nm. On the other hand, Figure 6 shows that absorption spectrum of $Co(H_2O)_6{}^{+2}$, with λ_{max} in the different solution (Table 3), one can safely assume a tetrahedral configuration for the complexes.

The absorption band of the pure ligand is affected by the solvent, as was shown in Figure 4. In Table 3, it is shown that the λ_{max} of the ethanol solution of the pure ligand has the shortest wavelength and the most intense. This band is caused by the conjugated double bonds in phenyl, which, with $-NH_2$ as substituent,

Table 3. A comparison of the absorption maxima of Co(Diphentu $_2Cl_2$ and $CoCl_2$ in the different solvents.

	Co (Diphentu) $_2Cl_2$ λnm (ϵ)	$CoCl_2$ λnm (ϵ)	Diphentu λnm (ϵ)
Acetone			
ν_1	678 (270)	670 (200)	
ν_2	600 (150)	580 (56)	
ν_3	380 (85)	none	
ν_4	350 (112)	none	340 (291)
Acetonitrile			
ν_1	680 (161)	680 (466)	
ν_2	590 (94)	688 (340)	
ν_3	390 (45)	350 (84)	
		310 (180)	
ν_4	350 (49)	290 (263)	301 (560)
Ethanol			
ν_1	645 (112)	650 (70)	
ν_2	582 (88)		
ν_3	380 (85)		
ν_4	340 (256)	285 (70)	296 (626)

has λ_{max} at 230 nm (8600) and at 280 nm (1430) (Williams and Fleming, 1968). The absorption band of the ethanol solution has a shoulder at 320 nm, ϵ = 466. The maxima for the ligand solutions are shifted to longer wavelengths compared to that of aniline.

A weak absorption band appears at 375 nm (ϵ=45) for the ethanol solution of the ligand. The C=S in thiocarbonate ester has weak absorption band at 330 nm (ϵ=5). It is possible that the weak band at 375 nm for the ethanol solution of the ligand may be due to the C-S group.

The absorption band in the 350 nm region shows that upon coordination, the peak due to the phenyl ring decreases in intensity and also, is shifted to longer wavelength. The structural formula of the complex is shown in Figure 7. The proximity of the phenyl rings to the central metal ion allows some interaction between the phenyl ring and the metal ion. The strong absorption band of the pure ligand is shifted to longer wavelength upon coordination. This interaction however, is affected by the solvent.

Potentiometric titrations were carried out, using aqueous solution of the titrant (either oxidizing agent or reducing agent) but non-aqueous solution of the complex. The titration curves show an abrupt and sudden change in potential as

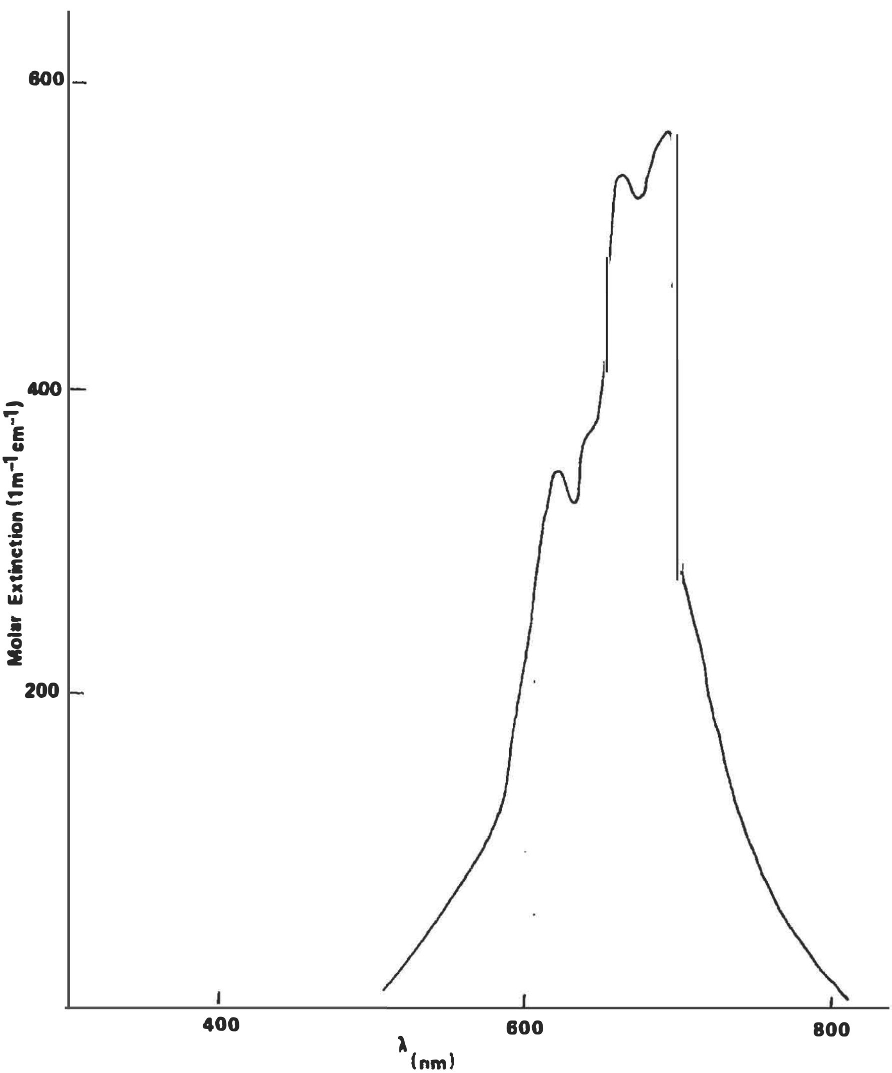


Figure 5. The absorption spectrum of $[CoCl_4]^{-4}$ (Schlaefer and Gliemann, p. 92), assigned to the transition $^4A_2$ (F) → $^4T_1$ (P) (Ballhausen and Jorgensen, 1955).

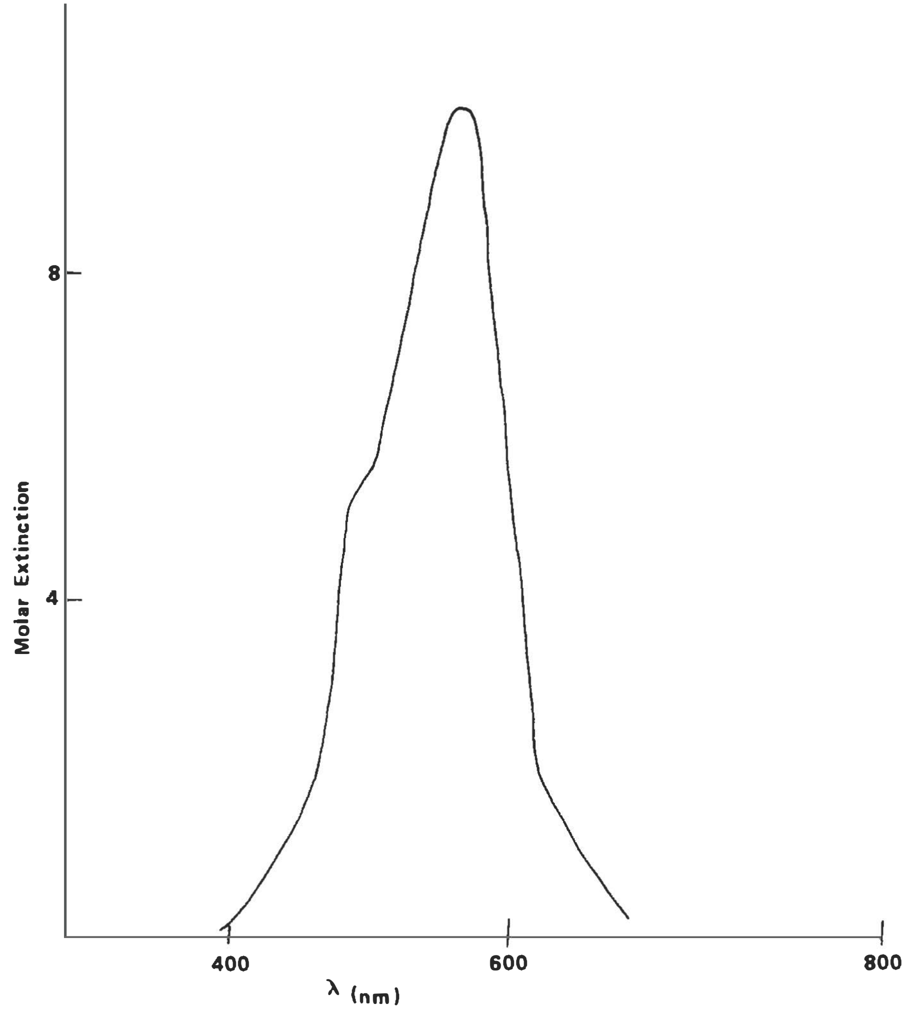


Figure 6. The absorption spectrum of $Co(H_2O)_6^{2+}$ (Schlaefer and Gliemann, p. 92) for the transition $^4T_{1g}(F) \rightarrow {}^4T_{1g}(P)$.

soon as few milliliters of the titrant were added. The change of potential indicates that there is a reaction going on, but whether the equivalence point coincides with the region of very large change in potential with the volume of titrant cannot be established. One property of the complex which can be monitored during a reaction is the absorption spectrum. In order to solve the problem of solvents, solid oxidizing or reducing agent was added to the solution of $Co(Diphentu)_2Cl_2$ and the spectrum is taken periodically. One limitation is that if the reagent is insoluble in

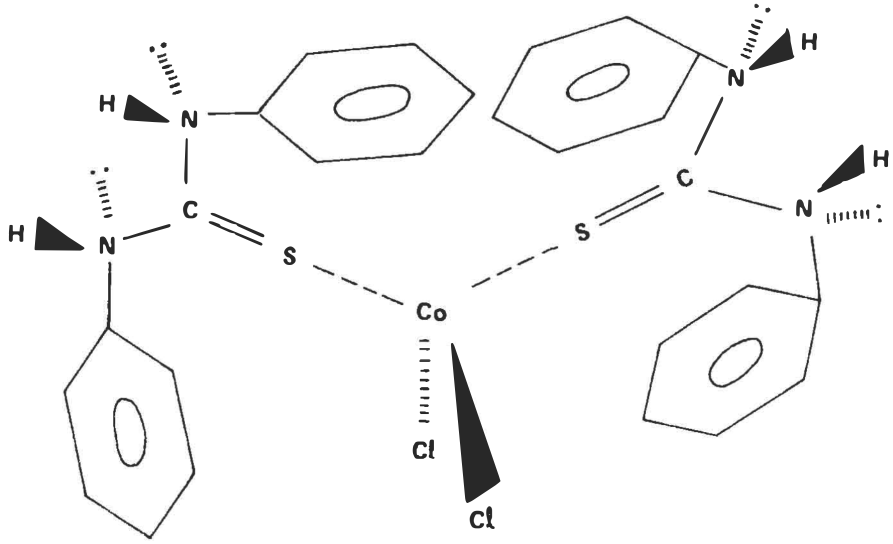


Figure 7. Structural formula of Co (Diphentu) $_2Cl_2$ showing an arrangement where the phenyl rings can be affected by coordination with the central metal ion.

organic solvent, then the oxidizing agent or reducing agent will just settle at the bottom of the cuvette. But this will on the other hand, make the change of the complex if any, slow enough to be measurable spectrophotometrically.

Figure 8 shows the change in the absorption spectrum of a solution of Co-(Diphentu)$_2$Cl$_2$ in acetone upon the addition of solid $K_3Fe(CN)_6$. Compared to the spectrum of the complex itself, the following changes are observable:

ν_1 increased in intensity, ϵ =882 but λ_{max} remained the same.

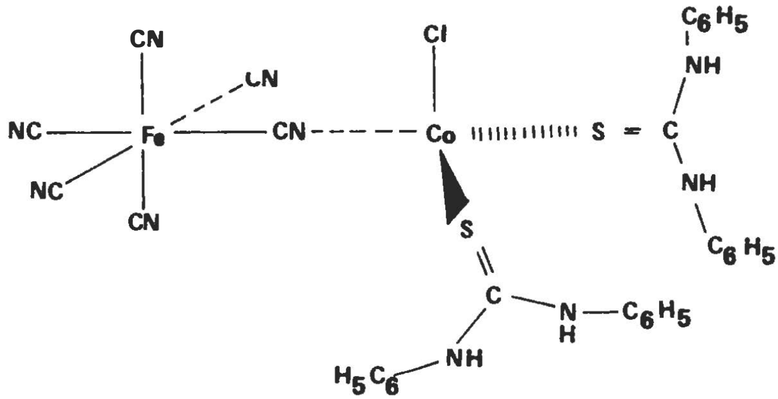
ν_2 Still a shoulder, but intensity increased

ν_3 became more intense, λ_{max} for the first 30 min. not shifted but after an hour, shifted to shorter wavelength

ν_4 became more intense, at the start not shifted relative to pure complex; after 30 min shifted to longer wavelength, but after an hour shifted to shorter wavelength.

The change in the spectra with time is detectable: the molar extinction changed – this means that the species is not the same as that in the pure complex. There is only one absorbing species in the solution, as shown by the common molar extinction at λ720 nm. $[Fe(CN)_6]^{4-}$ has an absorption maxim at 316 nm. (Huchital and Wilkins, 1967). The peak at around 350 nm would be due to the $[Fe(CN)_6]^{4-}$ formed upon reaction of $[Fe(CN)_6]^{3-}$ with the complex. One of the CN of

$[FE(CN)_6]^{3-}$ may have coordinated with $Co(Diphetu)_2Cl_2$ and form the interme-diate species



displacing one of the chloride ion. The shoulder at 400 nm which shifted back to 380 nm after an hour may be due to the CN- which was coordinated with cobalt at the start and after 30 minutes.

The changes in the absorption spectrum of the acetonitrile solution of Co–(Diphentu)$_2$Cl$_2$ after addition of solid $K_3Fe(CN)_6$ are shown in Figure 9. ν_1 which is the band arising from $^4A_2(F) \rightarrow {}^4T_1(P)$ transition in Co(II), tetrahedral complexes, did not change in wavelength, but there is a slight broadening of the band towards 550 nm. There is also a weak broad peak at 520 nm. An absorp-tion band at 430 nm 2 hours after the addition of $K_3Fe(CN)_6$ could be that of $Fe(CN)_6{}^{2+}$. The band at 520 nm may be due to Co(II) species while that at 430 nm may be due to $Fe(CN)_6{}^{4-}$.

In ethanol solution the change in the molar extinction of the absorbing species upon the addition of $K_3FE(CN)_6$ is in reverse to what happened in acetone solution. The molar extinctions decreased compared to that of the complex in ethanol, as shown in Figure 10. The decrease could mean the formation of a) octa-hedral Co(II) species which have small molar extinction, b) cobalt (III) species still with tetrahedral surroundings. It is possible that in the reaction with $Fe(CN)_6{}^{3-}$, one of the CN groups is attached to cobalt (II) as an additional ligand and not displacing chloride.

With $Na_2Cr_2O_7$ as oxidizing agent, the absorption peaks became weaker compared to those of the complex in acetone. The change of absorbance with wavelengths, upon the addition of solid $Na_2Cr_2O_7$ is shown in Figure 11. The changes can be summarized as follows:

- ν_1 decreased in intensity, i.e. molar extinction decreased, but λ_{max} the same
- ν_2 more distinct 600 nm
- ν_3 broader, becomes clearer after 30 minutes and after 77 minutes after addition of $Na_2Cr_2O_7$

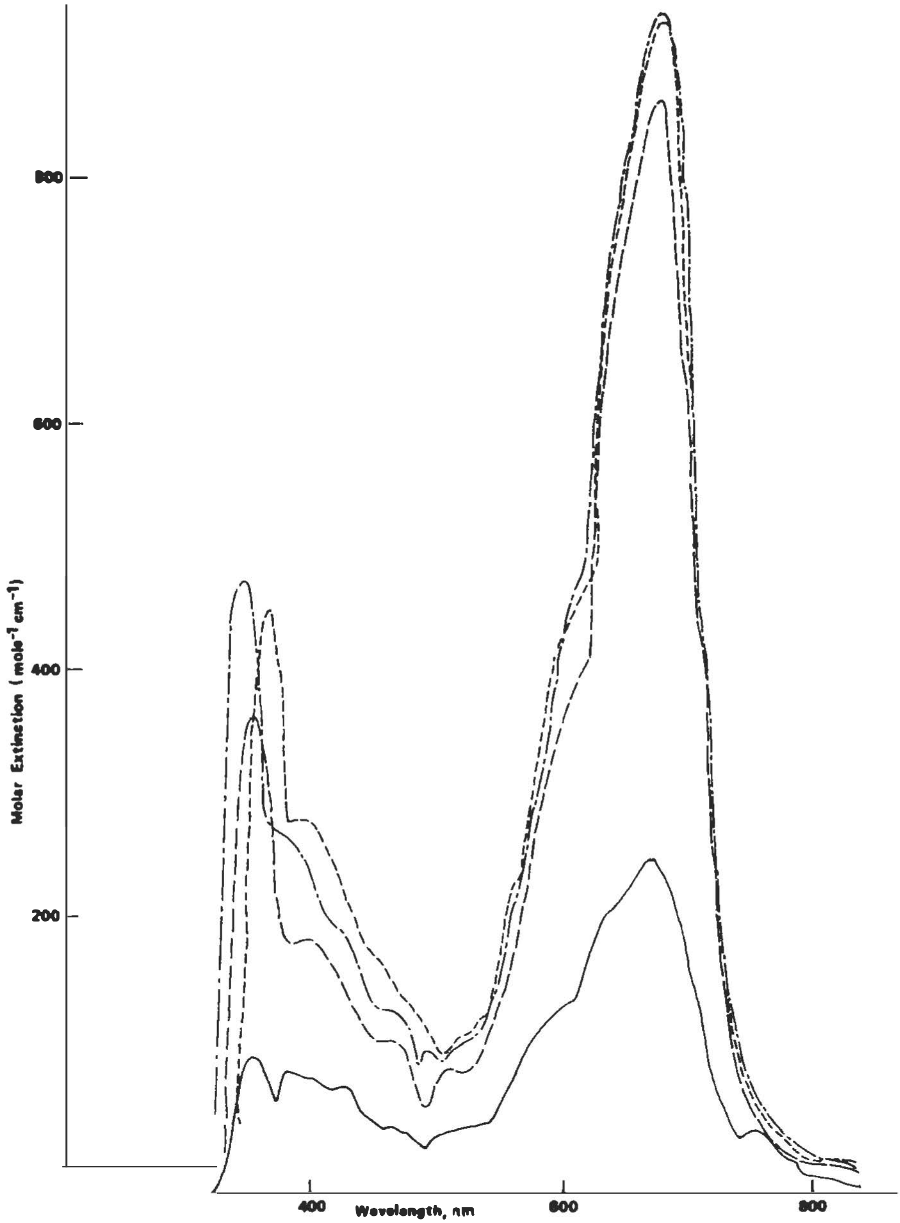


Figure 8. The absorption spectrum of Co (Diphentu) $_2Cl_2$ for acetone (————), upon addition of solid K_2 Fe $(CN)_6$ 1 min. (– – –) 30 min. (– – – –) 67 min. (–.–.–).

are summarized in Table 4. The two wavelengths in the columns of the oxidizing

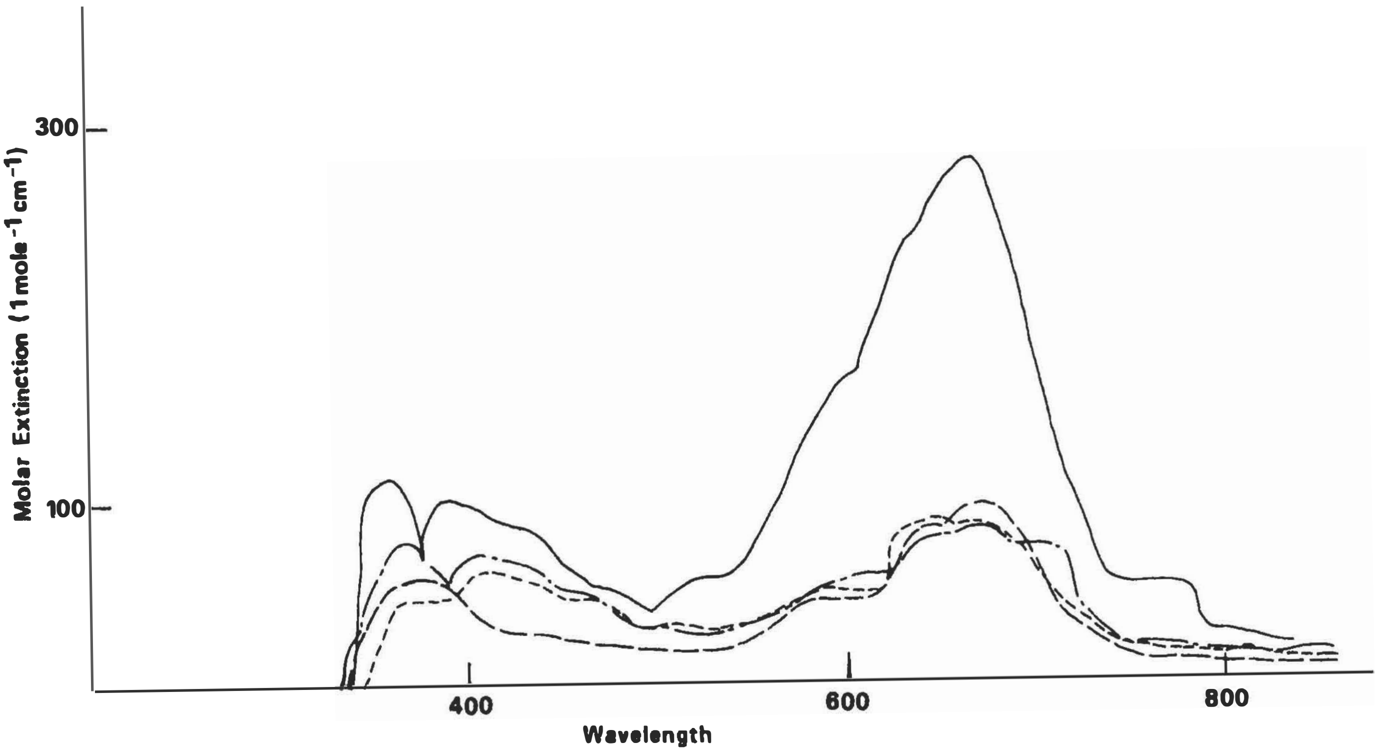


Figure 11. The absorption spectrum of Co (Diphentu) $_2Cl_2$ in acetone (————) plus $Na_2Cr_2O_7$ 1 min. (——), 30 min. (— — — — —), 77 min. (–.–.–).

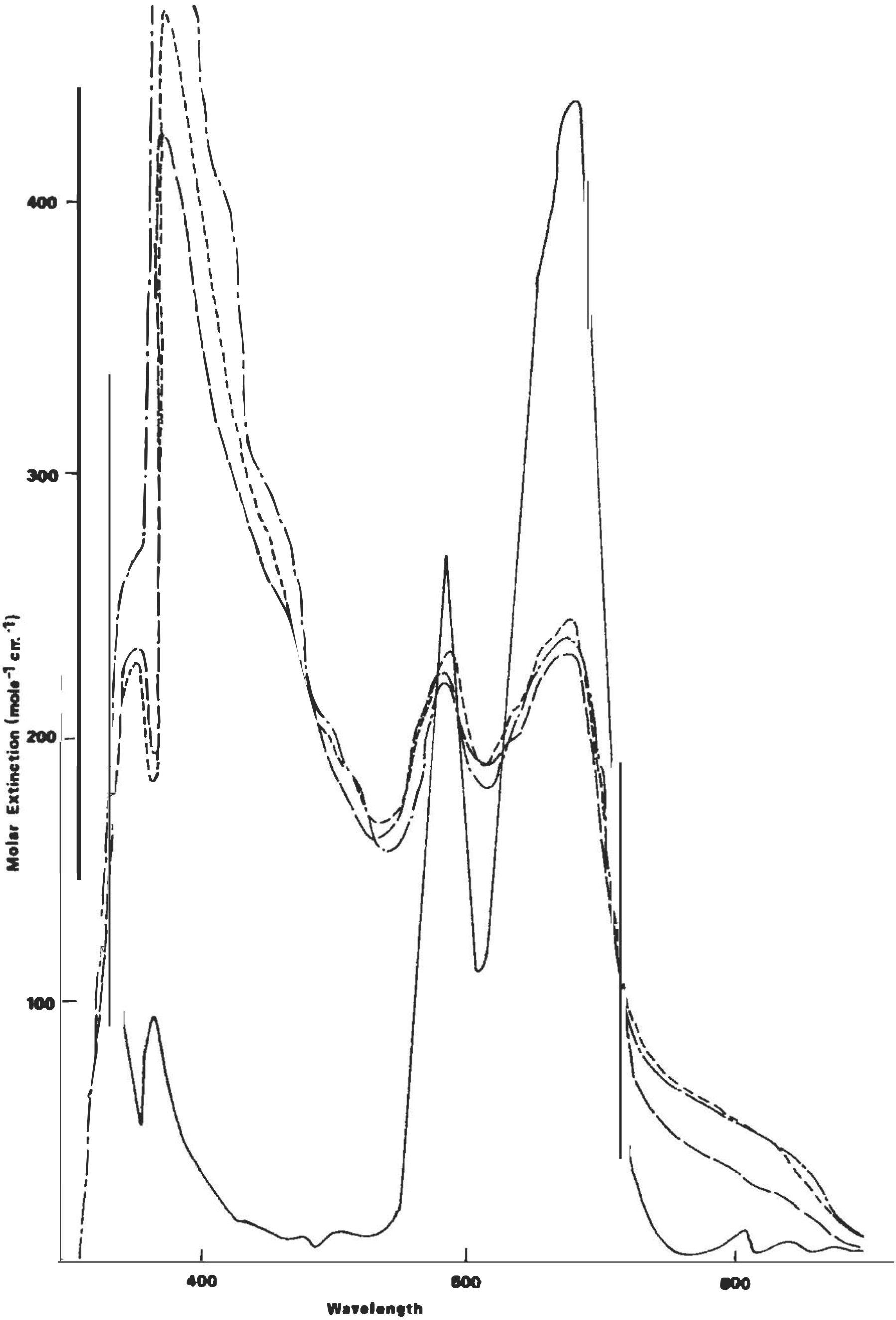


Figure 12. The absorption spectrum of Co (Diphentu) $_2Cl_2$ in acetonitrile (——————), upon addition of $Na_2Cr_2O_7$ 5 min. (– –), 40 min. (– – – –), 83 min. (–.–.).

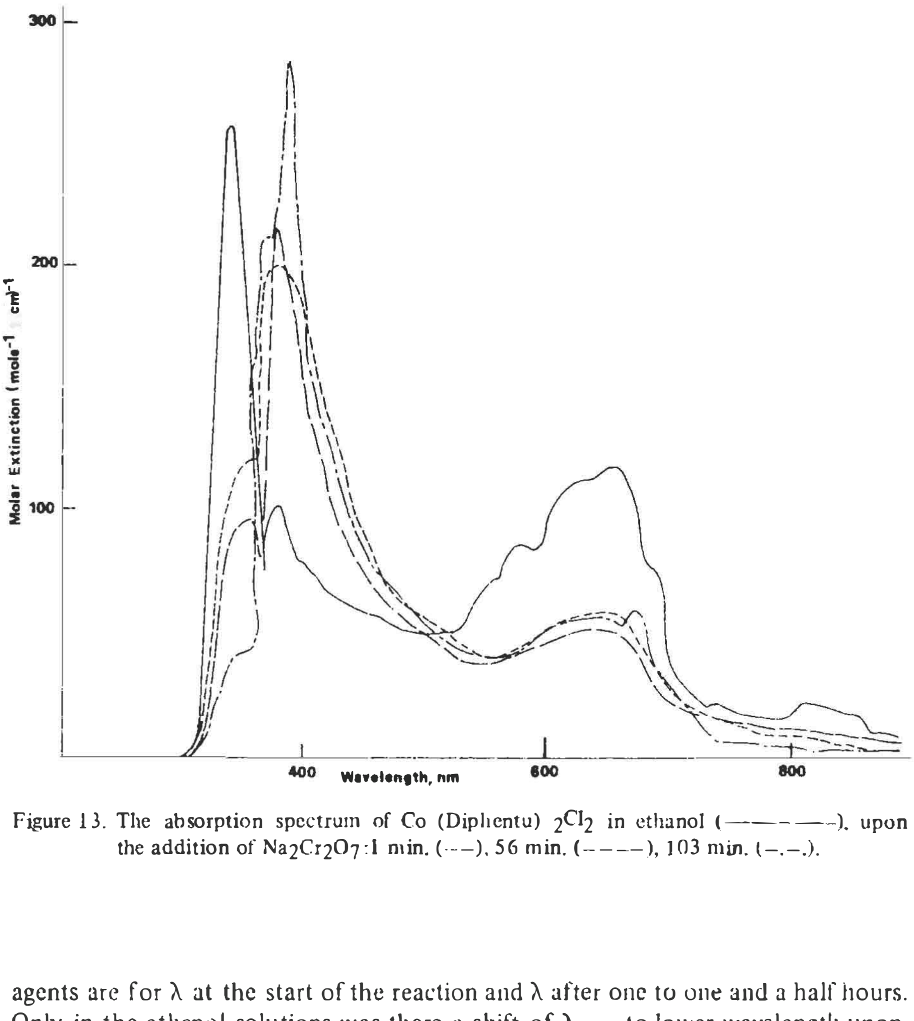


Figure 13. The absorption spectrum of Co (Diphentu) $_2Cl_2$ in ethanol (———————), upon the addition of $Na_2Cr_2O_7$:1 min. (---), 56 min. (– – – –), 103 min. (–.–.).

agents are for λ at the start of the reaction and λ after one to one and a half hours. Only in the ethanol solutions was there a shift of λ_{max} to lower wavelength upon the addition of $Na_2Cr_2O_7$. The shift was accompanied by a decrease in the intensity of the absorption band. In the other solvents, there was no shift in the λ_{max} but an increase in the intensity was observed in the acetone solutions of the complex upon the addition of $K_3Fe(CN)_6$. In the same solvent, the addition of $Na_2Cr_2O_7$ caused a decrease in intensity from $\epsilon 270$ of the complex to $\epsilon 89$ and 78.

In Table 5, the changes in the other absorption bands of $Co(Diphentu)_2Cl_2$ upon the addition of oxidizing agents are tabulated. The λ_{max} of ν_2 is shifted to longer wavelength and gained considerably in intensity upon the addition of K_3Fe-$(CN)_6$. Since ν_2 is still part of the absorption band ν_1 resulting from the d-d transi-

Table 4. Summary of the effect of an oxidizing agent on the $^4A_2(F) \rightarrow {}^4T_1$ (P) transition (ν_1) of Co (II) in Co (Diphentu) $_2Cl_2$.

Solvent	λ_{max} *nm* (ϵ) *of* ν_1		
	Complex	*Upon addition of* $K_3Fe(CN)_6$	*Upon addition of* $Na_2Cr_2O_7$
Acetone	670 (270)	670 (884) 670 (963)	670 (89) 670 (78)
Acetonitrile	680 (87)	680 (96)	680 (231)
		680 (84)	680 (235)
Ethanol	650 (117)	650 (46) 650 (45)	640 (50) 630 (59)

tion in Co(II), the increase in intensity is expected. In the other solvents, aceto-nitrile and ethanol, ν_2 decreased in intensity.

The absorption band indicative of an intermediate, namely, ν_3, underwent a shift and change in intensity upon the addition of $K_3Fe(CN)_6$ and $Na_2Cr_2O_7$ to Co(Diphentu)$_2$Cl$_2$. In acetone solution, it appears that an intermediate is formed instantaneously upon the addition of $K_3Fe(CN)_6$ as indicated by an absorption bank at 400 nm (205), which disappears with time, shifting back to 380 with ϵ81 after about an hour of reaction. The same shift to longer wavelength is brought about by addition of $Na_2Cr_2O_7$, but the intensity of the band decreased. The formation of a stable intermediate in the reaction of Co(Diphentu)$_2$Cl$_2$ with $K_3Fe(CN)_6$ and with $Na_2Cr_2O_7$ is evident in the appearance of a hump in the region 360 to 450 nm. This hump remains even until an hour after the start of the reaction.

The changes in ν_4 the absorption band of the ligand, upon the addition of oxidizing agents to Co(Diphentu)$_2$Cl$_2$ depends on the solvent. Before discussing the effect of oxidizing agents, a comparison of the absorption band of the pure ligand with that of the complex in the same solvent is useful. The absorption maxima of a) the pure ligand, b) Co(Diphentu)$_2$Cl$_2$ and c) $CoCl_2$ in the different solvents are tabulated in Table 6 with the corresponding molar extinction. These bands are referred to as charge transfer bands and they are caused by one or two of the following transitions: a) Metal to ligand electron transfer, b) ligand to metal electron transfer, c) n–π * transitions in an unsaturated system like an aromatic ring, d) transition within an isolated double bond such as C≡N in acetonitrile.

There is no charge transfer band for the acetone solution of $CoCl_2$: from this

Table 5. Summary of the effect of an oxidizing agent on the other absorption bands (ν_2, ν_3 and ν_4) of Cobalt (II) in Co (Diphentu) $_2Cl_2$.

Solvent	*Complex*	*Upon addition of $K_3FE\ (CN)_6$*	*Upon addition of $Na_2Cr_2O_7$*
		λ_{max} (ϵ) of ν_2	
Acctone	600 (156)	615 (415)	600 (52)
		610 (500)	600 (44)
Acetonitrile	590 (268)	590 (68)	600 (52)
		590 (49)	600 (44)
Ethanol	580 (86)	570 (31)	570 (42)
		570 (40)	600 (48)
		λ_{max} (ϵ) of ν_3	
Acetone	382 (100)	400 (205)	430 (30)
		380 (81)	400 (68)
Acetonitrile	370 (93)	360 (46);	450 (267);
		430 (35);	390 (425);
		430 (28)	450 (295);
			420 (400);
			380 (579)
Ethanol	380 (100)	400 (45)	390 (216)
		380 (54)	390 (200)
		λ_{max} (ϵ) of ν_3	
Acetonc	355 (112)	350 (390)	378 (58)
		340 (496)	360 (76)
Acetonitrile	320 (426)	350 (32)	360 (232)
		360 (25)	360 (366)
Ethanol	340 (257)	360 (33)	360 (95)
		330 (63)	350 (43)

it is safe to assume that the ν_4 of the ligand and Co(Diphentu)$_2$Cl$_2$ bands in CoCl$_2$ may be covered by the stronger aromatic charge transfer band in Co(Diphentu)$_2$Cl$_2$. With ethanol as solvent, the aromatic charge transfer band of the ligand is shifted to longer wavelengths upon coordination.

Upon the addition of $K_3Fe(CN)_6$, to the acetone solution of Co(Diphentu)$_2$Cl$_2$ the aromatic charge transfer band is shifted to shorter wavelength at the same time that it gains in intensity. The effect of adding $Na_2Cr_2O_7$ is the

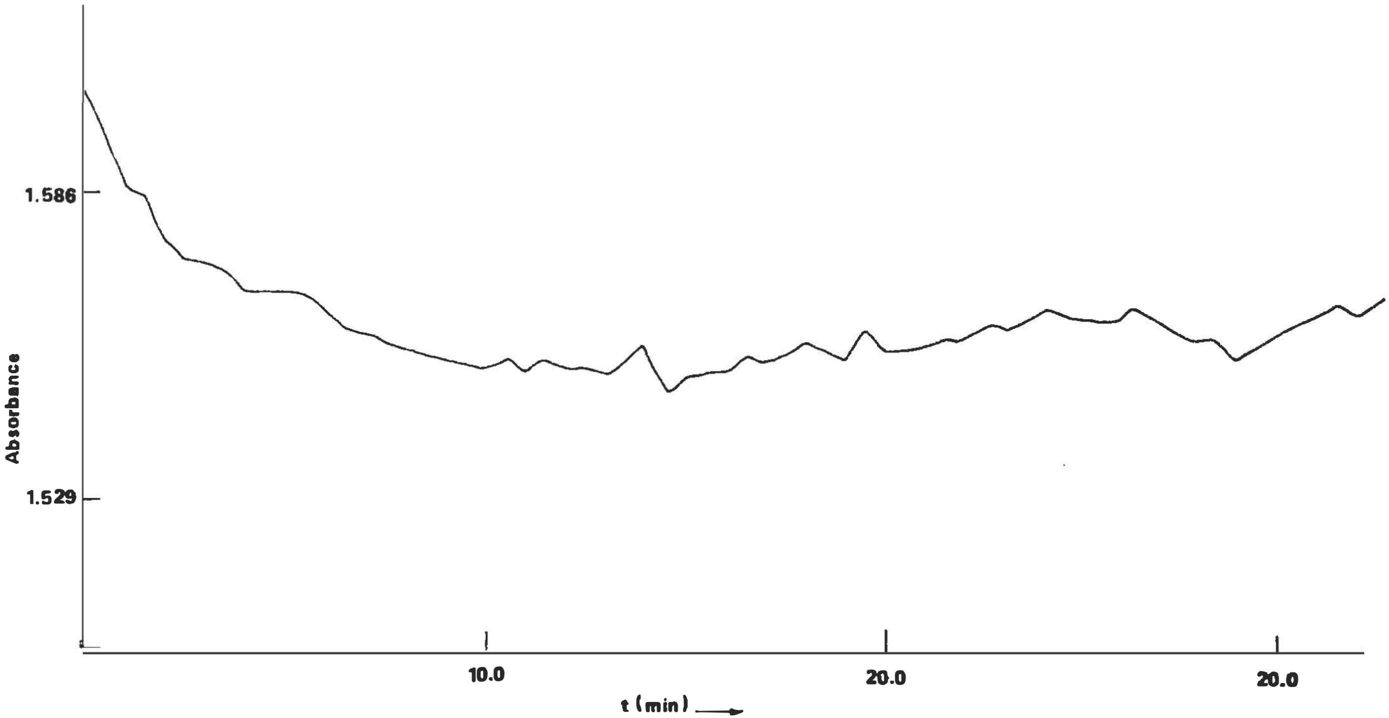


Figure 14. The change of absorbance of .02M Co (Diphentu) $_2Cl_2$ in CH_3CH_2OH with $K_3Fe(CN)_6$ (s) with time at d 650 nm.

Table 6. A comparison of the absorption band of the pure ligand with that of Co (Diphentu) $_2Cl_2$ and $CoCl_2$ in the same solvent.

Solvent	*N, N' –Diphenyl thiourea* λ_{max} (ϵ)	*Co (Diphentu)* $_2Cl_2$ λ_{max} (ϵ)	*CoCl* λ_{max} (ϵ)
Acetone	340 (291)	355 (112)	none
Acetonitrile	301 (560)	320 (426)	350 (84); 310 (180); 290 (263);
Ethanol	296 (626)	340 (257)	285 (70)

opposite: shift to longer wavelength and decrease in intensity. In acetonitrile solution, the shift of ν_4 is towards longer wavelengths and the intensity of the band decreases. The same effect was observed for the ethanol solution. All these indicate that the phenyl ring in the ligand of $Co(Diphentu)_2Cl_2$ is somehow affected by the reaction between the complex and the oxidizing agent.

The change in absorbance of the alcoholic solution of $Co(Diphentu)_2Cl_2$ with time was measured at 650 nm. The result is shown in Figure 14. For the first 11 minutes, the absorbance changed from 1.6053 to 1.552. After 15 minutes, the absorbance became 1.550. After additional 15 minutes the absorbance gradually increased again. The decrease in absorbance could be attributed to a decrease of the tetrahedral cobalt (II) because of the formation of an intermediate.

The calculation of the Dq values of $Co(Diphentu)_2Cl_2$ in solution was attempted. In the solid state, the Dq value is equal to 368 cm^{-1}, calculated using the empirical formula of Underhill and Billing (1966):

$$340\ Dq^2 - 18(\nu_2 + \nu_2)\,Dq + \nu_2\nu_3 = 0$$

This formula however, requires the two absorption bands of the complex, that at ~6300 cm^{-1} and that at ~15000 cm^{-1}. Only the latter band was measurable in this study such that this method of calculating Dq was not possible. Another method is to measure the lowest absorption band and the peak of this band in cm^{-1} is equal to 10 Dq. Again this was not possible. A third method is to fit the value of the absorption band in cm^{-1}, after dividing this by B, in the Tanabe-Sugano diagram of $\Delta E/B$ as a function of D_q/B. Doing this resulted in a $\Delta E/B$ value much smaller than that of the free ion. T.M. Dunn (in Lewis and Wilkins, 1965) in explaining the seeming discrepancy between the experimental $^4A_2 \rightarrow {}^4T_1(P)$ transition at 15,000 cm^{-1}, and the expected transition at 19,600 cm^{-1} attributes the error to the large reduction in energy distance between the ^4F and ^4P terms of the free ion (15,400 cm^{-1}) to about 10^4 cm^{-1} (Dunn, in Lewis and Wilkins. 1960). Such reduction has been attributed mainly to decreased interelectronic repulsions between the d orbitals resulting from charge transfer for ligand to central metal ion.

The experimental value of 350 cm^{-1} for Dq is very low so that the splitting of the free ion terms should not be large. However, in the Tanabe-Sugano diagram for d^7 tetrahedral, the separation between the F and P term is large indeed so that a fit cannot be done.

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Fabian Dayrit, Discussant

Spectroscopic studies of chemical reactions are generally very difficult and need a meticulous approach. There are usually many baseline and background studies that have to be carefully evaluated in order that the proper correlations of spectroscopic data with chemical reaction can be confidently assigned.

In studying the oxidation of bis – N, N'-diphenylthioureadichlorocobalt (II) in non-aqueous solvents (acetone, acetonitrile, ethanol), the following conditions should be established:

1. interaction of reagents with solvent, e.g. oxidation or complexation.
2. solubility of reagents with solvent.

Oftentimes, the solvent is more than just a passive spectator. At the least, the solvent will most certainly complex the metal species thereby altering its behavior. Under appropriate conditions, the solvent itself may react with the reagents.

The solubility (including possibilities of aggregation) of the metal in different solvents is important so that one may set up the proper kinetic expressions with which to model the chemical transformations.

One other interesting point that the study brings up is if the change transfer bands indicate an electron transfer reaction, is this an outer sphere or inner mechanism? What is a possible geometry of the transition state?

This spectroscopic study poses many interesting and challenging problems as what happens with such scientific problems, many more questions are usually uncovered in the process.

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ANTIMUTAGENIC EFFECTS OF SOME INORGANIC BIOCHEMICAL SYSTEMS

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ABSTRACT

Dimethylnitrosamine and benzo(a)pyrene are two carcinogens which induced the formation of micronucleated polychromatic erythrocytes in bone marrow cells of mice. This shows that both carcinogens are mutagenic and clastogenic.

Antimutagenic effects against dimethylnitrosamine and benzo(a)pyrene were studied using biochemical inorganic systems. The assessment of their antimutagenic effects was based on the reduction of micronucleated polychromatic erythrocytes. While the carcinogen was administered intraperitoneally, the inorganic ion was given orally. Except for magnesium and calcium ions, all the others were administered at the same time as the carcinogen. Magnesium and calcium ions were given an hour after the carcinogen.

Calcium was given as calcium chloride, magnesium as $MgCl_2 \cdot 6H_2O$, zinc as zinc chloride, manganese as $MnCl_2 \cdot 4H_2O$ and iron as $FeSO_4 \cdot 7H_2O$. Dolomite, a combination of calcium and magnesium, was also used.

Calcium ions, magnesium ions, manganese ions, zinc ions and ferrous ions all reduced the formation of micronucleated polychromatic erythrocytes induced by dimethylnitrosamine and benzo(a)pyrene. All exhibited antimutagenic and anticlastogenic effects.

The best effect was given by a combination of calcium and magnesium.

Introduction

In the past few years, there has been escalated efforts to uncover substances and physical agents that exhibit genetic toxicity not only to germ cells but also to somatic cells. Greater efforts are encouraged to discover the tendency of some systems to reduce or abolish the genotoxic effects of chemical and physical agents.

Antimutagenic effects of some organic systems have been studied in our laboratory. Antimutagenic effects against aflatoxin B 1, aflatoxin G 1, dimethylnitrosamine, mitomycin C and metronidazole have been studied (1). Vitamin A, E, C, riboflavin and thiamine exhibited antimutagenic effects. Vitamin C was also shown to exhibit antimutagenic effects against alkylating agents, intercalating

Table 1. Formation of Micronucleated Polychromatic Erythrocytes in Bone Marrow Cells as Induced by Dimethylnitrosamine.

Dose of dimethylnitrosamine mg/kg	*No. of micronucleated polychromatic erythrocytes per thousand***
Control*	0.33 ± 0.08
DMN 20	10.89 ± 1.23
15	9.11 ± 0.96
10	5.33 ± 0.34

*Control was untreated
**an average of 15 slides

Table 2. Formation of Micronucleated Polychromatic Erythrocytes in Bone Marrow Cells as Induced by Benzol(a)pyrene.

Dose of Benzo(a)pyrene mg/kg	*No. of micronucleated polychromatic erythrocytes per thousand***
375.00	9.78 ± 1.18
187.50	9.44 ± 1.08
93.75	6.45 ± 0.91
Control*	0.33 ± 0.08

*Control was untreated
**An average of 15 slides

agents, amine derivatives and sodium nitrite (2), and also against two pesticides (3). Vitamin E was also found to be antimutagenic against chloroform (4) and against hexachlorophene (5). Niacin was antimutagenic against metronidazole and benzidine (6).

Among inorganic biochemical systems, only cobalt chloride has been studied (7). It was shown to be antimutagenic against N-methyl-N-nitro-N-nitrosoguanidine. It was also antimutagenic against Trp-p-l, a carcinogen found in charred portions of broiled meat and fish (8). It is therefore of great interest if other inorganic biochemical systems also exhibit antimutagenic effects.

The inorganic systems reported in this study are those which contain calcium ions, magnesium ions, zinc ions, manganese ions and ferrous ions.

Table 3. Effect of Calcium Chloride on Micronuclei Formation of Bone Marrow Cells.

Dose of calcium chloride mg/kg	*No. of micronucleated polychromatic erythrocytes per thousand*
500	0.84 ± 0.07
400	0.84 ± 0.06
250	0.84 ± 0.05
125	0.84 ± 0.07
Control*	1.00 ± 0.05

*Control was given triple-distilled water

Table 4. Effect of Magnesium Chloride on Micronuclei Formation in Bone Marrow Cells.

Dose of Magnesium chloride mg/kg	*No. of micronucleated polychromatic erythrocytes per thousand*
450.0	0.16 ± 0.05
300.0	0.40 ± 0.12
225.0	0.50 ± 0.16
112.5	0.50 ± 0.15
Control*	1.00 ± 0.05

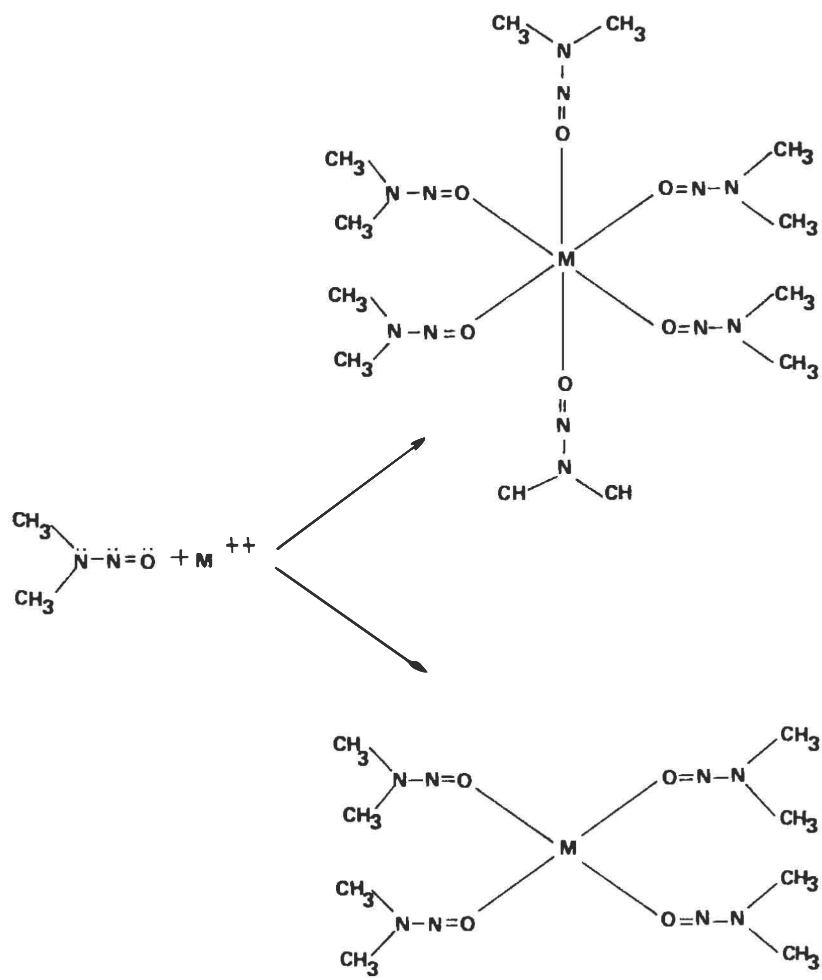
*Control was given triple-distilled water.

Materials and Methods

Dimethylnitrosamine was obtained from Aldrich Chemical Co., Milwaukee, Wisconsin. Benzo(a)pyrene was a gift from Dr. H. Matsushita, Institute of Public Health, Tokyo, Japan. The inorganic salts were purchased from J.T. Baker Chemical Company, N.J. The mice that were used were of the Swiss Webster strain.

Mutagenic and antimutagenic effects were assessed using the micronucleus test of Schmid (9). Mice weighing 20-25 grams were used.

Mutagenic and clastogenic effects of dimethylnitrosamine and benzo(a)pyrene, and the inorganic systems were determined separately.



Formation of DMN-metal ion complex.

For antimutagenic effects, dimethylnitrosamine and benzo(a)pyrene were given intraperitoneally, while the inorganic systems were administered orally at approximately the same time except for calcium and magnesium which were given an hour after the carcinogens. The carcinogens and the inorganic systems were administered twice, 30 hours and 6 hours prior to the preparation of the bone marrow.

Bone marrow of the femur was flushed into a test tube using fetal calf serum. Air dried smears were made from the pellet. These were stained and examined for micronuclei formation in polychromatic erythrocytes.

Table 5. Effect of Manganese Chloride on Micronuclei Formation in Bone Marrow Cells.

Dose of manganese chloride mg/kg	*No. of micronucleated polychromatic erythrocytes per thousand*
420	1.67 ± 0.08
320	1.67 ± 0.09
210	1.67 ± 0.07
105	1.67 ± 0.08
Control*	

*Control was given triple-distilled water

Table 6. Effect of Ferrous Sulfate on Micronuclei Formation in Bone Marrow Cells.

Dose of ferrous sulfate mg/kg	*No. of micronucleated polychromatic erythrocytes per thousand*
625.00	1.67 ± 0.21
312.50	1.34 ± 0.09
220.0	1.33 ± 0.08
156.25	1.33 ± 0.09
Control*	1.66 ± 0.12

*Control was given triple-distilled water.

Results and Discussion

Dimethylnitrosamine and benzo(a)pyrene induced the formation of micronucleated polychromatic erythrocytes (Tables 1 and 2). This indicates that these carcinogens affected the DNA of the bone marrow cells. Mitotic bone marrow cells with chromatid breaks or chromatid exchanges suffer from disturbance in the anaphase distribution of their chromatin. Chromosome pieces lag in the anaphase. After telophase, a sizable portion of the displaced chromatin is not included in the nuclei of the daughter cells. Instead, they form single or multiple micronuclei in the cytoplasm of these cells. Thus, both dimethylnitrosamine and benzo(a)pyrene are not only mutagenic but also clastogenic.

Table 7. Effect of Zinc Chloride on Micronuclei Formation In Bone Marrow Cells.

Dose of Zinc Chloride mg/kg	*No. of micronucleated polychromatic erythrocytes per thousand*
150.0	0.84 ± 0.07
100.0	0.95 ± 0.09
75.0	0.95 ± 0.09
37.5	0.95 ± 0.09
Control*	1.66 ± 0.12

*Control was given triple-distilled water

Table 8. Antimutagenic Effects of Calcium Ions Against Dimethylnitrosamine*

Dose of calcium chloride mg/kg	*No. of micronucleated polychromatic erythrocytes per thousand*
Dimethylnitrosamine alone	9.11 ± 0.96
Dimethylnitrosamine plus	
Calcium – 500	2.22 ± 0.05
Calcium – 250	2.33 ± 0.07
Calcium – 125	2.89 ± 0.08

*Dimethylnitrosamine – 15 mg/kg

Table 9. Antimutagenic Effects of Calcium Ions Against Benzo(a) Pyrene.

Dose of calcium chloride mg/kg	*No. of micronucleated polychromatic erythrocytes per thousand*
Benzo(a)pyrene alone*	9.44 ± 1.08
Benzo(a)pyrene plus	
Calcium – 500	2.89 ± 0.08
Calcium – 250	2.89 ± 0.08
Calcium – 125	2.67 ± 0.09

*Benzo(a)pyrene –187.5 mg/kg

Table 10. **Antimutagenic Effects of Magnesium Ions Against Dimethylnitrosamine.**

Dose of magnesium chloride mg/kg	*No. of micronucleated polychromatic erythrocytes per thousand*
Dimethylnitrosamine alone*	9.11 ± 0.96
Dimethylnitrosamine plus	
magnesium – 450.0	1.33 ± 0.09
magnesium – 225.0	2.22 ± 0.05
magnesium – 112.5	2.45 ± 0.10

*Dimethylnitrosamine – 15 mg/kg

Table 11. **Antimutagenic Effects of Magnesium Ions Against Benzo(a)pyrene.**

Dose of magnesium chloride mg/kg	*No. of micronucleated polychromatic erythrocytes per thousand*
Benzo(a)pyrene alone*	9.44 ± 1.08
Benzo(a)pyrene plus	
magnesium – 450.0	1.22 ± 0.11
magnesium – 225.0	2.11 ± 0.12
magnesium – 112.5	2.33 ± 0.09

*Benzo(a)pyrene – 187.5 mg/kg

Table 12. **Antimutagenic Effects of Zinc Ions Against Dimethylnitrosamine.**

Dose of Zinc chloride mg/kg	*No. of micronucleated polychromatic erythrocytes per thousand*
Dimethylnitrosamine alone*	9.11 ± 0.96
Dimethylnitrosamine plus	
Zinc chloride – 150.0	1.33 ± 0.11
Zinc chloride – 75.0	1.44 ± 0.12
Zinc chloride – 37.5	1.67 ± 0.09

*Dimethylnitrosamine – 15 mg/kg

Table 13. Antimutagenic Effects of Zinc Ions Against Benzo(a)pyrene.

Dose of Zinc chloride mg/kg	*No. of micronucleated polychromatic erythrocytes per thousand*
Benzo(a)pyrene alone*	6.45 ± 0..91
Benzo(a)pyrene plus	
Zinc chloride – 150.0	1.67 ± 0.12
Zinc chloride – 75.0	1.78 ± 0.13
Zinc chloride – 37.5	1.78 ± 0.12

*Benzo(a)pyrene – 93.75 mg/kg

Table 14. Antimutagenic Effects of Manganese Ions Against Dimethylnitrosamine.

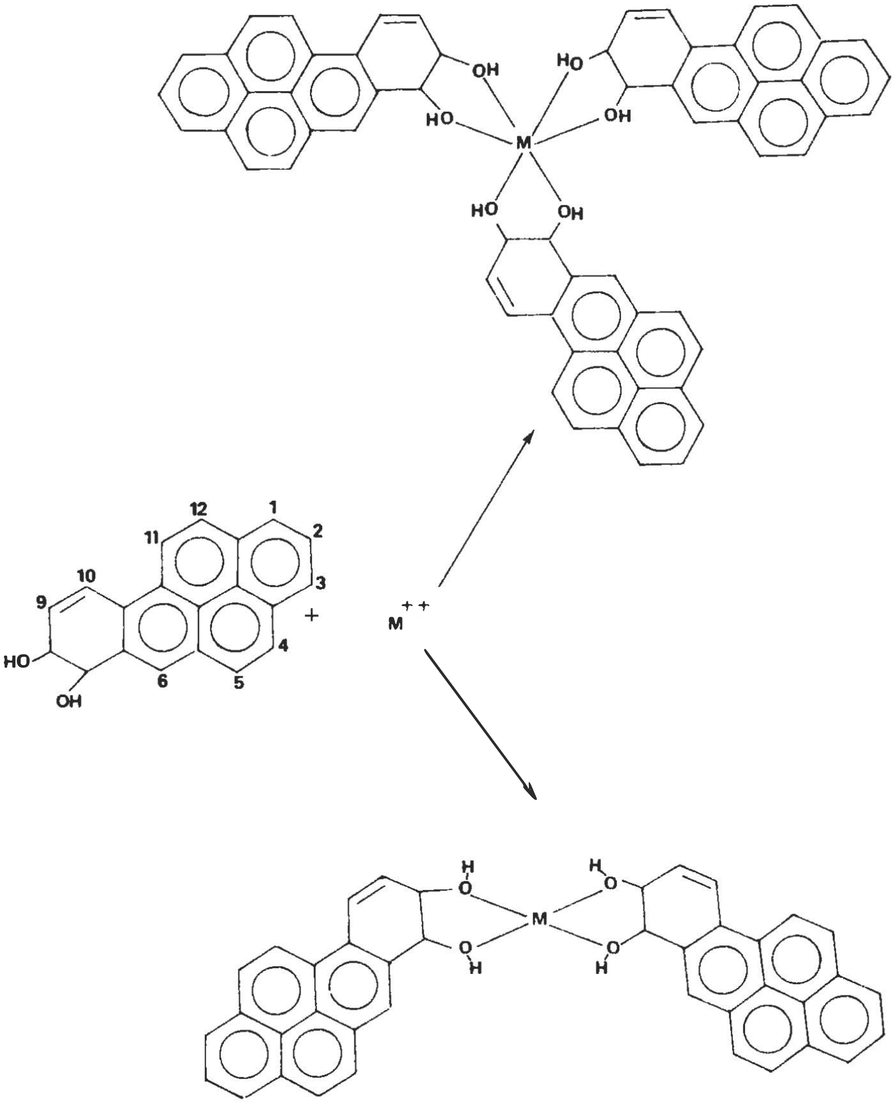
Dose of manganese chloride mg/kg	*No. of micronucleated polychromatic erythrocytes per thousand*
Dimethylnitrosamine alone	9.11 ± 0.96
Dimethylnitrosamine plus	
Mn chloride – 420	1.67 ± 0.15
Mn chloride – 210	1.78 ± 0.18
Mn chloride – 105	2.11 ± 0.15

*Dimethylnitrosamine – 15 mg/kg

Table 15. Antimutagenic Effects of Manganese Ions Against Benzo(a)pyrene.

Dose of manganese chloride mg/kg	*No. of micronucleated polychromatic erythrocytes per thousand*
Benzo(a)pyrene alone*	6.45 ± 0.91
Benzo(a)pyrene plus	
Mn chloride – 420	1.78 ± 0.14
Mn chloride – 210	1.89 ± 0.16
Mn chloride – 105	2.00 ± 0.18

*Benzo(a)pyrene – 93.75 mg/kg



Complex formation between a metal ion and BP-7, 8-diol.

Table 16. Antimutagenic Effects of Ferrous Ions Against Dimethylnitrosamine.

Dose of ferrous chloride mg/kg	*No. of micronucleated polychromatic erythrocytes per thousand*
Dimethylnitrosamine alone*	9.11 ± 0.96
Dimethylnitrosamine plus	
ferrous chloride – 625.00	1.78 ± 0.12
ferrous chloride – 312.50	2.00 ± 0.15
ferrous chloride – 156.25	2.11 ± 0.16

*Dimethylnitrosamine – 15 mg/kg

Table 17. Antimutagenic Effects of Ferrous Ions Against Benzo(a)pyrene.

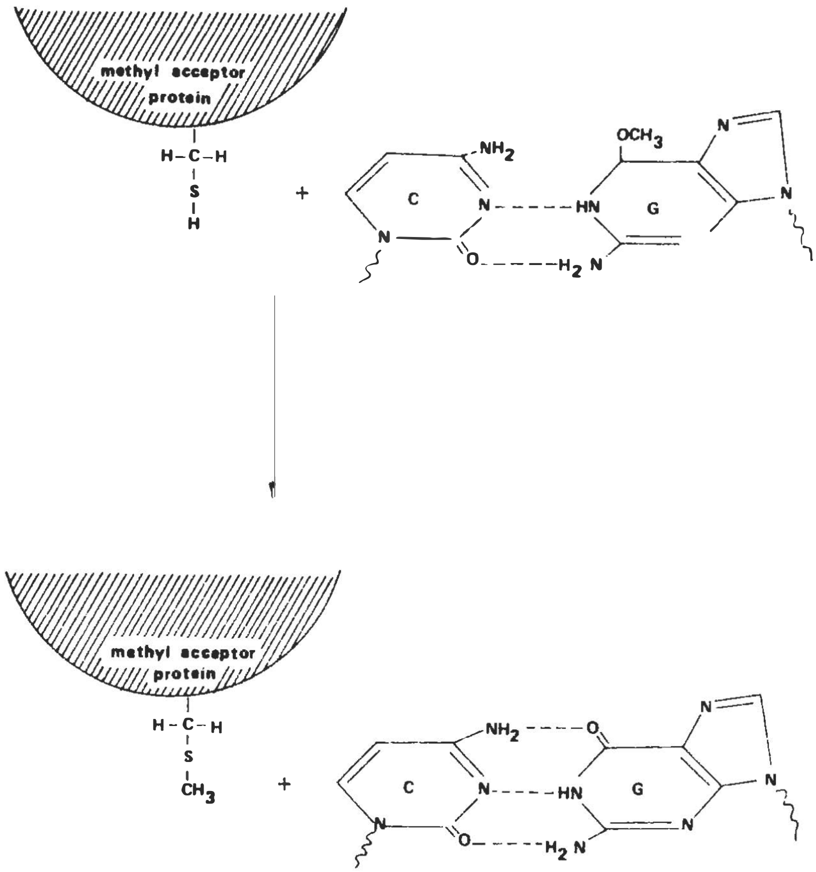
Dose of ferrous chloride mg/kg	*No. of micronucleated polychromatic erythrocytes per thousand*
Benzo(a)pyrene alone*	6.45 ± 0.91
Benzo(a)pyrene plus	
ferrous chloride – 625.00	2.11 ± 0.17
ferrous chloride – 312.50	2.33 ± 0.12
ferrous chloride – 156.25	2.67 ± 0.21

*Benzo(a)pyrene – 93.75 mg/kg

The inorganic biochemical systems used were also studied as regards their effect on DNA of the bone marrow cells. The results are shown in Tables 3 to 7. None of the systems tested induced the formation of micronucleated polychromatic erythrocytes. These systems did not affect the DNA of the bone marrow cells.

Calcium ions caused the reduction of micronucleated polychromatic erythrocytes induced by dimethylnitrosamine and benzo(a)pyrene (Tables 8 and 9). The same observation was made of magnesium ions (Tables 10 and 11), of zinc ions (Tables 12 and 13), of manganese ions (Tables 14 and 15), and of ferrous ions (Tables 16 and 17). A combination of calcium and magnesium gave the best reduction in the formation of micronucleated polychromatic erythrocytes (Tables 18 and 19).

It is very clear that the five metal ions counteract the mutagenic and clastogenic effects of dimethylnitrosamine and benzo(a)pyrene. Each of the metal ions



Demethylation reaction

through their vacant hybrid orbitals can interact with dimethylnitrosamine resulting in the inhibition of its metabolic activation to a mutagen.

Dimethylnitrosamine can readily bind with metal ions through the lone pairs of oxygen. Both calcium and magnesium ions can form hexacoordinated compounds. The transition metal ions, ferrous ions, zinc ions and manganese ions can form 4- and 6- coordinate complexes. Of the tetracoordinated compounds, the tetrahedral configuration is more favored for steric reasons.

Benzo(a)pyrene after metabolism forms diols (10) which can form metal complexes through the lone pairs of oxygen.

It is possible that metal ions can deplete the concentration of cytochrome P-450 in the cells. The enzymes in this system are responsible for the mutagenic activation of dimethylnitrosamine and benzo(a)pyrene (11).

Table 18. Antimutagenic Effects of Dolomite* Against Dimethylnitrosamine.**

Dose of Dolomite tablet/kg	*No. of micronucleated polychromatic erythrocytes per thousand*
Dimethylnitrosamine alone	9.11 ± 0.96
Dimethylnitrosamine plus	
Dolomite – 2 tablets	0.56 ± 0.08
Dolomite – 1 tablet	0.67 ± 0.08
Dolomite – ½ tablet	0.78 ± 0.08

*Dolomite – 1 tablet contains 390 mg calcium and 180 mg magnesium
**Dimethylnitrosamine – 15 mg/kg

Table 19. Antimutagenic Effects of Dolomite Against Benzo(a)pyrene.**

Dose of Dolomite tablet/kg	*No. of micronucleated polychromatic erythrocytes per thousand*
Benzo(a)pyrene alone	6.45 ± 0.91
Benzo(a)pyrene plus	
Dolomite – 2 tablets	0.89 ± 0.05
Dolomite – 1 tablet	1.11 ± 0.08
Dolomite – ½ tablet	1.11 ± 0.08

*Dolomite – 1 tablet contains 390 mg calcium and 180 mg magnesium
**Benzo(a)pyrene – 93.75 mg/kg

Co^{++} has been shown to increase the rate of heme oxidation which led to reduction in the activity of cytochrome P-450 (12). This effect was also observed with Fe^{++}, Zn^{++}, Mn^{++}, and other metal ions (13).

Thus, the antimutagenic effect of the metal ions in this study could be a consequence of reduced activity of cytrochrome P-450. Divalent metal ions have been shown not only to reduce the activity of cytochrome P-450 but also to enhance the activity of glutathione epoxide transferase (14). This enzyme opens up epoxides and therefore reduces their alkylating ability. Extent of alkylation of DNA by benzo(a)pyrene epoxides can thus be reduced in the presence of metal ions.

Another possibility is the activation of the adaptive response repair system by the metal ions. This repair system has been shown to remove methyl groups from 06 guanine (15). Methylated 06 guanine is formed in the presence of dimethylnitrosamine. Therefore, if DNA is alkylated by dimethylnitrosamine, the adaptive response repair mechanism can transform the altered base to its original form. This is illustrated on page 123.

Conclusion

Dimethylnitrosamine and benzo(a)pyrene are mutacarcinogens since they induce the formation of micronucleated polychromatic erythrocytes in bone marrow cells.

Their mutagenicity, however, was reduced when calcium ions, magnesium ions, ferrous ions, zinc ions, and manganese ions. Calcium and magnesium ions were administered an hour after the mutagen while the other ions were given at the same time as the mutagen.

A combination of calcium and magnesium gave the best anti-mutagenic effects.

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CHROMATOGRAPHIC ANALYSIS OF CARBOHYDRATES IN COCONUT WATER

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ABSTRACT

The water or liquid endosperm from newly opened mature coconuts was analyzed by high performance liquid chromatography (HPLC) using a silica-based micro-particulate cation exchange resin bed (Waters Sugar-PAK) column. Two samples of coconut water concentrate prepared by reverse osmosis at 20 and 30 bars pressure were also analyzed. Eleven HPLC elution peaks were observed corresponding to the following carbohydrates: glucose, fructose, sucrose, sorbitol, mannitol and oligosaccharides with degree of polymerization (DP) of 3, 4 5 and greater than 5. For coconut water from mature nuts the total concentration of sucrose, glucose and fructose was 30 g/l, that of galactose, xylose and mannose was 2.3 g/l, while the mannitol concentration was close to 0.3 g/l.

Gas chromatography (GC) was performed on aldononitrile and alditol acetate derivatives of standard and coconut water carbohydrates. Based on retention times the following sugars, which were not separately detected by HPLC, were observed but not quantitated by GC: arabinose, galactose, xylose and mannose.

Introduction

Coconut water is an important by-product of the coconut industry with an annual Philippine production estimated to be in excess of 2 x 10^9 liters. It is the liquid endosperm of coconut and has been used to a limited extent as a beverage, especially from immature nuts, as well as fermentation substrate for the production of vinegar and 'nata de coco'. It is an excellent substrate for producing feed yeast (Caday *et al.*, 1980; Marfa *et al.*, 1982) and rhizobia inoculant (Mamaril and Aspiras, 1982). Efficient utilization schemes for coconut water require complete and definitive data on its chemical composition. Unfortunately, such data are not available and only limited information is available in the literature (Raghavan, 1976; Philippine Coconut Authority, 1979; Hagenmaier, 1980; Banzon and Velasco, 1982).

Two of the most practical and sensitive methods for carbohydrate analysis are high performance liquid chromatography (HPLC) and gas-liquid chromatography (GLC). These chromatographic methods have been extensively developed since the pioneering work of Ramsey and Tswett early this century (McNair and Bonelli, 1967; Heftmann, 1975; Snyder and Kirkland, 1979). The development of rapid and automated HPLC methods, as well as highly selective columns, for saccharide analysis has been achieved within the last decade (Linden and Lawhead, 1975; Conrad and Palmer, 1976; Verhaar *et al.*, 1981). The use of such methods for coconut water analysis is facilitated by the availability of commercially available columns which can separate simple sugars and sugar alcohols (Waters Associates, 1982). These carbohydrates are the major components of coconut water. On the other hand, carbohydrate analysis by gas chromatography (GC) has been facilitated by rapid and practical procedure for derivatizing the carbohydrate components (Albersheim *et al.*, 1967; Crowell and Burnett, 1967; McGinnis, 1982).

The present paper deals with carbohydrate analysis using both liquid and gas chromatographic methods of fresh coconut water and of coconut water which had been concentrated by reverse osmosis. The experimental techniques are described for identifying and quantifying the carbohydrate components in coconut water. The HPLC results had been presented earlier (Bergonia *et al.*, 1984).

Materials and Methods

A schematic flow sheet of methodologies for sample preparation and HPLC analysis is shown in Figure 1.

Sample preparation. Fresh coconut water samples from newly-opened mature coconuts were obtained from the local market or from a desiccated coconut factory. Concentrated coconut water was prepared by reverse osmosis (del Rosario, 1984) and ultrafiltered through XM300 membrane before HPLC analysis.

HPLC Procedure. The coconut water samples, which have been filtered as described above, were injected into a Waters Liquid Chromatographic System consisting of a Model U6K Universal Injector, a Model 6000A Solvent Delivery System and a Model 401 Differential Refractometer. A Sugar-PAK 1 column was used. This semi-preparative column contains a micro-particulate cation exchange resin bed consisting of 10um particles which are irregular in shape. It was designed to separate sugar alcohols and simple sugars up to oligosaccharides with degrees of polymerization equal to four. The temperature of the column was maintained at 90°C in a fabricated glass water jacket using a Haake Water Bath Model D3 with a recirculation pump.

The chromatograms were printed by an Omni-Scribe chart recorder at 0.25, 0.50 and 1.00 cm/min chart speeds. Attenuation was always set at 8x and the carrier solvent was usually pumped at 0.5 ml/min. Degassed and fresh doubly-glass-distilled water was used as carrier solvent. Also used as carrier in the later runs was 0.0001 M calcium acetate pH 6.8. Injected volumes usually ranged from 5 to 25 ul of liquid, depending on the con-

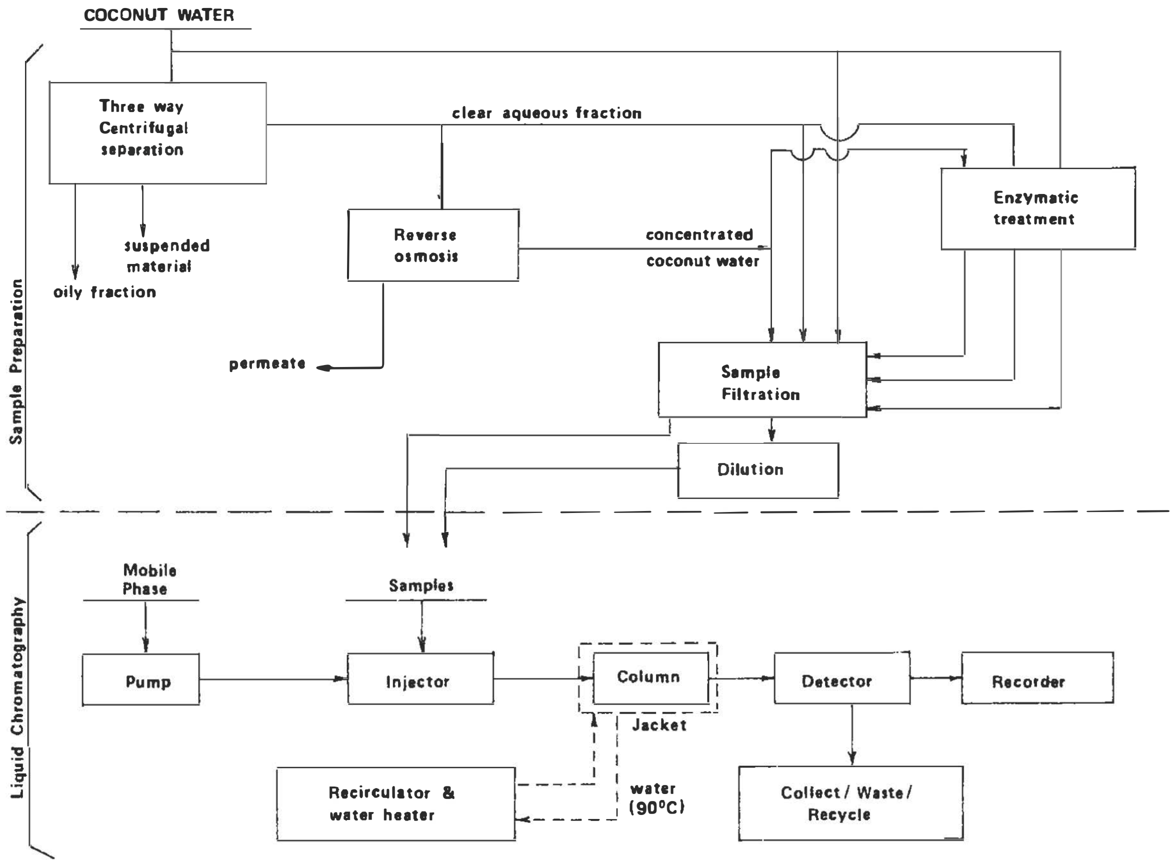

Figure 1. Flowsheet for Sample Preparation and HPLC Analysis.

centration of sugar in the samples. Back pressure ranged from 800 to 1300 psi, while elution time lasted from 12 to 15 minutes.

The peaks in the elution profiles were identified by "spiking" and quantitated using available standard sugars. Quantitation was based on peak height (Snyder and Kirkland, 1979). Mannitol was used as internal standard.

Invertase treatment of coconut water. To one milliliter of coconut water sample was added two milligrams of invertase powder (technical grade, Nutritional Biochemical Co., ICN Pharmaceuticals, Inc., Cleveland, Ohio, U.S.A.) suspended in one ml 0.04 M sodium acetate buffer at pH 5.0. The mixture was incubated at ca. 29°C for one hour and then heated in a boiling water bath for 20 min. The reacted samples were diluted with distilled water to ten times the original volume, filtered through Millipore 0.45um aqueous filter, and then chromatographed. For the control runs invertase suspensions were heated in a boiling water bath for 20 min before adding to coconut water samples.

Amylase treatment of coconut water. A commercial preparation of amyloglucosidase (Spiritamylase Novo 150L, 150 AGU/ml activity) was diluted 50 fold with 0.1M sodium acetate pH 4.8. A 2.0 ml aliquot of the diluted enzyme was added to the same volume of the solution of standard carbohydrate 5.0 mg/ml or coconut water sample, which had been diluted 1:1 with distilled water. For the control runs, the diluted enzyme was added to the same volume of the buffer. The mixtures were mixed well and allowed to stand for 45 minutes at ca. 30°C, and then placed in a boiling water bath for 20 minutes. The samples were cooled and then passed through a 0.45uM filter prior to HPLC analysis.

Backflushing of HPLC column. Backflushing was done by passing 100-150 ml of the carrier through the HPLC column in reverse direction whenever the back pressure exceeded 1500 psi. The back pressure was also reduced by not using the column for a few days. Sonic cleaning of the ends of the column greatly reduced the back pressure.

Sample preparation for GC analysis. A schematic diagram is presented in Figure 2 for sample treatment. Two types of carbohydrate derivatives were prepared for GC analysis, namely alditol acetates and aldo-nonitrile acetates.

Alditol acetate derivatives of coconut water carbohydrates and standard sugars were prepared using the method of Crowell and Burnett (1967) as modified by Manullang (1981). The coconut water sample (1.0 ml) was concentrated by vacuum evaporation in a rotary evaporator at 60°C prior to reduction of the component sugars to their corresponding alditols. The internal standard, 25 mg α-methyl-D-glucopyranoside, was added to the sample. Five milliliters of freshly prepared 0.5N NH_4OH containing 20 mg $NaBH_4$ per ml was added to the resulting syrup. The mixture was allowed to stand at room temperature for 15 hours. Concentrated acetic acid diluted 1:1 with absolute methanol was then added dropwise until gas evolution

Figure 2. Flowsheet for Sample Preparation for GC Analysis.

stopped. This mixture was concentrated to a syrup as mentioned above in a rotary evaporator. The concentrate was then washed free of diborane by the addition of 5 to 10 ml methanol and then dried at 60°C in vacuum. This washing and drying was done five times and then the syrup was heated in an oven at 105°C for 10-15 minutes.

The sample was then acetylated by adding 7.5 ml acetic anhydride and 0.5 ml concentrated sulfuric acid. The reaction mixture was placed in a water bath shaker for one hour at 50-60°C, and then cooled. About 70 ml cold water was added. The derivatives were then extracted thrice with methylene chloride, using 25, 15, 10 ml portions successively, and evaporated to dryness at 75°C each time. One ml water was added to the extract and also evaporated to dryness. Lastly, the derivatives were dissolved in 2.0 ml acetic anhydride prior to injection into the gas chromatograph.

For the standards, 5-, 10-, and 15- and 20-mg portions of arabinose, galactose, glucose, mannose and xylose were weighed in separate containers, such that one mixture contained equal amounts of each of the five standards. The resulting mixtures were treated as above in place of the coconut water syrup, including the addition of α-methyl-D-glucopyranoside as internal standard.

The derivatization procedure of McGinnis (1982) for preparing the aldononitrile acetates was followed with minor modifications. About 1 ml coconut water concentrate was lyophilized and then suspended in 1.0 ml pyridine containing 2.5% w/v hydroxylamine hydrochloride and 0.5% w/v α-methyl-D-glucopyranoside. The derivatizing mixture was heated in an oven for 45 minutes and cooled. Then 0.4 ml acetic anhydride was added and the resulting mixture heated for another hour and cooled. The mixture was evaporated to dryness by bubbling with N_2 gas. Washing was done using 1.0 ml each of 3N HCl, 0.5M $NaHCO_3$, H_2O and H_2O respectively, each time discarding the aqueous layer. Lastly, the derivatives were then taken up in $CHCl_3$ which had been previously dried over Na_2SO_4.

Gas chromatography. A Shimadzu GC-3BF gas chromatograph with FID detector was used for both alditol acetate and aldononitrile acetate derivatives. The column packing was 3% OV-225, injection temperature was 225°C and the column temperature was maintained constant at 200°C. The air and hydrogen pressures were 1.0 and 0.9 kg/cm^2, respectively. Nitrogen pressure was set at 0.8 and 1.4 kg/cm^2 for the alditol and aldononitrile acetates, respectively. The chromatograph sensitivity was set at 10, with range setting of 4. The chart speed was 2.5 mm/minute. For quantification, peak heights were compared to the α-methyl-D-glucopyranoside (5 mg/ml) internal standard.

Results and Discussion

HPLC Elution profiles

The high performance liquid chromatogram of fresh coconut water is presented in Figure 3a while that of coconut water, which had been concentrated by reverse osmosis and diluted tenfold prior to analysis, is shown

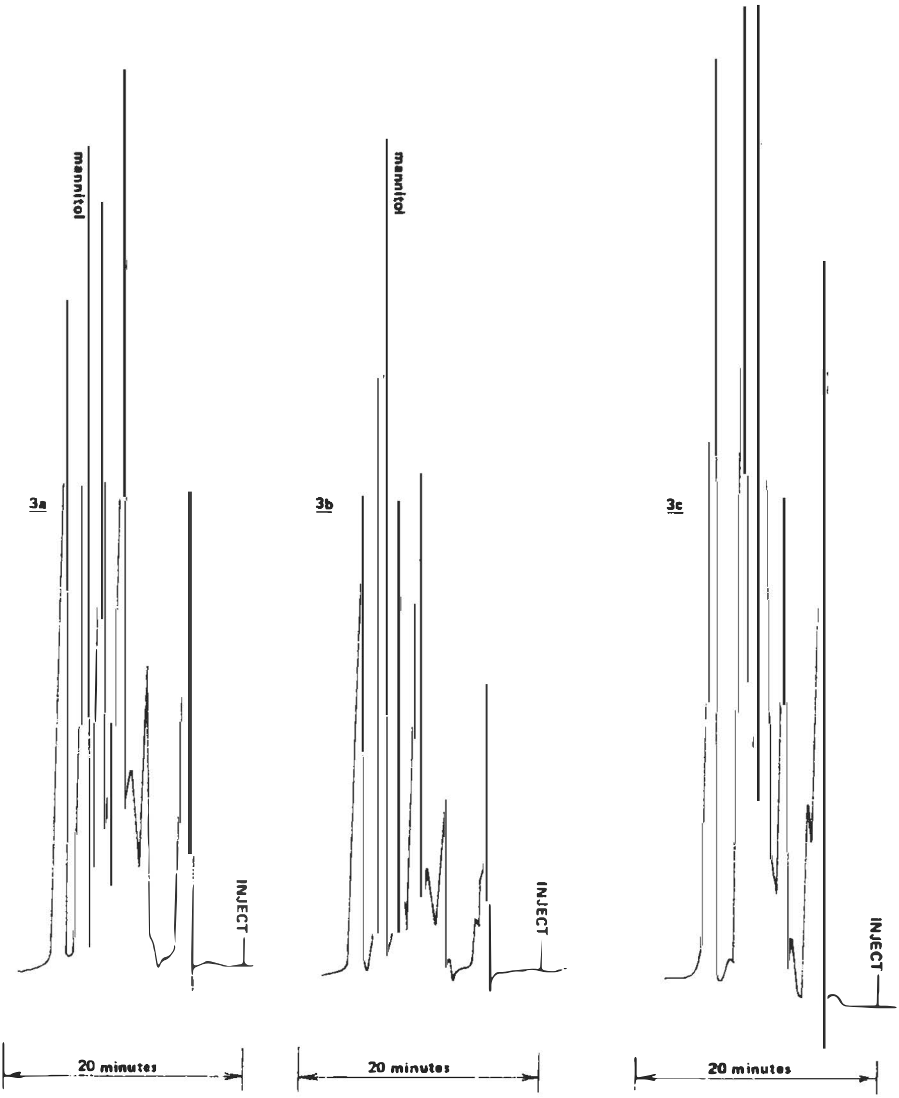

Figure 3. HPLChromatograms of $5 \mu l$ ultrafiltered coconut water (3a), $10 \mu l$ diluted coconut water concentrate (3b), and $3 \mu l$ coconut water (3c). Samples in Figures a and b also contained $50 \mu g$ mannitol as internal standard

in Figure 3b. The corresponding HPLC pattern for concentrated and undiluted coconut water at the same chart speed, i.e. 0.25 cm/min, is presented in Figure 3c. To the samples in Figures 3a and 3b, but not to the sample of Figure 3c, was added mannitol as internal standard. The elution profile of concentrated and diluted coconut water without added mannitol is shown in Figure 4. The elution patterns of the different coconut water samples showed eight major and three minor peaks which are numbered in the order of increasing retention time.

Identification of elution peaks

Table 1 lists the retention times of the HPLC elution peaks relative to peak no. 7. The retention time was also calculated for each "spiked" peak or the peak that increased in height after adding to the sample a known carbohydrate standard. This table shows that peak 3 is probably maltopentaose. Peaks 4 and 5, which are quite small and have wide spreads of retention times, are more difficult to assign but could correspond to maltotetraose and maltotriose. Peak 6 corresponds to sucrose, maltose or cellobiose, peak 7 is glucose while peak 8 could be mannose, galactose or xylose. Peak 9 is fructose, peak 10 is mannitol and peak 11 is sorbitol. Peaks 1 and 2 could correspond to oligosaccharides with degrees of polymerization (DP) greater than five.

An interesting broadening/splitting phenomenon for peak 6 was observed during the course of the HPLC experiments. Early HPLC profiles of coconut water showed a single peak 6 which was cleanly separated at the baseline from peak 7 (Figure 5a). Later profiles showed merging of peaks 6 and 7, i.e. reduced degree of resolution, accompanied by reduced peak 6 height and increased heights for peaks 7 (glucose) and 9 (fructose) as shown in Figures 4 and 5b. Further runs showed a pronounced broadening/splitting of peak 6 as presented in Figures 3a and 3b.

The same broadening/splitting phenomen was observed for two reagent grade samples (Baker and Mallinckrodt) of sucrose which were used as spiking standards. For example, Figure 5b is the HPLC profile of reagent grade sucrose taken after the Sugar-PAK column had been used many times. Figures 6a and 6b correspond to sucrose spiked with fructose and glucose, respectively. The figures indicate that the broadened/split peak for sucrose also contains invert sugar, i.e. glucose and fructose. Therefore, the broadening/splitting phenomenon observed for pure sucrose could be explained by sucrose inversion in the HPLC column. In fact, the manufacturer has cautioned the HPLC user about this problem and suggested methods for solving this (Waters Associates, 1982).

The identification of peak 6 was done with the aid of invertase (technical grade powder) whose elution profile is shown in Figure 7a (with added mannitol). A band was observed with the same retention time, within experimental error, as peak 6. This band cannot correspond to sucrose (which should have been hydrolyzed by the enzyme) and is probably a stabilizing agent. The elution pattern of fresh coconut water with added active invertase is presented in Figure 7b. The corresponding pattern with added inactive invertase is shown in Figure 7c. It is clearly seen in Figures 7a, b and c that

Table 1. Relative HPLC Retention Times of Standard and Detected Carbohydrates in Concentrated Coconut Water.

Standard/Peak No.	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
None*	0.49	–	–	–	–	0.78	1.00	1.09	1.14	–	1.41
Maltose	0.49	0.52	0.54	–	–	0.78*	1.00	1.09	1.14	–	1.41
Cellobiose	0.49	0.52	0.55	–	–	0.78*	1.00	1.09	1.14	–	1.41
Sucrose	0.49	0.51	0.54	–	–	0.78*	1.00	1.10	1.14	–	1.42
Glucose	0.49	0.52	0.55	–	–	0.78	1.00*	1.10	1.14	–	1.41
Fructose	0.49	0.51	0.54	–	–	0.78	1.00	1.09	1.14*	–	1.41
Xylose	0.49	0.52	0.55	–	–	0.78	1.00	1.09*	–	–	1.41
Galactose	0.49	0.52	0.54	–	–	0.79	1.00	1.08*	–	–	1.41
Inositol	0.50	0.52	0.55	–	–	0.79	1.00	1.09	1.11	1.20*	1.39
Mannitol	0.49	0.52	–	–	–	0.79	1.00	1.09	1.14	1.25*	1.42
Sorbitol	0.49	0.52	0.55	–	–	0.78	1.00	1.09	1.14	–	1.41*
None	–	–	0.56	0.63	0.71	0.78	1.00	1.09	1.14	1.26	1.42
Maltopentaose	–	–	0.56*	–	0.69	0.78	1.00	1.08	1.14	1.26	1.42
Maltotetraose	–	–	0.56	0.58*	0.71	0.76	1.00	1.06	1.12	–	1.40
Maltotriose	–	–	0.55	0.61	0.66*	0.77	1.00	1.08	1.14	1.25	1.41
Mannitol	–	–	0.58	0.66	0.73	0.79	1.00	1.10	1.14	1.26*	1.44
None	–	–	0.49	0.59	0.68	0.75	1.00	1.04	1.13	1.20	1.41
Mannose	–	–	–	0.60	0.70	0.78	1.00	1.08*	1.14	1.25	1.43
Xylose	–	–	0.51	–	0.71	0.76	1.00	1.07*	1.15	1.23	1.42
Arabinose	0.43	0.44	0.49	–	–	0.80	1.00	1.08	1.14 1.19*	1.29	1.47

*Concentrated coconut water with no added standard carbohydrate.

Figure 4. HPLC elution profile of 10μl diluted (10x) coconut water concentrate in carrier water.

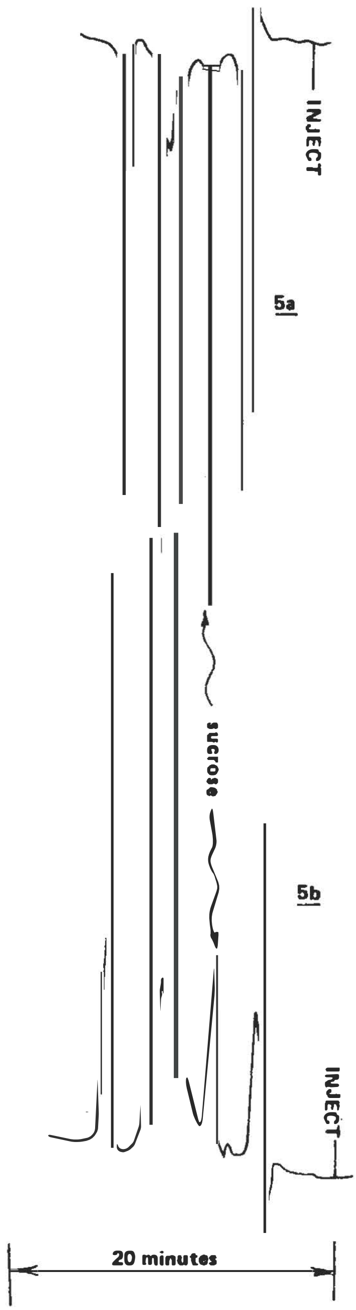

Figure 5. Elution profiles of 10μl diluted (10x) coconut water concentrate (early run –5a; later run –5b) with water as mobile phase.

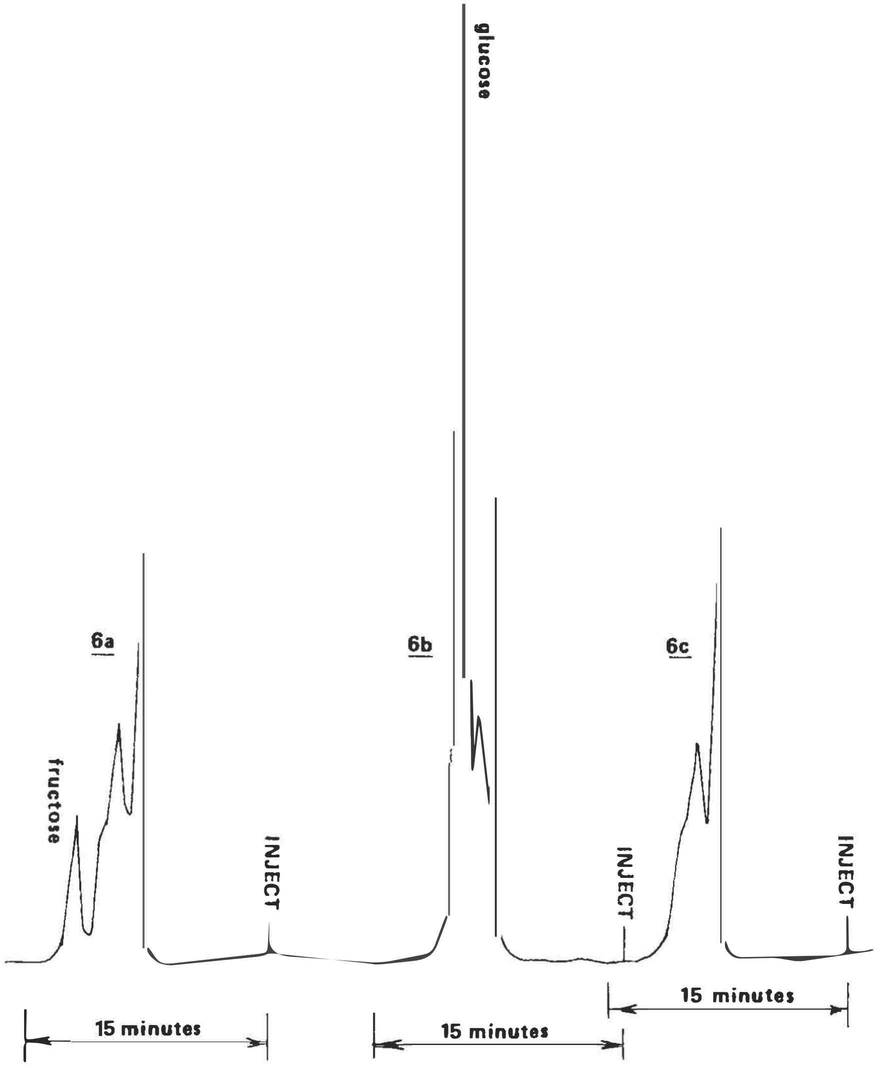

Figure 6. "Spiking" of 50μg sucrose samples with 10μg fructose (6a) and 40μg glucose (6b). Figure 6c is the HPLChromatogram of sucrose alone. The carrier used was 0.0001M calcium acetate.

with active enzyme, peak 6 of the original coconut water disappeared and only the residual band characteristic of the enzyme preparation remained. At the same time, the peak heights increased for peaks 7 and 9, which correspond to glucose and fructose, respectively. A control experiment was done wherein invertase was added, together with sorbitol as internal standard, to

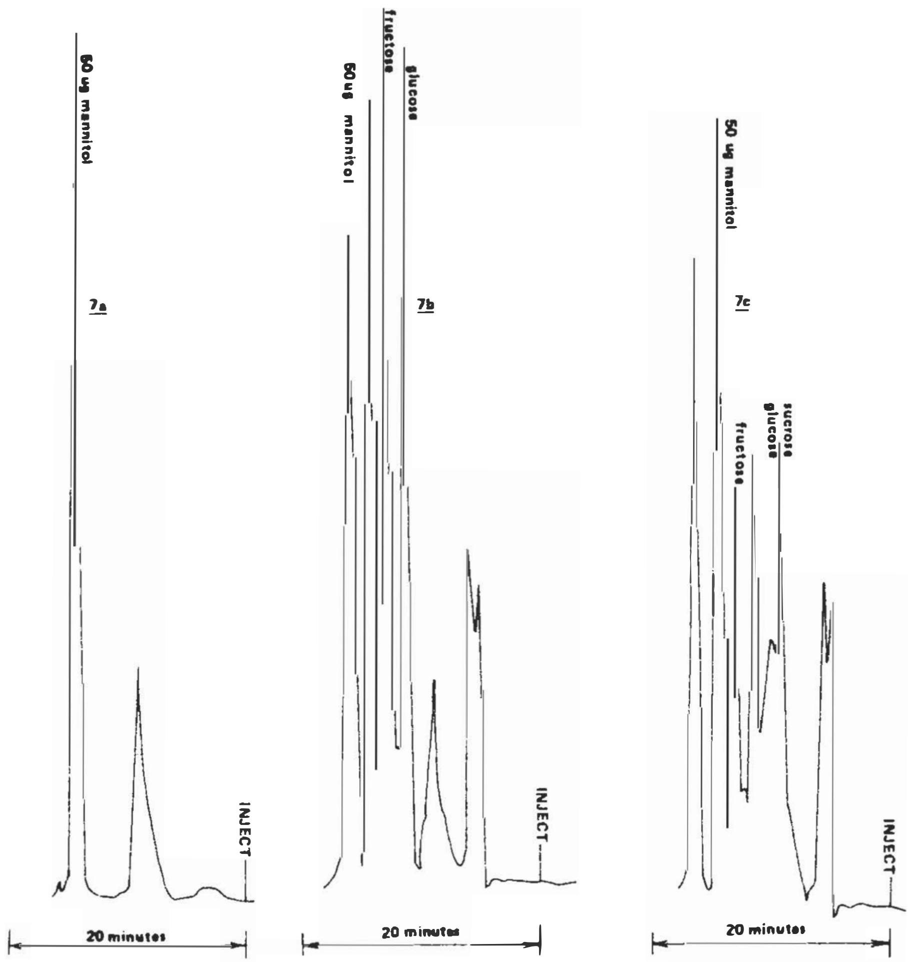

Figure 7. Elution profiles of invertase (7a), coconut water with active invertase (7b), and inactive invertase (7c) with mannitol as internal standard.

solution of maltose (Figures 8a and 8b) and sucrose (Figures 8c and 8d). The enzyme did not hydrolyze maltose, as expected, and did not change its HPLC profile. However, sucrose was hydrolyzed by the enzyme and its elution profile was drastically altered. This qualitative conclusion can be made inspite of complicating factors due to on-column hydrolysis of sucrose and the residual elution band of the invertase preparation. Reducing sugar analysis (using dinitrosalicylic acid; Miller, 1959) of the sucrose and maltose solutions, which had been treated with active invertase, showed a quantitative increase in reducing equivalents for sucrose but not for maltose. Both

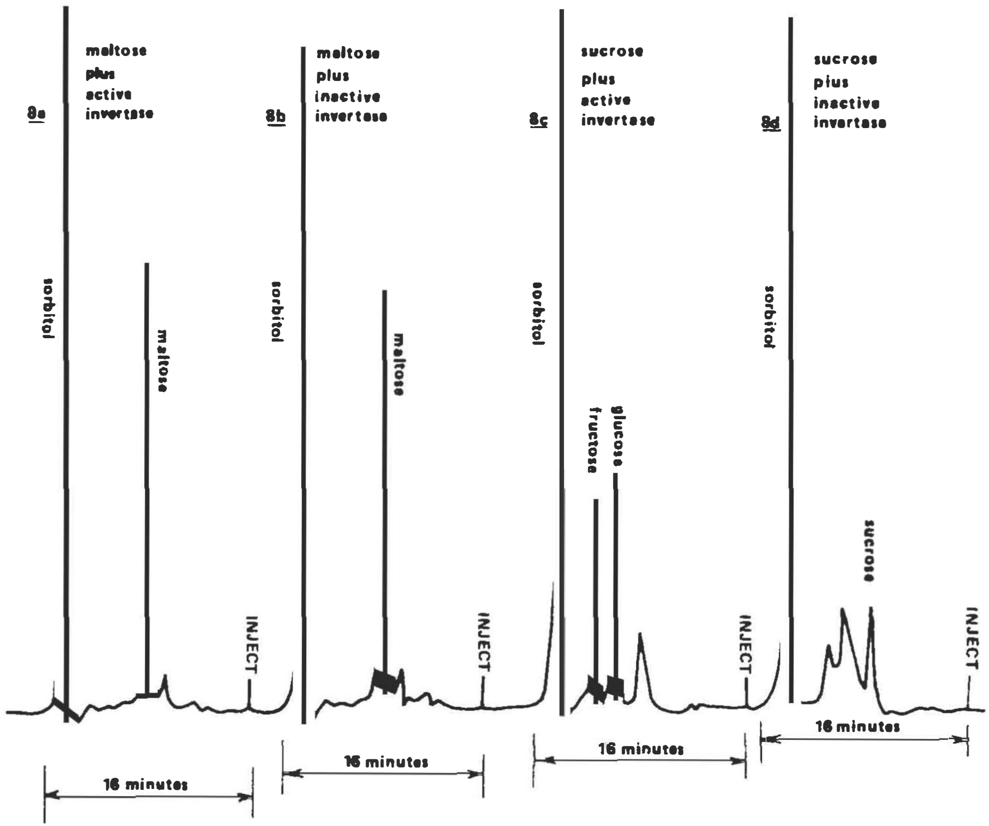

Figure 8. HPL Chromatograms of 10-μl samples of 4 mg/ml sugar and 0.1 mg/ml invertase in 0.005M acetate buffer pH 5.0 plus 50μg sorbitol as internal standard. The mobile carrier was 0.0001M calcium acetate.

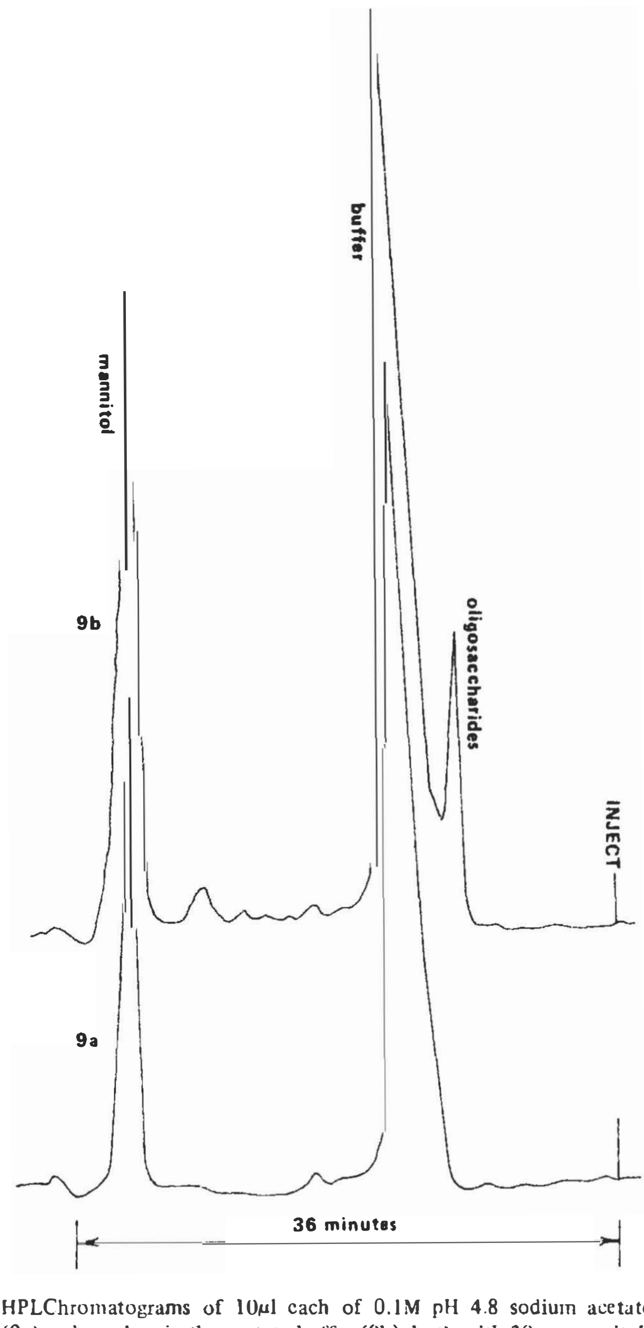

Figure 9. HPLChromatograms of 10μl each of 0.1M pH 4.8 sodium acetate buffer blank (9a) and amylase in the acetate buffer (9b), both with 30μg mannitol standard.

results of HPLC and reducing sugar determination show conclusively that peak 6 corresponds to sucrose and not maltose. The possibility of peak 6 being cellobiose is highly unlikely on the basis of the results of the above-mentioned treatment with invertase.

Amylase treatment of the samples was studied in terms of changes in the HPLChromatograms. Figure 9 shows that sodium acetate has a prominent HPLC peak while the commercial amylase preparation (Novo) also contained dextrins (DP > 5) and small amounts of monosaccharides. The action of the enzyme on starch is shown in Figure 10 where the emergence of a prominent glucose peak is seen after enzymatic treatment. After incubating maltose with the enzyme the HPLC peak increased its retention time from 0.61 to 0.77; this corresponds to the disappearance of the original maltose peak and the appearance of a glucose peak (Fig. 11). This shows the complete enzymatic hydrolysis of maltose to glucose.

After amylase treatment of coconut water, the glucose peak showed a significant increase in height. This increase in glucose concentration could only come from the hydrolysis of sucrose or oligosaccharides (maltose is absent as shown earlier). The sucrose peak height did not show a significant change as shown in Figure 12. Unfortunately, changes in the oligosaccharide peak height were masked by the presence of this peak in the enzyme preparation. Therefore, the conclusion that maltosaccharide peaks are present in coconut water derives partial but not definitive support from the increase in the glucose peak height after amylase treatment as well as from the expected retention times for such molecules as previously shown by the equipment and column manufacturer (Waters Associates). However, the presence of maltosaccharides in coconut water is *not* supportive of the previous findings of Balasubramiam (1976) that the polysaccharides of mature cocnut kernel consists of 61% galactomannan, 26% mannan and 13% cellulose. Needless to say, further research should be done in order to positively identify the HPLC oligosaccharide peaks.

Figure 13 shows HPLChromatograms of coconut water concentrates prepared by reverse osmosis at 30 and 20 bars pressure. The concentrates were prepared several months apart from mature coconuts purchased by the desiccated coconut factory. The close similarity of the chromatograms shows that the same major carbohydrate components are present in coconut water from mature nuts.

Results of gas chromatography

The gas chromatograms of the aldononitrile and alditol acetate derivatives of coconut water are presented in Figure 14(a) and (b), respectively. The use of pyridine as acetylation catalyst for the first type of derivatives resulted in severe solvent peak tailing which precluded accurate quantitation of the carbohydrate components. However, several peaks may be clearly seen

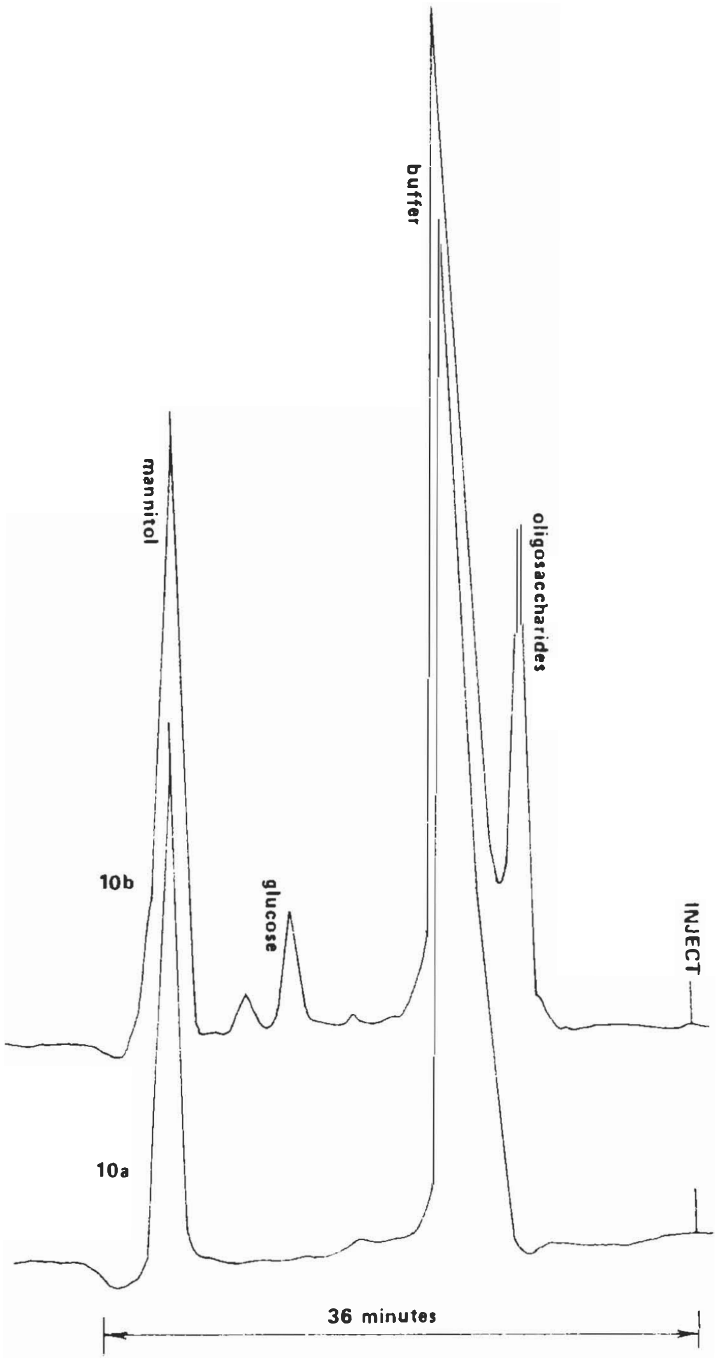

Figure 10. HPLChromatograms of the starch control (10a) and amylase treated starch (10b), both with 30μg mannitol standard.

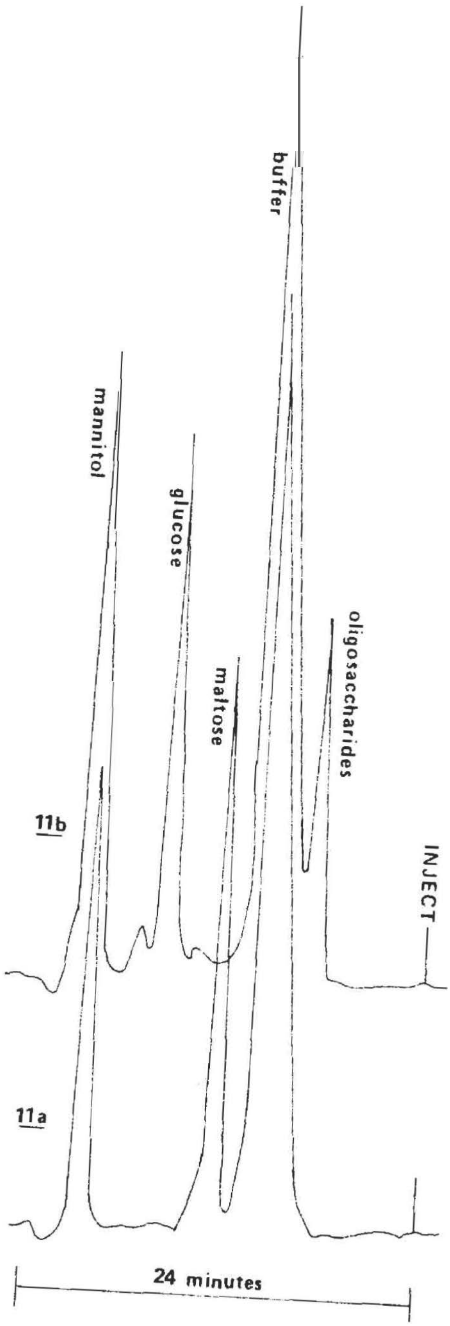

Figure 11. HPLChromatograms of 25μg maltose control (11a) and amylase-treated maltose (11b), both with 30μg mannitol standard.

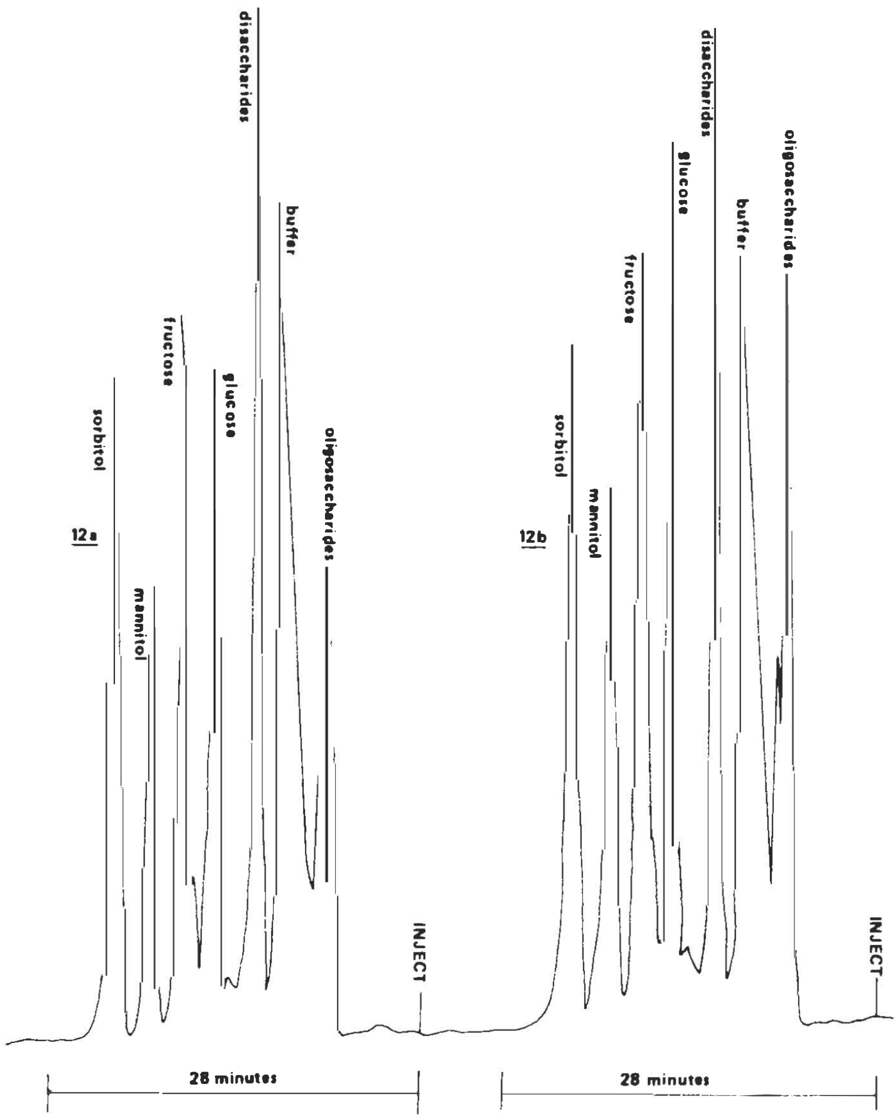

Figure 12. HPLC elution profiles of 10μl coconut water concentrate (control, 12a) and amylase-treated concentrate (12b), with 30μg mannitol as internal standard.

in the chromatogram in addition to the internal standard α-methyl-D-glucopyranoside. Based on the retention times of standard sugars the identified peaks correspond to glucose/galactose/mannitol, sorbitol, arabinose, xylose and mannose. However, a few of the observed peaks have not been identified so far.

The gas chromatogram of the alditol acetate derivatives of coconut water (Figure 14b) showed less severe solvent peak tailing and fewer carbohydrate peaks. The identified peaks correspond to glucose/sorbitol, mannose and internal standard which were co-eluted and small amounts of arabinose and galactose.

Quantitation of Carbohydrate Components

Although the results of GC analysis could not be quantitated the presence of some sugar components were established. Arabinose, galactose, xylose and mannose were shown to be present using GC, whereas they could not be resolved from one another and from the other sugars by HPLC.

The concentrations of the carbohydrate components of coconut water are given in Table 2, as well as concentration ratios relative to total carbohydrate. For coconut water samples from mature nuts with dried husk the highest concentrations were obtained for sucrose, glucose and fructose. The tabulated values of these concentrations are subject to error due to on-column sucrose hydrolysis as earlier mentioned in this paper. However, the total concentration of sucrose, glucose and fructose in fresh coconut water was found to be approximately constant, i.e. 30 ± 3g/1. Sorbitol is the fourth most abundant carbohydrate component in coconut water followed by oligosaccharides with degrees of polymerization (DP) greater than 5. The total concentration of galactose, xylose and mannose corresponding to peak 8 for fresh coconut water from mature dry nuts was approximately constant at 2.3 g/l. Likewise, the concentration of mannitol was close to 0.3 g/l.

The carbohydrate concentration values for coconut water from mature green nuts (with medium firm solid endosperm) are also presented in Table 2. The total concentration of sucrose, glucose and fructose was equal to 51.5 g/l. The concentration of sucrose was found to be less than half that of either glucose and fructose, unlike in samples of more mature coconut water. Likewise, for less mature coconut water, the concentrations of oligosaccharides (DP $>$ 5) and component 8, as well as the total carbohydrate concentration, are greater than those of more mature samples. These results are in agreement with previous literature reports and explain why coconut water from immature nuts is substantially sweeter than that from mature nuts (Sison, 1984; Banzon and Velasco, 1982; Anzaldo *et al.*, 1975).

It is evident in Table 2 that a wide variability of concentration values was observed for the carbohydrate components of different coconut water samples. The factors for variability include age and variety of coconuts, as well as statistical differences among samples. As previously mentioned, the separate concentration values for sucrose, glucose and fructose are uncertain due to on-column sucrose hydrolysis. Needless to say, further research

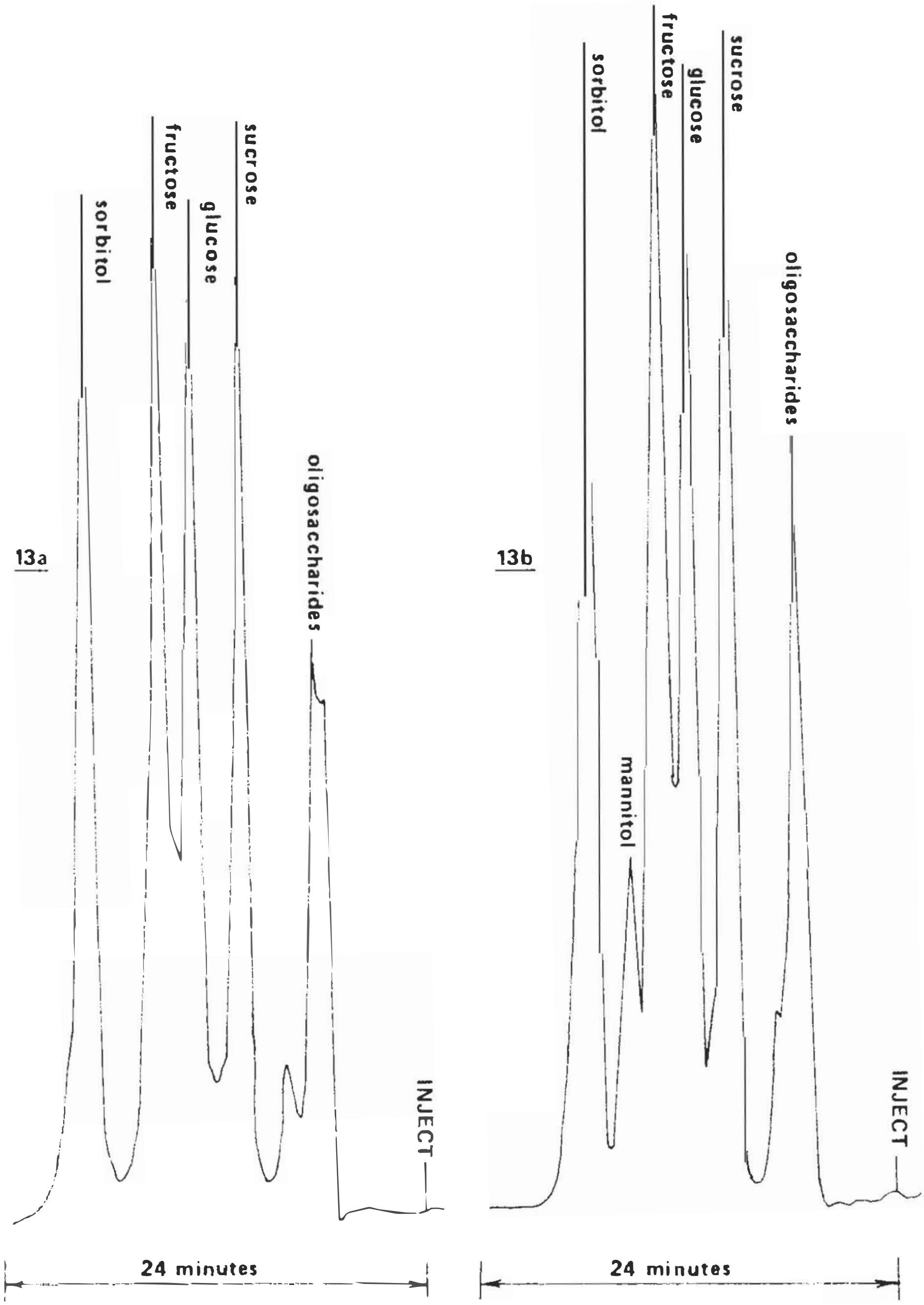

Figure 13. HPLChromatograms of 3μl each of coconut water concentrated by reverse osmosis at 30 bars (13a) and 20 bars pressure (13b), with 30μg mannitol as internal standard.

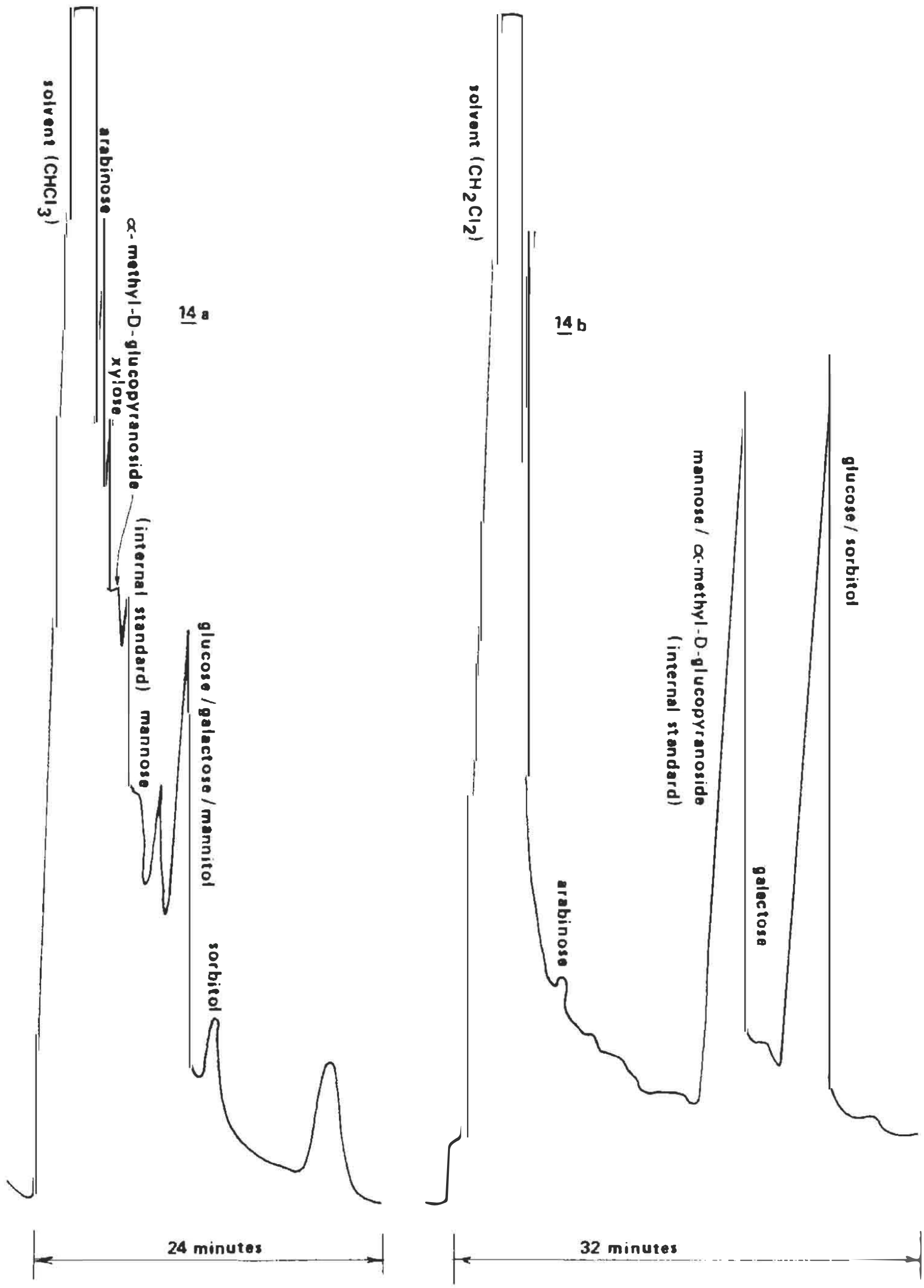

Figure 14. Gas chromatograms of the aldononitrile (14a) and alditol (14b) acetate derivatives of sugars in coconut water concentrate.

Table 2. Actual and relative concentrations of the carbohydrate components of coconut water.*

Sample		1 *DP>5*	2 *DP>5*	3 *DP5*	4 *DP4*	5 *DP3*	6** *Sucrose*	7 *Glucose*	8#	9 *Fructose*	10 *Mannitol*	11 *Sorbitol*	*Total*
Coconut water concentrate	30 bars (3 hrs.)	18.80 (11.90)	6.32 (4.00)	3.67 (2.32)	0.59 (0.37)	0.59 (0.37)	31.40 (19.88)	30.55 (19.34)	6.17 (3.91)	29.52 (18.69)	1.41 (0.89)	28.94 (18.32)	157.96
	20 bars (5 hrs.)	21.21 (12.62)	5.57 (3.32)	0.85 (0.51)	– –	– –	32.36 (19.20)	31.23 (18.59)	11.89 (7.08)	32.83 (19.54)	– –	32.17 (19.15)	168.01
Fresh coconut water (mature dry nuts)	XM300##	5.86 (11.05)	4.48 (8.45)	–	0.18 (0.34)	0.15 (0.28)	10.82 (20.41)	11.30 (21.31)	2.23 (4.20)	9.45 (17.82)	0.27 (0.51)	8.28 (15.62)	53.02
	PM30	5.29 (11.24)	4.05 (8.60)	–	0.24 (0.51)	0.16 (0.34)	9.55 (20.29)	9.96 (21.16)	2.03 (4.31)	8.28 (17.59)	0.28 (0.59)	7.23 (15.36)	47.07
	C1	9.34 (15.23)	4.69 (7.65)	–	0.38 (0.62)	0.27 (0.44)	16.78 (27.36)	5.72 (9.32)	2.72 (4.44)	6.10 (9.95)	0.35 (0.57)	14.98 (24.43)	61.33
	C2	7.40 (12.18)	5.66 (9.32)	–	0.44 (0.72)	0.26 (0.42)	20.04 (32.98)	6.90 (11.36)	2.35 (3.87)	6.13 (10.09)	– –	11.57 (19.05)	60.75
Fresh coconut water (mature green nuts)		5.92 (7.64)	7.85 (10.14)	–	0.29 (0.37)	0.20 (0.26)	8.89 (11.48)	23.60 (30.48)	4.52 (5.84)	19.00 (24.54)	0.32 (0.41)	6.85 (8.84)	77.44

* Actual concentrations expressed in grams/liter; relative concentrations based on total carbohydrate are given in parentheses.

** Calculations were based on an external sucrose standard and not the internal mannitol, due to on-column sucrose hydrolysis (Figure 2a-2b).

\# Galactose, xylose and mannose were co-eluted in peak 8.

\#\# XM30 and PM30 are samples of fresh coconut water which had been passed through these Amicon membranes; while C1 and C2 are two other samples which had been filtered through a Milipore 0.45 μm pore size membrane.

is needed in order to overcome these problems as well as to identify definitively all the carbohydrate components of coconut water. Furthermore, the effect of maturity on the carbohydrate profile of coconut water should be quite interesting in elucidating the physiology of coconut ripening.

Acknowledgements

The authors are grateful for financial support provided by the Australian Government and the National Institute of Science and Technology of NSTA under the ASEAN-NSTA-UPLB Project on the Management and Utilization of Food Waste Materials. The supply of coconut water samples by Blue Bar Coconut Philippines is acknowledged, as well as the kind assistance of Mr. Venuso Bibit (Blue Bar), Mrs. Olympia Gonzales (NSTA-NIST), Prof. L.S.P. Madamba (UPLB-BIOTECH) and Dr. W.G. Padolina (UPLB-BIOTECH).

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Florinia E. Merca, Discussant

This paper is supportive of any researches on the possible utilization of the carbohydrates from coconut water not only in yeast production but also in the food industry like in the production of industrial gels. I congratulate Dr. del Rosario and his co-workers on this paper.

Gas Chromatography (GC) is a rapid and accurate method for carbohydrate determination and is also widely used. Similarly, high performance liquid chromatography (HPLC) is indeed an excellent method for carbohydrates analysis. This method is also more rapid compared to GC because there is no need for derivatization – a procedure which entails possible loss of sample.

I have only one comment to make regarding the methodology used in the experiment. I noticed that you were not able to separate the monosaccharides clearly for both the GC and HPLC. I would suggest that perhaps another column be used for GC like Gas Chrom Q with 3% ECNSS which I have used before and obtained good separation. In addition, you can also use a Durrum Anion Exchange Resin for HLPC instead of a sugar – PAK 1 column for separating the monosaccharides arabinose, galactose, xylose and mannose. Sharper detection could perhaps be made by reacting the sample after passing thru the column with a Cu dye reagent Na bichinchoninate and determining its absorbance. A borate buffer pH 8.9 could be used as eluant.

R.R. del Rosario, Discussant

The author should be commended for a very thorough study on the carbohydrates of coconut water. This is by far the most comprehensive work involving the use of state-of-the-art methods for analysis of carbohydrates in coconut water.

The paper is essentially a comprehensive study on the use of gas-liquid chromatography (GLC) and high performance chromatography (HPLC) for carbohydrate analysis. It presents also the use of internal standards as well as enzyme hydrolysis for identification of unknown fractions.

The interpretation of results however is limited by certain problems in the analytic procedure used. In the case of the HPLC the use of a non-aqueous solvent system might help resolve the hydrolysis of sucrose, which interferes in the quantitative HPLC analysis of sucrose, glucose and fructose. For the GLC separation temperature programming would help separate the individual fractions or peaks and help improve quantitation. The efficiency of the derivatization process of the different sugars is not indicated and therefore may not permit direct comparison with the HPLC data.

In some analyses we have performed on coconut water by HPLC we encountered the presence of inositol. In the analyses presented however, I have not seen any mention of inositol being present. Another question that may be raised is whether the processing (reverse osmosis) used for concentration affects the composition of the coconut water.

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THE COCONUT PALM AS A SOURCE OF FIREWOOD

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ABSTRACT

Shell, husk and leaf petiole ("palapa") constitute firewood from the coconut palm. The energy output, E from P palms each bearing N nuts/bunch is E = (8.5 N + 8.4) p. Kitchen needs range from 300 MJ to 1400 MJ per month. Calculations from the energy equation indicate that at least 11 coconut palms can meet average kitchen needs indefinitely. Leaf petioles alone from about 90 palms can achieve same purpose.

We are going back to firewood. Liquefied petroleum gas has become too expensive, and worse, it may no longer be easily available because of restriction in foreign exchange outflow. There are several sources of firewood. The present paper deals with a source that has merited hardly any attention: The coconut palm.

While shell and husk of the "nut" are sometimes mentioned as being used for fuel, the petiole of the leaf ("palapa") is more extensively employed for this purpose by people in coconut areas. Flower/fruit stalks, spikes, flower sheaths, etc. also make good fuel (Cornista, 1983).

How firewood from the coconut compare with others of this kind is shown in Table 1. Coconut husk is nearly as good as, while the shell is better than the other listed firewoods as far as MJ/kg are concerned.

Table 1. Heating Value of Some Firewoods in MJ/Kg.

Coconut husk	14.7-17.5	Festin, 1976; Wilson, 1930
Coconut shell	23.0	Paddon & Parker, 1979
Ipil-Ipil, common	19.4-19.6	Aguilar, 1943; Wells, 1917
Ipil-Ipil, "giant"	17.4-18.6	Bawagan & Semana, 1976
Philippine woods	15.4-21.0	Aguilar, 1943; Cox, 1911

The task set in the present study is to determine how many coconut palms, contributing husk, shell and petiole as firewood, can sustain a kitchen indefinitely. Two quantities are needed: the energy output of a coconut palm and the energy requirement of the kitchen.

Energy output of a coconut palm. The biomass and associated energy from husk, shell and petiole are given in Table 2. Per month the coconut palm bears one

Table 2. Basic Data Used in Calculations

Mass/unit (in kg)		
husk	0.242	Hagenmaier 1980
shell	0.193	Hagenmaier 1980
petiole	0.5	Zuñiga et al. 1965
Energy/unit (in MJ)		
husk	4.05	Festin 1976; Wilson 1930
shell	4.44	Paddon and Parker 1979
petiole	8.4	Same value as for wood.

LPG, assumed as C_4H_{10}; 49.6 MJ/kg Hougen *et al.* 1954
Kerosene, 42.02 MJ/kg; 41.42 MJ/L. Hougen *et al.* 1954
Fuel wood assumed ave. 16.7 MJ/kg
Fuel biomass from coconut palm, per month: one bunch of nuts and one leaf petiole.

bunch of N nuts and sheds one leaf. The energy output, per month, of a coconut palm is therefore

$$
\begin{aligned}
E &= (4.05 + 4.44)\,N + 8.4 \\
&= 8.5\,N + 8.4 \text{ in MJ/month} \quad \text{------- Equation 1}
\end{aligned}
$$

The energy output of a coconut palm, as it varies with increasing number of nuts/bunch, is shown in chart 1. The equivalent in liters kerosene (41.4 MJ/L) and in wood fuel (16.7 MJ/kg) are also given. A coconut palm yielding one leaf petiole and a 10-nut bunch in one month produces 93.4 MJ of energy equivalent to 2.25 liters of kerosene or 5.6 kg wood fuel.

Number of coconut palms which yield energy equal to one LPG tank of 11 kg gas.

Putting E as equal to 546 MJ (The energy in 11 kg of LPG), the value of p may be solved in the equation:

$$E = (8.5N + 8.4)\,p \quad \text{----- Equation 2}$$

Chart 2 gives the calculated values of p as N varies from zero to 16. Thus when N is 8, p is 7. The energy value of 7 petioles and that of the husks and shells of 56 nuts equal the energy in one 11 kg LPG.

Firewood requirements of a family. Evidently firewood requirements depends on size of family, types of food cooked, efficiency of stove, kind of fuel, frequency of cooking, management of fuel, etc. NEDA, as reported by PCARRD, states that in a survey of 23,430 households, the monthly consumption was 22.1 kg of wood charcoal which it was stated, equal to 13.5 kg of LPG. Therefore

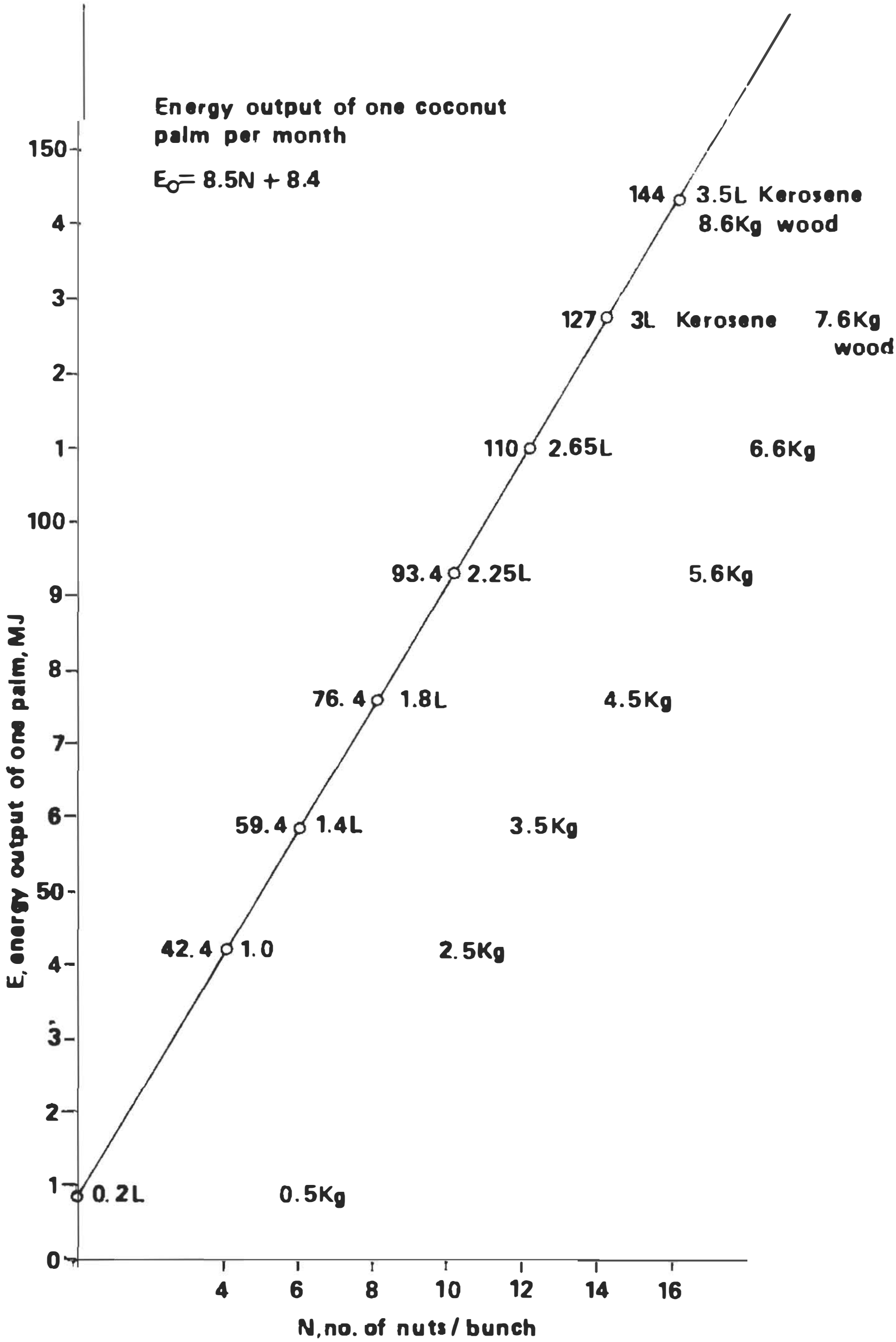

Chart 1. Energy Output of One Coconut Palm per Month.

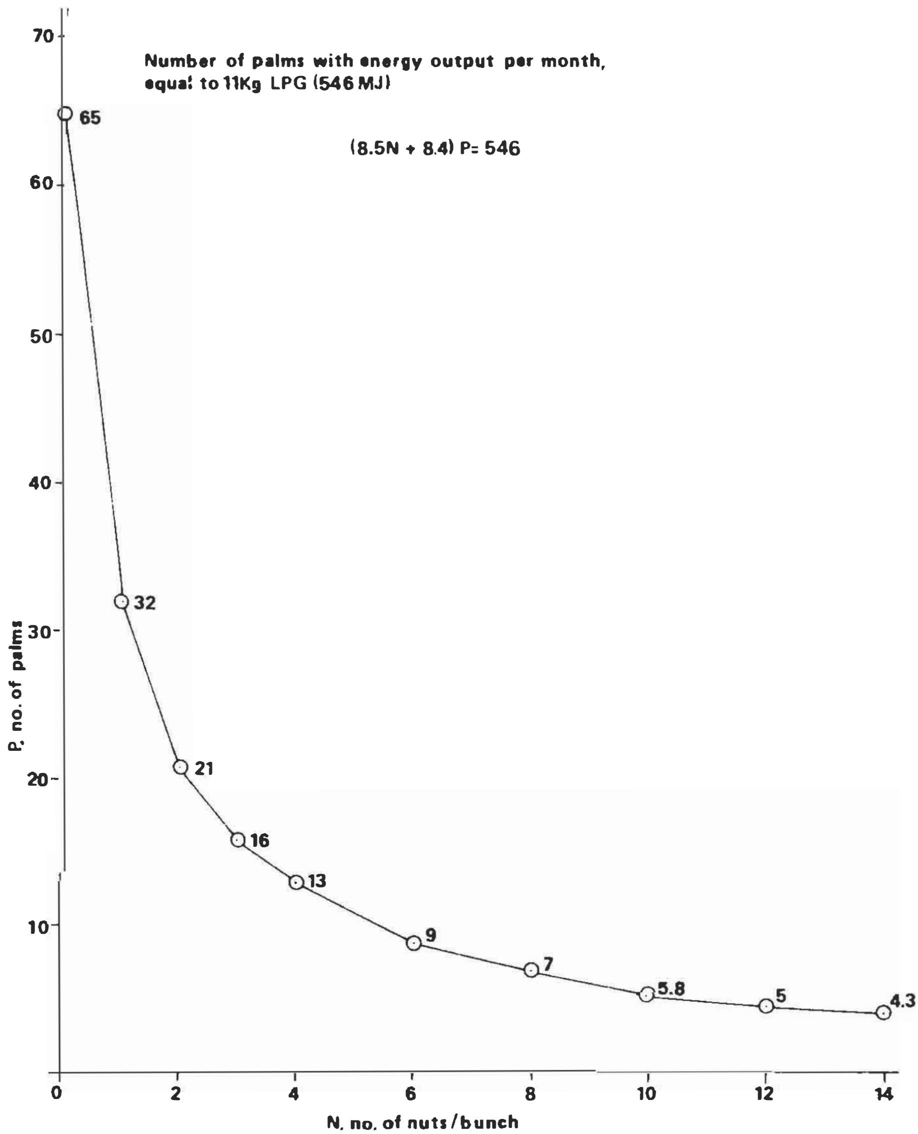

Chart 2. Number of Palms with Energy Output per Month, Equal to 11 Kg LPG (546 MJ).

this amounts to 670 MJ/month. The US Academy of Science in its recent publication, Firewood Crops, states that in a woodshort area such as India, the average user burns annually about a fifth of a ton of wood (about 300 MJ/month) and as much as over a ton (about 1400 MJ/month) in parts of Africa and Southeast Asia. LPG is the preferred fuel in cities and large towns; the consumption is about one

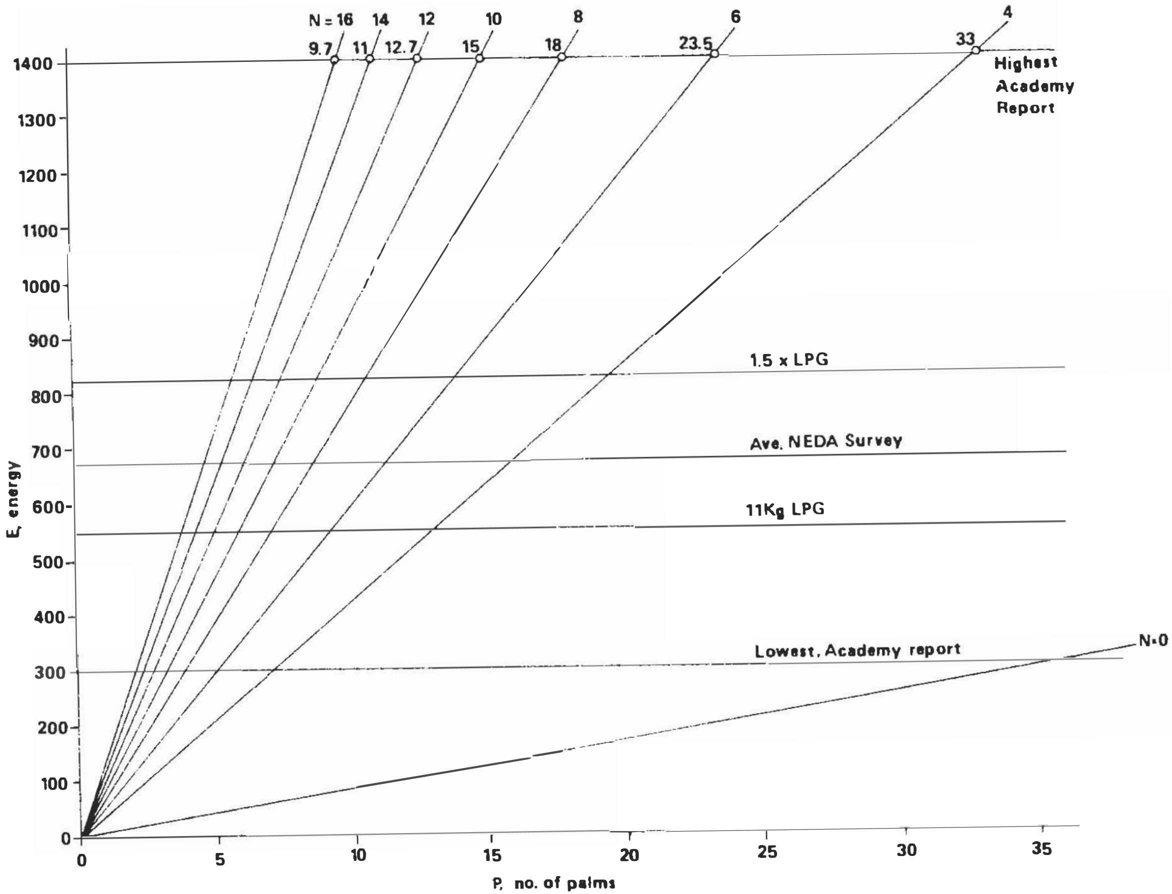

Chart 3. No. of Coconut Palms Whose Energy Meets Kitchen Firewood Needs.

11-kg tank per month (546 MJ/month). LPG, however is an "efficient" fuel, since a high degree of control can be exercised in its use, by way of limiting size of flame, instant ignition and instant shutting off. (Compare for example, with use of firewood).

Now, comes the question which we have sought to answer: how many coconut palms can supply indefinitely all the fuel needed by a kitchen? The fuel is to consist of husk, shell and leaf-petiole.

Number of coconut palms to fuel a kitchen. As stated earlier several factors determine the energy needs of a kitchen. Making use of the NEDA survey (670 MJ/month), the number of coconut palms, p, may be obtained from the equation:

$$p = \frac{670}{8.5\,N + 8.4}$$

p therefore depends also on N, the number of nuts/bunch. When N is 8, p is 9 palms. It is of interest to get a general picture of the situation, that is, what are the values of p for increasing kitchen energy demands say 300 MJ to 1400 MJ per month, and for increasing number of nuts per bunch? This information is obtained by using equation 2. Chart 3 summarizes the situation. Consider a coconut palm which bears an average of 8 nuts/bunch. When the husks, shells and petiole are used for fuel, the following values of p are obtained for selected kitchen energy requirements:

E (MJ/mo.)	P	Remarks
300	4	lowest, US Academy
546	7	LPG user
670	9	NEDA survey
820	11	1.5 times LPG
1400	18	highest, US Academy

To answer the question: how many coconut palms can sustain an average kitchen indefinitely with fuel? The answer is at least 11.

Coconut leaf petiole as firewood. The dried leaf petiole of the coconut (palapa) is more often used as firewood than the shell and husk of the "nut". This petiole was reported as weighing an average of 2 kg (Zuñiga, 1965). Losses in mass due to several causes and uncertainties in moisture content, leads to an approximation of 0.5 kg average weight per dry petiole. Like wood, its energy value would then be 16.7 MJ/kg. At an energy output of 8.4 MJ/month, the energy associated with p palms would then be:

$$E = 8.4\,p.$$

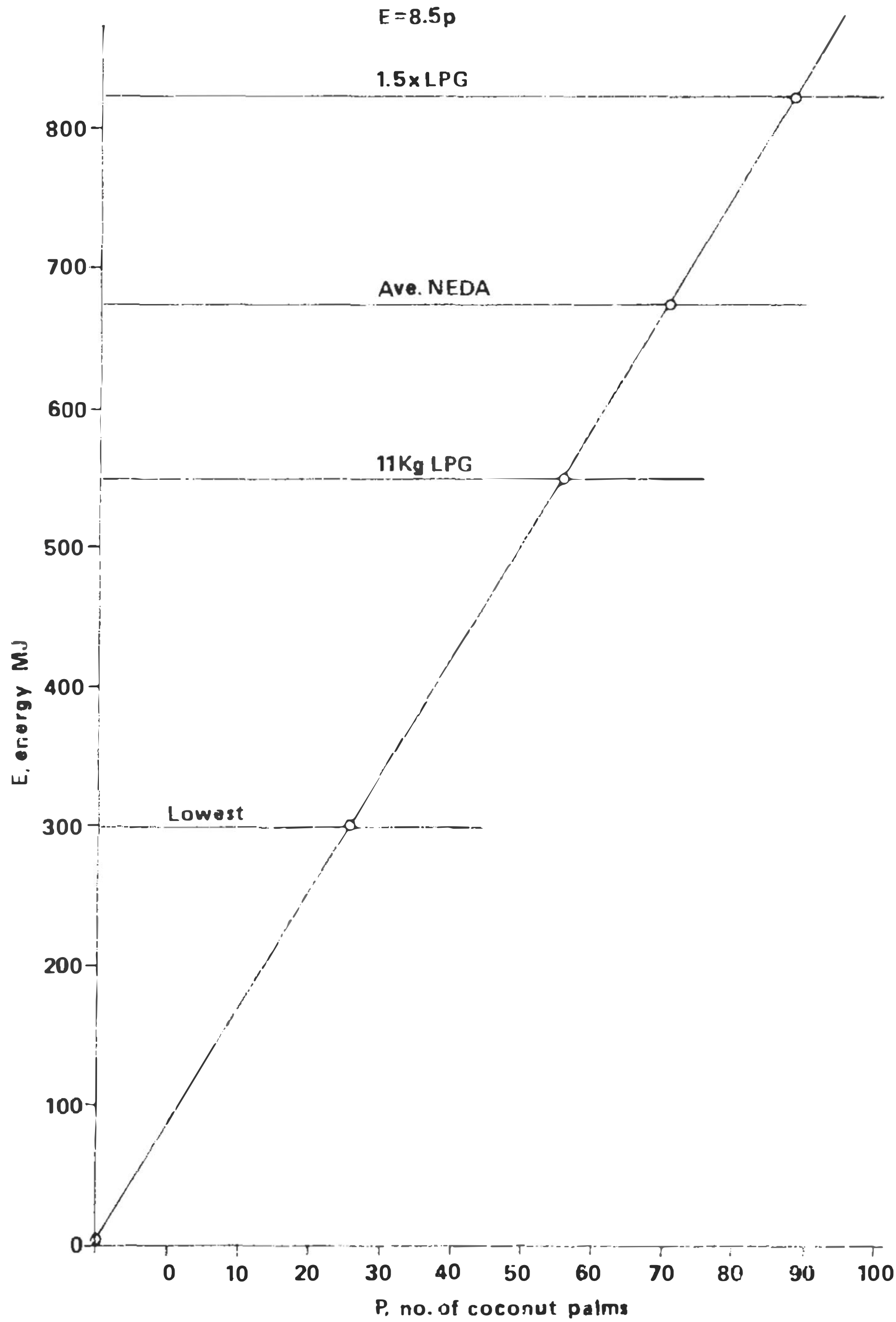

Chart 4. Energy Output/Month of Leaf Petioles in Relation to Number of Palms.

This relationship is shown in chart 4. It is indicated here that a kitchen that demands 670 MJ/month will need a grove of about 80 coconut palms. Even if the palms do not produce fruits or in the event that the palms are tapped for sap (tuba), or if all the fruits are sold, the leaf-petioles are still there to provide the fuel.

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Florentino O. Tesoro, Discussant

Introduction

It is recognized by economic planners that the core of economic development strategies for the future is energy. Thus, it is fitting and significant that energy is one of the subjects presented in this sixth annual scientific meeting of the National Academy of Science and Technology.

The paper of Dr. Banzon shows the potential of coconut husk, shell and petiole as firewood for domestic use, and is therefore relevant to the national economic development program.

The subject of firewood or dendro-thermal energy is one of the areas in which FPRDI is seriously doing R & D studies. As a matter of fact in the present organizational set-up of FPRDI, one program -- *The Dendro-Energy Program* is currently pursuing research projects on solid, liquid and gaseous fuels from wood. Coconut husks, shells and petiole are included in our research projects.

FPRDI contributions to the paper of Dr. Banzon are focussed: first, on some assumptions and relate them to information available from other sources. We would, in addition, like to highlight the influence of moisture content on the calorific value of wood or biomass because firewood is being used with certain moisture content and *never with zero* moisture content. Since the calorific value of wood is given on the *oven-dry basis*, such value has to be corrected for the influence of moisture content in actual use which in our view is a basic consideration.

A. *Coconut Palm As Energy Source*

If we graph the growth of forest trees, including coconut trees, with the ordinate as *rate of growth* and the abscissa *number of years*, we come up with a sigmoid curve, representing a slow start followed by an increasing growth, then a decline at old age. Finally, the tree dies. Such growth pattern, however, is influenced by soil fertility and climatic conditions.

In Laguna, farmers are able to harvest coconut fruits every 45 days because of the favorable climate and relatively fertile soil. But, in the Visayas, particularly in Cebu province, harvesting of coconut fruits every 2 to 3 months is a common practice.

Thus, in estimating the potential contribution of coconut trees to the overall firewood supply, we suggest that a comprehensive study be undertaken for the coconut producing provinces to account for the influence of soil type and climatic type as well as the influence of age of the tree during its productive period. All these relevant facts would lend support to the present paper.

B. *Firewood Requirements of a Family in the Philippines*

We fully agree with the author that firewood requirements depends on size of family, types of food cooked, efficiency of stove, kind of fuel, frequency of cooking, management of fuel and others. We could not reconcile, however the cited figures of 670 MJ/month/family with the figures in the report of Eric L. Hyman entitled "Wood As an Energy Source for the Philippines" presented at the 28th Natural Resources Management Forum on February 19, 1981 at the U.P. Asian Institute of Tourism (AIT) House, Diliman, Quezon City. The figures cited by Hyman on woodfuels consumption range from *one-half to one cubic meter per person per year*. Hyman cited Van Den Beldt's (1983 – personal communication) figure of 5 cubic meters per year for Philippine family of five. Knowland and Ulinski give figures for selected Asian Countries in 1976, as follows:

Fuelwood Consumption in Selected Asian Countries in 1976

Country	*Per Capita Commercial Energy Consumption (kg coal Equivalent)*	*Official Woodfuel Consumption (1000 m)*	*Per Capita Official Woodfuel Consumption (kg coal Equivalent)*	*Woodfuel as Percent of Total Energy*
Philippines	329	22,960	226	41*
Burma	49	19,611	273	85
India	218	118,179	83	28
Indonesia	218	111,708	360	62
Nepal	11	8,700	291	96
South Korea	1,020	7,350	91	8
Thailand	308	16,091	160	34
Malaysia	578	5,613	195	25

Source: Knowland and Ulinski 1979, Appendix I
*This number was erroneously listed as 0.41 in the source and error was duplicated in U.S. Interagency Task Force (1980)

(Taken from: Eric L. Hyman. 1981. Wood As An Energy Source for the Philippines, *p. 31*))

If the 5 cu.m. fuelwood per year for Philippine family of five is used in the estimate for "P" (no husk and shells), the figure of 80 obtained in the estimate could easily double to 160.

With reference to our work at FPRDI on stove designs and efficiency, we would like to cite the following results.

In a report (PCARRD-IBRD 5.4 entitled "Development of Efficient Household Fuelwood Stove) submitted by Estudillo and Toroy to PCARRD in 1982, actual experiments on the efficiency of different stove models were carried out. Based on the findings (page 50), a two-burner concrete stove consumed 0.900 kg (oven-dry weight) of fuelwood (ipil-ipil) to cook 1.10 kg. rice, 0.454 kg chicken, 0.200 kg vegetables and 0.800 liter water. From this information, 81.0 kg fuelwood would be consumed by family cooking three times a day for 30 days. The total energy consumption, therefore is *1352.7* MJ/mo. (16.7 MJ/kg fuelwood) which is twice the 670 MJ/month.

C. *Influence of Moisture Content on Heating/Calorific Values.*

The calorific values for coconut husk, shell and petiole as given in the report are based on *moisture-free materials*. As such, they are higher than the calorific values of air-dried materials which may contain 16 – 20% moisture. It is alright in the case of kerosene and LPG because they are practically moisture-free – for which the calorific values used do not need any correction.

Water adds to the weight of the material without increasing its calorific value and it takes energy to vaporize the water. Water also effects the ignition properties and efficiency of combustion. For example, oven-dry wood (zero MC) may have 15% more heat value than air-dry wood (12-20% MC) and 50% more than green wood (50-100% MC).

The effect of moisture is reflected in the following formulae for net heating value (NHV) of wood (Stephenson, J. Newell (Ed. Chief) 1955. Auxilliary Paper Mill Equipment, Vol. 4, First Edition. In Pulp and Paper Manufacture, McGraw Hill Book Company, Inc., New York p. 489):

$$NHV = HHV\,(1 - MC) - MC \times 1053$$

NHV is the Net Heating Value in BTU/lb.
HHV is the higher Heating Value in BTU/lb, oven-dry basis
MC is the moisture content
(1-MC) – This represents the moisture-free wood or biomass
MC X 1053 – This represents the loss due to heat of evaporation of moisture.

It is therefore, appropriate that the Net Heating value which varies inversely with moisture content, should be used instead of HHV. Thus, equations 1 & 2 will be affected. Overall, the use of Net Heating Value will increase the value of "P". The lower combustion efficiency in the case of husk, shell and petiole as compared to LPG and kerosene has to be accounted for in the equations, which will further increase "P". Such corrections, if accounted for, will alter charts 1, 2, 3, and 4.

Closing Remarks

In closing, we would like to thank NAST, specially Dr. Tito Mijares and the organizers of this scientific seminar, for inviting me and Dr. Pancracio V. Bawagan as discussants to the paper of Dr. Julian Banzon. Dr. Bawagan could not attend today's seminar because of prior appointment and besides we would be presenting the same views. We sincerely hope that the facts we presented here would be viewed as a contribution for the sake of science and never intended to contradict the views of the author, who we respect very much as a person and as a professor.

SOCIAL SCIENCES

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INSTITUTIONS IN THE TRANSFORMATION OF RURAL LIFE

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Introduction

Institutions are essential to socio-economic growth and change although there are prevailing institutions that tend to hinder growth. As Dorner has indicated, institutions which serve to provide the security necessary for supporting the processes of economic growth and development must be consistent among themselves to form an integrated, cohesive system.[1]

Institutions are a function of a nation's culture. For viability and effectiveness, they must conform to the value systems of a particular culture. If they do not conform, as in many imported institutions, they lose their effectiveness after a while and eventually fade away. Effective and viable, they become an integrated part of the building blocks in nation-building.

In agricultural and rural development, institutions serve as the channels for the adoption of innovations and provide means by which they could support rural development and structural transformation in the rural communities. First of all, they provide the mechanisms for the pooling of resources and talents among the small farmers and landless cultivators which otherwise remain fragmented and unutilized. For example, the individual small farmers and new lessees on the emancipated holdings can hardly take advantage of the advances in farm technology developed in regional experiment stations as well as in the International Rice Research Institute (IRRI) nor the necessary technical inputs for the new technology on their farms. By forming farmers' associations or cooperative organizations, these small farmers are enabled to acquire cheaper production inputs and avail themselves of the external economies of large-scale marketing and distributive organizations based in the urban centers.

Secondly, the gains made through improved technology in small agriculture, such as those obtained through the Green Revolution, may be sustained for the benefit of the rural communities. By institutionalizing extension education and administrative approaches, farm productivity can be ensured.

[1]Dorner, Peter. Institutions as aids to development in "The Future of Agriculture: Technology, Policies and Adjustments." Oxford Agricultural Economics Institute, 1974.

Thirdly, institutions are the venues for the training in local leadership and the strengthening of local government. Through farmers' associations and other institutions, potential local leaders are given the means and opportunities for training on the job and the necessary apprenticeship for local entrepreneurship and the exercise of local government functions. These institutions ensure, therefore, the development of local leadership for rural transformation and expand the prospects for the emergence of grassroots democracy.

Concepts of Institution-Building

Powelson's concept[2] of institutions at the micro and macro levels is pertinent to institution-building in the LDC's. Powelson (1974) considers institutions with fundamental bases at the micro and macro levels. At the micro-level institutions as part of a nation's cultural capital are determined or selected in an essentially economic manner, in terms of benefit, cost, supply and demand. According to this theory, institutions are selected by those groups capable of establishing them and for whom the institution's product has a great value than it costs here, both value and cost are subjectively determined.

In a developing country where growth-sensitive groups are achieving power, the new institutions will be those directed toward increasing the natural product. Two types of cost are involved: the sacrifice of the growth-sensitive groups who perceive benefits from the new institutions, and the losses of other groups. The cost of one group will be the value they must sacrifice. Where two institutions of equal effectiveness are substitutable for each other, the one less costly to the power groups will be selected.

From the macro-standpoint, institutions must conform in the long run to national values, or else they will perish. Conformity, however, has both positive and negative effects. Positively, in which values are the foundations of institutions, and the latter cannot survive without value support; negatively, in which values act as constraints, making certain institutional forms too costly.

Owens and Shaw have emphasized the need for building up of essential institutions that will harness the initiative and enthusiasm of the poor segments of the population in a developing country.[3] These institutions they term as problem-solving institutions, their formation and development of which should be certain principles. On the whole, those principles relate to the delineation of functions of the support at the local level, decentralization of functions of national government agencies concerned with rural transformation, the increase in the number of leadership functions at the local level, and the linkages of the rural village within the region and the nation.

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[2]Powelson, John. Institutions for Economic Growth Princeton: Princeton University Press, 1972.

[3]Owens, Edgar and Robert Shaw. Development Reconsidered: Bridging the gap between the government and people. Lexington, Massachussetts: D.C. Health and Co., 1972, pp. 21-30.

Weitz's (1971) concept of institution lies in the importance of public supporting systems, which consists of a network of factors external to the farm as a production unit but so organized as to provide "a system of assistance to the farmer" to increase production and improve his living conditions. Composed of large number of varying elements, the systems covers farm services (supply marketing, credits), public services (education and health), and physical infrastructures (road, irrigation, warehouses and dryers).[4]

However, to assist the small farmers directly and effectively, the public supporting systems are not enough. Weitz has pointed out that in the transition from subsistence to market-oriented production, the farmer in the LDC's lacks capital, knowledge, and initiative towards change, a weakness which prevents him (the small farmer) from taking advantage of the available supporting services. Experience in these countries including the Philippines shows that the small village producer does not always make use of the public supporting system even if it exists. In fact, he may not know how to use the system to his advantage, and the system itself may not be designed to serve the masses of small producers. There is need therefore for "an intermediate organizational structure between the individual farmer and the service system that will enable the small producer to utilize the services available. In Weitz's words: "An organizational structure is required that can operate for the village community, within the village community, and by the efforts of the village community.[5] And the village cooperative provides the answer to this organizational structure.

Emphasis on the historical perspective of community development as a process of growth and change in the rural areas of the LDC's is emphasized by Tavanlar (1977). Citing the programs and activities of the British authorities in Kenya in the early 50's, Tavanlar points out that the lessons in community development during the 50's and 60's in the Philippines should now be applied in developing an integrated program for rural development, one vital aspect of which is institution-building. The experience of this country in land institutional reforms, improvements in public administration and the development of the supporting services in the rural areas should as a matter of policy, be incorporated in new programs and strategies for agricultural and rural development.

Lessons from the Performance of Supporting Systems and Other Institutions in the Last Three Decades

The slow growth of productivity on the farms, the inequitable distribution of income among the people, and the persistent problem of unemployment and underemployment in the rural areas arise from a complex combination of socio-economic factors. Certainly, one factor contributing to the situation is the inade-

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4Weitz, p. 111-112.

5Weitz, *op. cit.*, p. 96.

quacy and underdevelopment of existing support services and other institutions which should give support and assistance to the rural population. Other factors would include the following:

The agricultural research and extension systems which have been organized with a view to providing the extension – educational support to small farmers and farm workers have not succeeded in bringing improved technology and the necessary technical information to all farmers. The common criticisms that the extension service tended to assist large and well-to-do farmers, leaving the small and underprivileged ones to their own devices, still holds to lay. The agricultural research system, on the other hand, as represented in recent years by PCARRD, is just beginning to overcome the many years of lethargy and neglect of essential applied researches on desirable or appropriate technology for crop, livestock and fishery production and has only recently inaugurated programs for the establishment of regional research centers and the proper evaluation and improvement of farming systems by regions.

The supply of technical inputs for production and the marketing and storage of cereals and other commodities are still inefficient and underdeveloped. The necessary development and integration of private marketing and distribution facilities in the different regions has remained unfulfilled. The growth of small supply stores in the barrios as well as the development of supply-distribution of essential farm inputs (seeds, fertilizers, insecticides, etc.) under private enterprise remains inadequate and fragmented to this day. The leadership of NGA in the purchase and distribution of rice and corn has helped stimulate increased cereal production through price support and a price stabilization scheme, but the necessary assistance and stimulus to the establishment of private storage, drying and marketing facilities have not been realized.

The development of agricultural credit for the rural communities is quite remarkable, but not consistent policy has been followed in the assistance to rural banks in their capital build-up and in their efforts towards viability and increasing effectiveness. Starting with 26 banks in the 50's, the rural bank system has grown into more than 800 unit banks in the early 70's. Mainly concentrated in loan assistance for production among small farmers, these rural banks have to be guided in providing credit for small traders and small manufacturing enterprises in the rural communities.

On the institutionalization of land-reform implementation, there is apparently more to criticize in the breach rather than in the performance. The organization of a separate Ministry of Agrarian Reform has apparently resulted in the concentration of reform activities in one single agency, but the coordination of interdependent and mutually-supporting activities for agrarian reforms remains as difficult as ever.

Package Program Under Land Reform

Perhaps the most important development in institution-building in this country is the package program for the land-reform areas. This consists of, besides the transfer of small landholdings to their present occupants or tenants, the provision of cheap and readily available technical inputs, a workable credit system, essential storage and marketing facilities, and organization for the improvement of community living.

The food production program launched by the present administration is designed primarily to achieve self-sufficiency in rice, corn, and other primary crops. However, by the very nature of rice production based on the output of small operating units, the principal beneficiary of the integrated food production program (e.g. Masagana 99) are the small lessees and new owners who are recipients of land reform.

The development of supply institutions, of credit and marketing facilities, and of farmers' organizations (that will spread the benefits of the supporting systems among the rural communities and directly to the farm households) are absolutely necessary to a successful land reform program. This is one way of restating the fundamental truth that an integrated rural development program is essential to the success of agrarian reform. Unless this fundamental truth is recognized and implemented decisively the land reform administration, agrarian reform in this country will be a protracted and fragmented program, and, therefore ineffective as an instrument for overall national development.

Evaluation of Performance: Supporting Systems in Action

A brief evaluation of the performance of the principal supporting systems operating in the rural communities is made with two main objectives, namely: (a) to determine the institutional effectiveness of each supporting system in terms of direct assistance provided to the farmers at the village or local level and the prospects of extending such assistance to more farmers or more barrios that need such assistance; and (b) to point up the policy implication of such performance, or the need for improving or adjusting policies and policy instruments in view of the needs and aspirations of the rural population.

The review of the performance of the supporting systems and their supplementary institutions in the last ten years or so, will find that they have common constraints in terms of organizational, administrative and policy difficulties, which must be overcome if these institutions are to attain greater effectiveness and viability. Some of these common constraints are the following.

a. *Inadequacy of trained manpower to undertake the necessary activities in the different regions.* This is especially true in the case of the Bureau of Agricultural Extension, not to mention the Ministry of Agrarian Reform, the field workers which have to carry a heavy case load, too heavy perhaps to permit close and effective working relationships with the farmers to be assisted. In the case of the PCARRD, the number and quality of scientific manpower needed for the different regional experiment stations to meet total requirements will remain insufficient for sometime to come.

b. *Programming of assistance activities by regions is still in its initial stages.* There are organizational and management problems to be faced if the various supporting systems are to be effective instruments in giving direct assistance to the farmers and rural groups they are designed to serve. There is still need to decentralize the planning and programming of activities of the various public support services and to relate them to the regional development plans and programs of NEDA.

While it is recognized that the NEDA has started to decentralize its planning functions and the different supporting systems have their regional offices, the practice of decentralized planning, particularly for rural development, has to be observed in each region of the archipelago and the implementation of the development plan and program for each region has to be done in concert among the participating support services.

c. *Many of the supporting systems have not developed the capability to harness local leadership or tap leadership potential in the rural communities that will supplement their field force in implementing their support services.* An institutional framework covering the leadership requirements for general and specific tasks in rural development must be devised in order to delineate functions and specify responsibilities at the regional and local levels.

d. *Linkages with related supporting services and with the institutions at the regional and local levels are still weak and uncoordinated.* This is especially true with the land-reform program and with the other public supporting systems. Only the agricultural research system (PCARRD) has exerted considerable effort in establishing regional linkages as well as international linkages. But even with PCARRD, the internal linkages will have to be strengthened with common programs for the training of scientific manpower and the assurance for funding at considerably high levels will have to be defined in policy.

Policy Implications

The development of institutions in a growing economy is not an easy task. It requires resources, time and, more important, administrative or development management skills and innovative, dedicated and competent field personnel.

The policies and measures essential to the achievement of institutional effectiveness and viability range far and wide – from an administrative policy that will ensure decentralization of support services and regional planning to a system of incentives and awards for the private sector and for outstanding performance in the public service. These policies would be concerned also with training (formal and informal) to generate competent and skilled field personnel and development managers. In some cases these will require domestic and foreign fellowships for advanced studies in the sciences and in public administration.

An administrative policy on decentralization of the national public support services and the coordination of symbiotic and related activities is needed at the regional and local levels. This will help remedy present fragmentation and tendencies toward further proliferation of local agencies serving agriculture. It must also be supplemented by the decentralization of planning activities under NEDA and their tie-up with related programming activities of the support services at the local level.

In developing the capability for harnessing local leadership potential, the supporting services need organizational skills and management competence among their top and middle personnel. To be able to establish supplementary institutions to the public support services, there should be an increase in the number of skilled organizers for cooperatives as well as farmers' associations. And for this purpose, a combination of policy measures would be essential joint training programs with institutes or development centers designed or assigned to work in the rural areas, promotional-educational programs on farmers' and consumers' cooperatives, and a system of incentives awards for outstanding field organizers or innovators.

A specified policy covering a system of incentives and awards for outstanding performance would be the motivation and generating force in establishing the linkages with the private sector as well as with institutions or agencies, both public and private, operating at the regional and local levels. Concurrently, a continuous dialogue with the leaders of private business/industry should be undertaken by the public supporting systems. Through this approach they could harness the active support of the local groups or associates for their programs of assistance and of providing guidance in the continuing review and evaluation of their programs and activities for and with the rural people.

Lastly, a development strategy for institution-building, calling for a combination of policies and policy instruments, will ensure a high pay-off in institutional effectiveness and viability as well as the proper timing of implementation. Perhaps the best guide for such a strategy is a concrete knowledge of past performance among the supporting systems and a recognition of the kind and quality of available leadership in these institutions, together with an appreciation of the prevailing socio-political situation in the country.

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Paz Eulalia L. Saplala, Discussant

In stating the functions that institutions serve in agricultural and rural development, Dr. Dalisay underscores what present structures have not been able to do. His paper gives a comprehensive view of institutions in the transformation of rural life and perhaps suggests the answer to this nagging question: Why is the poor farmer still poor?

I am essentially in agreement with points stressed by Dr. Dalisay in his paper and I feel these to be the following: (1) the need for an integrated cohesive system of institutions for the transformation of rural life, (2) the need to augment trained manpower in the field; for emphasis, may I add, the need to train or even re-train extension agents, development managers and the farmers themselves; and (3) in the area of policy making, the need to formulate a development strategy in institution building that is based on a concrete knowledge of past performance of support systems, and of the leadership available in these systems, and an appreciation of the socio-political situation in the Philippines.

Dr. Dalisay's analytical appraisal of the problem of institution building for rural development is both vertical and horizontal. On the vertical aspect, I wish to stress three points. First, there is the need to strengthen policies at the top, but such policies must be informed by what takes place in the system. A communication strategy should work up and down the ladder, with policies moving downward, but also with correct accurate information moving upward to enlighten policy makers.

A second point in the vertical appraisal is the stress laid by Dr. Dalisay on the need to decentralize planning and programming of activities of various support services and to relate them to the regional development plans and programs of NEDA. There is a need to involve people lower in the ladder in organizational and management functions.

A third point in this vertical appraisal is the need to identify the local leaders who can complement and strengthen the field force. The question that arises here is, how does one identify the local leaders or the persons with leadership potential? What role will be assigned, if any, to traditional authority figures if they are not identified as the leaders.

In the horizontal appraisal, Dr. Dalisay examines each aspect of the public support systems, pointing out where the inadequacy or the failure may lie. Undoubtedly, institution building involves a complex interlinking of various elements. The problem then is how can all the variables crucial to institution building be developed simultaneously, for any weakness in one or more parts may render the whole system inoperable. To effect a meaningful transformation of rural life and to strengthen the socio-economic-political-cultural village units, there must be a synchronization of forces.

Perhaps one of the most crucial factors, if not the most crucial factor, in institution building is the human element: The people — such as the farmers, the extension agents, the scientific workers, the policy makers; and their values, attitudes, motivations, knowledge, work ethic, aspiration, and vision of the good life. If institution building is to be integrative and cohesive, as it must be, attention must be paid to the human element, for it is man who puts up the system *for* man and it is man who can make the system work or fail. As Dr. Dalisay points out, it is necessary to educate the farmer so that he will know how to make use of the service systems available to him. Furthermore, it is also necessary to identify the potential leaders on the local level and to train such persons so that they can help in the implementation of programs.

The training and education program for farmers, extension agents and development managers should include not only technical information but also socio-cultural material that will help the trainee understand the national and local value systems and cultural milieu. The socio-cultural training of our field men always lags behind technological and scientific training, and yet is this socio-cultural understanding that is crucial to successful implementation of innovations and new programs. It was gratifying to learn, for example, that in an irrigation project being set up in Sri Lanka, an anthropologist is part of a team composed of an engineer, an agriculturist, an economist, and other technical people.

Dr. Dalisay mentions the need for an awards and incentive program, particularly for outstanding field organizers and innovators. In addition to these external motivations, I believe there should be developed in the people engaged in institution building an inner-directed force, a sense of mission, so to speak. One writer attributes much of the success of the kibbutz in building up rural Israel to the dedication of the men and women assigned to manage the kibbutz. For these young people, work on the kibbutz was an ideological and a moral, not just an economic, commitment.

Our country has been engaged in institution building for rural development for many years now, but as Dr. Dalisay points out, there is an inadequacy in each of the support systems. My question is, who or what group of people will correct this situation. Who will be ultimately responsible for the *reconstruction* of our institutions into an integrated cohesive system? When all these words will have been expressed in this chamber, where will they go and who will next listen and take action.

In a research work my colleagues and I conducted among Central Luzon rice farmers, one farmer sadly but perhaps accurately expressed his status in our society: The small rice farmer is the forgotten man in Philippine economy. Many of the farmers we talked to in the field looked upon their state as that of being in bondage to the soil. Their dream was to obtain freedom for their children, if not for themselves, from captivity to the soil. If the development of rural life through institution building is effective, the farmer and his family should be able to increase his productivity to a substantial degree but at the same time, he and his family should also be active participants in the meaningful transformation of his village into a strong socio-political-cultural unit of the nation. He should find his freedom through the soil and not away from it.

Virginia PB. Samonte, Discussant

The paper of Academician, Dr. Amando M. Dalisay, brings to sharp focus institutions as crucial and vital forms and forces in the transformation of community life in rural Philippines. It has been propounded that institutions serve as channels for the adoption of innovations and provide the means to support development in the countryside. As such, technology generating functions as well as technology extending and diffusing functions have become institutionalized to a large extent by the public sector. In this connection, there has also been an almost contemporaneous emergence of agriculture-based organizations and on a wider scale integrated rural development-based organizations, as witness such organizations on the rural social landscape as supply, credit and marketing cooperatives, irrigators' associations, agrarian reform beneficiaries associations, Samahang Nayon, Seed Growers Association, Philippine Coconut Producers Federation, Swine and Feedgrain Association, Federation of Free Farmers and myriad others. In most instances these organizations serve as the structure for action programs but in some daringly conceived strategies, these organizations serve as the setting for the double purpose of action-cum-research programs.

In relation to the concept of institution building as presented in the paper, conceptual contributions may be derived from Philippine experience as empirically documented in many studies which analyzed the nature, structure, multi-functions and effectiveness of rural based organizations; also touching on the dynamics of perceptions and role performance of the members and leaders, the communication flow and the social and economic forces in which they operate; and even further on to the qualitative aspect of the level of satisfaction of the persons concerned. What may not be very apparent and this needs more empirical investigating is that agricultural technology, many times not singly but packaged and even at times large scale integrated rural development programs which form sets of innovative ideas and practices by themselves, use these organizations that are likewise novel or innovative social structures by themselves, still alien and untried in the life of the farmers. What may further compound the organizational set-up is for instance a building-up situation where an agricultural project is an undertaking of three parent organizations following a system of division of labor in terms of technological and financial requirements, personnel, legitimation, and field support.[1]

Institution building involves in the ultimate analysis the taking on of institutional roles and norms by the individual actors concerned such as farmers or change agents as they interact in the day-to-day transactions of these support organizations. However when these institutional roles only reach farmers who are initially already advantaged by socio-economic access, these support organizations may degenerate into elitist enclaves and fall short of evolving into institutions that can meet the

[1]Cuyno, R., Organizing for change: the Philippine rainfed upland rice project, a temporary cooperative system for developing and diffusing agricultural knowledge, Ph. D. Dissertation, Michigan State University, 1974, pp. 264-265.

problems and needs of the great mass of small farmers. What is proposed in the paper is the need for an intermediate organizational structure between the individual farmer and the service or support organization which should be scaled to the barrio level just as analogously the indigenous sari-sari store is structurally and culturally comfortable to the great mass of small farmers.

As part of institution building particularly for farmers' associations, one study conceptualized their development as consisting firstly of the organizational stage when positions were structured and the roles and functions of these positions were learned and performed by position holders, secondly by the operational stage when the organizations engaged in activities in pursuit of their objectives, and the final stage when the organizations had stabilized and integrated their operations with other organizations. It was reported however that some of these farmers' associations were usually organized by mother agencies and thus they had not yet been completely weaned from their mother agencies either because they did not develop fast enough to fend for themselves or they were not given the proper care and sustenance, thus stunting their development.[2]

The paper gives due emphasis on the evaluation of the performance of support organizations or institutional effectiveness in terms of direct contributions to the farmers and as strategies to meet the needs and aspirations of the rural people. In evaluating these organizations, many problems and constraints particular to specific organizations or common to several organizations have been documented. One cited problem is the need to harness local leaders to supplement the personnel of some organizations in rendering support services. This being the situation, it is important that the actual and influential leaders be identified and not go only by the readily visible or formal leaders. Methodological devices and studies have to be designed and conducted to uncover the actual and influential leaders. Furthermore, the members need equal attention and training in the ways of being active and concerned members for as one study revealed the member-participation could not check the excesses of the officers and employees of a cooperative.[3] Furthermore with regard to the evaluation of these support organizations, while their effectiveness is usually measured against their specific objectives and goals, in a larger sense a societal appraisal should show how these organizations reflect and contribute towards the attainment of the social values of economic security and social well-being considering conditions of low incomes and status loss due to unemployment or disemployment.

Closely related to this is the deplorably significant lesson brought to the fore by Dr. Dalisay that our existing agricultural research and extension support institu-

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[2]Dumagat, F., Some reflections on the factors of effectiveness and viability of rural organizations. *Journal of Agricultural Economics and Development*, Vol. XI, No. 1, January, 1981, pp. 23-45.

[3]Dumagat, F., Studies of member-participation and business operation of three types of cooperative organizations. Terminal Report. Agricultural Credit and Cooperatives Institute, UPLB, College, Laguna, September 1979, p. 41

tions have not succeeded in bringing improved technology to the small and under-privileged farmers to this very day. For certain there are many factors involved here but it seems that farm technology in the form and manner that it is being generated and extended may be now becoming a stratifying criterion among the farmers when before it was mainly land tenure. Consequently, the social gap or distance between the small farmers and the big farmers may be ever "wider-ing."

On the other hand institutions need time to grow and flourish into a viable and regular part of the life in the barrios; they cannot be hurried or rushed on a crash basis nor press released into instant impact. This calls for an historical perspective or a long term view on institutions as underscored in the paper. Fortunately there is now a growing body of literature on support organizations and institutions since the 1950's to the present and concomitantly there is this pressing need to review these studies with the end in view of extracting theoretical or conceptual paradigms as well as deriving pragmatic or action-oriented propositions or principles for better understanding and implementation of development programs. Recently some starting efforts have been made toward this direction on the part of PCARRD in the form of state of the art papers or reviews but a more theoretical and pragmatic synthesis of the literature is needed to capture both the substance and soul of what Dr. Dalisay calls "institutions in the transformation of rural life."

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CONSISTENCY CONDITIONS FOR GROUP DECISIONS

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ABSTRACT

Some group decision rules that do not automatically satisfy Pareto optimality can be modified to do so by representing the alternatives in terms of lexicographically ordered vectors that depend on the feasible set. Certain conditions that have been considered as requirements for consistent group decisions might then be violated however. Less restrictive versions of those "consistency conditions" are proposed.

Introduction

A number of propositions in the literature on social choice -- the Chernoff (1954)-Sen (1977) Property α and Plott's (1973) path independence among them -- have been proposed as desiderata for consistent group decisions. In this paper we propose less restrictive versions of these "consistency conditions" that conform better to the logic of these requirements. We will describe an internally consistent group decision rule which violates the consistency conditions but satisfies the revised versions.

Preliminaries

The feasible alternatives constitute a nonnull set A in the set X of all possible alternatives, and a rule or procedure f is needed to determine a nonnull subset f(A) as the group's decision or choice set. Each person $k = 1, \ldots, n$ in the group is assumed to have a preference system U^k for evaluating alternatives $x, y, \ldots$ in x. From a knowledge of U^k one can infer whether or not xP^ky (k prefers x to y). Putting xR^ky if and only if $\neg yP^kx$, where $\neg$ denotes negation, R^k is k's ordering relation (reflexive, complete and transitive) on X; $R_A{}^k$ is his ordering on A. Writing $\{U^k\} = (U^1, \ldots U^n)$, $f(A)$ is short for $f(A, \{U^k\})$.

We will say that an ordering relation Q on X is nondictatorial if there is no k such that $Q_A = R_A^k$ for all A.

Assumption 1. There is a nondictatorial Q on X that is determined by $\{U^k\}$.

An example is provided by what Sen (1977) calls the "majority closure method," i.e. the transitive closure of the majority decision relation, which would have xQy if and only if there exist $z_1, \ldots, z_m \in X$ such that $x = z_1$, $y = z_m$, and for $i = 1, \ldots, m-1$, z_i gets at least as many votes in the group as z_{i+1} does in a pairwise comparison. The problem however is that this method allows a Pareto inferior alternative to belong to the choice set (Ferejohn and Grether 1977). As usual, x is Pareto inferior (or, simply, inferior) in A if there is a y in A such that $yR^k x$ for all k and $yP^h x$ for some h, in which case y dominates x (or yDx). In order to rule out dominated alternatives in $f(A)$, we can employ a simple device.

Assumption 2. $xP_A y$ if and only if the first nonvanishing component of $r_A(x) - r_A(y)$ is positive, where $r_A(x) = (p_A(x), q(x))$, $p_A(x) = 1$ if x is undominated in A, 0 otherwise; and $q(x) \geq q(y)$ if and only if xQy.

The function q is either real-valued or vector-valued; in the latter case, $q(x) > q(y)$ means that the first nonvanishing component of $q(x) - q(y)$ is positive, i.e. the $q(x)$'s are ordered lexicographically. Putting $xR_A y$ if and only if $\sim yP_A x$.

Assumption 3. $f(A) = \{x \in A \mid \forall y \in A: xR_A y\}$.

Noting that not every x in A can be inferior if A is a closed set, which we assume, the lexicographic ordering of the alternatives by Assumption 2 assures a nonnull $f(A)$ containing no dominated points. In effect the procedure f in Assumption 3 would have two stages f_1 and f_2 whereby f_1 first selects undominated points after which f_2 then picks out the choice in accordance with Q. Specifically, define

$$A_1 = f_1(A) = \{x \in A \mid \forall y \in A: \sim yDx\}$$

$$A_2 = f_2(A_1) = \{x \in A_1 \mid \forall y \in A_1: xQ_A y\}.$$

Then $f(A) = f_2(f_1(A)) = A_2$. Supplementing the majority closure method with the f_1 stage thus eliminates inferior alternatives from its $f(A)$. In the next section we describe a rule satisfying the Assumptions where the ordering by Q is itself lexicographic, but first we note some consequences for later use. (Lemma 1 is obvious; x is Q-greatest in a set B if xQy for all y in B.)

Lemma 1. If $A \subseteq B$, then if x is Q-greatest in B, x is Q-greatest in A.

Lemma 2. If $A \subseteq B$, then $A \cap B_1 \subseteq A_1$.

Since $A \cap B_1 = \{x \in A \cap B \mid \forall y \in B: \sim yDx\}$, and $(x \in A \cap B \,\&\, \forall y \in B: \sim yDx) \rightarrow (x \in A \,\&\, \forall y \in A: \sim yDx)$, if $A \subseteq B$, we get Lemma 2.

Lemma 3. If $x \in A_1 \cap B_2$ and $A_2 \subseteq B_1$, then $x \in A_2$.

Suppose the hypothesis is true, so that $x \in A_1 \cap B_1$ (because $B_2 \subseteq B_1$) and $\forall y \in B_1: xQy$. Since $A_2 \subseteq B_1$, x is Q-greatest in A_2 by Lemma 1. Hence $x \in A_2$ given that $x \in A_1$.

Lemma 4. $f_2(A_2 \cup B_2) \subseteq f_2(A_1 \cup B_1)$.

Assume $x \in f_2(A_2 \cup B_2)$. Then $x \in A_2 \cup B_2$ and $\forall y \in A_2 \cup B_2: xQy$. Since $A_2 \cup B_2 = \{y \in A_1 \mid \forall z \in A_1: yQz\} \cup \{y \in B_1 \mid \forall z \in B_1: yQz\}$, it follows that $x \in A_1 \cup B_1$ and $\forall z \in A_1 \cup B_1: xQz$.

Lemma 5. If $x \in A_1 \cup B_1$ and x is Q-greatest in $A_2 \cup B_2$, then $x \in A_2 \cup B_2$.

If the hypothesis is true, then xQy for all $y \in A_2 \cup B_2 = \{y \in A_1 | \forall z \in A_1 : yQz\} \cup \{y \in B_1 | \forall z \in B_1 : yQz\}$. So if $x \in A_1 \cup B_1$, we have $x \in A_2 \cup B_2$

A Group Decision Rule

Consider a committee whose members evaluate the alternatives in terms of the same set of criteria ranked in the same order of importance or priority. To each x corresponds a vector $u(x) = (u_1(x), u_2(x), \ldots)$ where u_i is a numerical function such that $u_i(x) > u_i(y)$ if x is better than y in terms of the ith criterion. While $u(x)$ is the same for all, different members may have different standards of acceptability with respect to any particular criterion: person k considers x acceptable as regards the ith criterion if and only if $u_i(x) \geqslant u_i^{k*}$. Writing $q_i^k(x) = \min \{u_i(x), u_i^{k*}\}$ and $q^k(x) = (q_1^k(x), q_2^k(x), \ldots)$, we assume that $xP^k y$ means $q^k(x) > q^k(y)$. Person k's ordering is thus determined by $u^{k*} = (u_1^{k*}, u_2^{k*}, \ldots)$, so that different members would have different orderings in general.

To obtain a decision rule under the Assumptions, we need only define $q(x) = (q_1(x), q_2(x), \ldots)$, where $q_i(x) = \min \{u_i(x), u_i^*\}$ and u_i^* is the median u_i^{k*}, assuming an odd number of members. The rationale for defining u_i^* as the median is that by Black's (1948) theorem on single-peaked preferences, it is the only choice for u_i^* that can win by simple majority rule over any other "candidate" for u_i^* (Encarnación 1969). Writing $\{u^{k*}\} = (u^{1*}, \ldots, u^{n*})$ and $u^* = (u_1^*, u_2^*, \ldots)$, $\{u^{k*}\}$ thus determines u^*, giving the ordering relation Q on X *in advance of any feasible set A*. Given A, $\{u^{k*}\}$ also determines $\{R_A^k\}$, which is needed only to eliminate inferior alternatives to get $A_1 = f_1(A)$, and Q_A then automatically yields $f_2(A_1) = f(A)$. Schematically,

$$
\begin{array}{ccccc}
\{u^{k*}\} & \rightarrow & u & & \\
\downarrow & & \downarrow & & \\
\{R^k\} & & Q & & \\
\downarrow & & \downarrow & & \\
\{R_A^k\} & \rightarrow & R_A & \rightarrow & f(A)
\end{array}
$$

where $\{R_A^k\}$ and Q (through Q_A) determine R_A. The $\{U^k\}$ in Section 2 is given by $\{u^{k*}\}$ in the decision rule described, which we will denote by f^*. To be sure, f^* involves special assumptions, but we need only a counter-example to the consistency conditions. We only claim that f^* is internally consistent and not patently unreasonable, which will serve for the purpose.

It might be noted that f^* does not require an ordering relation R on X that suffices to yield R_A given A, contrary to Arrow's collective rationality condition which would have such an R in place of R_A in Assumption 3. Arrow's argument is that such a transitive R would make the group's decision independent of the particular sequence in which the feasible alternatives are presented for choice: "the basic problem is . . . the independence of the final choice from the path to it. Transitivity will insure this independence: from any [feasible set] there will be a chosen alternative" (Arrow 1963, p. 120). But clearly, transitivity on A and not necessarily on X would do for the purpose, as in Assumption 3. Collective rationality, which demands more than is really needed, is an unnecessary requirement.

Related to this point, Arrow's (1963, p. 26) argument for his independence of irrelevant alternatives (IIA) condition is that the group choice in A should be invariant with respect to changes in $\{R^k_{X-A}\}$, where X-A is the set of x's not in A. One could accept this requirement as reasonable, but Arrow's formalization of it makes R_A uniquely determined by $\{R^k_A\}$, which demands more than what was intended because of the Arrow format wherein R is uniquely determined by $\{R^k\}$. We observe that $f^*(A)$ depends only on R^k_A and Q_A and in no way varies with $\{R^k_{X-A}\}$. The f^* rule is thus in conformity with the motivation behind IIA but obviously fails it because $f^*(A)$ depends also on Q_A. In our view IIA, in requiring more than what is called for, is unnecessarily restrictive.

Consistency Conditions

Let g be a group decision rule, reserving the use of f for one that satisfies the Assumptions. Plott (1973) has pointed out that if path independence ("the independence of the final choice from the path to it" in the literal sense) is the objective of transitivity, one may even dispense with the latter if path independence can be had without it. He has proposed a formalization of this property.

Path independence (PI). If $A = B \cup C$, then $g(A) = g(g(B) \cup g(C))$.
Clearly $f(A)$ is path independent in the literal sense since R_A is transitive, yet it can violate PI. Since PI implies Property α, a violation of α will also show failure of PI.

Property α. If $A \subset B$, then $A \cap g(B) \subset g(A)$.
This condition has been considered as a "fundamental consistency requirement of choice" by many writers; see the references cited by Sen (1977, p. 67) and Kelly (1978, p. 26, n.2). But suppose f^* applies and consider Fig. 1 where the value of u_i^{k*} is indicated on the u_i axis by the numeral k. Person 1 has $u_1^{1*} = u_1(z)$, so he prefers z to x to y. Person 2 considers all three alternatives acceptable as regards u_1, and he prefers y to z to x on account of u_2. Person 3, who discriminates among the alternatives in regard to u_3, prefers z to y to x. The group's u^* is such that $q(x) > q(y) > q(z)$ because of u_4. Let $A = \{x, y\}$ and $B = \{x, y, z\}$. Then $f^*(A) = \{x\}$ but $f^*(B) = \{y\}$ because zDx, so that α is violated by $g = f^*$.

The idea behind the PI condition is that the choice in $A = B \cup C$ should come from the choices in B and C and should not depend on how A is disaggregated into

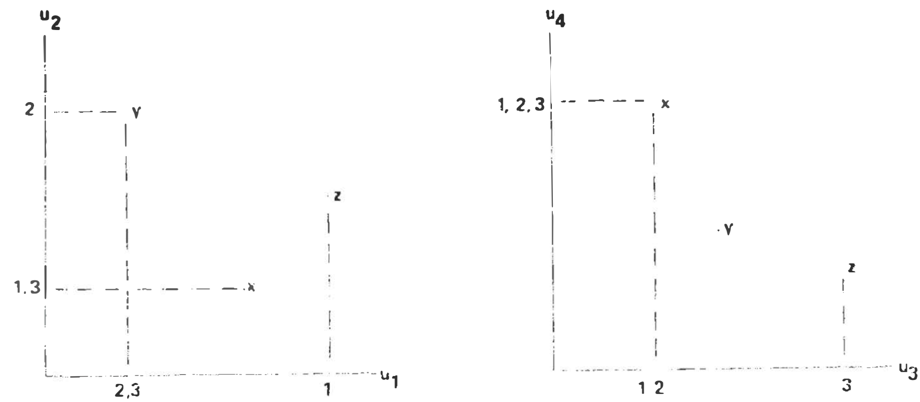

Figure 1

B and C. But this means that if the condition is to be reasonable, the choices in B and C should qualify as possible choices in the larger set A, which requires under the Assumptions that they be undominated in A. A revised version of *PI* follows from the Assumptions.

Theorem PI'. If $A = B \cup C$ & $f(B)) \subset A_1$ & $f(C) \subset A_1$, then $f(A) = f(f(B) \cup f(C))$.

Proof. Suppose the hypothesis is true. First we show that $f(A) \subset f(f(B) \cup f(C))$. Clearly $A_1 \subset B_1 \cup C_1$. Hence if $x \in f(A)$, then $x \in A_1$, x is Q-greatest in A_1 and $x \in B_1 \cup C_1$. Also, $B_2 \cup C_2 \subset A_1$, so that x is Q-greatest in $B_2 \cup C_2$ by Lemma 1. This with $x \in B_1 \cup C_1$ and Lemma 5 gives $x \in B_2 \cup C_2$, and therefore $x \in f(B_2 \cup C_2)$. To show $f(f(B) \cup f(C)) \subset f(A)$, suppose $x \in f(f(B) \cup f(C))$. This means $x \in B_2 \cup C_2$ and x is Q-greatest in $B_2 \cup C_2$. Since $B_2 \cup C_2 \subset A_1$, we have $x \in A_1$ so that $x \in A_2$ if x is Q-greatest in A_1. This is so, by Lemma 1, since $A_1 \subset B_1 \cup C_1$ and x is Q-greatest in $B_1 \cup C_1$, by Lemma 4, from the fact that $x \in B_2 \cup C_2$ and is Q-greatest in $B_2 \cup C_2$

The rationale for α is that an alternative chosen in B, if still available when the feasible set has been reduced to A, should be among those chosen in A because it is "best" in the larger set and should therefore be best also in the smaller one. This would seem reasonable enough, but it implicitly assumes that the choices in A qualify as possible choices in B, which may not be the case. Making this assumption explicit,

Theorem α'. If $A \subset B$ & $f(A) \subset B_1$, then $A \cap f(B) \subset f(A)$

Proof. Let the hypothesis be true. The conclusion is falsified if and only if there is an x such that $x \in A \cap B_2$ & $\sim x \in A_2$. Suppose such an x. Since $A \subset B$, Lemma 2 gives $A \cap B_1 \subset A_1$ so that $x \in A_1 \cap B_2$ since $x \in A \cap B_2$ and $B_1 \cap B_2 = B_2$. But $A_2 \subset B_1$ from the hypothesis, and therefore $x \in A_2$ by Lemma 3, contradicting $\sim x \in A_2$.

Four related conditions may be discussed together. Condition $\beta +$ was introduced by Bordes (1976), β by Sen (1969), ϵ by Blair (as reported by Sen (1977, p. 69)) and δ by Sen (1971). Since $\beta+$ implies β, β implies ϵ, and ϵ implies δ, we need consider only $\beta+$ and δ.

Property $\beta+$. If $A \subset B$ & $A \cap g(B) \neq \phi$, then $g(A) \subset A \cap g(B)$.

Condition δ. If $x \in g(A)$ & $y \in g(A)$ & $A \subset B$, then ($\{x\} \neq g(B)$ & $\{y\} \neq g(B)$)

Suppose x is inferior in B and y is not. Then $\{x\} \neq f^*(B)$ but $\{y\} = f^*(B)$ is possible, showing failure of δ and the other conditions. These conditions put requirements on alternatives chosen in A when the feasible set is enlarged to B. As with *PI* and α, they fail to hold because of the possibility that an alternative chosen in a set may be dominated in a larger set. Restricting this possibility, the revised conditions become theorems as shown in the case of $\beta+$.

Theorem $\beta+'$. If $A \subset B$ & $f(A) \subset B_1$ & $A \cap f(B) \neq \phi$, then $f(A) \subset A \cap f(B)$.

Proof. Suppose there exists $y \in A \cap f(B)$, and suppose $x \in A \subset B$ and $x \in f(A)$. Then x is Q-greatest in A and therefore xQy since $y \in A$, so that $x \in f(B)$ since $y \in f(B)$ and x is undominated in B given the proviso that $f(A) \subset B_1$. Hence $x \in A \cap f(B)$.

Sen's (1971) Condition γ, which is equivalent to the following statement, is quite different from the others as it follows from the Assumptions.

Theorem γ. If $x \in f(A)$ & $x \in f(B)$, then $x \in f(A \cup B)$.

Under the hypothesis, x is in A_1 and in B_1 and Q-greatest in A_1 and in B_1, therefore $x \in A_1 \cup B_1$ and x is Q-greatest in $A_1 \cup B_1$, giving the conclusion. The reason for the difference is the fact that the hypothesis of γ does not allow x to be inferior in any of the sets considered. Plott's (1973) Axiom E, also called the Generalized Condorcet property by Blair *et al.* (1976), is a weaker version of γ and therefore also true.

There are other consistency conditions – Axioms 1 and 2 of Plott (1973) which are variations of the *PI* condition, α – of Sen (1977) and *B3* of Batra and Pattanaik (1972) which are weaker versions of α, and δ^* of Richelson (1978) which is a weaker version of δ – that are failed by f^*, but suitable reformulations are consequences of the Assumptions. In each case, the needed amendment is simply to make the alternatives chosen in smaller sets qualify as possible choices in some appropriate larger set.

Concluding Remarks

Noting that Properties α and $\beta+$ together are equivalent to Arrow's (1959) Definition C4 of a rational choice function, the consistency conditions are completely straightforward requirements on an individual's decision making: they are implied by the existence of a preference ordering (Arrow 1959, Theorem 2). They are however less compelling for group choices because of features in the latter which are absent for an individual, in particular, Pareto properties of alternatives depend on the feasible set. While it is quite correct to say that one can infer an individual's choices over larger sets from his choices over two-element sets, this may not hold for the group, for if the Pareto property of an alternative is considered important, group evaluation of an alternative may vary with the feasible set. Using the f^* rule defined in Section 3 we have shown possible conflicts between Pareto optimality and most of the consistency conditions (the α and β+ classes in contrast to the γ class), accordingly we would propose revised conditions which interestingly enough are consequences of the Assumptions in Section 2. Group decision rules that satisfy the consistency conditions obviously satisfy the proposed revisions, so the latter are less restrictive.

It might be argued that instead of abandoning Property α, which seems generally considered to be fundamental, and replacing it with α' one could equally well retain α and reject f^* as "unreasonable." (Indeed that was the reaction of a reader of an earlier draft of this paper.) But f^* is internally consistent while α is supposed to be a necessary condition for consistency. Given any feasible set A, $f^*(A)$ is derived from a relation which is nondictatorial and transitive on A, hence path independent; moreover, $f^*(A)$ is Pareto optimal and independent of alternatives outside A. Such properties would seem to be both necessary and sufficient for a valid counter-example to α. Also, the only difference between α and α' is that the latter makes explicit what must be implicitly assumed by α if Pareto optimality is necessary, viz. that the choices in the smaller set qualify as possible choices in the larger set. Clearly we have a conflict here between Pareto optimality and α which is resolved by α', and we would conclude that α' is the more reasonable requirement.

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Fr. Bienvenido F. Nebres, S.J., Discussant

I used to be hesitant about discussing applications of mathematical logic to various sciences. The reason is that these applications seem so esoteric. However, in recent years we have seen the languages developed in mathematical logic having more and more importance in various aspects of computer science. It seems to me that present efforts at formalization of aspects of the social sciences can help in computer modeling of social science-type situations.

I would like to thank Dr. Encarnación for a very interesting and well-written paper. My only regret is not having familiarity with the earlier literature on the subject. Thus I cannot properly weigh the arguments in favor of the modification α' of property α. However, I find the presentation clear – in particular, breaking up the steps in the construction of the choice function so as to explicitate the elimination of dominated points first. This then clarifies the introduction of the additional condition

$$f(B) \subset A_1, (f(A) \subset B_1) \text{ in Theorem } PI' \text{ (Theorem } \alpha'\text{)}.$$

What I found more intriguing from a mathematical point of view was the "unreasonable" function f^*. According to Dr. Encarnación, an earlier reader suggested getting rid of functions such as f^*. Mathematical experience, however, shows that such unreasonable functions often hold the key to a deeper understanding of a theory. For example, that most unreasonable function, the Dirac δ - function, arising from physics opened the way to the theory of generalized functions (distributions) and a new era in analysis and partial differential equations. I would just like to indicate one question which f^* brings up:

Person k's ordering is given by $q^k = (q_1^k, q_2^k, q_3^k)$ and on calculation:

$$q^1(z) > q^1(x) > q^1(y)$$

$$q^2(y) > q^2(z) > q^2(x)$$

$$q^3(z) > q^3(y) > q^3(x)$$

A "naive" look at the orderings of choices would indicate that z should be first, y second, x third. That is, the q function should give: $q(z) > q(y) > q(x)$.

As a matter of fact, the q-ordering is the reverse: $q(x) > q(y) > q(z)$. What happens? The definition of q is dependent on the q_i and on the medians u_1^* of u_i^{1*}, u_i^{2*}, u_i^{3*}, the criteria for acceptability. In the case of the choice function f^*, the medians u_1^* dampen the contribution of the q_i's.

Of course, the question raised by this discrepancy between the individual choice functions q^k and the decision rule q for the group is no longer one of consistency, which is the concern of the paper. It is a question of *correctness* of formalization. One of the central questions in theoretical computer programming today is correctness of programs: How do I know that the program I wrote does what I intended it to do? Similarly, in our case, the discrepancy between the q^k and q raises a question of correctness of formalization: Does the construction of the q^k and q do what we meant them to do, i.e., give a mathematical formalization for informal decision processes? More precisely, are there other ways of constructing q^k, q (for example, using a different u_i^* than the median) which avoids seeming violations of intuition such as comes up in the function f^*?

In any case, I would like to thank Dr. Encarnación once more for this paper. I hope it stimulates greater interest in the challenge of developing mathematical formalisms in the social sciences

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FERTILITY AND FAMILY PLANNING BEHAVIOR IN THE BICOL RIVER BASIN

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Introduction

The Bicol region, consisting of six provinces (two of them separate islands) is located at the southern tip of Luzon. In 1975, it had a total population of 3.2 million, or 8 percent of the national population. The region is one of the least developed areas of the country. Moreover, it is one of the regions with the highest fertility, infant mortality and rate of out-migration. In view of these characteristics, serious efforts have been undertaken to accelerate the development of the region.

In order to provide a greater understanding of the long-term impact of development efforts in the area, the first Bicol Multipurpose Survey (BMS) in what is to be a series of surveys at appropriate intervals, was conducted in 1978. One of the key areas of interest for planning in the region is its demographic development. One aspect of this relates to the levels, trends and determinants of fertility and family planning practice. This paper reports on the analysis of fertility and family planning behavior in the Bicol River Basin based on the data obtained from the 1978 BMS.

This paper is organized as follows. Section II describes salient economic-demographic characteristics of the region in the context of national trends. Section III describes the demographic data collected by the 1978 BMS. Section IV presents tabulations of major demographic parameters by selected socio-economic characteristics. Section V presents the analytical framework for examining the determinants of fertility and family planning practice. Section VI presents the regression results. The last section concludes.

Economic-Demographic Characteristics

The Bicol region had a population of 3.2 million in 1975, constituting 8 percent of the national population. The region's land area comprises 7 percent of the national territory. Selected socioeconomic indicators shown in Table 1 suggest that the region is one of the poorest in the country. It ranked second from the bottom of 13 regions in terms of per capita regional output in 1977 and average family income in 1975, and was fourth highest in terms of poverty incidence in 1975. In terms of level of urbanization, it ranked fourth from the bottom in 1975. As a rough indicator of infrastructure development, it had the lowest road density in 1975 among all regions.

The depressed socioeconomic conditions in the region are related to its demographic performance. See Table 2. The total fertility rate estimated at around 1975 was the highest in all regions, while the percent decline in total fertility rate from around 1960 to 1975 was the lowest. Mortality rates as measured by the infant mortality rate and the life expectancy at birth are still high relative to the advanced regions of Central Luzon and Southern Tagalog, although not as high as in the Mindanao regions. The depressed conditions in the region is related to large-scale out-migration. Bicol, together with the Ilocos and Visayan regions have been consistent net-out migration regions.

Demographic Data in the 1978 Bicol Multipurpose Survey (BMS)

The Bicol Multipurpose Survey was designed, among others, to provide information necessary for the systematic assessment of the impact of development efforts in the region under the Bicol River Basin Development Program (BRBDP) of the government. Among the areas of concern addressed by the survey are agricultural production and productivity; levels and distribution of income: time allocation and employment: fertility, mortality, and family planning use; health and nutritional status; contribution of women: and the perceived and objective quality of life. This section describes the demographic data contained in the 1978 BMS.

Fertility. Two types of fertility data can be derived from the survey, namely: the number of children ever born and the number of children born during the last five years, 1973-1977. We describe below the procedures in which these data were obtained by the 1978 BMS and indicate potential threats to their reliability.

Reasonably accurate data on total number of children ever born can usually be obtained from a carefully collected pregnancy histories of ever-married women. The procedure involves intensively questioning each ever-married woman in the household regarding all her pregnancies that terminated either into a live birth or a non-live birth and in the case of the first category, whether the child is still alive or not. Specific information on each of these types of pregnancies are then obtained, e.g., age and sex of child and whether still living in the household or not. For those children who have died, additional information on age at death is obtained. Where pregnancy intervals are long, e.g., more than three years, respondents are encouraged to recall possible omissions.

A less intensive approach to collecting children ever born data would be to simply ask the respondent to list down all children born alive and still surviving, all children born alive but are now dead, and all children born alive but are now living elsewhere. This approach attempts to improve upon the single

Table 1. Selected Socioeconomic Indicators by Region.

Region	*Population (sq. km.)*[a] *(millions)*	*Land Area (sq. km.)*[a] *(000)*	*Per Capita Output, 1977 (₱000)*[b]	*Average Family Income 1975*[a] *(₱)*	*Poverty Incidence, 1975*[c] *(Percent)*	*Percent Urban, 1975*[c]	*Road Density (km./sq. km. of alienable land) 1975*[b]
Philippines	42.1	300.0	1,733	5,840	45.3	33.4	0.68
Luzon							
Bicol	3.2	17.6	906	4,280	55.5	18.4	0.34
Ilocos	3.3	21.6	1,068	5,575	38.5	21.1	1.12
Cagayan Valley	1.9	36.4	1.072	5,102	45.6	13.0	0.49
Central Luzon	4.2	18.2	1,379	5,773	28.9	33.9	0.67
Southern Tagalog	5.2	46.9	1.694	7,775	45.9	31.8	0.58
Metro Manila	5.0	0.6	4.474	10,469	30.9	100.0	4.41
Visayas							
Western Visayas	4.1	20.2	1,933	5,484	48.0	26.7	0.44
Central Visayas	3.4	15.0	1,405	5,172	59.9	28.9	0.91
Eastern Visayas	2.6	21.4	935	4,834	56.0	18.7	0.49
Mindanao							
Western Mindanao	2.0	18.7	1,014	5,662	45.9	14.9	0.40
Northern Mindanao	2.3	28.3	1.275	3,803	72.8	23.2	0.92
Southern Mindanao	2.7	31.7	1,769	6,307	41.5	26.7	n.a.
Central Mindanao	2.1	23.3	905	5,025	31.7	15.5	n.a.

SOURCES: [a]NEDA, *1981 Philippine Statistical Yearbook*, Manila, 1981.
[b]NEDA, *Five-Year Philippine Development Plan, 1978-1982*. Manila 1977.
[c]World Bank (1980).
[d]Pernia and Paderanga (1981, Table 4).

Table 2. Selected Demographic Indicators by Region

Region	*TFR 1973-77*[a]	*Percent Change in TFR*[a] *1958-62 to 1973-77*	*IMR (q_0) 1970*[b]	*Life Expectancy 1970*[b]	*Net Migration Rates 1960-70*[c] *(Per 1,000 Population)*	*1970-75*[d]
Philippines	5.20	–19.5	93.1	59.3	–	–
Luzon						
Bicol	6.03	–13.1	99.1	55.7	–34	–10
Ilocos	4.90	–23.0	87.9	57.6	–60	–13
Cagayan Valley	5.41	–23.8	103.2	53.0	+16	–2
Central Luzon	4.47	–30.2	82.7	60.2	–20	+6
Southern Tagalog	4.79	–24.9	75.2**	59.5**	+120	+4
Metro Manila	3.11	–38.6	–	–	–193***	+15
Visayas						
Western Visayas	5.04	–20.2	99.1	57.4	–64	–4
Central Visayas	4.70	–21.8	85.6	59.1	–97	–11
Eastern Visayas	5.81	–15.4	97.5	53.0	–84	–2
Mindanao						
Western Mindanao	4.99	–35.8*	131.9*	47.6*	+32*	–11
Northern Mindanao	5.76	–21.7*	135.1*	50.0*	+58*	+16
Southern Mindanao	5.44	–26.0*	111.6*	49.8*	+109	+10
Central Mindanao	5.22		–	–	–	–9

SOURCES: [a]de Guzman (1977) for 1958-1972 figures based on 1968 and 1973 NDS; de Guzman (unpublished) for 1973-77 based on 1978 RPFS.
TFR stands for total fertility rate.
[b]Flieger, W., *et al.* (1981). Estimates are for both sexes. Infant mortality rates (IMR) are measured in terms of probability of dying from birth to age one.
[c]Flieger, W., *et al.* (1976)
[d]NCSO (1981).

*Old regional classification.
**Includes Metro Manila.
***City of Manila only

question approach on total number of children ever born used by censuses in the past. Nonetheless, without the intensive probing required in obtaining a complete pregnancy history, chances are high in the latter approach for respondents, especially older women, to omit or fail to recall children born alive but who have either died early in infancy or who have since left home. As a consequence, the children ever born data for older women may tend to be understated.

The 1978 BMS did neither of the above approaches for obtaining children ever born data, that is, in the 1978 BMS, no direct questions on children ever born were asked. Instead, the respondent, who was the spouse of the household head, was asked to list all household members including own children, alive or dead. The own children data was then expected to provide the children ever born information. The potential problem with this indirect approach to gathering children ever born data is that the chances are high that older women will fail to include a child as a member of the household if, either the child has died some years back, or the child has already left the household. For younger women, the problem may not be as serious since these women would usually have a smaller number of children, and these children would still be young and mostly likely to be still living in the household with their mothers. Whether in fact children ever born data obtained by the 1978 BMS through the household listing mechanism will be underestimated for older women, of course, remain to be seen. Rough checks for possible underreporting will be made below.

Another feature of the children ever born data in the 1978 BMS is the fact that children reported in the household roster refer only to own children of the household head's spouse or the woman respondent herself if she is the household head. The children of *other* ever-married women in the household were not coded in relation to their own mothers, hence the number of children ever born of these other women in the household cannot be obtained. The data on children therefore refer only to children of ever-married women who are either the spouses of household heads or are household heads themselves, and not to *all* ever-married women in the household. This limits the comparability of the 1978 BMS data with data from other surveys that do obtain data on children of all ever-married women in the household. Nonetheless, this omission is probably not crucially important in terms of the main purpose of the BMS which is to analyze the determinants of demographic behavior rather than to estimate regional fertility levels as such.

The second type of fertility data referred to earlier is the number of children born during the past five years, 1973-1977. This information was obtained by the use of a restricted pregnancy history in which respondents were asked for each year from 1973 to 1977 whether they were pregnant, and if so, how the pregnancy terminated.* Note that the questions were phrased in terms of "Were you preg-

*Additional questions on pre-natal, delivery and child care were also asked.

nant last year?", "How many times were you pregnant during the preceding four years, in 1976?, 1975?, 1974?, 1973?". A follow-up question on pregnancy termination (i.e., live birth, still birth, or miscarriage) was then asked of each pregnancy. Can women in general accurately recall pregnancies *as pregnancies*, or can they recall pregnancies better if these were related to specific live births during the past five years? Secondly, even if they can recall all pregnancies, would they voluntarily report all such pregnancies?

If indeed women can better recall pregnancies that terminated as live births than just any pregnancy, then the number of reported pregnancies during the past five years will tend to be understated in this survey. Furthermore, even if they can recall all pregnancies, it is possible that they may not report those pregnacies that terminated as still births or miscarriages for the simple reason that they may not want to talk about such experiences, especially if they were emotionally traumatic ones, to interviewers who are strangers to them. Again this will tend to underestimate pregnancies and may affect any contemplated analysis of pre-natal care. This problem of pregnancy recall and reporting, however, may not affect the data on live births since the pregnancies that would tend to be recalled and reported will be precisely those that terminated as live births.

There is a potentially serious source of error with respect to live births, however. This error is related to the time reference in which pregnancies (and live births) are to be reported.* Pregnancies (live births) may be reported as occurring within the period 1973-1977 when in fact they occurred outside this reference period, if so, the total number of births will be overestimated for the period. On the other hand, pregnancies (live births) actually occurring during the reference period may be mistakenly thought of by respondents as occurring outside the reference period; as a consequence, the number of live births for the period would be understated. The latter type of error has been found by demographers to be more likely in cases where the reference period is 12 months. We do not have information on what direction the error in the aggregate will take if the overall reference period is five years.

Furthermore, demographers assume that in the case of the 12 months reference period, the reporting error does not vary with age of woman. This appears to be a reasonable assumption since the reference period is short enough so that neither younger nor older women would have great difficulty in determing whether a recent birth occurred within the reference period. Whether this assumption can reasonably apply to multiple reference periods encompassing five years remains to be seen. Younger women who are in the early or middle stages of building their families will tend to have most of their pregnancies (births) during the recent past. Hence, these women will have a harder time figuring out whether a pregnancy (birth) occurred in any specific year within the five-year period. It is possible that

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**Errors due to misplacement of births occurring in each year are even more likely and, therefore, we consider only the lesser problem of event misplacement for the five year period.

they would either bunch up their pregnancies during the five-year period or that some pregnancies may be pushed farther back in time beyond the reference period. On the other hand, older women who either have completed their fertility or were in the final stages of completing their family size in the past five years will tend to have fewer pregnancies to remember than the former group of younger women. They will, therefore, tend to have less errors in reporting pregnancies (births) as occurring within the reference period. Thus, it is possible that errors arising from the failure of women to correctly report pregnancies (live births) as occurring within the reference period under consideration could very well vary significantly by age of woman and by stage in the reproductive life cycle. In the next section, we shall examine whether these potential errors are reflected in the 1978 BMS data.

Mortality. Direct mortality information was obtained by the 1978 BMS. This information refers to deaths to any member of the family during the past 12 months. Likewise, mortality information can be obtained indirectly from the household roster of children who have died among children ever born.

Data on the proportion of children surviving out of children ever born by age of ever-married women have been used by demographers to estimate Brass-type infant and childhood mortality rates. However, in the 1978 BMS data, only children ever born and children surviving of women who are either the spouse of the household head or the household head herself can be extracted from the roster. The children of other ever-married women cannot be so determined as described earlier. Hence, estimates of Brass-type infant and childhood mortality rates from the 1978 BMS may not correctly measure mortality conditions in the region unless the children ever born and children surviving of women whose data are available from the survey are more or less the same as those women whose data are not available.

On the other hand, the direct mortality information available may not be adequate in providing reliable mortality measures, especially for adult mortality. One major reason is that the base population is relatively small (i.e., 1,903 households multiplied by approximately 6 members per househod yields only a population of 11,418, which is too small for reliable estimation of age-specific death rates). Furthermore, direct mortality information can be seriously underestimated even in well designed surveys for the simple reason that respondents may not want to talk about deaths in the family, especially to interviewers whom they hardly know, and hence are unlikely to report such deaths. (See Madigan, *et al.*, 1976).

While the estimation of mortality parameters as such is beyond the scope of this report, we are interested in some measure of child mortality as a potential determinant of fertility. The data on the number of children surviving out of children ever born should be adequate for our present purposes.

Migration. Data on in-migration were obtained from questions on how long the family has lived in the barangay, and if less than five years, where the head of the household previously resided. Data on out-migration, perhaps the more interesting information from Bicol's standpoint, can be inferred from the question on whether a member of the respondent's immediate family (spouse or children) lived in the house during the past six months preceding the interview. However, for family members who were absent during the past six months, as additional data on current residence and reason for their absence were obtained. In addition, the residence question was restricted to family members only. More seriously, the out-migration of entire households would obviously not be captured by this single survey. Comparison of households in the 1978 BMS with the results of the 1983 BMS currently being fielded should offer interesting data on population mobility. Like mortality, migration analysis is beyond the scope of this paper.

Family Planning. Information on family planning behavior include knowledge of family planning methods and source of this knowledge, ever use and current use of specific methods, and knowledge of family planning clinics, their distance and cost of travel. In addition, respondents were queried on whether or not they have ever been visited by family planning or government personnel who discussed family planning with them, and whether or not they themselves have ever visited a family planning clinic.

Other Fertility Related Information. The 1978 BMS obtained information on whether or not respondents wanted additional children as well as of their desired number of children if they were to start all over again. The second question asks women to respond on the basis of a hypothetical situation. The high correlation between actual and desired family size which is observed both in the Philippines and elsewhere may mean that women do act upon their fertility desires, and that those who desire large families tend to produce them. If this is true, then desired family size would be a sensitive indicator of demand for contraception, all things being equal. However, the validity of such an interpretation may be questioned on the grounds that it is too difficult for a respondent to isolate herself from actual family circumstances. As a consequence, the respondent may report a large desired family size to rationalize the number of children already born but not planned. (Herrin and Pullum, 1981).

The data on currently married women by family size who state they want no more children may be more informative as an indicator of family size preferences at least given present circumstances because it is not affected by rationalization and it requires less abstraction.

Data on marriage patterns are revealed by information on age at marriage of ever-married women, as well as by information on the marital status of women 15 years and over.

The growing interest in the effects of intermediate variables on fertility has led to a number of studies which examined the effect of breastfeeding on the length of birth intervals, and hence on over-all fertility. In the 1978 BMS, however, breastfeeding information was not obtained in relation to pregnancy or birth intervals. Rather, the breastfeeding information was asked only of living children born during the past two years. The emphasis, it appears, was more on breastfeeding's link with the nutritional status of the living child, rather than on its potential effect on birth intervals.

The amount of demographic information that were collected by or can be extracted from the survey, with its various limitations, defines the type and depth of analysis that can be made. Needless to emphasize at this point that, given the need to obtain as comprehensive a set of information as possible on many other, and perhaps even more important concerns of the BMS, and given cost and time constraints, the demographic data that could feasibly be collected from this survey could not have the same range and detail as those usually obtained from surveys designed solely to measure fertility and family planning use. Nevertheless, as the last section of this report will suggest, with the benefit of hindsight and accumulated demographic survey experience, that modifications both in analytical objectives and in data collection procedures could significantly improve the cost-effectiveness of the BMS demographic survey module.

Fertility and Family Planning: An Overview and Assessment

Children Ever Born and Children Surviving. Table 4 presents the data on children ever born and proportion of children surviving of children ever born. The data are classified by age of woman, by selected areal characteristics and by the characteristics of the woman and her household, i.e., her educational attainment, work status and type of housing construction. The latter characteristic proxy for the income variable.*

Before presenting the results, we first examine the children ever born data for potential underreporting. A rough check can be made by looking at the data on the proportion of children surviving out of children ever born. If these proportions are too high relative to what might be expected on the basis of independent Philippine studies, then the children ever born data from this Bicol survey could very well be understated, reflecting the tendency for women to underreport children who have died long ago or have since left home in the listing of household members.

Data on children ever born and proportion surviving for Bicol, Misamis Oriental and for the country as a whole are shown in Table 3. Note the definition of ever-married women are not strictly comparable.

First, as one may readily observe, the proportions surviving of children among rural Bicol women compared to rural Misamis Oriental women tend to be higher in all ages except the first two youngest ages. In 1970, the average mortality conditions in Misamis Oriental and the Bicol region are not very different, with life expectancy at birth being 56 years in Bicol and 55 years in Misamis Oriental, and the probability of dying before age 1 being 0.10309 and 0.09906, respectively. (Flieger, *et al.,* 1981). One would therefore expect the differentials in proportion

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*Estimates of household income, the subject of a separate study on the BMS data, could not as yet be incorporated in the present analysis.

Table 3. Mean Number of Children Ever Born of Ever-Married Women and Proportion Surviving of Children Ever Born: Bicol, Rural Misamis Oriental and Philippines.

	Mean Number of Children Ever Born of Ever-Married Women							
	Total	*15-19*	*20-24*	*25-29*	*30-34*	*35-39*	*40-44*	*45-49*
Bicol (1978)[a]	5 60	(1.00)[d]	2.01	3.33	4.79	6.34	7.66	8.11
Rural Bicol (1978)[a]	5.66	(1.11)[d]	2.03	3.33	4.81	6.42	8.07	8 58
Rural Mis. Or. (1972)[b]	–	0.76	2.18	3.89	5.33	7.03	7.43	8.17
Philippines (1978)[c]	4.58	0.85	1.89	2.96	4.27	5.66	6.74	7.00
	Proportion Surviving of Children Ever Born							
Bicol (1978)[a]	.89	(.91)[d]	.90	.91	.91	.89	.88	.88
Rural Bicol (1978)[a]	.89	(.90)[d]	.91	.92	.91	.88	.87	.82
Rural Mis. Or. (1972)[b]	–	.99	.93	.91	.90	.87	.84	82
Philippines (1978)[c]	.90	.93	.93	92	.92	.90	.88	.87

[a]Based on the 1978 BMS. Refers only to ever-married women who are spouses of household heads or are household head themselves.

[b]Based on survey in rural Misamis Oriental in 1972. Refers to all ever-married women in the households who gave self-reports (excludes proxy-reported women). See Madigan, *et al.* (1974).

[c]Based on the 1978 Republic of the Philippines Fertility Survey (RPFS). Refers to all ever-married women in the households, presumably all were self-reports.

[d]Less than 20 cases.

Table 4. Mean Number of Children Ever Born (CEB), and Proportion Surviving of Children Ever Born (PS), by Age of Women, by Province, and by Location, and Selected Characteristics of the Woman, Bicol River Basin, 1978.

Age of Woman	All Women		Province: Camarines Sur		Province: Albay/Sorsogon		Location: Rural		Location: Urban/Poblacion	
	CEB	*PS*	*CEB*	*PS*	*CEB*	*PS*	*CEB*	*PS*	*CEB*	*PS*
15-19	(1.00)[a]	(0.90)[a]	(1.20)[a]	(0.83)[a]	(0.83)[a]	(1.00)[a]	(1.11)[a]	(0.90)[a]	(0.50)[a]	(1.00)
20-24	2.01	0.90	2.03	0.89	1.98	0.91	2.03	0.91	1.91	0.88
25-29	3.33	0.91	3.37	0.90	3.27	0.92	3.33	0.92	3.33	0.87
30-34	4.79	0.91	4.49	0.90	4.64	0.92	4.81	0.91	4.74	0.91
35-39	6.34	0.89	6.49	0.90	6.12	0.89	6.12	0.88	6.17	0.91
40-44	7.66	0.88	7.56	0.87	7.80	0.89	8.07	0.87	6.72	0.88
45-49	8.11	0.83	8.10	0.96	8.12	0.91	8.58	0.86	7.21	0.90
Total (u)[b]	5.60	0.89	5.65	0.90	5.54	0.90	5.66	0.89	5.48	0.90
Total (s)[c]	5.60		5.56		5.55		5.78		5.23	
n	1,257		759		498		893		964	

[a]Less than 20 cases.
[b]Unstandardized.
[c]Age-standardized against all women age distribution.

Table 4 (cont.)

Age of Woman	*Education*[a]				*Work Status*[b]				*Housing Index*[c]			
	0-7 Years		*8 + Years*		*Working*		*Not Working*		*Light*		*Medium/Heavy*	
	CEB	*PS*	*CEB*	*PS*	*CEB*	*PS*	*CEB*	*PS*	*CEB*	*PS*	*CEB*	*PS*
15-19	(100)[a]	(0.89)[a]	(1.00)[a]	(1.00)[a]	(0.67)[a]	(1.00)[a]	(1.12)[a]	(0.89)[a]	(0.87)[a]	(1.00)[a]	(1.33)[a]	(0.75)
20-24	2.06	0.89	1.85	0.94	1.83	0.91	2.13	0.90	2.03	0.90	(1.89)[a]	(0.91)[a]
25-29	3.50	0.90	2.95	0.92	3.33	0.90	3.33	0.92	3.44	0.90	3.09	0.92
30-34	5.06	0.90	3.98	0.94	4.83	0.92	4.73	0.90	5.03	0.90	4.42	0.92
35-39	6.68	0.89	5.04	0.90	6.34	0.89	6.35	0.90	6.72	0.87	5.89	0.93
40-44	8.27	0.87	5.72	0.89	7.59	0.88	7.79	0.86	8.27	0.85	6.78	0.92
45-49	8.52	0.86	6.58	0.95	7.94	0.87	8.48	0.90	8.27	0.85	7.92	0.90
Total (u)[b]	5.99	0.88	4.41	0.92	5.79	0.89	5.33	0.89	5.59	0.87	5.60	0.92
Total (s)[c]	5.93		4.52		5.55		5.69		5.88		5.21	
n	952		305		753		504		767		486	

[a]Less than 20 cases.
[b]Unstandardized.
[a]Age-standardized against all ever-married women age distribution

surviving of children ever born especially of older women to be much closer. Thus, it would appear that the children ever born data for rural Bicol might be understated most particularly for older women.

Secondly, the proportion surviving of children ever born among all Bicol women age 45-49 years tends to be higher than that of the national sample. Since mortality rates in Bicol are expected to be higher than the national average over the past decade, one in fact should expect the reverse to be the case. Moreover, the proportions surviving for Bicol women age 35 years and over should likewise be expected to be somewhat lower than the national average. Thus, there are indications that the number of children ever born derived from the household listing of family members are underreported especially for older women. However, the level of underreporting do not appear to be large enough to affect our conclusions regarding the overall levels and patterns of children ever born by age of woman. This may not be true, however, if we wish to compare sub-group differentials of children ever born by age of woman. As Table 4 shows, the pattern of proportions surviving of children ever born by age of woman tends to be erratic in several specific sub-groups of women. This is probably due to the small sample sizes within sub-groups. In spite of this problem, it is still instructive to examine sub-group differentials aggregated for all ages of women since errors will be minimized in the averaging process. As a consequence, the differentials between sub-groups might still be preserved.

Data shown in Table 4 reveal higher mean number of children ever born of women (standardized for age distribution of all women) in Camarines Sur than in Albay/Sorsogon (5.6 vs. 5.5); in rural than in urban or municipal poblacion (5.8 vs. 5.2 and 5.3, respectively); with 7 or less years of education than with 8 years or more (6.0 vs. 4.6); who are non-working than working (5.7 vs. 5.5); and in lower than in higher economic status as proxied by the type of housing construction (5.9 vs. 5.3). These differentials are in the direction expected and is broadly consistent with the Bicol data from the 1979 and 1980 Area Fertility Surveys shown in Table 5 and with the national data shown in Table 6.*

Fertility During the Period 1973-1977. The mean number of live births by age of woman during the period 1978-1977 obtained from the abridged pregnancy history information are shown as Estimate A in Table 7. The sample of women include only those who were married continuously during the interval, i.e., currently married women, married in 1972 or before. The data are shown with comparable data for the Philippines as obtained by the 1978 RPFS. It may be readily observed that for Bicol the mean live births to younger women, i.e., 20-24 and 25-29 years, appear too low compared with what might be expected on the basis of the age pattern of recent fertility shown by the Philippine data. Did younger Bicol women actually have lower fertility during the 1973-77 period than the

*The sample sizes of the Area Fertility Surveys were approximately 4,000 households for each survey round.

Table 5. Mean Number of Children Ever Born of All Ever-Married Women Age 15-54, Area Fertility Surveys of 1979 and 1980, Bicol Region.

Age of Woman	*1979*	*1980*	*Residence*	*1979*	*1980*
15-19	0.83	1.39	Rural	5.27	5.26
20-24	1.90	2.00	Semi-urban	4.85	4.98
25-29	3.32	3.34	Urban	4.58	4.71
30-34	4.70	4.63			
35-39	6.24	6.01	*Education*	*1979*	*1980*
40-44	6.91	7.59	No Schooling	6.96	5.97
45-49	8.11	7.18	Elementary	5.55	5.61
50-54	8.04	7.51	High School or Vocational	3.95	4.19
			College +	3.71	3.58
All Women	5.19	5.20	*Socioeconomic Status*	*1979*	*1980*
			Low	5.29	5.31
			Middle	4.58	4.70
			High	4.69	4.79

SOURCE: Concepcion, M.B. and J. Cabigon (1982), pp. 87-88.

Table 6. Mean Number of Children Ever Born of All Ever-Married Women Age 15-49; 1978 Republic of the Philippines Fertility Survey.

Age of Woman		*Region of Residence*	
15-19	0.85	Metro Manila	3.58
20-24	1.89	Luzon	4.79
25-29	2.96	Visayas	4.71
30-34	4.27	Mindanao	4.61
35-39	5.66		
40-44	6.74	*Type of Residence*	
45-49	7.00		
All Women	4.58	Urban	5.15
		Rural	6.04
Level of Education		*Husband's Occupation*	
No schooling	5.81	Professional	3.65
Primary	5.71	Clerical	3.39
Intermediate	4.62	Sales	4.13
High School	3.83	Self-empl. Agri.	5.09
Some College	2.76	Non self-empl. Agri.	4.97
College w/ degree	3.10	Unskilled	4.61

Source: 1978 RPFS

Table 7. Mean Number of Live Births During 1973-1977 to Women Continuously Married During This Interval: Bicol and the Philippines.

Age Five Years Ago	*Current Age*	*Births in the Past Five Years, 1973-1977*		
		Bicol		*Philippines*[c]
		A[a]	*B*[b]	
10-14	15-19			(1.51)[d]
15-19	20-24	1.72	2.19	2.17
20-24	25 29	1.77	2.11	1.83
25-29	30-34	1.47	1.82	1.44
30-34	35-39	1.28	1.58	1.18
35-39	40-44	0.98	1.16	0.75
40-44	45-49	0.48	0.47	0.28
All Women		1.19	1.43	1.20
n		1,042	1,042	7,239

[a]From the 1978 BMS based on data from the abridged pregnancy history.

[b]From the 1978 BMS based on data on children born during 1973-1977 period as recorded in the household list.

[c]NCSO, *et al.* (1979; Table 5.10) from the 1978 RPFS.

[d]Less than 20 cases.

national average, or do the data indicate underreporting by younger women in Bicol? The second possibility appear more plausible when we consider the data in Table 8. This table presents estimates of age-specific fertility rates for all women in Bicol and the Philippines obtained from the 1979 Area Fertility Survey (AFS) and the 1978 RPFS, respectively. The rates are average rates centered in 1975. The AFS rates are averages for 1974, 1975 and 1976 rates, while the RPFS rates are averages for single years from 1973 through 1977. Consider first the age-specific fertility rates for all women. As might be expected, the fertility rates for Bicol would tend to be higher than the national average. The age-pattern of Bicol rates are consistent with the national pattern. Unfortunately, we can not estimate age-specific fertility rates for all women in Bicol from the 1978 BMS for comparison. This is because the abridged pregnancy history information was obtained only for the respondent (i.e., spouse of household head or female household head).

Next consider the age-specific marital fertility rates for Bicol as estimated from the abridged pregnancy history information, Estimate A, and for the Philippines, which represents the average rates of single year rates for the 1973-77 period. We should expect that the Bicol rates should conform to the age-pattern of marital

Table 9. Percentage Distribution of Women Who Reported Having Heard of Specific Methods of Contraception and Who Reported Ever Use: Philippines and Bicol, 1978.

	Percent Who Had Ever Heard			Percent Ever Used	
	Philippines[a]	*B*	*Bicol*[b]	*Philippines*[a]	*Bicol*[b]
Modern Program Methods					
Pill	90.2	77.7	57.4	24.7	19.9
	86.4	57.9	39.6	7.0	4.4
Female sterilization	74.7	25.4	11.9	4.5	1.5
Male sterilization	69.6	13.2	7.2	0.6	0.2
Other	39.9	8. 7		2.9	
Other Program Methods					
Rhythm	65.9	32.6	36.1	23.1	19.5
Condom	87.6	63.3	44.8	20.1	11.5
Non-Program Methods					
Abstinence	36.3	2.7	9.1	10.2	7.4
Withdrawal	65.3	19.5	10.7	31.0	6.4
Douche	21.2	1.0		2.2	
Other	4.0		5.6	1.0	1.6

[a]Based on the 1978 RPFS; women are ever-married women age 15-45 years. NCSO, *et al.* (1979, p. 125). Column A refers to percentage of women who reported ever heard only after probing, while Column B refers to percentage of women who mentioned the method spontaneously.

[b]Based on the 1978 BMS; women are currently married women age 15-45 years. The number of ever-married and currently married in the BMS sample are 1,257 and 1,229, respectively. The percentage refers to women who mentioned specific methods spontaneously except for rhythm, abstinence and withdrawal where respondents were specifically asked regarding their awareness of such methods.

dren born during the period 1973-1977 as reported in the household list. We therefore obtained these data and compared them with data from the abridged pregnancy history. These data are shown as Estimated B in Tables 7 and 8. Note that the estimated births during the period based on data from the household list are higher than those obtained from the abridged pregnancy history. Likewise, for age-specific marital fertility rates, Estimate B is higher than Estimate A. It would thus appear that data from the abridged pregnancy history are unreliable both in terms of the age pattern and the level of fertility during 1973-1977. The data from the household list would, therefore, be more indicative of the true levels of recent fertility although the levels for the young age group 20-24 and 25-29 in Table 7 still appear too from what might be expected on the basis of the Philippine age pattern.

Awareness of Family Planning Methods and Source of Information. Table 9 presents the percentage distribution of women who reported having heard of specific methods of contraception and who reported ever use. The data from the 1978 BMS are compared with data for the Philippines derived from the 1978 RPFS. For the Philippines, two sets of percentages for ever heard are distinguished: column A percentages refer to women reporting ever heard of specific methods only after probing, while column B percentages refer to women spontaneously reporting awareness of specific methods. The percentages for Bicol, on the other hand, refer only to spontaneous reports of specific methods except for rhythm, abstinence and withdrawal. For these three methods, interviewers were specifically instructed to probe respondents for possible awareness. The more useful information would have been the reports of ever heard *after* probing for each method, since this insures comparability of responses among women. Nonetheless the data in Table 9 indicate that the level of awareness of specific methods, especially of program methods among Bicol women, is lower than the average for the Philippines and suggest the need for additional efforts toward providing such information. Table 10 shows the percentage distribution of respondents who reported ever heard of specific methods by source of information. Note that the role of mass media in providing information appears to be surprisingly minimal. Family planning and other government workers appear to be the major sources of information although private doctors and relatives and friends are also important sources.

Family Planning Practice. Data on ever use and current use of family planning methods shown in Tables 9 and 11, respectively, reveal low levels of contraceptive use in Bicol compared to the average for the Philippines. In the case of modern and more effective methods, i.e., pill, IUD, and sterilization, the current prevalence rate for Bicol women is only 7 percent as opposed to 17 percent for the Philippines in 1978. Overall contraceptive prevalence rate in 1978 is 32 percent for Bicol and 48 percent for the Philippines.

Data on contraceptive prevalence rates obtained by the Area Fertility Surveys shown in Table 12 reveal that Bicol had the lowest rate for all methods among the six surveyed regions in the Philippines. The prevalence rate for modern methods is only about half or less than those of the other regions.

Differentials in contraceptive use by selected characteristics of the woman are shown in Table 13. As might be expected, greater contraceptive use is found among women in urban than in rural areas and among women of higher education and higher economic status. It is interesting to note that contraceptive prevalence rates are higher in Camarines Sur than in Albay and Sorsogon, and among non-working women than working women. Non-working women, however, tend to use mainly the less effective methods.

Table 10. Percentage Distribution of Currently Married Women Respondents Who Reported Ever Heard of Specific Methods by Source of Information, Bicol River Basin, 1978.

Source of Information	*Modern Program Methods*				*Other Program Methods*		*Non-Program Methods*		
	Pill	*IUD*	*Female Steril-ization*	*Male Steril-ization*	*Rhythm*	*Condom*	*Abstinence*	*Withdrawal*	*Others*[a]
Family planning workers	47.5	46.8	51.4	51.7	46.8	48.9	16.1	44.7	34.8
Other govenment workers	7.2	7.8	6.2	10.1	5.6	6.9	3.6	4.5	11.6
Mass media	3.7	4.3	4.8	7.9	6.1	3.5	3.6	3.8	8.7
Private doctors	19.1	18.7	19.2	18.0	18.5	17.3	6.3	9.2	17.4
Relatives/neighbors/ friends	21.8	22.0	16.4	12.4	18.0	22.5	36.6	28.0	20.3
Others	0.7	0.4	2.1	0.0	5.0	0.9	33.8	9.8	7.2
Total Percent	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Percent Reporting Ever-Heard	57.4	39.6	11.9	7.2	36.1[b]	44.8	9.1[b]	10.7[b]	5.6
n = 1,229									

[a]Includes foam, diaphragm and folk methods.

[b]Percentage of respondents reporting ever heard only after probing.

Table 11. Percentage Distribution of Currently Married Women Age 15-49 Who Are Currently Using Specific Contraceptive Methods: Philippines and Bicol, 1978.

Method	*Philippines*[a] *1978 RPFS*	*Bicol*[b] *1978 BMS*
Modern Program Methods	*16.6*	
Pill	6.0	4.4
IUD	3.1	1.2
Female sterilization	6.2	1.5
Male sterilization	0.9	0.2
Other modern methods	0.4	
Other Program Methods	*16.0*	*14.2*
Rhythm	11.3	11.2
Condom	4.7	3.0
Non-Program Methods	*15.1*	*10.3*
Abstinence	2.4	5.0
Withdrawal	12.5	4.6
Other	0.2	0.7
Total	47.7	31.8
Sample Size	6,684	1,229

[a]Based on the 1978 RPFS. Data refer to women who were married and living with their husbands at the time of the survey, who believed they were physically able to bear more children and who were not pregnant at the time of interview. NCSO, *et al.* (1979, p. 130).

[b]Based on the 1978 BMS. Data refer to women who were married and living with their husbands.

The levels of and differentials in contraceptive use in Bicol are bound to be related to both the demand for children and to the effective cost of contraception. In the subsequent sections, we examine the correlates of both fertility and family planning behavior on the basis of the analytical framework described in the next section.

Analytical Framework

General Framework. A general framework for understanding the dynamics of change arising from rural development activities is described below.* The major components of this framework include (a) a theory of household or other micro unit behavior; (b) the physical, social and economic environment; (c) autonomous changes in this environment; and (d) exogenous shocks to this environment arising from rural development activities.

*The major outlines of this framework were discussed in the Workshop on Fertility Impacts of Rural Development and Agricultural Practices: A Search for Linkages, held in Bangkok, Thailand on November 21-29, 1979, which the author participated.

Table 11. Percentage Distribution of Currently Married Women Age 15-49 Who Are Currently Using Specific Contraceptive Methods: Philippines and Bicol, 1978.

Method	*Philippines[a]* *1978 RPFS*	*Bicol[b]* *1978 BMS*
Modern Program Methods	*16.6*	*7.3*
Pill	6.0	4.4
IUD	3.1	1.2
Female sterilization	6.2	1.5
Male sterilization	0.9	0.2
Other modern methods	0.4	–
Other Program Methods	*16.0*	*14.2*
Rhythm	11.3	11.2
Condom	4.7	3.0
Non-Program Methods	*15.1*	*10.3*
Abstinence	2.4	5.0
Withdrawal	12.5	4.6
Other	0.2	0.7
Total	47.7	31.8
Sample Size	6,684	1,229

[a]Based on the 1978 RPFS. Data refer to women who were married and living with their husbands at the time of the survey, who believed they were physically able to bear more children and who were not pregnant at the time of interview. NCSO, *et al.* (1979, p. 130).

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Table 12. Contraceptive Prevalence Rates by Type of Method, Selected Regions: Area Fertility Surveys 1978, 1979, 1980.

Method/Year	REGION					
	Central Luzon	Western Visayas	Northern Mindanao	Metro Manila	Southern Tagalog	Bicol
Modern Program Methods						
1978	13.5	6.7	12.1	21.0	a	a
1979	17.8	9.0	12.6	25.1	18.2	5.6
1980	20.3	12.0	12.5	26.6	18.8	6.2
Other Program Methods						
1978	7.6	18.6	13.1	15.9	a	a
1979	10.5	18.5	15.4	16.2	9.8	12.8
1980	6.7	17.2	14.1	14.7	9.2	11.0
Non-Program Methods						
1978	9.6	7.5	3.8	6.6	a	a
1979	10.9	7.5	3.0	10.0	6.8	7.1
1980	7.6	7.4	4.6	8.9	5.6	8.7
All Methods						
1978	30.7	32.8	29.0	43.5	a	a
1979	39.2	35.0	31.0	51.3	34.8	25.5
1980	34.6	36.6	31.2	50.2	33.6	25.9

[a]Not included in the 1978 survey round.
SOURCE: Concepcion, M.B. and J.B. Cabigon (1982; Tables 4.6 and 4.7).
*Rates refer to current contraceptive use of currently married women age 15-44 years.

In a general sense, the household or other micro unit, in an attempt to enhance its welfare, is viewed as actively responding to a set of opportunities and constraints in the context of social and cultural decision processes. The physical environment includes the natural resources endowments of the community including risks to production due to natural calamities such as typhoons. The economic and social environment, on the other hand, includes among others (a) the structure of markets and prices for factors and products, and (b) the social structure and social organization which defines, for example, land tenure status, crop sharing arrangements, patterns of family and non-family labor utilization and compensation, and social, economic and political alliances which influence cooperative behavior and community participation. Autonomous changes in the environment include, for example, changes in international prices for agricultural export crops, national trends in prices, technology changes, etc. Another source of shocks to the environment is the set of rural development interventions. These interventions

Table 13. Percentage of Currently Married Women Age 15-49 Currently Using Contraceptive Methods, by Selected Characteristics of the Woman, and by Type of Method, Bicol River Basin, 1978.

Category of Woman	*Modern Program Methods*	*Other Program Methods*	*Non-Program Methods*	*All Methods*
All Women	7.3	14.2	10.3	31.8
Province				
Camarines Sur	6.0	15.2	13.6	34.7
Albay/Sorsogon	9.5	13.0	5.4	28.0
Location				
Poblacion/Urban	10.5	17.6	13.0	37.8
Rural	6.1	9.7	10.6	29.7
Education of Woman				
0-7 Years	6.2	9.8	10.6	26.6
8+ Years	9.8	22.2	7.7	39.7
Work Status				
Working	10.5	5.3	3.1	18.9
Not Working	2.7	28.0	21.2	51.9
Housing Index				
Light	2.7	4.0	3.5	10.2
Medium/Heavy	12.9	24.6	13.4	50.9

include (a) the provision of physical infrastructures such as roads, irrigation, flood control, electrification, etc.; (b) the provision of social infrastructures and services in the area of health, education, nutrition, environmental sanitation, and family planning; (c) agricultural programs, such as land reform, development of cooperatives, provision of extension services and rural credit, and of various input subsidies and price supports; and (d) industrial development interventions such as tax and other incentives, credit and various subsidies to small and large-scale enterprises.

In this framework, either sources of change (autonomous shocks or government interventions) affect the structure of opportunities and constraints facing households. These households are then expected to respond to these changes in a manner they perceive will improve their present economic and social position. Depending upon the nature of the emerging structure of opportunities and constraints, we may expect a "multiphasic response" from these households in terms of social, economic and demographic adjustments.

Determinants of Fertility and Family Planning Behavior. On the basis of a synthesis of the demographic, sociological, psycho-social and economic studies on fertility, one can view the determinants of fertility and family planning behavior, within the above general framework, as working through one or more of the following components.*

a) the demand for children, N, i.e., the number of surviving children parents would want if fertility regulation were costless;
b) the potential output of surviving children, S. i.e., the number of surviving children parents would have if they did not deliberately limit fertility; and
c) the effective cost of fertility regulation, C.

Given a set of preferences, the demand for children, N, is a function of income and the price of children relative to other goods. All things being equal, an increase in income increases the demand for children because parents can afford more goods including children. However, an increase in income also changes the price of children relative to other goods through various ways depending upon the nature of the income change. For example, if child bearing and rearing is intensive of the mother's time, an increase in income due to an increase in the mother's wage rate increases the opportunity cost of children, i.e., the income foregone by the mother by spending more time in child bearing and rearing than in the labor market. Furthermore, children are valued not only as a "consumption" good but also as productive agents and as a source of old age security. Children are also valued as a general source of risk insurance, i.e., insurance against events that threaten normal consumption streams.** The sources of risk may include weather-induced risk which affects agricultural production and the risk to women of substantial loss in economic welfare if widowed or if their husbands become seriously ill or disabled. Off-farm incomes of children may help maintain consumption standards in the face of poor harvests. Likewise, economic welfare of widowed women might be maintained with the support of surviving children. An increase in income widens the range of investment alternatives for parents, since with higher income parents can have more effective access to capital markets, This reduces the effective cost of these alternatives. If these investment alternatives are substitutes for the economic support to be derived from children, then we expect a substitution away from children.

The number of potential surviving children, (S), depends on natural fertility and the probability of infants surviving to adulthood. Natural fertility, that is fertility in the absence of voluntary control, is expected to be related to factors affecting fecundity, fetal mortality, etc. such as the age and health of the mother. Infant mortality, likewise, is expected to be related to factors affecting the health and nutrition of children such as breastfeeding, consumption of goods and services

*See for example the synthesis provided by Easterlin, *et al.* (1981).

**See Cain (1981).

and the education of the woman. The factors affecting natural fertility and infant survival are in turn affected by household income, such that as incomes rise, the potential number of births and the infant survival probabilities increase, leading to higher potential numbers of surviving children.

The motivation to practice fertility control arises when the potential number of surviving children exceeds the desired number. The efficiency by which parents can practice fertility control which eventually determine their actual completed family size, depends upon the attitudes of parents towards fertility control, the cost of information and supplies/services of specific contraceptive techniques and on income.

How do rural development efforts affect fertility and family planning decisions within the simple framework described above? Among other major mechanisms, rural development efforts are expected to increase production and employment opportunities in the rural areas, thereby increasing the wage rates of both husbands and wives. Changes in the wage rates, as we have earlier indicated, both have positive effects (pure income effect) and negative effects (price effect) on the demand for children, the latter would be expected to be larger in the low income setting of Bicol. Likewise, changes in wage rates would tend to increase the potential number of surviving children, as the resulting increase in incomes lead to better nutrition and health of mothers and their children. Development efforts, specifically in the area of health and nutrition, also directly affect the potential number of surviving children.

Where the net effects of all the above changes lead to a greater potential relative to desired number of children, the motivation to practice family control increases. The higher income of households increases their ability to obtain contraceptive information and supplies/services. The family planning program in turn is expected to generate more favorable attitudes towards contraception, e.g., by eliminating legal barriers to the practice of contraception. Moreover, by increasing the flow of information and access to contraceptive supplies and services, the program reduces the effective cost of contraception, thereby increasing the ability of parents to equate their desired and potential number of children.

Empirical Models. The demographic behavior that we observe are the number of births, the number of children who have died, and the use of contraception. This section outlines the empirical models for analyzing the correlates of these objective indicators.

Three sets of models will be examined. The first of these views children ever born, child deaths and ever use of contraception as jointly determined by common set of factors. The model can be written as follows:

(1) CEB: AGEW, AGEM, EDW, $\widehat{\text{WAGEH}}$, $\widehat{\text{WAGEW}}$, HHASSETS, LOC, RDA

(2) CDEATH: AGEW, AGEM, EDW, $\widehat{\text{WAGEH}}$, $\widehat{\text{WAGEW}}$, HHASSETS, LOC, RDA

(3) EVERUSE: AGEW, AGEM, EDW, $\widehat{\text{WAGEH}}$, $\widehat{\text{WAGEW}}$, HHASSETS, LOC, RDA

(4) WAGEH: AGEH, EDH, LOC, RDA
(5) WAGEW: AGEW, EDW, LOC, RDA

The definition and measurement of variables as well as the hypotheses are summarized in Table 14.

The second model views the number of births during the past five years (or past two years) and use of contraception during the respective reference periods as jointly determined by common factors, including the number of children already born at the beginning of the reference period. This model can be written as follows:

(6) BIRTHS: AGEW, AGEM, DDW, PPARITY, WAĜEH, WAĜEW, HHASSETS, LOC, RDA
(7) FPUSE: AGEW, AGEM, EDW, PPARITY, WAĜEH, WAĜEW, HHASSETS, LOC, RDA

Finally, we consider a third model which looks at current fertility preference, measured by whether or not the woman wants additional children, and actual use of family planning methods. Thus we have

(8) ADDCHILD: AGEW, AGEM, EDW, LIVINGCHILD, WAĜEH, WAĜEW, HHASSETS, LOC, RDA
(9) CFPUSE: AGEW, AGEM, EDW, LIVINGCHILD, WAĜEH, WAĜEW, HHASSETS, LOC, RDA

Both WAĜEH and WAĜEW are estimated from (4) and (5).

Regression Results

Male and Female Wage Rates. As described earlier, rural development efforts are expected to effect fertility and family planning behavior either directly through increasing access to basic services such as health and family planning services, or indirectly through their impact on production and employment, and therefore on the wage rates of both husbands and wives. We assume that the main impact of the rural electrification, irrigation and road network development programs in Bicol is through their effect on wage rates. In addition, the development of road network is expected to facilitate household's access to health and family planning services found in the municipal poblacions or cities.

Table 15 shows the effect of electrification, irrigation and road network development on the wage rates of female respondents and of males 25 years and older.* The road network development is proxied by travel time to the poblacion. Note that the development variables are indeed significant in explaining wage differentials. Specifically, female wage rates tend to rise in irrigated areas, presumably through increased demand for adult labor generated by this more labor

*The dependent variables are the natural logarithm of the hourly wage rates of females respondents and of males 25 years old and over, respectively.

Table 14. List of Variables and Major Hypotheses

Symbols	*Definition/Measurement and Hypotheses*
Dependent	
1. ADDCHILD	Dummy variable (=1 if the woman reported that she wanted additional children at the time of interview; 0 = otherwise).
2. BIRTH 73 (76)	Number of children born during the period 1973-1977 (1976-1977).
3. CEB	Number of children ever born.
4. CDEATH	Reciprocal of the proportion of children surviving of children ever born.
5. CFPUSEA	Dummy variable (=1 if the woman is using any method of contraception at the time of interview; 0 = otherwise).
6. CFPUSEM	Dummy variable (=1 if the woman is using any modern method of contraception at the time of interview, i.e., pill, IUD, sterilization or injection; 0 = otherwise).
7. EVERUSEA	Dummy variable (=1 if the woman has ever used any family planning methods; 0 = otherwise).
8. EVERUSEM	Dummy variable (=1 if the woman has ever used any modern method of contraception, i.e., pill, IUD, sterilization or injection; 0 = otherwise).
9. FPUSEA 73 (76)	Dummy variable (=1 if the woman used any family planning methods during the period 1972-1977 (1976-77); 0 = otherwise).
10. FPUSEM 73 (76)	Dummy variable (=1 if the woman used any modern method of contraception during the period 1972-1977 (1976-77); 0 = otherwise).
11. WAGEH	Natural logarithm of the hourly wage rate of the husband.
12. WAGEW	Natural logarithm of the hourly wage rate of the wife.
Independent	
Personal Characteristics	
13. AGEW	Age of wife in completed years.
14. AGEWK	Dummy variable (=1 if the woman age belong to category K; 0 = otherwise, where K is coded as 1 = age 15-24 years 2 = age 25-29 years 3 = age 30-34 years 4 = age 35-39 years 5 = age 40-44 years 6 = age 45-49 years The number of children ever born is expected to increase with age, but the rate of increase declines at older ages due to declining fecundity, hence AGEW will have a non-linear relationship with CEB. Perception of declining fecundity among older women may reduce the need for contraception, hence family planning use will be less among older women.

Table 14 (Continued)

Symbols	Definition/Measurement and Hypotheses
	AGEW will be positively related to the mean age of children and, therefore, negatively related to child survival rates.
15. AGEM	Age at marriage in completed years. Higher age at marriage reduces the reproductive life span and is, therefore, expected to be negatively related to CEB, but may be positively related to BIRTHS or ADDCHILD, and therefore negatively to family planning use, if women try to catch up with delayed fertility.
16. EDW	Educational attainment of the wife, measured as the highest grade of schooling completed in years.
17. EDWK	Dummy variable (=1 if the women's level of educational attainment belong to category K; 0 = otherwise, where K is coded as 1 = no schooling or finished up to four years of schooling 2 = finished 5 to 7 years of schooling 3 = finished 8 years of schooling or more (EDW) = [EDW (5-7), EDW (8+)] In the absence of wage information, EDW proxies for the wife's wage rate. The higher the education of the woman, the higher the potential wage rate and, therefore, the value of her time or opportunity cost of children. Increased education also means greater knowledge of family planning methods, hence, it will be expected to be positively related to family planning use. Increased education increases the health and nutrition knowledge of the woman and is, therefore, expected to be negatively related to child deaths.
18. LIVING CHILD	Number of surviving children at time of interview.
19. LIVING CHILD K	Dummy variable (=1 if belong to category K and 0 = otherwise, where K is coded as 1 = 0-2 living children 2 = 3-4 living children 3 = 5-6 living children 4 = 7 or more living children (LIVING CHILD) = [LIVING CHILD (3-4), LIVING CHILD (5-6), LIVING CHILD (7+)] The larger the number of living children the woman already has, the less likely she will want additional children and more likely she will practice family planning.
20. PPARITY 5(2)	Number of children ever born prior to 1973 (1976).
21. PPARITY 5(2) K	Dummy variable (=1 if in category K, 0 = otherwise; where K is coded as 1 = 0-2 children born prior to 1973 (1976) 2 = 3-4 children born prior to 1973 (1976) 3 = 5-6 children born prior to 1973 (1976) 4 = 7 or more children born prior to 1973 (1976)

Table 14 (Continued)

Symbols	*Definition/Measurement and Hypotheses*
	(PPARITY) = [PPARITY (3-4), PPARITY (5-6), PPARITY (7+)]
	The higher the PPARITY, the closer is the woman to her desired fertility and hence the less likely she will have more additions to current stock, and more likely to practice contraception.
22. PLIVINGCHILD 73 (76)	Number of surviving children prior to 1973 (1976).
23. PLIVINGCHILD 73 (76)	Dummy variable (=1 if in category K, 0 = otherwise; where K is coded as 1 = 0-2 living children prior to 1973 (1976) 2 = 3-4 living children prior to 1973 (1976) 3 = 5-6 living children prior to 1973 (1976) 4 = 7+ living children prior to 1973 (1976)
	(PLIVINGCHILD) = [PLIVINGCHILD (3-4), PLIVINGCHILD (5-6), PLIVINGCHILD (7+)]
	The higher the PLIVINGCHILD previous to the reference period, the less the additional number of births and the greater the use of contraception during the reference period.
Household Characteristics	
24. $\hat{WAGEH}$ ($\hat{WAGEW}$)	Natural logarithm of the hourly wage rate of the husband (wife) predicted from husband's (wife's) background characteristics, locational characteristics and rural development indicators. An increase in $\hat{WAGEH}$ and $\hat{WAGEW}$ are expected on balance to reduce the dependence on children as productive agents, old age security and risk insurance, while an increase in $\hat{WAGEW}$ is expected on balance to increase the value of time of the mother. Both variables are expected to be negatively related to fertility and positively to family planning practice. Moreover, an increase in both will tend to reduce CDEATH due to greater health and nutrition consumption possibilities, hence both wage variables will be negatively related to CDEATH.
25. HOUSE	Dummy variable (=1 if the house is made of light construction materials; 0 = otherwise). In the absence of wage information, this variable proxies for the husband's wage rates, which determines the largest component of household incomes, the value of children as productive agents, old age security and risk insurance will tend to be higher, leading to a greater demand for children. HOUSE is expected to be positively related to fertility and negatively to family planning use. Additionally, HOUSE is expected to be positively related to CDEATH due to the effect of income constraints on health and nutrition of children.

Table 14 (Continued)

Symbols	*Definition/Measurement and Hypotheses*
26. OWNHOUSE	Dummy variable (=1 if the household own the house; 0 = otherwise).
27. OWNLAND	Dummy variable (=1 if the household own agricultural land; 0 = otherwise). Both OWNHOUSE and OWNLAND proxy for household productive assets which determine the household's non-labor income. Both are expected to be positively related to fertility, and negatively to family planning and child deaths.
Locational Characteristics	
28. LOC	Location variable (=1 if the barangay is located in K and 0 = otherwise, where K is coded as CITY - urban (city) POBLACION = municipal poblacion RURAL = rural barangay (LOC) = (MUN POBLACION, RURAL) Location reflects access to economic and social services related to health, family planning and high wage employment, hence, wage rates will tend to be higher in cities than in either poblacion or rural barangays. Fertility and child deaths are expected to be lower in cities than in poblacions or rural barangays, but conversely for family planning use.
29. PROV	Province (= 1 if in province K, and 0 = otherwise, where K is coded as 1 = Sorsogon 2 = Albay 3 = Camarines Sur (PROV) = (ALBAY, CAM SUR)
30. RESBGY	Length of residence in barangay (=1 if household head has resided in barangay for 5 years or more; 0 = otherwise). This is a control variable for length of exposure to the community environment and to the rural development activities in the community.
31. RDA	Rural development activities are proxied by AELEC, IRRIG and TRAVELPOB.
32. AELEC	Dummy variable (=1 if the barangay is electrified; 0 = otherwise).
33. IRRIG	Dummy variable (=1 if the barangay has irrigation facilities; 0 = otherwise).
34. TRAVELPOB	Travel time in minutes from the rural barangay to the municipal poblacion. Rural electrification, the provision of irrigation facilities and the development of road networks are expected to increase employment opportunities, and hence wage rates, which in

intensive agricultural technology. Similarly, male wage rates tend to rise in irrigated areas, in areas with better road network and to some extent in electrified areas, after controlling for personal characteristics and location of residence. It appears therefore that rural development efforts in Bicol have had a significant impact on the income generating potentials of individuals and households. Exogenous changes in wage rates in turn influence fertility, family planning and other aspects of household decisions as revealed by the regression results below.

Children Ever Born and Ever Use of Family Planning Methods. Table 16 presents the regression results on children ever born (CEB), child deaths (CDEATH), and ever use of family planning methods (EVERUSEA and EVERUSEM). In this single period framework, the dependent variables are jointly determined by a common set of exogenous factors. This statistical approach was adopted to eliminate simultaneity bias with respect to the relationships between CEB and CDEATH and between CEB and EVERUSEA or EVERUSEM. The sample includes married women age 15-49 years, currently living with their husbands who in turn are the household heads. The wage rates of the wife and of the husband are predicted on the basis of the relationships shown in Table 15. The results in Table 16 may be summarized as follows:

(1) We expected both wage rate variables to be negatively related to children ever born, CEB, and child deaths, CDEATH, and to be negatively related to the two alternative measures of ever use of family planning methods, EVERUSEA and EVERUSEM. The results reveal that only the wage rate of the wife, WAGEW, is significantly related to CEB, while only the wage rate of the husband, WAGEH, is significantly related to CDEATH and EVERUSEA or EVERUSEM.

(2) We expected the effect of non-labor incomes proxied by OWNHOUSE and OWNLAND to be positively related to CEB and negatively related to CDEATH and EVERUSEA or EVERUSEM. The results reveal only OWNHOUSE is significantly with respect to CEB.

(3) CEB increases with age of woman, AGEW, but increases more slowly at older ages reflecting declining fecundity. It would also reflect underenumeration of children ever born by older women. AGEW was expected to be positively related to CDEATH since AGEW reflect the exposure of children to the risks of mortality, that is, children of older women are expected to be older on the average than the children of younger women. AGEW however is not significantly related to CDEATH except in one age group, and suggest the presence of reporting error on the part of older women who might have tended to report only surviving children.

The ever use of family planning methods declines significantly at older ages as expected.

(4) Age at marriage, AGEM, is significantly related with lower children ever born as expected. It is likewise negatively related to CDEATH and EVERUSEA.

(5) The educational attainment of the wife, EDW, is negatively related to CEB and positively related to everuse of family planning as expected. Since the value of time aspect of education is already captured in the WAGEW variable, the

education of the wife is here interpreted as reflecting aspirations for different lifestyles that compete with large number of children in the case of its relation with CEB, and greater knowledge and more favorable attitudes toward family planning methods in case of its relation with EVERUSEA and EVERUSEM. We also expected EDW to be negatively related with CDEATH, however, the relationship is not significant.

(6) Households who have resided on the barangay for five years or more, RESBGY (5+), tend to have larger CEB and practice more modern contraception than recent residents. The greater practice of contraception among the longer time residents can be interpreted as a response to their higher fertility compared to recent residents.

(7) Controlling for personal and household characteristics, we expect area of residence to reflect differentials in access to health and family planning services and such differentials in turn will affect fertility, child mortality and family planning use. We expect a gradient of low to high fertility as one moves from city to poblacion to rural barangays, and conversely for child mortality and family planning use. The results of our regressions, however, do not exhibit consistent patterns of areal differentials, except that CDEATH increases the farther the rural barangay is to the municipal poblacion as expected. The use of family planning methods tends to be higher in rural areas than in the city or poblacion contrary to expectations. One possible explanation for this contrary finding might be related to reporting errors on the part of rural respondents who might feel more intimidated regarding questions on family planning and therefore would tend to give false reports of ever use. On the other hand, rural women may indeed use more family planning methods than their poblacion or city counterparts if family planning workers personally visit rural women more than they do poblacion or city women to encourage use of contraception. Note that the data on Table 13 showing higher contraceptive use among poblacion/urban women than rural women do not control for other factors, and hence the findings in Table 13 are not necessarily inconsistent with our regression results. Finally, note that contraceptive use in Albay is much lower than in Camarines Sur and Sorsogon.

Table 17 provides an alternative specification whereby the wage variables are substituted by the developmental variables, AELEC and IRRIG. Additionally, HOUSE can be looked upon as an indicator of household income. Note that HOUSE is consistently significant and in the expected direction in its relation with CEB, CDEATH, EVERUSEA and EVERUSEM, that is, poorer households tend to have more children, experience higher child mortality, and use less contraception than better-off households. Poverty is clearly related to the demographic behavior of households.

Fertility and Family Planning Practice in the Past Five Years. The effects of rural development activities in Bicol could be more properly assessed in terms of their effects on current or more recent demographic behavior. The time dimension is obviously important. One cannot properly infer that rural development activities

Table 16. Regression on Childern Ever Born, Child Deaths and Ever Use of Family Planning Methods, Bicol River Basin, 1978.

Variables	*Mean*[a]	*CEB*[b]	*CDEATH*[b]	*EVERUSEA*[b]	*EVERUSEM*[b]
AGEW (25-29)	0.165	1.351***	−0.033	0.160***	0.135***
	(0.371)	(5.279)	(−1.074)	(2.864)	(2.777)
AGEW (30-34)	0.215	2.724***	0.004	0.148***	0.185***
	(0.411)	(10.537)	(0.136)	(2.639)	(3.781)
AGEW (35-39)	0.183	4.281***	0.033	0.093	0.130***
	(0.387)	(15.720)	(1.004)	(1.567)	(2.528)
AGEW (40-44)	0.172	5.711***	0.055*	0.076	0.065
	(0.377)	(20.681)	(1.653)	(1.257)	(1.242)
AGEW (45-49)	0.167	5.919***	0.021	−0.148**	−0.079
	(0.373)	(20.761)	(0.603)	(−2.380)	(−1.465)
EDW (5-7)	0.498	−0.099	−0.026	0.093**	0.036
	(0.500)	(−0.564)	(−1.205)	(2.443)	(1.072)
EDW (8+)	0.247	−0.652**	−0.007	0.229***	0.094*
	(0.432)	(−2.344)	(−0.212)	(3.776)	(1.777)
AGEM	20.698	−0.091***	−0.002*	−0.005**	−0.002
	(6.691)	(-9.544)	(−1.665)	(−2.202)	(−0.902)
OWNHOUSE	0.908	0.420*	−0.006	−0.045	−0.053
	(0.289)	(1.876)	(−0.229)	(−0.930)	(−1.249)
OWNLAND	0.129	0.245	−0.013	−0.52	−0.021
	(0.335)	(1.265)	(−0.540)	(−1.241)	(−0.582)
RESBGY (5+)	0.773	0.741***	0.020	0.032	0.074**
	(0.419)	(4.438)	(0.975)	(0.880)	(2.352)
MUN POBLACION	0.146	−0.600	0.032	0.061	0.095*
	(0.354)	(−2.287)	(1.021)	(1.070)	(1.910)
RURAL	0.712	−0.085	0.018	0.206***	0.121**
	(0.453)	(−0.339)	(0.586)	(3.784)	(2.559)
RURAL x TRAVELPOB	45.785	0.0001	−0.0002*	−0.0002	−0.0004*
	(69.181)	(0.100)	(−1.699)	(−0.950)	(−1.722)

Table 16 (Continued)

Variables	*Mean*[a]	*CEB*[b]	*CDEATH*[b]	*EVERUSEA*[b]	*EVERUSEM*[b]
CAM SUR	0.602	−0.050	0.031	−0.026	−0.036
	(0.490)	(−0.262)	(1.349)	(−0.641)	(−0.999)
ALBAY	0.257	−0.335	0.002	−0.162***	−0.053
	(0.437)	(−1.567)	(0.084)	(−3.469)	(−1.299)
WAGEW	−0.099	−0.723**	−0.011	−0.013	0.014
	(0.445)	(−2.521)	(−0.322)	(−0.211)	(0.251)
WAGEH	0.456	0.212	−0.093*	0.370***	0.125*
	(0.328)	(0.536)	(−1.943)	(4.294)	(1.669)
Constant		3.312	1.180	0.179	0.026
$\bar{R}^2$		0.538	0.017	0.141	0.078
F		77.891	2.144	11.842	6.549
n		1,188	1,188	1,188	1,188
Mean		5.675	1.133	0.486	0.228
Std. Dev.		3.131	0.259	0.500	0.420

[a]Standard deviation in parenthesis.
[b]t-value in parenthesis.
* ** ***Significant at the 0.10, 0.05 and 0.01 levels, respectively.

Table 17. Regression on Children Ever Born, Child Deaths and Ever Use of Family Planning Methods, Bicol River Basin, 1978.

Variables	*Mean*[a]	*CEB*[b]	*CDEATH*[b]	*EVERUSEA*[b]	*EVERUSEM*[b]
AGEW (25-29)	0.165	1.363***	−0.033	0.169***	0.136***
	(0.371)	(5.334)	(−1.062)	(3.035)	(2.802)
AGEW (30-34)	0.215	2.744***	−0.001	0.181***	0.192***
	(0.411)	(10.797)	(−0.044)	(3.262)	(4.001)

Table 17 (Continued)

Variables	*Mean*[a]	*CEB*[b]	*CDEATH*[b]	*EVERUSEA*[b]	*EVERUSEM*[b]
AGEW (35-39)	0.183	4.304***	0.028	0.128**	0.139***
	(0.387)	(16.131)	(0.871)	(2.208)	(2.746)
AGEW (40-44)	0.172	5.733***	0.049	0.114*	0.074
	(0.377)	(21.220)	(1.503)	(1.937)	(1.452)
AGEW (45-49)	0.167	5.925***	0.017	−0.112*	−0.071
	(0.373)	(21.200)	(0.492)	(−1.842)	(−1.340)
EDW (5-7)	0.498	0.275*	−0.29	0.105***	0.043
	(0.500)	(−1.748)	(−1.546)	(3.066)	(1.439)
EDW (8+)	0.247	−1.115***	−0.020	0.264***	0.113***
	(0.432)	(−5.745)	(−0.849)	(6.222)	(3.074)
AGEM	20.698	−0.092***	−0.002*	−0.005**	−0.002
	(6.691)	(−9.697)	(−1.641)	(−2.236)	(−0.929)
HOUSE (Light)	0.608	0.260*	0.051***	−0.121***	−0.055**
	(0.488)	(1.843)	(3.032)	(−3.919)	(−2.074)
OWNHOUSE	0.908	0.375*	−0.010	−0.039	−0.045
	(0.289)	(1.660)	(−0.331)	(−0.792)	(- 1.061)
OWNLAND	0.128	0.258	−0.011	−0.069*	−0.026
	(0.335)	(1.328)	(−0.488)	(−1.638)	(−0.720)
RESBGY (5+)	0.773	0.734***	0.021	0.037	0.077**
	(0.419)	(4.400)	(1.028)	(1.016)	(2.429)
MUN POBLACION	0.146	−0.327	0.051*	0.015	0.069
	(0.354)	(−1.351)	(1.763)	(0.280)	(1.498)
RURAL	0.712	0.167	0.057**	0.066	0.069*
	(0.453)	(0.833)	(2.386)	(1.513)	(1.823)
RURAL x TRAVELPOB	45.785	−0.002	−0.0002	−0.001**	−0.0004**
	(69.181)	(−0.204)	(−1.295)	(−2.307)	(−2.204)
AELEC	0.376	0.048	−0.018	0.044	0.029
	(0.485)	(0.318)	(−0.983)	(1.346)	(1.034)
IRRIG	0.546	−0.201	−0.029*	0.018	0.005

Table 17 (Continued)

Variables	Mean[a]	CEB[b]	CDEATH[b]	EVERUSEA[b]	EVERUSEM[b]
	(0.498)	(−1.547)	(−1.869)	(0.649)	(0.206)
CAM SUR	0.602	- 0.100	0.025	−0.004	−0.027
	(0.490)	(−0.520)	(1.086)	(−0.087)	(−0.728)
ALBAY	0.257	−0.418*	−0.012	−0.128***	−0.038
	(0.437)	(−1.923)	(−0.476)	(−2.700)	(−0.932)
Constant		3.526	1.114	0.446	0.115
$\bar{R}^2$		0.537	0.022	0.136	0.078
F		73.598	2,433	10.875	6.275
N		1,189	1,189	1,189	1,189
Mean		5,675	1,133	0.486	0.228
Std. Dev.		3,131	0.259	0.500	0.420

[a]Standard deviation in parenthesis.
[b]t-value in parenthesis.
* ** ***Significant at the 0.10, 0.05 and 0.01 levels, respectively.

influence behavior that have occurred in the past prior to the period where the cumulative impacts of such rural development activities can be felt and observed. Our previous discussion on the determinants of children ever born should therefore be interpreted in this light. Childbearing decisions among older women in the early part of their reproductive life cycle may not be related to changes brought about by recent rural development activities.

The correlates of recent demographic behavior can be examined from Tables 18 and 19 for the period 1973-1977, and from Tables 22 and 23 for the period 1976-1977. We first present the results of the regression on births and family planning practice during the period 1973-1977. The sample of currently married women age 15-49 years with husband present was further restricted to include only women who were married prior to 1973. Births during the period 1973-1977 are based on data from the household list and not from the abridged pregnancy history, since the former appear to be more reasonable than the latter in terms of reliability and accuracy, as described earlier. Correspondingly, the use of family planning methods refers to reported ever use from the period 1972-1973 through 1976-1977 for which data was collected and coded. Since the reported fertility of the youngest age group of women appear to be too low relative to what might be expected, we excluded this group from the sample. The results in Table 18 are highlighted below.

(1) The exogenous increase in the husband's wage rate, WAGEH, partly due to the effects of rural development activities in the area, significantly reduces births during the recent five-year period, BIRTHS73, and increases the use of contraceptive methods, FPUSEA73, during this period. The Coefficient of WAGEW* however is not significant for BIRTHS73 and FPUSEA73, but is significant for FPUSEM73, while the coefficient of WAGEH* is not significant for FPUSEM73.

(2) The coefficient of OWNHOUSE on BIRTHS73 is significant and positive indicating the expected positive wealth effect of non-labor incomes on current fertility.

(3) The age of the woman reckoned in terms of her approximate age at the beginning of the reference period, AGEW73 (i.e., displaced five years from age at interview) is negatively related both with BIRTHS73 and with FPUSEA73 and FPUSEM73 as expected.

(4) The educational attainment of the woman is negatively related to BIRTHS76 and positively related to FPUSEA76 as expected. Its relationship with FPUSEM76, however, is not significant.

(5) Age at marriage, AGEM, is positively related with BIRTHS73 as might be expected if women who marry late tend to catch up on their fertility in the current period. They will therefore be observed to have higher current fertility, although as we have observed earlier, AGEM will eventually be negatively associated with the total number of children ever born. We expect AGEM to be negatively related to family planning use. The positive coefficient of AGEM on FPUSEA76 is therefore unexpected and may be capturing other variables related to AGEM but positively related to family planning use, i.e., more favorable attitude toward

Table 18. Regression on Fertility and Family Planning Practice During the 1973-1977 Period, Bicol River Basin, 1978.

Variables	*Mean*[a]	*BIRTH73*[b]	*FPUSEA73*[b]	*FPUSEM73*[b]
AGEW73 (25-29)	0.241	-0.312***	-0.079	0.065
	(0.428)	(−2.856)	(−1.413)	(1.377)
AGEW73 (30-34)	0.215	−0.685***	−0.219***	−0.052
	(0.411)	(−5.371)	(−3.304)	(−0.932)
AGEW73 (35-39)	0.205	−1.239***	−0.246***	−0.131**
	(0.404)	(−8.718)	(−3.374)	(−2.129)
AGEW73 (40-44)	0.201	−2.021***	−0.485***	−0.254***
	(0.401)	(−13.464)	(−6.291)	(−3.905)
EDW (5-7)	0.485	0.007	0.068*	0.022
	(0.500)	(0.083)	(1.675)	(0.639)
EDW (8+)	0.232	0.290	0.168	0.055
	(0.423)	(−2.253)	(2.547)	(0.984)
AGEM	20.238	0.041***	0.008*	0.004
	(4.210)	(4.850)	(1.825)	(1.133)
OWNHOUSE	0.920	0.253**	0.010	-0.044
	(0.271)	(2.275)	(0.168)	(−0.914)
OWNLAND	0.126	−0.123	−0.008	0.018
	(0.332)	(−1.362)	(−0.177)	(0.469)
MUN POBLACION	0.156	−0.284**	0.042	0.108
	(0.363)	(−2.365)	(0.677)	(2.078)
RURAL	0.705	−0.160	0.207***	0.158***
	(0.456)	(−1.369)	(3.451)	(3.137)
RURAL x TRAVELPOB	45.221	−0.001	−0.0002	−0.001***
	(70.745)	(−1.028)	(−0.719)	(−2.615)
RESBGY (5+)	0.862	−0.104	0.003	0.047
	(0.345)	(−1.199)	(0.064)	(1.265)
CAM SUR	0.599	0.086	−0.005	−0.041
	(0.490)	(0.985)	(−0.110)	(−0.081)
ALBAY	0.255	0.034	−0.148***	−0.089**
	(0.436)	(0.343)	(−2.946)	(−2.103)
PPARITY73 (3-4)	0.240	−0.100	0.093*	0.004
	(0.427)	(−1.173)	(1.920)	(0.106)
PPARITY73 (5-6)	0.202	0.204*	0.135**	0.044
	(0.402)	(1.780)	(2.301)	(0.896)
PPARITY73 (7+)	0.315	0.437***	0.173***	0.110**
	(0.465)	(3.391)	(2.604)	(1.970)
WAGEW	−0.100	0.017	0.085	0.102*
	(0.453)	(0.132)	(1.248)	(1.790)
WAGEH	0.481	−0.535***	0.315***	0.080
	(0.326)	(−2.894)	(3.317)	(0.162)
Constant		1.633	0.052	0.067
$\bar{R}^2$		0.322	0.145	0.069
F		24.293	9.315	4.650
n		981	981	981

Table 18 (Continued)

Variables	Mean[a]	BIRTH73[b]	FPUSEA73[b]	FPUSEM73[b]
Mean		1.417	0.431	0.200
Std. Dev.		1.083	0.495	0.400

[a]Standard deviation in parenthesis.
[b]t-value in parenthesis.
* ** ***Significant at the 0.10, 0.05 and 0.01 levels, respectively.

Table 19. Regression on Fertility and Family Planning Practice During the 1973-1977 Period, Bicol River Basin, 1978.

Variables	Mean[a]	BIRTH73[b]	FPUSEA73[b]	FPUSEM73[b]
AGEW73 (25-29)	0.241	−0.338***	−0.061	0.065
	(0.428)	(−3.116)	(−1.085)	(1.375)
AGEW73 (30-34)	0.215	−0.700***	−0.207***	−0.054
	(0.411)	(−5.538)	(−3.141)	(−0.978)
AGEW73 (35-39)	0.205	−1.262***	−0.236***	−0.133**
	(0.404)	(−8.921)	(−3.239)	(−2.173)
AGEW73 (40-44)	0.201	−2.035***	−0.476***	−0.254***
	(0.401)	(−13.619)	(−6.190)	(−3.923)
EDW (5-7)	0.485	−0.004	0.108***	0.048
	(0.500)	(−0.061)	(2.980)	(1.587)
EDW (8+)	0.232	−0.338***	0.268***	0.120***
	(0.423)	(−3.730)	(5.737)	(3.059)
AGEM	20.238	0.040***	0.010**	0.005
	(4.210)	(4.728)	(2.314)	(1.385)
OWNHOUSE	0.920	0.255**	0.007	−0.036
	(0.271)	(2.292)	(0.125)	(−0.752)
OWNLAND	0.126	−0.121	−0.033	0.013
	(0.332)	(−1.336)	(−0.717)	(0.334)
MUN POBLACION	0.156	−0.199*	−0.028	0.064
	(0.363)	(−1.806)	(−0.486)	(1.331)
RURAL	0.705	0.025	0.032	0.105***
	(0.456)	(0.265)	(0.662)	(2.611)
RURAL x TRAVELPOB	45.221	−0.0001	−0.0005**	−0.001***
	(70.745)	(−0.287)	(−2.051)	(−2.759)
RESBGY (5+)	0.852	−0.110	0.007	0.050
	(0.345)	(−1.277)	(0.161)	(1.335)
CAM SUR	0.599	0.074	0.032	−0.027
	(0.490)	(0.833)	(0.704)	(−0.703)
ALBAY	0.255	−0.013	−0.099*	−0.071*
	(0.436)	(−0.133)	(−1.941)	(−1.645)
PPARITY (3-4)	0.240	−0.121	0.092*	0.005
	(0.427)	(−1.283)	(1.900)	(10.120)

Table 19 (Continued)

Variables	*Mean*[a]	*BIRTH73*[b]	*FPUSEA73*[b]	*FPUSEM73*[b]
PPARITY (5-6)	0.202	0.184	0.142**	0.044
	(0.402)	(1.610)	(2.405)	(0.888)
PPARITY (7+)	0.315	0.414***	0.189***	0.113**
	(0.465)	(3.214)	(2.858)	(2.017)
AELEC	0.391	−0.151**	−0.019	−0.005
	(0.488)	(−2.193)	(−0.533)	(−0.157)
IRRIG	0.545	−0.131**	0.058*	0.026
	(0.498)	(−2.205)	(1.900)	(1.018)
HOUSE	0.584	0.161**	−0.146***	−0.059**
	(0.493)	(2.511)	(−4.413)	(−2.130)
Constant		1.344	0.269	0.061
$\bar{R}^2$		0.325	0.144	0.069
		23.444	8.879	4.463
		981	981	981
Mean		0.431	0.431	0.200
Std. Dev.		0.495	0.495	−0.400

[a]Standard deviation in parenthesis.
[b]t-value in parenthesis.
* ** ***Significant at the 0.10, 0.05 and 0.01 levels, respectively.

contraception arising from experiences prior to marriage, such experiences may include labor force participation.

(6) The areal variables tend to exhibit the same inconsistent pattern as revealed earlier, e.g., family planning use tend to be higher in the rural barangays than in the city/poblacion. However, we note that the practice of modern family planning methods declines with distance from the poblacion. Finally, women in Albay tend to practice less contraception than their counterparts in Camarines Sur and Sorsogon.

(7) Of great interest is the relationship between past fertility on the one hand, and current fertility and current family planning behavior on the other. One would expect that women with higher number of children at the beginning of the reference period would tend to have less births during this period, since these women would already be close to achieving their desired fertility. Consequently, they are expected to use family planning methods more than their lower previous fertility counterparts.

The results of the regression, however, show that women with higher number of children, PPARITY73, at the beginning of the reference period tended to have more births during the interval 1973-1977. On the other hand, PPARITY73 is positively related to family planning use, FPUSEA73 and FPUSEM73, respectively. What might explain these apparent inconsistencies? Several hypotheses may be

Table 20. Regression on Fertility and Family Planning Practice During the 1973-1977 Period, Bicol River Basin, 1978.

Variables	*Mean*[a]	*BIRTH73*[b]	*FPUSEA73*[b]	*FPUSEM73*[b]
AGEW73 (25-29)	0.241	−0.339***	−0.080	0.055
	(0.428)	(−3.195)	(−1.466)	(1.200)
AGEW73 (30-34)	0.215	−0.666***	−0.221***	−0.060
	(0.411)	(−5.411)	(−3.509)	(−1.136)
AGEW73 (35-39)	0.205	−1.218***	−0.250***	−0.137**
	(0.404)	(−9.026)	(−3.612)	(−2.354)
AGEW73 (40-44)	0.201	−2.005***	−0.490***	−0.259***
	(0.401)	(−13.976)	(−6.675)	(−4.186)
EDW (5-7)	0.485	0.017	0.069*	0.022
	(0.500)	(0.205)	(1.691)	(0.651)
EDW (8+)	0.232	−0.280**	0.167**	0.054
	(0.423)	(−2.178)	(2.538)	(0.978)
AGEM	20.238	0.040***	0.008*	0.004
	(4.210)	(4.794)	(1.946)	(1.210)
OWNHOUSE	0.920	0.246**	0.009	−0.047
	(0.271)	(2.207)	(0.159)	(−0.981)
OWNLAND	0.126	−0.126	−0.008	0.018
	(0.332)	(−1.393)	(−0.181)	(0.452)
MUN POBLACION	0.156	−0.287**	0.043	0.108**
	(0.363)	(−2.382)	(0.692)	(2.075)
RURAL	0.705	−0.156	0.210***	0.160***
	(0.456)	(−1.335)	(3.509)	(3.162)
RURAL x TRAVELPOB	45.221	−0.001	−0.0002	−0.001***
	(70.745)	(−1.011)	(−0.753)	(−2.622)
RESBGY (5+)	0.862	−0.101	0.006	0.047
	(0.345)	(−1.166)	(0.133)	(1.273)
CAM SUR	0.599	0.102	−0.005	−0.037
	(0.490)	(1.167)	(−0.108)	(−0.987)
ALBAY	0.255	0.040	−0.149***	−0.087**
	(0.436)	(0.408)	(−2.972)	(−2.063)
PLIV CHILD73 (3-4)	0.267	0.011	0.112**	0.033
	(0.443)	(0.121)	(2.472)	(0.854)
PLIV CHILD73 (5-6)	0.225	0.223**	0.158***	0.080*
	(0.418)	(2.050)	(2.835)	(1.707)
PLIV CHILD73 (7+)	0.226	0.505***	0.064***	0.126**
	(0.419)	(4.024)	(2.838)	(2.322)
WAGEW	−0.100	−0.001	0.068	0.100*
	(0.453)	(−0.010)	(1.261)	(1.761)
WAGEH	0.481	−0.526***	0.316***	0.014
	(0.326)	(−2.840)	(3.326)	(0.171)
Constant		1.616	0.041	0.058
$\bar{R}^2$		0.320	0.147	0.069
F		24.031	9.472	4.654
n		981	981	981

Table 20 (Continued)

Variables	*Mean*[a]	*BIRTH73*[b]	*FPUSEA73*[b]	*FPUSEM73*[b]
Mean		1,417	0.431	0.200
Std. Dev.		1.083	0.495	0.400

[a]Standard deviation in parenthesis.
[b]t-value in parenthesis.
* ** ***Significant at the 0.10, 0.05 and 0.01 levels, respectively.

Table 21. Regression on Fertility and Family Planning Practice During the 1973-1977 Period, Bicol River Basin, 1978.

Variables	*Mean*[a]	*BIRTH73*[b]	*FPUSEA73*[b]	*FPUSEM73*[b]
AGEW73 (25-29)	0.241	−0.371***	−0.056	0.057
	(0.428)	(3.541)	(−1.039)	(1.243)
AGEW73 (30-34)	0.215	−0.704***	−0.200***	−0.059
	(0.411)	(5.779)	(−3.197)	(−1.122)
AGEW73 (35-39)	0.205	−1.260***	−0.227***	−0.135**
	(0.404)	(−9.418)	(−3.304)	(−2.332)
AGEW73 (40-44)	0.201	−2.040***	−0.468***	−0.255***
	(0.401)	(−14.346)	(−6.402)	(−4.137)
EDW (5-7)	0.485	0.002	0.109***	0.049
	(0.500)	(0.035)	(3.019)	(1.595)
EDW (8+)	0.232	−0.334***	0.269***	0.120***
	(0.423)	(−3.678)	(5.764)	(3.044)
AGEM	20.238	0.040***	0.010**	0.005
	(4.210)	(4.778)	(2.327)	(1.414)
OWNHOUSE	0.920	0.243**	0.005	−0.040
	(0.271)	(2.188)	(0.091)	(−0.831)
OWNLAND	0.126	−0.125	0.033	0.013
	(0.332)	(−1.383)	(−0.708)	(0.324)
MUN POBLACION	0.156	−0.193*	−0.027	0.064
	(0.363)	(−1.752)	(−0.473)	(1.338)
RURAL	0.705	0.032	0.034	0.107***
	(0.456)	(0.347)	(0.708)	(2.651)
RURAL x TRAVELPOB	45.221	−0.0002	−0.001**	−0.001**
	(70.745)	(−0.315)	(−2.136)	(−2.791)
RESBGY (5+)	0.852	−0.109	0.011	0.050
	(0.345)	(−1.262)	(0.239)	(1.347)
CAM SUR	0.599	0.088	0.032	−0.024
	(0.490)	(0.992)	(0.696)	(−0.626)
ALBAY	0.255	−0.010	−0.102**	−0.070*
	(0.436)	(−0.098)	(−1.997)	(−1.633)
PLIV CHILD73 (3-4)	0.267	0.011	0.102**	0.029
	(0.443)	(0.120)	(4.243)	(0.752)

Table 21 (Continued)

Variables	*Mean*[a]	*BIRTH73*[b]	*FPUSEA73*[b]	*FPUSEM73*[b]
PLIV CHILD73 (5-6)	0.225	0.226**	0.159***	0.078*
	(0.418)	(2.084)	(2.851)	(1.656)
PLIV CHILD73 (7+)	0.226	0.509***	0.184***	0.122**
	(0.419)	(4.062)	(2.855)	(2.255)
AELEC	0.391	−0.153**	−0.021	−0.005
	(0.488)	(−2.220)	(−0.595)	(−0.161)
IRRIG	0.565	−0.134**	0.058*	0.025
	(0.494)	(−2.260)	(1.899)	(0.983)
HOUSE	0.584	0.177***	−0.140***	−0.056**
	(0.493)	(2.747)	(−4.247)	(−1.994)
Constant		1.313	0.268	0.056
$\bar{R}^2$		0.323	0.146	0.069
F		23.301	8.949	4.443
n		981	981	981
Mean		0.431	0.431	0.200
Std. Dev.		0.495	0.495	0.400

[a]Standard deviation in parenthesis.
[b]t-value in parenthesis.
* ** ***Significant at the 0.10, 0.05 and 0.01 levels, respectively.

suggested. First, the PPARITY73 variable does not take into account child deaths. Higher PPARITY73 women may also have larger numbers of child deaths, hence given the demand for a certain number of surviving children, these women may be observed to be "replacing" these dead children with current births. To eliminate this possibility, we ran another regression replacing PPARITY73 with the number of surviving children prior to the reference period, PLIVCHILD73. This is shown in Table 19. The effect of PLIVCHILD73 is still positive on BIRTH73 as well as on the two family planning variables. Hence, the potential confounding effect of child deaths is not important.

A second possible interpretation is that women who have had higher fertility in the past would tend to be those women who are more fecund.* (Note that we have already controlled for age of women, age at marriage, and demand for children-related variables, but not adequately for supply-related variables.) These more fecund women would then be expected to continue their high fertility into the current period.

Another possible explanation is related to the effect of temporary separation among spouses. All things being equal, spouses who tend to be separated more often, e.g., the husband temporarily migrates to find work, would tend to have

*This interpretation was suggested by Dr. Vicente B. Paqueo.

lower fertility in the past as well as in the present. Additionally, this type of couple would tend to practice less contraception because there is less need to do so. On the other hand, spouses who are always together will tend to have larger number of children in the past and would tend to continue to do so in the current period.

Finally, there is the possibility that higher previous parity women tend to be women who do not breastfeed their infants, so that birth intervals tend to be shorter. Thus, they will be observed to have more births both in the past and in the current period compared to breastfeeding mothers.

Clearly, the effect of such factors as temporary separation of spouses which might be important in the Bicol context, and breast-feeding on fertility and birth intervals needs to be looked into. In populations which are still characterized by high fertility such as Bicol, the above intermediate variables may have significant impacts on fertility differentials. Unfortunately, the 1978 BMS do not have the data on these intermediate variables as they are related to pregnancy or birth intervals.* We therefore leave this matter for future investigation.

The effect of PPARITY73 or PLIV CHILD73 on the use of family planning is positive as expected. However, the fact that higher PPARITY73 or PLIV CHILD73 women also had more births during the period may indicate contraceptive failure, i.e., the higher recent births occurred in spite of family planning use due to improper use of the method or to discontinued use of the method arising from lack of supplies, side effects, etc. The possibility of simultaneity of relationships cannot be discounted, however. On the one hand, higher recent births may be due to contraceptive failures among users as suggested above. On the other hand, the greater use of contraception among high previous parity women who continued to have high fertility in the current period might reflect the increased desire for these women to practice contraception precisely to limit their already high past and current fertility. Additional work in determining the simultaneous relationships between births and family planning use is therefore recommended.

Tables 19 and 21 examine the correlates of current fertility and family planning practice using a different specification to highlight the role of rural development efforts. As can be readily noted, both AELEC and IRRIG are negatively and significantly related to BIRTH73 while IRRIG is positively and significantly related to FPUSE73. Furthermore, the use of family planning methods tend to decline with increasing travel time from the rural barangay to the poblacion, suggesting the important role road development can play in improving access to basic services such as family planning services.

Fertility and Family Planning Practice During the Two-Year Period, 1976-1977. The impact of development variables on the most recent fertility and family planning behavior can be examined from Tables 22 and 23. The findings are more or less similar as those found for the period 1973-1977.

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*As described in Section III, breastfeeding information was obtained only for living children born during the past two years.

Table 22. Regression on Fertility and Family Planning Practice During the 1976-1977 Period, Bicol River Basin, 1978.

Variables	*Mean*[a]	*BIRTH76*[b]	*CEFPUSEA76*[b]	*CFPUSEM76*[b]
AGEW76 (25-29)	0.190	−0.066	−0.018	0.009
	(0.392)	(−0.680)	(−0.214)	(0.165)
AGEW76 (30-34)	0.232	0.199**	−0.043	−0.059
	(0.423)	(−1.964)	(−0.506)	(−1.080)
AGEW76 (35-39)	0.217	−0.356***	−0.135	−0.097**
	(0.412)	(−3.369)	(1.527)	(−1.708)
AGEW76 (40-44)	0.201	−0.666***	−0.228***	−0.139***
	(0.401)	(−6.067)	(−2.480)	(−2.336)
AGEW76 (45-49)	0.122	−0.909***	−0.367***	−0.171***
	(0.328)	(−7.953)	(−3.833)	(−2.774)
EDW (5-7)	0.485	0.110**	0.030	0.025
	(0.500)	(2.371)	(0.777)	(1.016)
EDW (8+)	0.232	−0.072	0.115*	0.048
	(0.423)	(−0.949)	(1.807)	(1.157)
AGEM	20.237	0.016***	0.003	0.0004
	(4.210)	(3.454)	(0.815)	(0.165)
OWNHOUSE	0.920	0.149**	0.044	0.041
	(0.271)	(2.261)	(0.800)	(1.138)
OWNLAND	0.126	−0.020	−0.013	−0.031
	(0.332)	(−0.365)	(−0.297)	(−1.085)
RESBGY (5+)	0.862	−0.023	−0.027	0.018
	(0.345)	(−0.455)	(−0.619)	(0.654)
MUN POBLACION	0.156	−0.183**	0.031	0.017
	(0.363)	(−2.563)	(0.522)	(0.445)
RURAL	0.705	−0.139**	0.178***	0.030
	(0.456)	(−1.988)	(3.053)	(0.785)
RURAL x TRAVELPOB	45.221	−0.0002	−0.0001	−0.0002
	(70.745)	(−0.716)	(−0.271)	(−1.147)
CAM SUR	0.599	0.001	−0.025	−0.086***
	(0.490)	(0.015)	(−0.581)	(−3.055)
ALBAY	0.255	0.015	−0.147***	−0.090***
	(0.436)	(0.251)	(−2.998)	(−2.858)
PLIV CHILD76 (3-4)	0.282	0.026	0.114**	0.013
	(0.450)	(0.469)	(2.497)	(0.432)
PLIV CHILD76 (5-6)	0.261	0.047	0.127**	0.045
	(0.439)	(0.749)	(2.423)	(1.324)
PLIV CHILD76 (7+)	0.293	0.213***	0.104*	0.021
	(0.455)	(3.052)	(1.774)	(0.545)
$\hat{\text{WAGEW}}$	−0.100	−0.062	0.036	−0.014
	(0.453)	(−0.788)	(0.554)	(−0.337)
$\hat{\text{WAGEH}}$	0.481	−0.139	0.368***	0.080
	(0.326)	(−1.252)	(3.980)	(1.344)
Constant		0.536	0.0002	0.094
$\bar{R}^2$		0.211	0.114	0.045

Table 22 (Continued)

Variables	*Mean*[a]	*BIRTH76*[b]	*CEFPUSEA76*[b]	*CFPUSEM76*[b]
		13.445	7.024	3.263
n		981	981	981
Mean		0.587	0.334	0.095
Std. Dev.		0.596	0.472	0.293

[a]Standard deviation in parenthesis.
[b]t-value in parenthesis.
* ** ***Significant at the 0.10, 0.05 and 0.01 levels, respectively.

Table 23. Regression on Fertility and Family Planning Practice During the 1976-1977 Period, Bicol River Basin, 1978.

Variables	*Mean*[a]	*BIRTH76*[b]	*CFPUSEA76*[b]	*CFPUSEM76*[b]
AGEW76 (25-29)	0.190	−0.074	0.006	0.013
	(0.392)	(−0.756)	(0.072)	(0.252)
AGEW76 (30-34)	0.232	−0.216**	0.006	−0.050
	(0.423)	(−2.157)	(0.073)	(−0.920)
AGEW76 (35-39)	0.217	−0.372***	−0.085	−0.088
	(0.412)	(−3.546)	(−0.964)	(−1.558)
AGEW76 (40-44)	0.201	−0.685***	−0.171*	−0.128**
	(0.401)	(−6.302)	(−1.860)	(−2.174)
AGEW76 (45-49)	0.122	−0.924***	−0.322***	−0.164***
	(0.328)	(−8.132)	(−3.352)	(−2.672)
EDW (5-7)	0.485	0.088**	0.064*	0.026
	(0.500)	(2.114)	(1.814)	(1.152)
EDW (8+)	0.232	−0.134**	0.209***	0.048*
	(0.423)	(−2.479)	(4.586)	(1.652)
AGEM	20.237	0.016***	0.004	0.0004
	(4.210)	(3.313)	(0.976)	(0.156)
OWNHOUSE	0.920	0.150**	0.032	0.040
	(0.271)	(2.268)	(0.575)	(1.109)
OWNLAND	0.126	−0.013	−0.031	−0.035
	(0.332)	(−0.246)	(−0.677)	(−1.191)
RESBGY (5+)	0.862	−0.026	−0.017	0.020
	(0.345)	(−0.504)	(−0.406)	(0.709)
MUN POBLACION	0.156	−0.138**	−0.034	0.012
	(0.363)	(−2.102)	(−0.620)	(0.325)
RURAL	0.705	−0.053	0.011	0.005
	(0.456)	(−0.932)	(0.241)	(0.162)
RURAL x TRAVELPOB	45.221	−0.0001	−0.0004*	−0.0003*
	(70.745)	(−0.339)	(−1.773)	(−1.693)
CAM SUR	0.599	−0.011	−0.007	−0.082***
	(0.490)	(−0.209)	(−0.165)	(−2.865)

Table 23 (Continued)

Variables	*Mean[a]*	*BIRTH76[b]*	*CFPUSEA76[b]*	*CFPUSEM76[b]*
ALBAY	0.255	−0.007	−0.120**	0.085
	(0.436)	(−0.1 14)	(−2.386)	(−2.651)
PLIV CHILD76 (3-4)	0.282	0.027	0.106**	0.011
	(0.450)	(0.500)	(2.311)	(0.381)
PLIV CHILD76 (5-6)	0.261	0.49	0.118**	0.043
	(0.439)	(0.787)	(2.235)	(1.273)
PLIV CHILD76 (7+)	0.293	0.213***	0.100*	0.019
	(0.455)	(3.057)	(1.691)	(0.515)
AELEC	0.391	−0.011	0.031	0.011
	(0.488)	(−0.258)	(0.899)	(0.501)
IRRIG	0.545	−0.053	0.055*	−0.0004
	(0.498)	(−1.487)	(1.828)	(−0.024)
HOUSE	0.584	0.068*	−0.084***	−0.019
	(0.493)	(1.775)	(−2.608)	(−0.904)
Constant		0.461	0.223	0.152
R^2		0.211	0.101	0.044
F		12.879	5.985	3.073
n		981	981	981
Mean		0.527	0.334	0.095
Std. Dev.		0.596	0.472	0.293

[a]Standard deviation in parenthesis.
[b]t-value in parenthesis.
* ** ***Significant at the 0.10, 0.05 and 0.01 levels, respectively.

Table 24. Regression on Current Fertility Preferences and Current Use of Famiy Planning Methods, Bicol River Basin, 1978.

Variables	*Mean[a]*	*ADDCHILD[b]*	*CFPUSEA[b]*	*CFPUSEN[b]*
AGEW (25-29)	0.135	−0.033	−0.126	−0.087
	(0.341)	(−0.469)	(−1.412)	(−1.620)
AGEW (30-34)	0.233	−0.101	−0.068	−0.004
	(0.423)	(−1.458)	(−0.760)	(0.069)
AGEW (35-39)	0.209	−0.114	−0.140	−0.054
	(0.407)	(−1.577)	(−1.500)	(−0.969)
AGEW (40-44)	0.199	−0.160**	−0.209**	−0.082
	(0.399)	(−2.160)	(−2.185)	(−1.421)
AGEW 45-49)	0.195	−0.184**	−0.340***	−0.112*
	(0.396)	(−2.452)	(−3.500)	(−1.919)
EDW (5-7)	0.493	−0.042	0.019	0.006
	(0.500)	(−1.427)	(0.515)	(0.271)
EDW (8+)	0.229	−0.025	0.097	0.036
	(0.421)	(−0.523)	(1.587)	(0.985)

Table 24 (Continued)

Variables	*Mean*[a]	*ADDCHILD*[b]	*CFPUSEA*[b]	*CFPUSEN*[b]
AGEM	20.119	0.001	−0.001	0.002
	(4.209)	(0.471)	(−0.145)	(−0.750)
OWNHOUSE	0.922	0.017	0.001	0.031
	(0.269)	(0.416)	(0.025)	(0.972)
OWNLAND	0.129	−0.019	0.003	−0.036
	(0.335)	(−0.572)	(0.072)	(−1.388)
MUN POBLACION	0.155	0.051	0.084	0.045
	(0.362)	(1.132)	(1.459)	(1.288)
RURAL	0.708	0.092**	0.183***	0.032
	(0.455)	(2.113)	(3.266)	(0.945)
RURAL x TRAVELPOB	45.729	0.0001	−0.0001	−0.0002
	(70.568)	(0.716)	(−0.565)	(−1.145)
RESBGY (5+)	0.857	−0.045	0.035	0.028
	(0.351)	(−1.473)	(0.853)	(1.151)
CAM SUR	0.601	0.047	0.007	−0.059**
	(0.490)	(1.467)	(0.167)	(−2.340)
ALBAY	0.254	−0.029	−0.088*	−0.059**
	(0.436)	(−0.806)	(−1.885)	(−2.096)
LIVING CHILD (3-4)	0.279	−0.284***	0.141***	0.026
	(0.449)	(−1.260)	(2,791)	(0.857)
LIVING CHILD (5-6)	0.287	−0.378***	0.102*	0.006
	(0.452)	(−9.097)	(1.898)	(0.173)
LIVING CHILD (7+)	0.329	−0.427***	0.093	−0.025
	(0.470)	(−9.456)	(1.593)	(−0.707)
$\widehat{WAGEW}$	−0.103	0.045	0.033	0.004
	(0.448)	(0.917)	(0.522)	(0.108)
$\widehat{WAGEH}$	0.475	0.050	0.324***	0.049
	(0.326)	(0.728)	(3.659)	(0.912)
Constant		0.516	0.042	0.118
$\bar{R}^2$		0.182	0.099	0.045
F		11.696	6.297	3.267
n		1,011	1,011	1,011
Mean		0.163	0.292	0.076
Std. Dev.		0.370	0.455	0.265

[a]Standard deviation in parenthesis.
[b]t-value in parenthesis.
* ** ***Significant at the 0.10, 0.05 and 0.01 levels, respectively.

Desire for Additional Children and Family Planning Practice. Tables 24 and 25 present the results of regression on current fertility preferences and current use of contraceptive methods. The sample of women are the same as in the previous case. The period of reference is the time of interview where women were asked about whether or not they want additional children, and whether or not they are currently practicing a specific method of contraception. Our major interest in this analysis is to examine whether current fertility preference are matched by appropriate contraceptive behavior to effectuate such preferences. We would expect women who report that they desire no more additonal children to practice family planning, especially the more effective methods. If they do not, either they are not serious about their desires or that they are unable to practice family planning due to constraints related to lack of knowledge or steady supply of services. The results are summarized below.

(1) Older women tend to desire less additional births but practice less contraception, perhaps due to the belief that they are no longer fecund and therefore no longer need such practice. It might also be that they are unable to do so due to high effective cost of contraception.

(2) Women with larger numbers of surviving children desire less additional births as expected, but they also practice less contraception which is unexpected.

(3) Rural women tend to desire more additional children and also tend to practice contraception more than women in cities or poblacions.

(4) Neither the wage rates of the husband nor the wife are significantly related to ADDCHILD but the husband's wage is positively related to use of some method of contraception, CFPUSEA.

It would thus appear on the basis of these results that current fertility preferences are not matched by effective use of contraception. Thus, either the desires are not real, or if real, the effective cost of contraception is too high preventing potential users from actually using specific methods. Note the level of contraception in the current period is 29 percent for all methods and only 8 percent for modern methods.

Index of Family Planning Efforts. An important factor influencing the prevalence of contraceptive use is the effort provided by the family planning program. This program is expected to provide information on specific contraceptive methods and providjng services to those who desire to practice contraception. How well is the program being implemented in the Bicol River Basin? As a partial answer to such question, we examined below the correlates of one indicator of family planning effort, namely, the extent to which eligible women are visited by a family planning personnel or other government workers who talk to these women about family planning (FPPVISIT). The reference period is 1972-1977, and the data refers to women who reported being ever visited by a family planning or government worker. Table 26 presents the results of the regression on FPPVISIT.

As the results indicate, family planning workers tend to visit women who are highly educated, women who reside in electrified and irrigated areas, and women in rural barangays. Women who are visited less include those living farther away from the rural barangays and those who are relatively poor as proxied by the HOUSE variable. Interestingly enough, family planning workers do not seem to discriminate between women of different age groups or of women with high or low previous parity. One would expect, for example, that family planning workers

Table 25. Regression on Current Fertility Preferences and Current Use of Family Planning Methods, Bicol River Basin, 1978.

Variables	*Mean*[a]	*ADDCHILD*[b]	*CFPUSEA*[b]	*CFPUSEM*[b]
AGEW (25-29)	0.135	−0.031	−0.126	−0.086
	(0.341)	(−0.441)	(−1.400)	(−1.595)
AGEW (30-34)	0.233	−0.094	−0.045	0.003
	(0.423)	(−1.355)	(−0.501)	(0.053)
AGEW (35-39)	0.209	−0.104	−0.109	−0.044
	(0.407)	(−1.134)	(−1.162)	(0.778)
AGEW (40-44)	0.199	−0.150**	−0.177*	−0.072
	(0.399)	(−2.021)	(−1.848)	(1.253)
AGEW (45-49)	0.195	−0.173**	−0.307***	−0.101*
	(0.396)	(−2.300)	(−3.151)	(−1.731)
EDW (5-7)	0.493	−0.026	0.047	0.012
	(0.500)	(−0.985)	(−1.397)	(0.594)
EDW (8+)	0.229	0.023	0.181***	0.057**
	(0.421)	(0.678)	(4.147)	(2.191)
AGEM	20.119	0.022	−0.0001	−0.002
	(4.209)	(0.569)	(−0.022)	(−0.800)
OWNHOUSE	0.922	0.014	−0.007	0.027
	(0.269)	(0.335)	(−0.127)	(0.838)
OWNLAND	0.129	−0.019	−0.004	−0.034
	(0.335)	(−0.579)	(−0.105)	(−1.340)
MUN POBLACION	0.155	0.022	0.018	0.032
	(0.362)	(0.546)	(0.330)	(1.013)
RURAL	0.708	0.052	0.044	0.013
	(0.455)	(1.492)	(0.987)	(0.495)
RURAL x TRAVELPOB	45.729	0.0001	−0.0004*	−0.0002
	(70.569)	(0.525)	(−1.755)	(−1.523)
RESBGY (5+)	0.857	−0.044	0.045	0.031
	(0.351)	(−1.389)	(1.105)	(1.291)
CAM SUR	0.601	0.046	0.013	−0.064**
	(0.490)	(1.415)	(0.305)	(−2.502)
ALBAY	0.254	−0.026	−0.072	−0.64**
	(0.436)	(−0.714)	(−1.501)	(−2.241)
LIVING CHILD (3-4)	0.279	−0.284***	0.140***	0.025
	(0.449)	(−7.250)	(2.759)	(0.826)
LIVING CHILD (5-6)	0.287	−0.378***	0.102*	0.003
	(0.452)	(−9.084)	(1.889)	(.0.092)
LIVING CHILD (7+)	0.329	−0.427***	0.092	−0.026
	(0.470)	(−9.445)	(1.576)	(−0.745)
AELEC	0.386	0.015	0.072**	0.024
	(0.487)	(0.576)	(2.180)	(1.214)
IRRIG	0.550	0.033	0.029*	0.008
	(0.498)	(1.482)	(1.936)	(0.453)
HOUSE	0.591	−0.007	0.031	0.016
	(0.492)	(−0.292)	(−1.894)	(0.885)

Table 25 (Continued)

Variables	*Mean*[a]	*ADDCHILD*[b]	*CFPUSEA*[b]	*CFPUSEM*[b]
Constant		0.518	0.215	0.128
$\bar{R}^2$		0.181	0.090	0.045
F		11.131	5.521	3.158
n		1,011	1,011	1,011
Mean		0.163	0.292	0.076
Std. Dev.		0.370	0.455	0.265

[a]Standard deviation in parenthesis.
[b]t-value in parenthesis.
* ** ***Significant at the 0.10, 0.05 and 0.01 levels, respectively.

Table 26. Regression on Family Planning Efforts (FPPVISIT) Bicol River Basin, 1978.

Variables	*Mean*	*Std. Dev.*	*Coefficient*	*t-value*
AGEW (25-29)	0.135	0.341	0.075	0.799
AGEW (30-34)	0.233	0.423	0.151	1.590
AGEW (35-39)	0.209	0.407	0.152	1.531
AGEW (40-44)	0.199	0.399	−0.053	−0.518
AGEW (45-49)	0.195	0.396	−0.007	−0.063
EDW (5-7)	0.493	0.500	0.065*	1.812
EDW (8+)	0.229	0.421	0.127**	2.742
OWNLAND	0.129	0.335	−0.087*	−1.894
MUN POBLACION	0.155	0.362	0.035	0.611
RURAL	0.708	0.455	0.088	1.833
RURAL x TRAVELPOB	45.729	70.568	−0.0006*	−2.650
RESBGY (5+)	0.857	0.351	0.029	0.664
CAM SUR	0.601	0.490	−0.053	−1.171
ALBAY	0.254	0.436	0.009	0.183
PPARITY (3-4)	0.234	0.424	0.005	0.107
PPARITY (5-6)	0.196	0.397	0.001	0.013
PPARITY (7+)	0.306	0.461	0.072	1.263
AELEC	0.386	0.487	0.112***	3.147
IRRIG	0.550	0.498	0.067**	2.193
HOUSE	0.591	0.492	−0.056*	−1.711
Constant			0.143	
$\bar{R}^2$			0.068	
F			4.679	
n			1,010	
Mean			0.361	
Std. Dev.			0.481	

* ** ***Significant at the 0.10, 0.05 and 0.01 levels, respectively.

would tend to put more efforts on visiting women who already have larger numbers of children. This does not appear to be the case on the average as suggested by our results.

One noteworthy finding, however, is that family planning visits tend to concentrate in rural areas, than in poblacions or in cities, although such visits decline with increasing distance to the poblacion. This may explain the consistent findings earlier which reveal higher family planning use among rural women in poblacions or in cities, after controlling for personal and household factors.

Conclusion

This study on the correlates of fertility and family planning behavior in the Bicol River Basin is part of a larger study aimed at assessing the long term impact of rural development programs in the area. A major survey conducted in 1978 provided most of the baseline data upon which future assessment of impact can be based. The 1983 survey currently being fielded should offer greater possibilities for assessing impact within a dynamic framework. Thus far, our assessment have relied only upon cross-sectional analysis, and inferences regarding impact must necessarily be guarded. The overall results may be summarized as follows.

(1) Analysis of the 1978 BMS demographic data reveal high fertility in Bicol relative to the national average and this finding is consistent with independent estimates obtained by the Area Fertility Surveys of 1979 and 1980 and the National Demographic Surveys of 1968, 1973 and 1978. The relatively low levels of development in Bicol are implicated as creating conditions supporting high fertility in the region.

(2) However, signs of change in fertility and family planning behavior are evident in the data, and that these changes especially in the more recent periods can be directly and indirectly related to the impact of development programs in the area. Thus, we find that rural electrification, provision of irrigation and development of rural road networks are positively related to increased wage rates of husbands and wives, and that these changes in the wage rates in turn significantly influenced current fertility and family planning behavior as well as child survival rates.

(3) Intensification of rural development efforts in Bicol is clearly needed both to consolidate the gains already achieved as well as to strengthen the region's capacity for self-sustaining economic and demographic development. With respect to family planning efforts, program emphasis might be placed on specific areas and target groups which might have high expected pay-offs. For example, family planning use is consistently lower in Albay than in the other provinces. The pattern of family planning visits do not appear to discriminate between high versus low parity women. Women who reported they no longer want additional children are found not to be practicing contraception enough to make their fertility desires effective. Relatively few women reported mass media as a major source of family

planning information. Considerations of these findings could provide the basis for strengthening family planning program efforts in the area.

(4) Data from the second round BMS currently being conducted should provide additional information for a systematic assessment of fertility impacts of rural development. This leads us to a consideration of how demographic data may be collected more efficiently in future surveys. With the benefit of hindsight, it would appear that a detailed pregnancy history approach would at once be able to collect information more effectively on all live births, infant and child mortality, pregnancy wastage, and with possible modifications, on breastfeeding, incidence of temporary separation of spouses, and the timing of the use of contraception. These information should allow more refined analysis of fertility change in a low income setting where biological factors might still be significant factors in determining fertility differentials. Similarly, in the area of impact assessment, the detailed data on pregnancy intervals may provide additional sensitive indicators of emerging patterns of fertility behavior. On the other hand, direct information on current mortality may not provide sufficiently stable estimates, especially of adult mortality, given the limited sample size. Hence, general mortality studies, if desired, may have to rely on data sources other than the BMS. Additional questions on the migration of household members would be extremely useful in understanding the mechanisms by which low income households cope with poverty. Matching of households in two surveys should capture the migration of entire households. Migrant households could then be examined for their characteristics and inferences could be made regarding the determinants of migration in the context of the development programs already in place or yet to be implemented. The prospects for a more systematic assessment of the demographic impact of rural development appears bright. This should lead not only to more information immediately needed for policy and program purposes, but should also lead to a greater understanding of the dynamics of social change in contemporary rural settings.

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BACTERIA IDENTIFIED IN DIARRHEAL STOOLS OF EARLY CHILDHOOD AND SENSITIVITY TESTS, METRO MANILA (1980-1982)

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Introduction

Despite remarkable advances in medicine and public health, diarrheal diseases continue to be a major cause of morbidity and mortality in childhood throughout the world, but particularly in developing countries. In infancy, diarrhea is estimated to cause higher mortality than all other infections combined. WHO Assistant Director General, WW Furth, recently stated that diarrheal diseases accounted for five million deaths annually in children below the age of five years in the developing countries.

In the Philippines, the latest health statistics show that among the ten leading causes of infant mortality gastroenteritis and colitis was second in the list, resulting in 12,800 deaths under 5 years (1978).

The consensus is that for years to come, diarrheal diseases will remain a scourg of populations in developing countries. In view of this, there has been increasing interest in and concern for diarrheas. The World Health Organization (WHO has led in undertaking studies to provide measures to control and prevent these disorders. Researches on different aspects of diarrheal diseases have resulted in increased knowledge and information.

The causes of diarrhea in childhood are varied and may range from a trivial dietary indiscretion to severe or intractable conditions such as cholera or malabsorption syndromes. It is reported that about ten years ago or so, the etiology of diarrheas could be determined in only 20% to 30% of cases. Recent researches have however made it possible to identify the etiologic agent in 70-80% of diarrhea cases.

About the same period as the present report, also in Metro Manila, viral studies of stool specimens in gastroenteritis of children have identified rotavirus in 42% of diarrhea under 2 years and 29% in the age group 2-10 years. Possibly the two studies (bacterial and viral) may complement each other, as a contribution to efforts to determine the role of infections in the etiology of diarrheas in developing countries.

Objectives

General

1. To study the role of bacteria in the etiology of diarrhea in infants and young children of a developing country.
2. To identify specific bacteria in diarrheal stools.
3. To perform bacterial sensitivity tests.
4. To complement current or on-going researches on other infectious agents of childhood diarrheas, such as viruses.

Specific

1. To determine what bacteria are commonly associated with diarrheas of infants and young children in Metro Manila.
2. To determine the distribution of bacterial infectious diarrheas per month.
3. To observe the frequency of pathogenic bacteria in different age groups.
4. To study sensitivity tests of identified bacteria in diarrheal stools, to current anti-microbials.
5. To determine changes in the pattern of bacterial infections of childhood diarrheas.

Materials and Methods

Fresh diarrhea stool specimens were obtained from the patient into specimen bottles and transported immediately to the laboratory. Cultures were made within 15 minutes after receiving the specimen. The stool was streaked into one SS (Salmonelia Shigella) medium and one EMU (Eosin Methylene Blue) Media in petri dishes. After 18-24 hours, cultures were read and biochemical studies for further differentiation and antibiotic sensitivity tests were then performed. The Kirby Bauer, single disc agar diffusion method for sensitivity test were followed. Each organism was cultured in Trypticase soy broth until turbidity matching *Mc Farland* scale No. 5 were reached, where each ml. of broth contains 108 organisms. Then a cotton swab was used to inoculate the organism to a Muller-Hinton Agar plate.

Five minutes later, seven to ten antibiotic discs were placed in each plate with a distance of 25 mm between each disc and 9 mm away from the side. Readings were made 18 hours later, the zone size was measured and the degree of sensitivity assessed according to the Kirby Bauer table.Diagrams of the procedure are depicted in the Annexes (1a, 1b and 1c).

Results and Discussion

Stool specimens from infants and children under 5 years old were included in this study. These were patients who were admitted for acute diarrhea in two hospitals in Metro Manila. Among the staff of this research, two were involved in the study in both hospitals.

As it was not intended to compare the results of the two groups, the findings and data were tabulated and presented separately as Group A (3 year study, 1980 to 1982) with a total of 624 and Group B (1980 and 1981) with 1480 specimens. The data of Group A are presented in Tables 1 to 5 and those of Group B in Tables 6 to 10.

Table 1. Stool Cultures in 3 Years (CMCP)*

1980	–	157
1981	–	266
1982	–	201
Total	–	624

*Children's Medical Center Philippines.

In 1980 and 1981 the first three months of the year were peak months for infant diarrhea (Table 2 and Fig. 1).

Table 2. Stool Cultures By Month and Year

	1980	*1981*	*1982*
January	19.7%	20.6%	5.9%
February	15.2	9.0	6.9
March	14.0	6.	8.9
April	8.	8.	6.
May	3.	7.5	4.
June	3.	7.	8.9
July	8.	6.7	7.9
August	4.	7.5	12.
September	3.	5.6	14.
October	9.	7.5	8.9
November	5.	10.	3.9
December	5.	6.7	6.9

It is evident that in all the three years, three-fourths of the specimens were from infants below one year old. These were also the findings in Group B and in other studies of acute diarrheas.

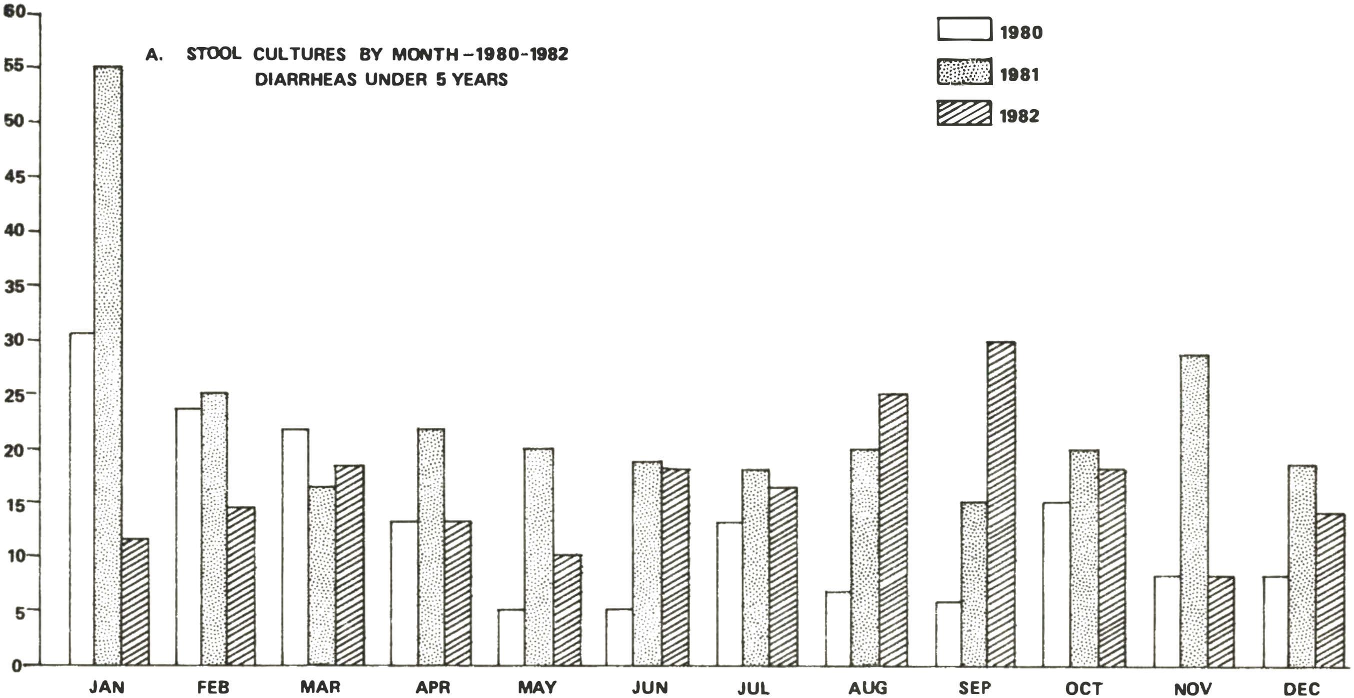

Figure 1. Group A. (CMCP)

Table 3. Diarrheal Stool Culture By Age

	1980	*1981*	*1982*
0 – 1 year	75.0%	77.8%	76%
1 – 2 years	15	13	13.9
2 – 5 years	9.5	9	9.9

In this series E. coli was the most common bacteria identified for all three years and were almost equal from year to year. (Table 4 and Fig. 2).

Table 4. Most Common Bacteria Identified Per Year, Children's Medical Center Philippines

	Organisms	*1980 No. 157*	*1981 No. 266*	*1982 No. 201*
1.	E. coli	33.75%	31.5%	33.8%
2.	Enterobacter	7.6	11.6	12.4
3.	Salmonella	10.8	9.3	15.9
4.	Proteus	23.5	34.9	15.4
5.	Arizona	10.1	4.8	11.9
6.	Citrobacter	4.4	9.0	6.4
7.	Shigella	3.8	2.6	1.4
8.	Pseudomonas	4.4	4.5	3.4

The above list is far from complete. Recent researches, in particular by the Scientific Working Group of WHO on Bacterial Enteric Infections, have given much attention to "Watery diarrheas" (Vibro Diarrhea and *E. coli*) and invasive pathogens (*Shigella, Campylobacter, Jejuni*) enteroinvasive (*E. coli, Salmonella* and *Yersinia enterocolitica*). The methods for their accurate identification have not been availed of in the present study. Serotyping of *E. coli* was not done as researches state there is lack of correlation of serotype with pathogenicity and is not a useful procedure.

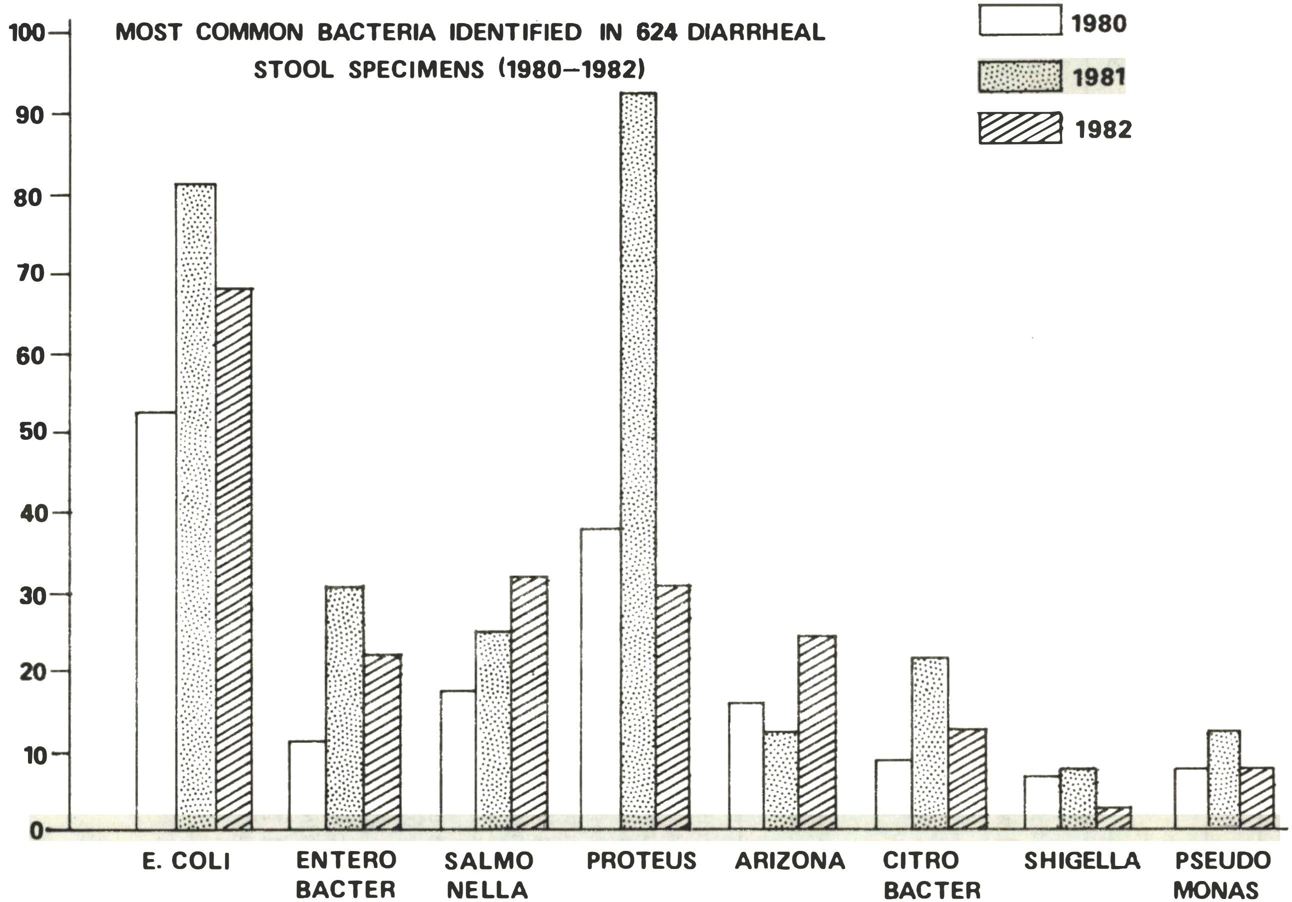

Figure 2. Group A (CMCP)

Table 5. Bacteria Identified in Different Age Groups Per Year From 1980 to 1982

(1980) Specimens Tested: 157				*Number of Cases Positve For:*				
Age Group	*E. Coli*	*Proteus*	*Enterobacter*	*Salmonella*	*Pseudomonas*	*Citrobacter*	*Arizona*	*Shigella*
0 – 1 year	33	35	10	13	6	5	13	1
1 – 2 years	15	2	1	1	1	2	2	2
2 – 5 years	5	0	1	3	0	0	1	3

(1981) Number Tested: 266				*Number of Cases Positive For:*				
Age Group	*E. Coli*	*Proteus*	*Enterobacter*	*Salmonella*	*Pseudomonas*	*Citrobacter*	*Arizona*	*Shigella*
0 – 1 year	55	79	28	21	9	19	10	2
1 – 2 years	16	10	2	2	2	3	2	1
2 – 5 years	15	4	1	2	1	2	1	4

(1982) Number Tested: 201				*Number of Cases Positive For:*				
Age Group	*E. Coli*	*Proteus*	*Enterobacter*	*Salmonella*	*Pseudomonas*	*Citrobacter*	*Arizona*	*Shigella*
0 – 1 year	51	26	20	25	5	10	19	1
1 – 2 years	9	5	4	3	1	3	4	0
2 – 5 years	8	0	1	4	1	0	1	2

Table 8. Sensitivity Tests: Positive (P) and Resistance (R), Children's Medical Center, Philippines, 1982

Organisms		*Amika-cin*	*Amoxil-lin*	*Ampicil-lin*	*Cephalo-thin*	*Chloram-phenicol*	*Colymy-cin*	*Gentamy-cin*	*Kanamay-cin*	*Nalidixic Acid*	*Tobramy-cin*	*Cefota-xime*	*Netromy-cin*	*Sisomy-cin*
	P	59	3	10	2	17	17	62	30	57	17	23	57	20
E. Coli	R	2	16	48	4	40	1	5	34	5	6	3	2	4
	P	26	6	4	34	2	15	12	2	18	3	18	26	9
Salmonella	R	4	10	23	1	23	5	23	19	8	14	1	1	14
	P	28	0	6	0	7	6	23	13	24	4	10	26	6
Proteus	R	2	7	19	2	18	8	8	18	6	4	0	1	3
	P	25	2	2	2	10	13	20	15	22	11	15	12	7
Enterobacter	R	2	16	23	3	12	2	3	10	3	7	1	19	11
	P	23	2	3	2	4	9	20	5	20	7	15	19	11
Arizona	R	1	11	20	0	2	3	4	19	4	4	0	3	1
	P	10	3	6	2	6	6	9	10	11	6	5	9	5
Citrobacter	R	0	2	6	0	7	–	2	4	1	0	0	0	1
	P	6	0	1	3	2	2	3	1	0	3	0	3	2
Pesudomonas	R	1	2	5	0	0	0	1	2	2	1	2	0	0

In the second hospital group of acute diarrheas of early childhood specimens and cultures were as follows:

Table 9. Stool Cultures By Year, Lungsod ng Kabataan (LnK)

1981	562
1982	918
Total	1,480

The last four months of 1981 were peak months for infant diarrheas while August to October showed a high incidence in 1982.

Table 10. Stool Cultures By Month, Lungsod ng Kabataan (LnK)

Month	*1982*		*1982*	
	No.		*No.*	
January	15	2.6	58	6.3
February	20	3.5	56	6
March	25	4.4	77	8
April	19	3.3	70	7.6
May	33	5.8	78	8
June	66	11	85	
July	96	17	75	8
August	64	11	95	10
September	59	10	111	12.7
October	53	9.4	96	10.4
November	44	7.8	83	9
December	68	12	34	3.7
Total	562		918	

As in the first group and in fact in any study on acute diarrhea in children, infants under 1 year are most affected as shown in Table 11.

Again E, coli followed by Enterobacter, Proteus, and Salmonella take the lead among bacteria identified. The more recent and sophisticated procedures were not availed of so that this list does not include recently reported new pathogens like rotavirus, Canpylobacter jejune and E. coli types (enterotoxigenic and enteroinvasive).

Summary and Conclusion

In 1980 to 1982, among 2,104 stool specimens of infants and young children who were confined in 2 hospitals in Metro Manila, cultures and sensitivity tests gave findings that are presented in this report.

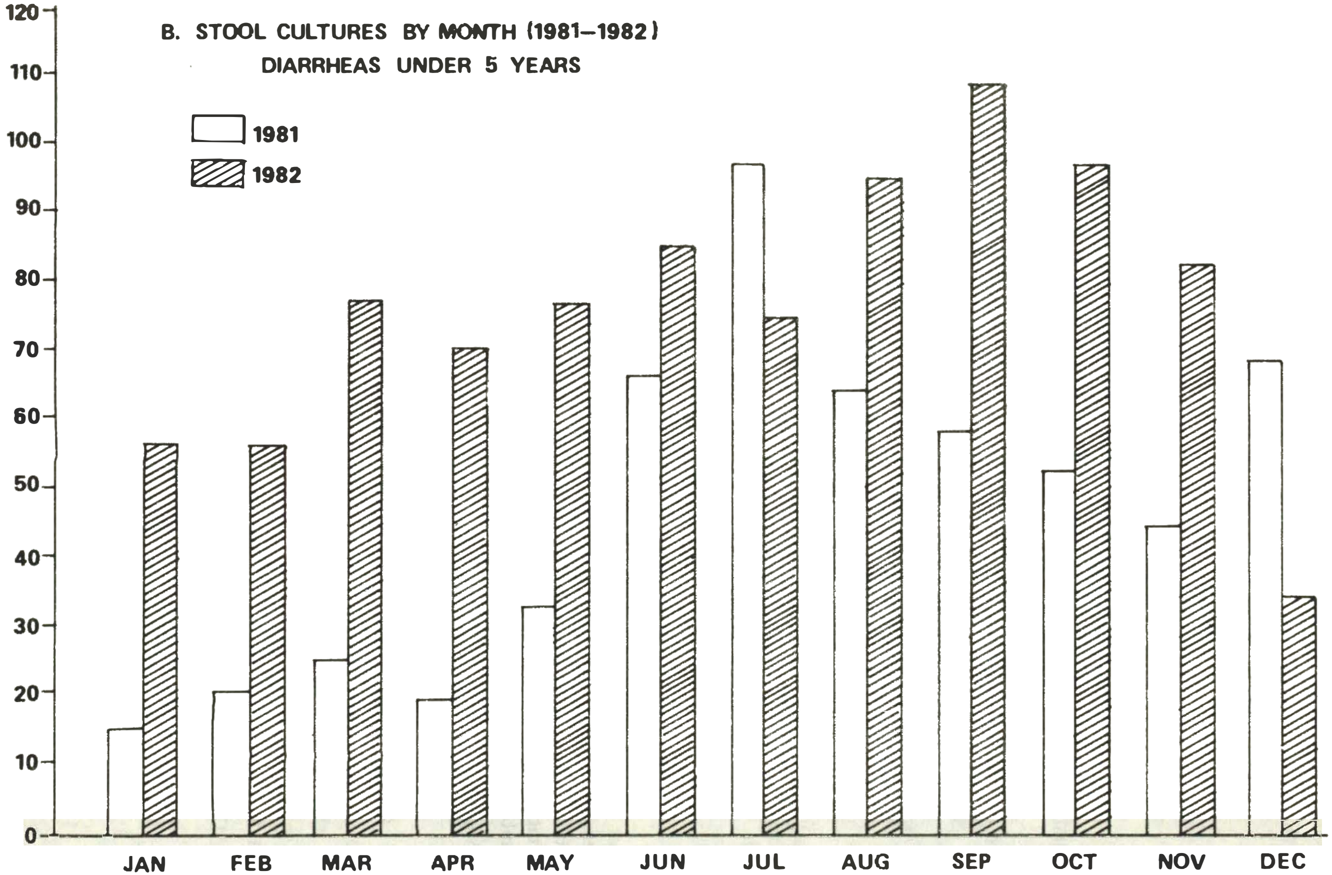

Figure 3. Group B (LNK)

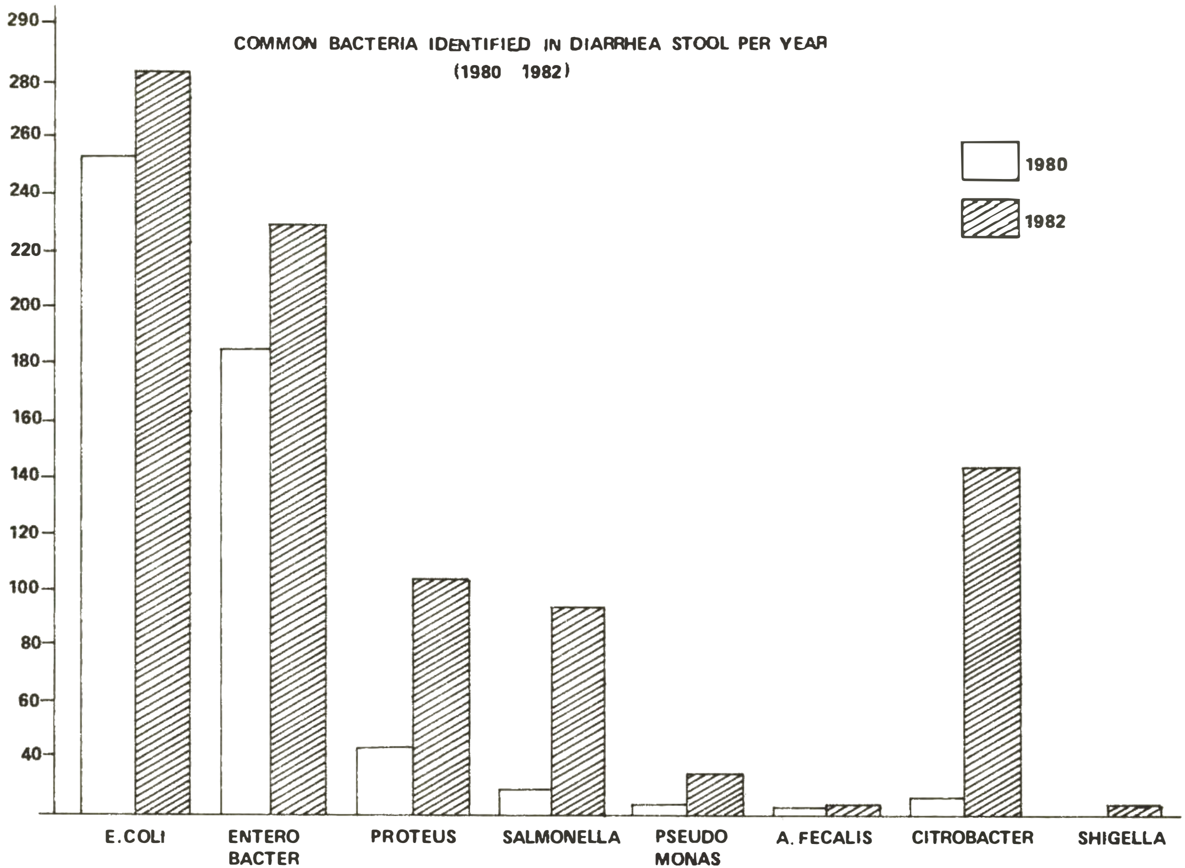

Figure 4. Group B (LNK)

Table 11. Stool Cultures By Age, Lungsod ng Kabataan (LnK)

	1981		1982	
Age	*No.*	*%*	*No.*	*%*
0 – 1 year	368	65	626	68
1 – 2	110	19.5	144	15.6
2 – 5	84	14.7	148	16
Total	562		918	

Table 12. Most Common Bacteria Identified Per Year, Lungsod ng Kabataan (LnK)

	Organisms	*1981*	*1982*
1.	E. coli	253	282
2.	Enterobacter	186	230
3.	Proteus	43	104
4.	Salmonella	30	95
5.	Pseudomonas	17	33
6.	Alkaligenes fecalis	4	13
7.	Citrobacter	27	145
8.	Shigella	0	7

The main objective was to identify bacteria associated with diarrheas in early childhood and to determine antimicrobials to which such bacteria are sensitive or resistant. A viral study was not undertaken but, by coincidence, this was done about the same time at San Lazaro Hospital by a research team, also in Metro Manila.

In the first hospital (Group A), the study included 624 cultures and in the second 1480 (Group B), giving a total of 2,104. In the research staff, two members were involved in both groups.

Infants topped the list and constituted about 75% of the total patients in Group A and 65 to 68% in Group B.

The incidences by month showed high figures, either the first three months (Group A) or the last four months (Group B) of the year.

The most common bacteria identified in the first group were Proteus, E. coli and Enterobacter while in the second the order was E. coli, followed by Enterobacter, Proteus and Salmonella.

Sensitivity tests showed a significant number sensitive to Gentamycin, followed by Amikacin, Tobramycin and Kanamycin. Almost consistently, there

Table 14. Sensitivity Positive (P), and Resistance (R), Group B, 1981

Organisms		*Gentamycin*	*Amikacin*	*Kanamycin*	*Ampicillin*	*Cefotoxim*	*Tobramycin*	*Chloramphenicol*	*Cephalothin*	*Neomycin*	*Carbenicillin*	*Colistin*
	P	203	78	55	36	27	–	–	–	–	–	–
E. coli	R	36	8	98	136	1	–	–	–	–	–	–
	P	147	54	48	–	–	66	51	–	–	–	–
Enterobacter	R	22	6	57	–	–	3	72	–	–	–	–
	P	36	17	–	–	–	–	16	–	–	–	–
Proteus	R	7	3	–	–	–	–	14	–	–	–	–
	P	18	8	–	–	18	–	–	13	–	–	–
Citrobacter	R	6	1	–	–	0	–	–	2	–	–	–
	P	18	–	–	–	22	7	–	–	8	–	–
Salmonella	R	10	–	–	–	0	7	–	–	10	–	–
	P	12	10	–	–	–	12	–	–	–	9	5
Pseudomonas	R	5	1	–	–	–	2	–	–	–	5	4

was resistance to ampicillin, chloramphenicol and neomycin in the commonly identified bacteria. This was maintained from year to year in the 3-year study.

In 1982 when discs of new preparations became available for testing, cifatoxin and tobramycin showed the highest sensitivity with Gentamycin third or fourth in the list. On this year resistance was also high to ampicillin, chloramphenicol and kanamycin.

A viral study by another research team on a similar age group, also in Metro Manila, showed an incidence of rotavirus in 42% under 1 year and 29% for the age group 2-10 years old.

It is expected that a number of questions, complications and suggestions will arise from this simple study. Many lessons have been learned; perhaps some procedures may be disregarded while many omissions will surface out. All these will result in a more effective and efficient steps in the diagnostic work-up of diarrheas.

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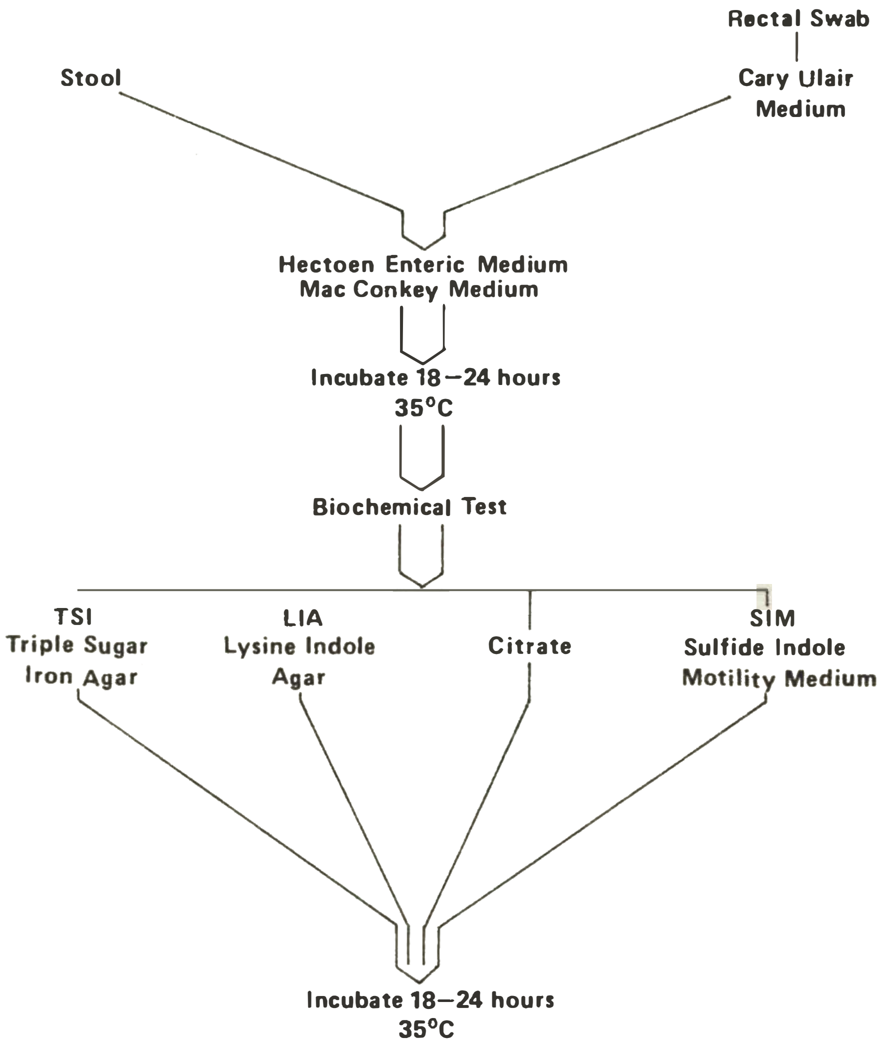
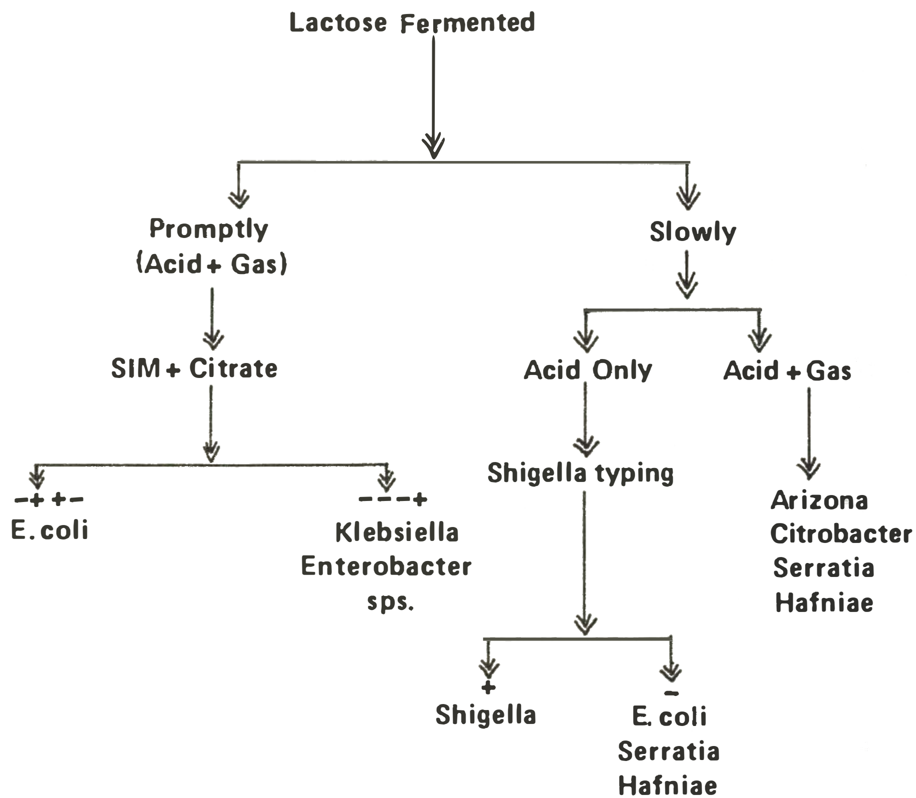
ANNEX I_a

Collection, Processing and Identification of Bacteria in Stool Specimens and Rectal Swab

Unless the specimen can be taken immediately to the laboratory and properly handled, all swabs may be added to a screw capped vial container of Cary and Blair and transported to the laboratory for culture.

Fresh stool specimens are directly plated to the medium as illustrated.




Lactose Fermented
Promptly (Acid + Gas)
Slowly
SIM + Citrate
Acid Only
Acid + Gas
-++-
E. coli
---+
Klebsiella
Enterobacter
sps.
Shigella typing
Arizona
Citrobacter
Serratia
Hafniae
+
Shigella
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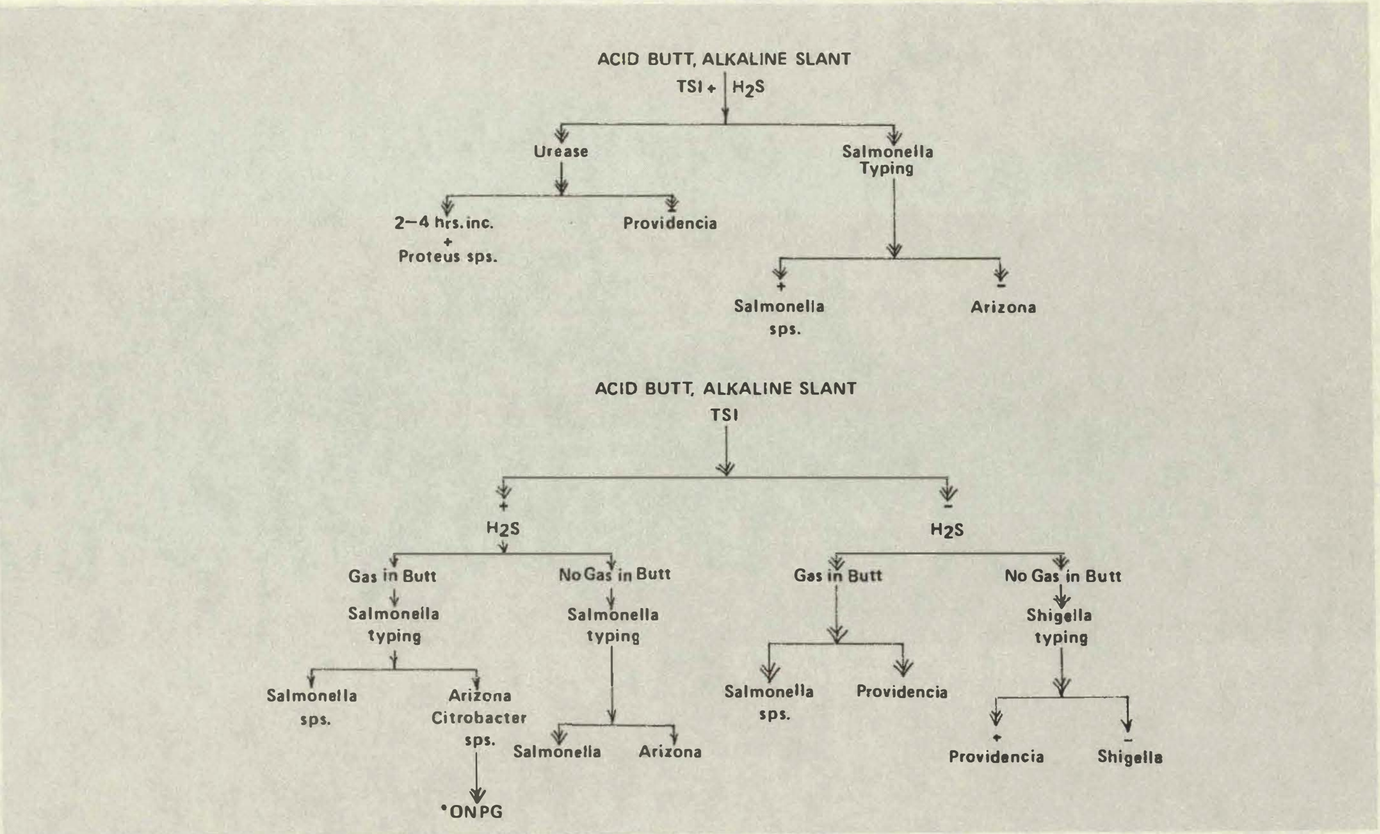
E. coli
Serratia
Hafniae

ANNEX I_c



*Orto-nitrophenyl Galactosidase

Virginia Basaca-Sevilla, Discussant

I have always hoped that researchers on the subject of etiologies of diarrheas do not encounter difficulties ordinary laboratories like the Bureau of Research and Laboratories are faced with, everyday. But the statement of the authors at the end of the paper like "expectation of questions, complications, suggestions, disregarding of procedures and omission" make me surmise that most probably they did have problems similar to us. We have to admit that each agency or institution doing this kind of work, has a different work environment and clientele and their own work limitations which may be funding for supplies and reagents, technical personnel, interested clinicians and enough time without sacrificing time for service work load. To solve part of this, we have learned to collaborate with other institutions so that objectives of a particular study can effectively be divided and accomplished efficiently. I hope my guess is also right that there was not much funding problem since the researchers proceeded to sensitivity testing (which is expensive) of all isolates, without having to go through proving that the isolate surely caused the diarrhea or they were also very fortunate in having pure cultures on isolation.

Allow me to add a little bit of information gathered from the data of others working on the etiologies of diarrhea whether as a routine effort or for research.

Using accepted standard technics and the minimum of standard media and reagents like Cary and Blair, MacConkey, S.S. Agar, Nutrient Agar Bile Salts Medium, Selenite broth and Peptone water, the BRL cultures rectal swabs samples from diarrheal patients to isolate Salmonellas, Shigellas, Vibrio choleras, V. parahemolyticus, Edwardsiella tardas and E. coli.

For 1982, there were 407 or 21.40% isolations for bacterial enteric pathogens, from 1901 rectal swab samples from diarrheic children confined at San Lazaro Hospital. Of the isolates, 51.38% were Salmonellas, 36.57% were Vibrio choleras, 4.62% were Shigellas, 0.46% V. parahemolyticus, 3.93% non-agglutinable vibrios, and 3% biochemically Salmonellas. In 1983, of 1,691 samples from diarrheic children confined in the said hospital there were positive isolations in 363 or 21.52%. Of the bacterial enteric pathogens, 59.35% were Salmonellas, 33.42% Vibrio choleras, 5.88% were Shigellas, 1.07% V. parahemolyticus, 0.26% biochemically Shigellas. From the no more than 2 years of age, there were 65 or 3.41% isolates for E. coli in 1982 and 119 or 7.3% in 1983.

Of the 1,266 samples from the regional and provincial surveillance system from children with diarrhea in 1982, the BRL found that 190 or 15% had positive bacterial enteropathogenic isolation. Of these isolates 73.71% were Salmonellas, 24.22% were V. choleras and 1.03% each of V. parahemolyticus and biochemically Salmonellas. In 1983 there were 226 or 11.23% isolations from 2,011 samples. Of the isolates 59.91% were Salmonellas, 37.65% were V. choleras, 1.21% were Shigellas, 0.8% E. tardas and 0.4% Arizona Hinshawa. There were 104 or 8.21% E. coli isolated in 1982 and 108 or 5.37% in 1983.

Of 74 strains of E. coli isolated by the BRL from children below 2 years of age, 33 or 44.59% were found to be toxigenic by Dr. Antonio Jacalne of the Institute of Public Health, U.P. utilizing the intestinal loop test in rats. The most common salmonella serotypes isolated are S. typhimurium, S. senftenberg, S. worthington, S. anatum, S. stanley, S. newport and S. derby. It is mostly V. cholera ogawa that's isolated and Shigella Group B. The youngest child from whom isolation was made for cholera, shigella or salmonella is one month old.

The report of the preliminary evaluation of a study on the etiologies of pediatric diarrheas in the National Children's Hospital done by the Research Institute of Tropical Medicine showed that the prevalence of rotavirus in 620 patients studied was 16%, for Salmonella 57%, for enterogenic coli 24%, for the shigellas 10%, for the choleras 4.81%, for the campylobacter 0.6% and for the E. histolyticas 4.19%, and for the Giardia lamblia 0.32%. This is research data.

The research paper under discussion gives the prevalence of isolation for Salmonellas in the Children's Medical Center as 10.8% for 1980, 9.3% for 1981 and 15.9% for 1982. Shigella prevalence varied from 1.4% to 3.8%. From the Lungsod ng Kabataan the Salmonella prevalence was 5.3% for 1981 and 10.45% for 1982. The prevalence of isolations for Salmonellas, Shigellas and Vibrio choleras are certainly much lower in these institutions. In both hospitals the E. coli isolation predominate varying from 31% to 45%.

It is hoped that the information and experience of others will add to the data obtained by the researchers of this study. It is further hoped that more funds will be provided to adequately serve each patient suffering from diarrheas as the determination of the etiology of diarrheas is not done only when there is a research going on but an everyday activity of each laboratory, whether it is a public health laboratory or a hospital laboratory.

To save money and time it is suggested that sensitivity tests be not a routine procedure in enteric bacteriology except in certain situations where surveillance of the response to antibiotics is regularly being done for certain microorganisms like S. typhi or S. para A. This regular monitoring is done by the Central Laboratory. Sensitivity tests also should be done on specific strains of organisms not grouped together. It is further hoped that as we know more and more of the etiologies of our diarrhea, the control and eradication should not be far off.

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EFFECT OF TREATMENT REGIMEN ON REINFECTION OF SOIL-TRANSMITTED HELMINTHIASES IN THE PHILIPPINES

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The control of soil-transmitted helminthiases, namely: ascariasis, trichuriasis and hookworm infection, particularly in developing countries like the Philippines is definitely not an easy thing to do. This is because of the several factors that come into play in their transmission. Some of these factors are poor environmental sanitation, poor personal hygiene, lack of health education, inadequate supply of potable water in the area and low economic status of the people.

Several studies have been done in the recent past in an attempt to determine the most practical yet most effective method of controlling the soil-transmitted helminthiases particularly ascariasis which is usually the most common of them all. Some of these studies focused on the determination of the minimum effective dose of anthelmintics (Chen, E.R. *et al.*, 1980, Abidin, S.A.N. *et al.*, 1980); frequency of drug administration (Chen, E.R. *et al;* 1983); the use of medicinal plants with anthelmintic properties (Unhanand, M. 1980; Unhanand, M. *et al.*, 1980; Keittivuti, B. *et al.*, 1983; Sahu, R. B. *et al.*, 1983, Unhanand, M. *et al.* 1983), comparison of mass over selective treatment (Cabrera, B. D. *et al.*, 1983) and clinical trials and review of new broad spectrum anthelmintics (Harinasuta, C. 1980; Harinasuta, C. 1980; Dissanaike, A.S. *et al.*, 1980; Kobayashi, A. 1980; Yokogawa, M. 1980, Abidin, S.A.N. *et al.*, 1980; Seo, B.S. 1980; Margono, S.S. *et al.*, 1980; Muttalib, M.A. *et al.*, 1983; Kan, S.P. *et al.*, 1983; Keittivuti, A. *et al.*, 1983; Kan, S.P. 1983; Ismail M.M. *et al.*, 1983, Yokogawa, M. 1983).

This paper is a compilation of data on several methods tried in the field by the author using the various treatment regimen of soil-transmitted helminthiases. Stool examination follow-up was done after each treatment regimen to determine reinfection rates of ascaris, trichuris and hookworm infections.

It must be emphasized here that reinfection is an important factor to consider in attempting to control soil-transmitted helminthiases in a given community or the entire country. A previous report by Cabrera B.D. 1978 has shown that the significant rise in reinfection rates for ascaris, trichuris and hookworm among subjects given treatment only once were 4 months for ascaris and 2 months for both trichuris and hookworm. It is for this reason that this work was done inasmuch as very few other studies in the past have considered this particular aspect in control programs.

Table 1. Comparison of Reinfection Rates of Ascariasis Among Children in Three Selected Areas, 1983.

Place	*Post Treatment Stool Follow-up (Months)*			
	3rd	*6th*	*9th*	*12th*
Puting Sapa* (155)	3.2	82.2	94.8	97.7
Pangpang** (37)	4.5	30.0	52.9	—
San Narcisco*** (51)	9.0	13.6	43.9	64.1

* = Treatment given only once (group 1).
** = Treatment given every 4 months for one year (group 2).
*** = Treatment given every 4 months for 3 years (group 3).
( ) = Number of study subjects

Materials and Methods

Preliminary stool surveys were made to determine the prevalence of ascariasis, trichuriasis and hookworm infection. From this data, we were able to select the subjects to be included in the treatment. Broad spectrum anthelmintics were then given to those found positive for eggs of any of the 3 soil-transmitted helminths. This was followed by a reexamination of the stool of all treated subjects, 10-14 days after treatment. All those found negative for eggs became the subjects for the re-infection rate study. About 243 children and 221 adults were involved in the three reinfection rate studies, done separately and at different times and areas. All study subjects gave zero reinfection rates during the first month observation. The succeeding stool examinations were done at the 3rd, 6th, 9th and 12th months. It is from the results of these post-treatment stool follow-up that reinfection rates were determined. The methodology applied were practically the same for all the 3 groups except for the frequency and duration of treatment regimen.

The three reinfection studies were divided into 3 groups based on the frequency and duration of the treatment regimen. Hence, in group 1 the subjects were treated with Pyrantel pamoate and/or Mebendazole 10 mg/kg body weight single dose or 100 mg twice a day for 3 days respectively. This treatment regiment was given only once and the second year was devoted to reinfection rate determination. In group 2 the subjects were given Flubendazole alone and Flubendazole with Levamisole, 500 mg tablet single dose and 500 mg tablet plus 10 mg Levamisole tablet respectively. The treatment was given every 4 months for one year; then followed by reinfection rate determination every 3 months lasting for only 9 months. In group 3, the subjects were given Oxantel-pyrantel (Quantrel) 5mg/kg

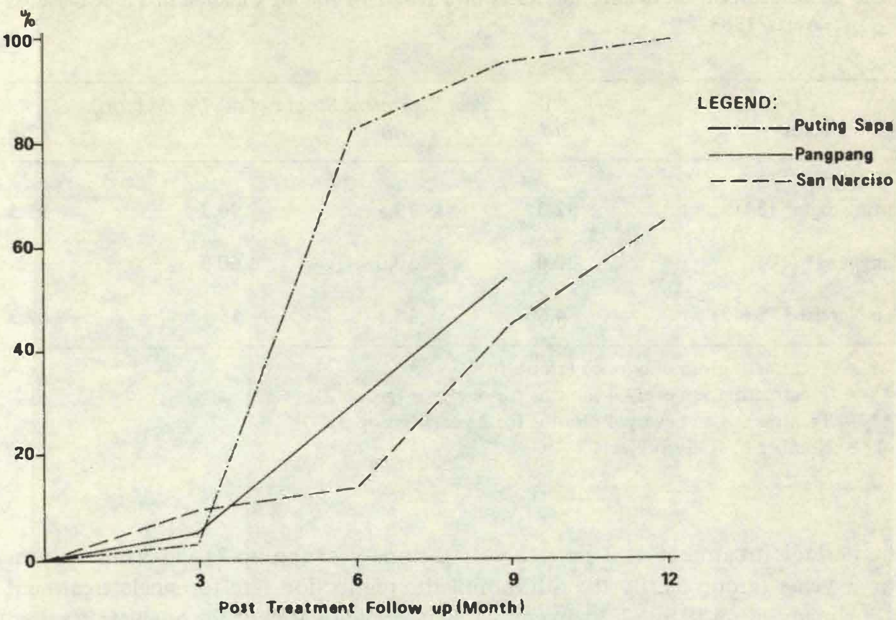

Figure 1. Comparison of Reinfection Rates of Ascariasis Among Children in Three Selected Areas.

body weight single dose every 4 months for the first two years, then 10 mg/kg. body weight single dose every 4 months for one more year or a total of 3 years. The 4th year was devoted to reinfection rate determination.

Results and Discussion

The 3 groups included in the present study came from three selected areas in the Philippines. The subjects were composed of both children and adults. The pre-treatment prevalence rates of ascaris, trichuris and hookworm among children in the 3 selected areas were 83, 93 and 69 percent respectively for group 1; 63, 88 and 24 percent respectively for group 2 and 77, 86 and 17 percent respectively for group 3. Among adults in the same order of helminths, the prevalence rates were 81, 93 and 76 percent for group 1; 50, 89 and 32 percent for group 2 and 71, 83 and 12 percent for group 3.

The reinfection rates of ascariasis among children following a successful treatment from the 3 groups is shown in Table 1 and Figure 1. The data on the 3rd month in table 1 appears to be in agreement with previous findings. The reinfection rates from the 3 areas ranged from 3 to 9 percent. It is very evident in this table particularly from the 3rd to the 12 months, that single treatment regimen (group 1), gave the fastest and the highest reinfection rates when compared with

Table 2. Comparison of Reinfection Rates of Trichuriasis Among Children in Three Selected Areas, 1983.

Place	Post Treatment Stool Follow Up (Months) 3rd	6th	9th	12th
Puting Sapa* (84)	52.3	79.5	90.3	91.5
Pangpang* (10)	30.0	50.0	60.0	–
San Narciso*** (43)	4.5	12.1	15.1	62.3

* = Treatment given only once (group 1).
** = Treatment given every 4 months for one year (group 2).
*** = Treatment given every 4 months for 3 years (group 3).
( ) = Number of study subjects

the periodic treatment of 3 times a year for one year (group 2) and 3 times a year for 3 years (group 3). By the 6th month the reinfection rate for single treatment was already more than 82.2 percent, while periodic treatment for one year resulted only in 30 percent reinfection. The result in periodic treatment for 3 years gave a much lower reinfection rate of 13.6 percent. Looking at the 9th month, single treatment resulted in 94.8 percent reinfection rate as compared to 52.9 and 43.9 percent reinfection rates for one year and 3 years treatment regimen respectively. At 12 months post treatment, single treatment gave a 97.7 percent reinfection rate of 64 percent. From past experience we presume that the reinfection rate of group 2 on the 12th month would be a little higher than group 3, probably around 70 percent.

The reinfection rates of trichuriasis are shown in Table 2 and Figure 2. At the 3rd month post treatment, trichuriasis reinfection rates for single and periodic treatment for one year were 52.3 and 30.0 percent respectively, while periodic treatment for 3 years was only 4.5 percent. At the 6th month, single treatment and periodic treatment for one year gave 79.5 and 50.0 percent reinfection rates respectively while periodic treatment for 3 years gave a 12.1 percent rate. At the 9th month, the reinfection rates for single and periodic treatment for one year were 90.3 and 60.0 percent respectively, while periodic treatment for 3 years was 15.1 percent. At the 12th month, rates of 91.5 and 62.3 percent were obtained for single and periodic treatment respectively. As in the case with ascariasis, the reinfection rates of trichuriasis were lower in the periodic treatment for a period of 3 years than in the other treatment regimen.

The hookworm reinfection rates in the 3 groups representing various treatment regimen are shown in Table 3 and Figure 3. It is quite apparent that reinfection rates in periodic treatment for a year and also periodic treatment for 3 years were

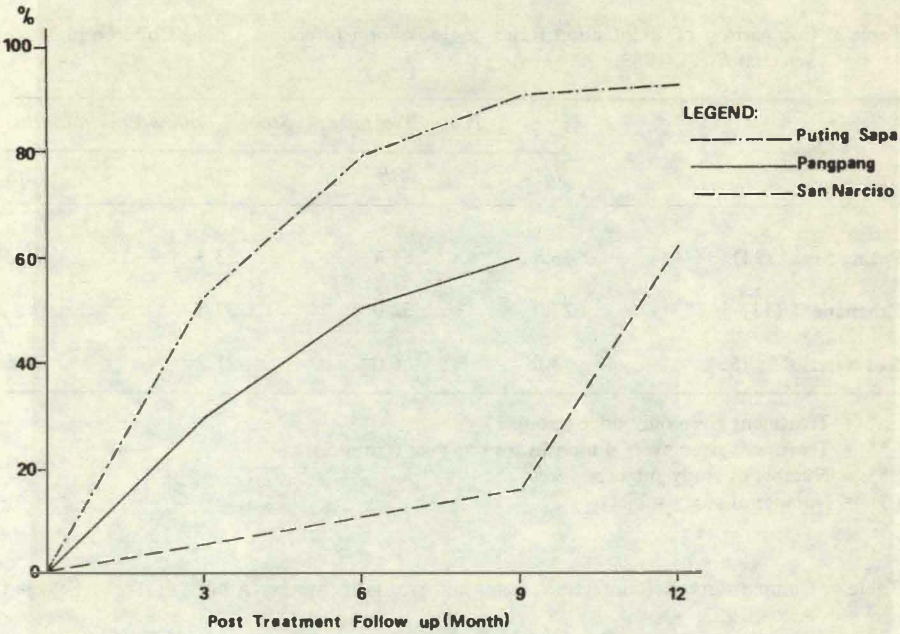

Figure 2. Comparison of Reinfection Rates of Trichuriasis Among Children in Three Selected Areas.

very much lower when compared to the rates obtained under a single treatment regimen.

Of the three soil-transmitted helminths where single treatment regimen was applied, ascaris has the lowest reinfection rate (3%) at the 3rd month observation period while trichuris and hookworm have much higher reinfection rates (52 and 47%) respectively. This is probably because it takes around 4 months for ascaris to show a significant rise in reinfection while trichuris and hookworm need only 2 months for a significant rise in reinfection (Cabrera, B.D. 1978). At the 6th month, single treatment reinfection rates for ascaris, trichuris and hookworm were about the same, around 80 percent. With periodic treatment for one year (group 2) the reinfection rates for ascaris and hookworm were about the same (30%) but higher rates (50%) were obtained with trichuris. In the periodic treatment for 3 years (group 3), the reinfection rates for ascaris and trichuris, were about equal 13 and 12 percent, but lower rates for hookworm were obtained (6%). At the 9th month, single treatment reinfection rates for the three helminths were about equal with rates over 90 percent. With periodic treatment for one year, trichuris had the highest reinfection rate, followed by ascaris, with hookworm having the lowest rate. The Pangpang study on reinfection (group 2) was terminated at the 9th month due to non-cooperation of the subjects. The rates for the periodic treat-

Table 3. Comparison of Reinfection Rates of Hookworm Infection Among Children in Three Selected Areas, 1983.

Place	Post Treatment Stool Follow-Up (Months)			
	3rd	6th	9th	12th
Puting Sapa* (94)	46.8	84.4	93.3	93.3
Pangpang** (43)	27.0	32.0	37.8	–
San Narciso*** (53)	3.0	6.0	21.2	24.5

* = Treatment given only once (group 1).
** = Treatment given every 4 months for one year (group 2).
*** = Number of study subjects.
( ) = Number of study subjects

Table 4. Comparison of Reinfection Rates of Ascariasis Among Adults in Three Selected Areas, 1983.

Place	Post Treatment Stool Follow-up (Months)			
	3rd	6th	9th	12th
Puting Sapa* (145)	0.0	50.8	84.7	95.7
Pangpang** (21)	2.5	6.6	12.9	–
San Narcisco*** (55)	3.6	9.3	20.7	28.7

* = Treatment given only once (group 1).
** = Treatment given every 4 months for one year (group 2).
*** = Treatment given every 4 months for 3 years (group 3)
( ) = Number of study subjects.

ment for 3 years (group 3) were the lowest when compared to groups 1 and 2. The same trend was maintained at 12th month post treatment observation.

Looking at figures 1, 2 and 3 for ascaris, trichuris and hookworm respectively, it appears that single treatment regimen (group 1) gave the highest and fastest reinfection rates in all the three soil-transmitted helminthiases. This rate was followed by the periodic treatment regimen for one year (group 2) and the lowest reinfection rates for the three helminths were obtained from the periodic treatment regiment for 3 years (group 3).

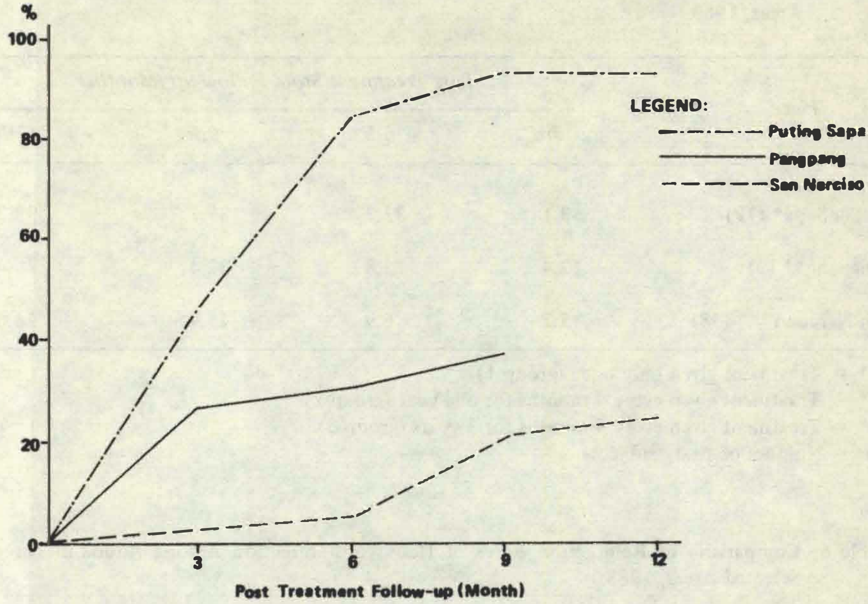

Figure 3. Comparison of Reinfection Rates of Hookworm Infection among Children in Three Selected Areas.

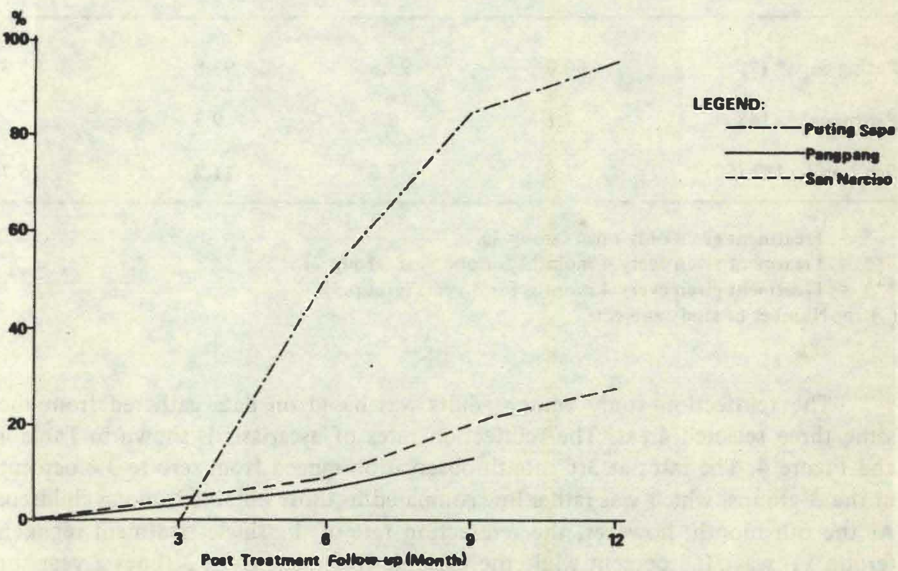

Figure 4. Comparison of Reinfection Rates of Ascariasis Among Adults in Three Selected Areas.

Table 5. Comparison of Reinfection Rates of Trichuriasis Among Adults in Three Selected Areas, 1983.

Place	*Post Treatment Stool Follow-up (Months)*			
	3rd	*6th*	*9th*	*12th*
Puting Sapa* (79)	53.1	83.7	89.1	93.2
Pangpang** (9)	12.4	25.8	32.4	–
San Narcisco*** (38)	5.2	6.9	15.4	26.6

* = Treatment given only once (group 1).
** = Treatment given every 4 months for one year (group 2).
*** = Treatment given every 4 months for 3 years (group 3).
( ) = Number of study subjects

Table 6. Comparison of Reinfection Rates of Hookworm Infection Among Adults in Three Selected Areas, 1983.

Place	*Post Treatment Stool Follow-up (Months)*			
	3rd	*6th*	*9th*	*12th*
Puting Sapa* (7)	60.0	93.8	93.8	95.3
Pangpang** (14)	7.1	8.5	9.3	–
San Narciso*** (60)	1.6	5.6	11.2	15.7

* = Treatment given only once (group 1).
** = Treatment given every 4 molnths for one year (group 2).
*** = Treatment given every 4 months for 3 years (group 3).
( ) = Number of study subjects.

The reinfection study among adults was based on data gathered from the same three selected areas. The reinfection rates of ascariasis is shown in Table 4 and Figure 4. The rates at 3rd month observation ranged from zero to 3.6 percent in the 3 groups, which was rather low compared to those obtained among children. At the 6th month, however, the reinfection rate of the single treatment regimen (group 1) was 50.8 percent while the periodic treatment given 3 times a year for one year (group 2) was only 6.6 percent and 9.3 percent for the periodic treatment 3 times a year for 3 years (group 3). At the 9th month, the reinfection rate for

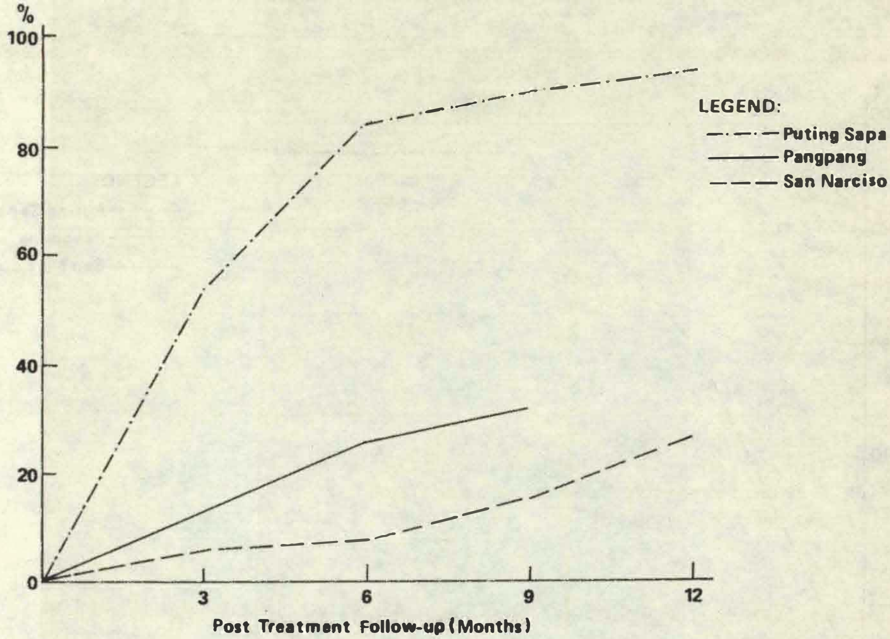

Figure 5. Comparison of Reinfection Rates of Trichuriasis Among Adults in Three Selected Areas.

group 1 was 84.7 percent as compared to 12.9 and 20.7 percent for groups 2 and 3 respectively. At the 12th month, group 1 had a reinfection rate of 95.7 percent compared to 28.7 percent for group 3. It is quite evident from these data that periodic treatment given 3 times a year for three years was much better than the single treatment regimen.

The reinfection rates of trichuriasis are shown in Table 5 and Figure 5. It can be seen here that the reinfection rates at the 3rd month were higher than those of ascariasis. Single treatment regimen (group 1) registered a 53 percent rate while the periodic treatment regimen for one year (group 2) and the periodic treatment for 3 years (group 3) were 12.4 and 5.2 percent respectively. At the 6th month observation, the single treatment regimen registered a 83.7 percent rate as compared to 25.8 and 6.9 percent for groups 2 and 3 respectively. At the 9th month, the reinfection rate for the single treatment gradually increased to 89 percent as compared to 32 and 15 percent for groups 2 and 3 respectively. At the 12th month, group 1 reached 93.2 percent while group 3 reinfection rate was only 26.6 percent. The reinfection rates for the three helminths at the 12th month were all over 93 percent.

The reinfection rates for hookworm infection are shown in Table 6 and Figure 6. With the exception of the single treatment regimen (group 1) which

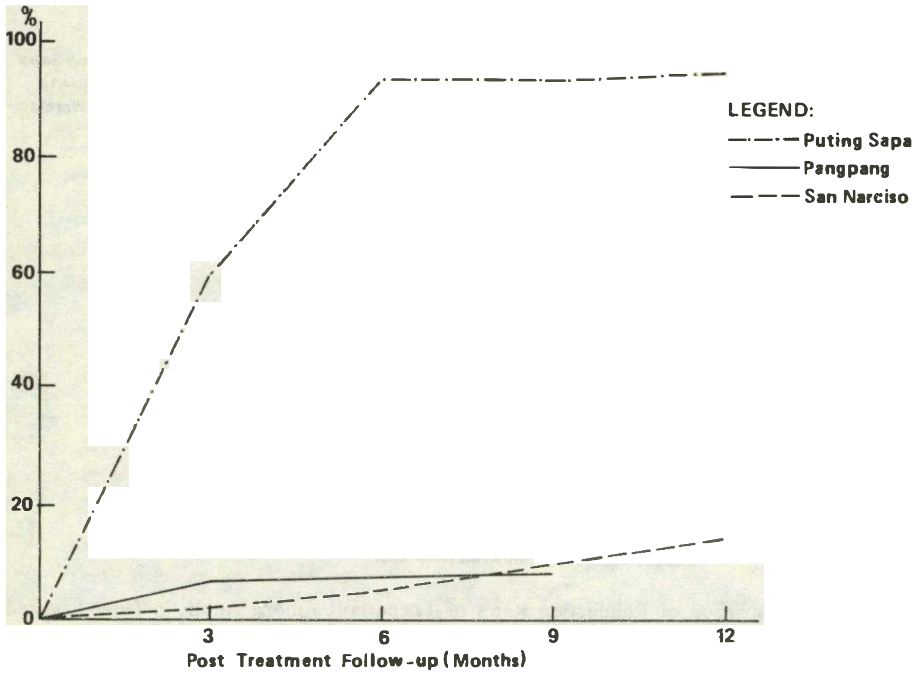

Figure 6. Comparison of Reinfection Rates of Hookworm Infection Among Adults in Three Selected Areas.

gave a reinfection rate of 60 percent at the 3rd month, the rates for groups 2 and 3 were quite low ranging from 1.6 to 7 percent respectively. At the 6th month, group 1 gave a 93.8 percent reinfection rate while groups 2 and 3 gave 8.5 and 5.6 percent respectively. While the single treatment regimen remained more or less stationary at 9th and 12th months observation, the periodic treatment regimen for one year and also for 3 years maintained a low level of reinfection rates ranging from 9 to 15.7 percent respectively.

Comparing the reinfection rates of ascariasis among children with those among adults for the 3 groups, we noticed that the adults showed consistently lower rates than children during all the periods of observation. The difference in rates were evident in groups 2 and 3 where the periodic treatment regimen was applied. In group 1, where single treatment regimen was applied, the reinfection rates for both children and adults were not much different.

In the case of trichuriasis reinfection rates, the adults showed lower rates than children among those given periodic treatment. There was no difference at all between reinfection rates among children and adults where single treatment regimen was applied. In fact, adults showed slightly higher reinfection rates.

In hookworm, the reinfection rates among adults were higher than in children probably because farming was the principal occupation in Puting Sapa (group 1). In groups 2 and 3 where periodic treatment was applied, it was quite evident that the reinfection rates obtained among adults were much lower than those of children.

Summary and Conclusion

Reinfection rates of soil-transmitted helminthiases from 3 groups of subjects given broad spectrum anthelmintics and using different treatment regimen are hereby presented.

The data gathered showed that subjects given a single treatment regimen (group 1) had the highest and fastest reinfection rates, followed by those given periodic treatment of 3 times a year for one year (group 2). The lowest reinfection rates were obtained from those given periodic treatment every 4 months for 3 years (group 3). In general, adults showed lower reinfection rates when compared to children particularly on those subjects that were given periodic treatment regimen.

From this study, there seems to be justification in recommending the adoption of periodic treatment for 3 years in the control and/or eradication of soil-transmitted helminthiases in this country. This statement is based on the low reinfection rates of the 3 common intestinal helminths when subjects were given the above treatment regimen. The low reinfection rates may be explained by th death or non-infectivity of the eggs or larvae in soil within a 3-year period and hence transmission is minimized and eventually stopped.

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MATH/PHYSICS

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CYCLE GRAPHS

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For any given graph G, the *cycle graph* $C(G)$ has vertices which correspond to the chordless cycles of G, and two distinct vertices of $C(G)$ are adjacent if and only if the corresponding chordless cycles have at least one edge in common. The graph G is *cycle-vanishing* if the iterated cycle graph $C^n(G)$ is acyclic for some finite integer n; otherwise G is *cycle-persistent*. This paper gives a characterization of cycle-vanishing graphs, and in particular proves that $C^3(G)$ is acyclic if G is cycle vanishing.

Introduction

All graphs considered in this paper are finite, loopless and without multiple edges. Definitions of undefined terms and notions can be found in [3].

A *chord* in a cycle is an edge joining two non-consecutive vertices in the cycle.

Given a graph G, the associated *cycle graph* $C(G)$ has vertices which correspond to the chordless cycles of G, and two vertices of $C(G)$ are adjacent if and only if the corresponding chordless cycles of G have at least one edge in common. In particular, if G is acyclic then $C(G)$ is the null graph which we denote by ϕ. For example, if G is the graph shown in Figure 1(a), the chordless cycles of G are A_1 = 1231, A_2 = 236542, A_3 = 456874, and A_4 = 2368742. Using a_i to denote the vertex corresponding to the cycle A_i, the cycle graph $C(G)$ is shown in Figure 1 (b).

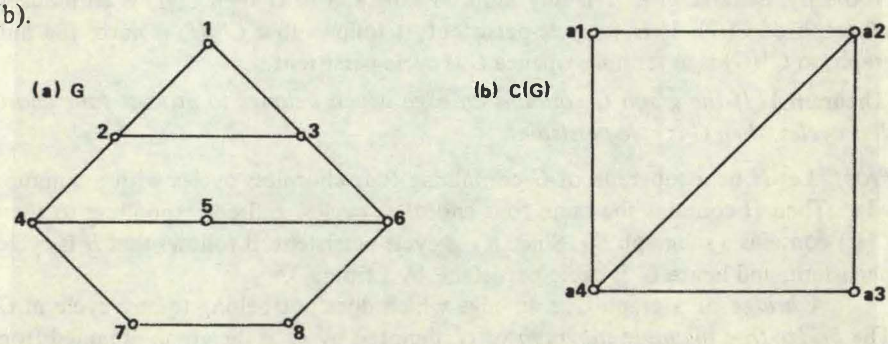

Figure 1. A graph G and its cycle graph $C(G)$.

If $C^n(G)$ denotes the n-fold cycle graph of G, then G is a *cycle-vanishing graph* if $C^n(G) = \phi$ for some positive integer n and otherwise G is a *cycle-persistent* graph. For example, if G is the graph in Figure 1(a), then $C^2(G) = K_2$, the complete graph of order 2, and $C^3(G) = \phi$; hence G is cycle-vanishing. It is easily verified that $C(K_4) = K_4$, so the complete graph of order 4 is cycle-persistent. The problem of classifying cycle-vanishing graphs is the main concern of this paper.

The idea of cycle graph is motivated by the concept of *line graph* of a graph [5]. This is the graph $L(G)$ whose vertices correspond to the edges of G and two vertices are adjacent if and only if the corresponding edges have a vertex in common. Perhaps the idea of *clique graphs* [4] was also motivated by the same concept.

Some Basic Properties

If H is any subgraph of G, the *induced subgraph* $\bar{H}$ is the subgraph with the same vertex set as H and such that two vertices in $\bar{H}$ are adjacent if and only if they are adjacent in G. If $\bar{H} = H$, then H is simply an *induced subgraph* of G.

Lemma 1. *If C is any cycle in a graph G, then each edge of C belongs to a chordless cycle of G contained in the induced subgraph $\bar{C}$.*

Proof. If C is chordless, then $\bar{C} = C$ and the lemma holds. So suppose C has chords. Then C has order $n \geqslant 4$, and we may suppose the lemma holds for all cycles of smaller order in G. Any chord of C divides C into two cycles C' and C'' each of order less than n. Since all chords of $\bar{C}$ belong to C, then $\bar{C}'$ and $\bar{C}''$ are subgraphs of $\bar{C}$. The lemma therefore follows by induction on n.

Lemma 2. *If H is an induced subgraph of G, and C is any cycle in H, then C is chordless in H if and only if it is chordless in G.*

Proof. If $\bar{C}$ is the subgraph of G induced by C it is also the subgraph of H induced by C, since $\bar{H} = H$. So the lemma follows.

Lemma 3. *If G has an induced subgraph which is cycle-persistent, then G is cycle-persistent.*

Proof. By Lemma 2, if H is any induced subgraph of G then $C(H)$ is an induced subgraph of $C(G)$. If H is cycle-persistent, it follows that $C^n(H)$ is never the null graph, so $C^n(G)$ is never null, whence G is cycle-persistent.

Theorem 1. *If the graph G contains an edge which belongs to at least four chordless cycles, then G is cyle-persistent.*

Proof. Let H be a subgraph of G containing four chordless cycles with a common edge. Then $\bar{H}$ contains the same four chordless cycles, and corresponding to them $C(\bar{H})$ contains a subgraph K_4. Since K_4 is cycle-persistent, it follows that $\bar{H}$ is cycle-persistent, and hence G is cycle-persistent, by Lemma 3.

A *bridge* of a graph G is an edge which does not belong to any cycle in G. The *bridge-free spanning subgraph* of G, denoted by $\tilde{G}$, is the graph obtained from G by deleting all its bridges.

Lemma 4. *A graph G is cycle-persistent if and only if its bridge-free spanning subgraph $\widetilde{G}$ is cycle-persistent.*
Proof. The cycles of G are precisely the cycles of $\widetilde{G}$, so $C(G) = C(\widetilde{G})$, whence the lemma follows.

This lemma shows that in order for G to be cycle-persistent, it is necessary and sufficient for some component of G to be cycle-persistent. We can sharpen this result. Recall that a *cut vertex* of a graph G is any vertex v such that the graph $G-v$, induced by all vertices of G except v, has more connected components than G has. A *block* is a connected graph which has no cut vertices, and a *block of a graph* G is a maximal connected subgraph which is a block. In a block of order at least 3, any two vertices lie on a common cycle.

Theorem 2. *Let G be a connected bridgeless graph of order at least 3. Then $C(G)$ is connected if and only if G is a block.*
Proof. First assume that G is a block. Since its order is at least 3, it contains a cycle. If G is a cycle, $C(G) = K_1$ so $C(G)$ is connected. Now suppose G contains more than one cycle, and therefore at least two chordless cycles. Let A, B be two chordless cycles, with corresponding vertices a, b in $C(G)$. If A, B have a common edge, then a and b are adjacent. If A, B have no common edge they are joined by a path P, since G is connected. Let us assume that P has order at least 2 (P may be of order 1 but this case is easier to handle). Let u, v be the end vertices of P, with u in A and v in B. Let w be adjacent to u in A, and let x be adjacent to u in P (x may coincide with v). Since G has no cutvertices, there is a path Q with end vertices w and x, which does not pass through u (Figure 2). We may assume Q has the least order among such paths. With the path wux, the path Q forms a cycle C. If C has chords, the construction ensures that any chord it has must be incident with u. Thus, whether C is chordless or not, there is a sequence of chordless cycles which begins with A and ends with a cycle C' containing the edge ux, and consecutive cycles share a common edge (which happens to be incident with u). The subpath of P which joins C' and B has smaller order than P. Thus, iteration of the construc-

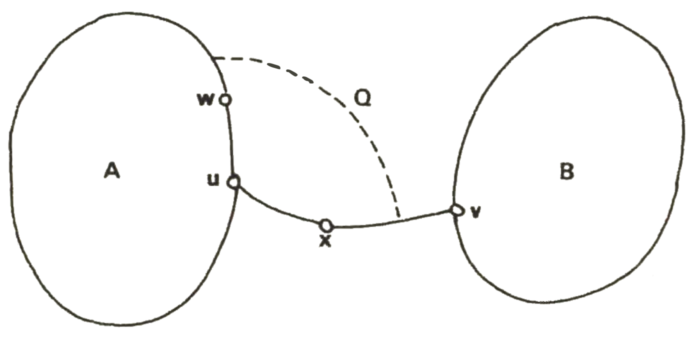

Figure 2. Construction for the sufficiency part of Theorem 2.

tion yields a sequence of chordlesss cycles $A = A_1, A_2, \ldots, A_n = B$ with the property that consecutive cycles have a common edge. Consequently, there is a corresponding path $a = a_1, a_2, \ldots, a_n = b$ in $C(G)$, whence $C(G)$ is connected.

Conversely, assume that G is not a block. Since G is connected and bridgeless each of its blocks has order at least 3. Since G is not a block, it has at least one cut vertex, say x. Therefore x is adjacent to vertices u, v, w such that u, v and x lie on a chordless cycle A and w lies in a component of the subgraph induced by $G - x$ different from the one which contains u and v (Figure 3). The edge xw lies in some chordless cycle B. Any sequence of chordless cycles $A = A_1, A_2, \ldots, A_n = B$ such that no two consecutive cycles are disjoint must be such that some pair shares only the vertex x. Thus, if a and b are the vertices of $C(G)$ corresponding to A and B, there is no path between them, so $C(G)$ is disconnected.

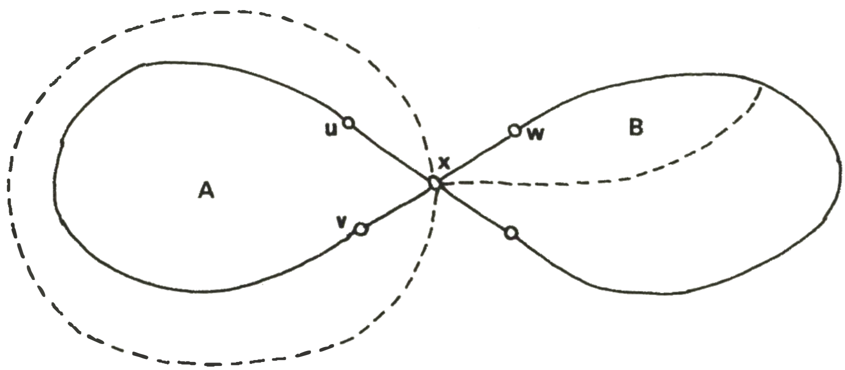

Figure 3. Construction for the necessity part of Theorem 2.

Corollary. For any graph G, the connected components of $C(G)$ are the cycle graphs of the blocks of G with at least 3 vertices.

Characterization of Cycle-Vanishing Graphs

A cycle C *intercepts* a tree T if the intersection of C and T is precisely the set of end vertices of T. For convenience, suppose C is a cycle embedded in the euclidean plane: two paths intercepted by C are *parallel* if they can be drawn in the interior of C so that they are internally disjoint (though they may have end vertices in common). Two paths intercepted by C are *skew* if they are disjoint but are not parallel. These definitions are illustrated in Figure 4.

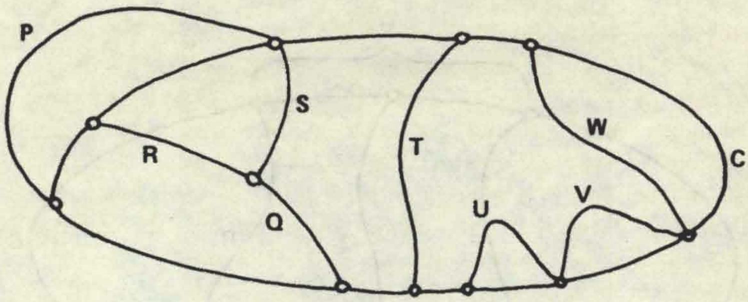

Figure 4. A family of paths each intercepted by the cycle C. The paths P, QS, T, U, V and W are pairwise parallel; the paths p and QR are skew; the paths QR and QS are neither parallel nor skew.

Lemma 5. *A graph G contains a cycle which intercepts two skew paths if and only if it contains a cycle which intercepts a tree with three end vertices.*

Proof. This is simply a matter of two ways of describing the same configuration. Let S, T, U be the three branches of a tree with three end vertices; let the paths P, Q, R join the end vertices of the tree to form a cycle which intercepts the tree, so that P joins the end vertices of ST, Q joins the end vertices of TU, and R joins the end vertices of SU (Figure 5).

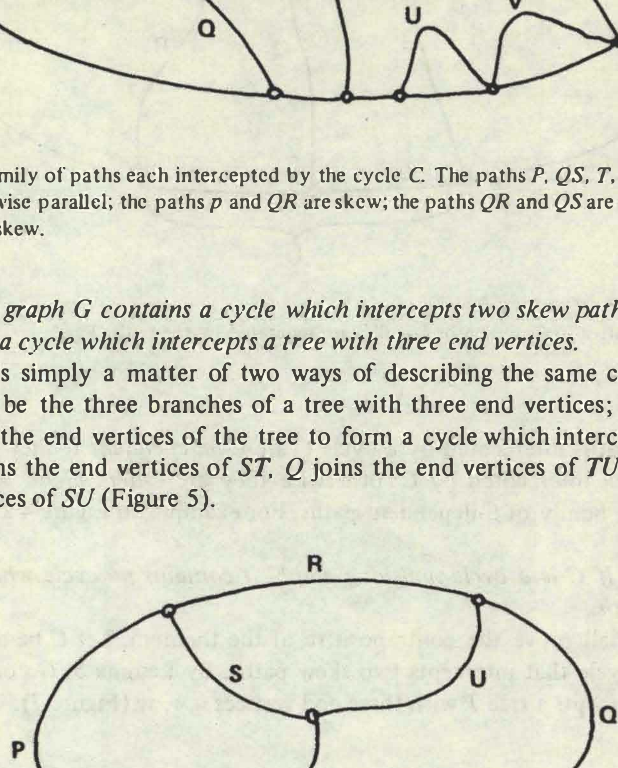

Figure 5. The configuration for Lemma 5.

Then P, T, U, and R form a cycle which intercepts the skew paths Q and S.

Let C be a cycle which intercepts three parallel paths P, Q, R. Then Q *separates* P and R (with respect to C) if C contains paths U and V such that Q joins U and V, and $PURV$ is a cycle which intercepts Q (Figure 6). For example, note in Figure 4 that T separates P and U, but U does not separate T and V, relative to C.

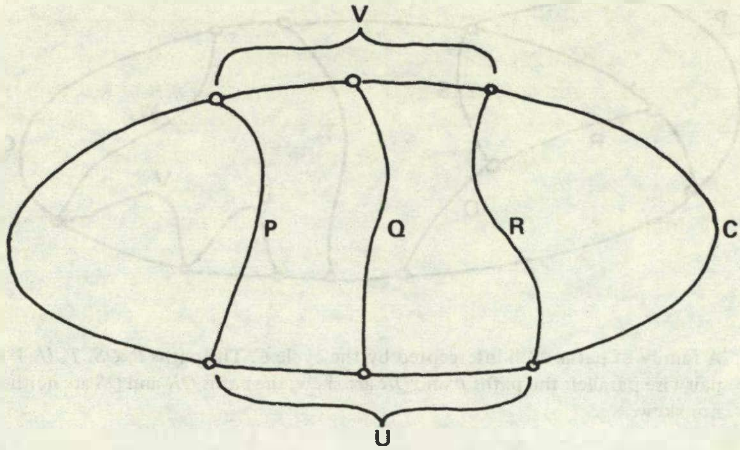

Figure 6. Relative to C, the paths P and R are separated by the path Q.

Two paths intercepted by a cycle C are *C-independent* if they are separated by some path intercepted by C; otherwise they are *C-dependent*. An *ideal* of C is a maximal family of C-dependent paths. For example, in Figure 4 an ideal of C is $\{T, U, V, W\}$.

Theorem 3. *If C is a cycle-vanishing graph, it contains no cycle which intercepts two skew paths.*

Proof. We shall prove the contrapositive of the theorem. Let C be a graph which contains a cycle that intercepts two skew paths. By Lemma 5, G contains a cycle C which intercepts a tree T with three end vertices u, v, w (Figure 7).

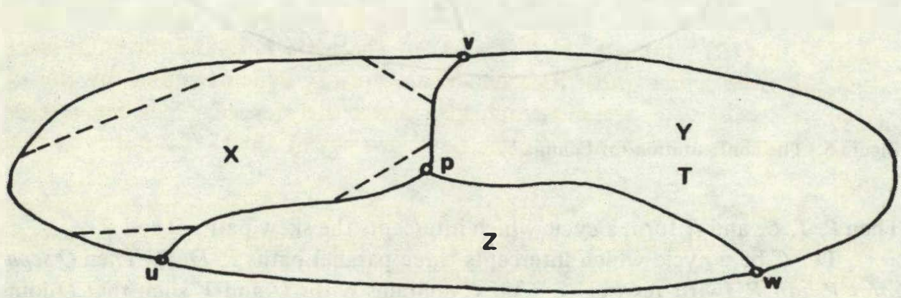

Figure 7. A cycle C intercepting a tree T with three end vertices u, v, w.

In Figure 7, we show the cycles X, Y, Z each being formed by a pair of branches of T and a path in C. We can assume that T has the least number of edges among all trees with three end vertices intercepted by some cycle in G. Furthermore, among all cycles intercepting T, we assume that C has the shortest length. Then the subgraph $\bar{X}$ induced by X does not contain edges like the ones indicated by the dashed lines in Figure 7. This condition also holds in the induced subgraphs $\bar{Y}$ and $\bar{Z}$. Hence, any chord in X, Y, or Z is incident with the vertex ρ common to the three branches of T. Therefore there is a sequence of chordless cycles A_1, A_2, . . ., A_n, A_1 in G such that consecutive cycles share a common edge (which happens to be incident with p). This sequence of chordless cycles in G correspond to the cycle $a_1a_2 \ldots a_na_1$ in $C(G)$ where a_i is the vertex corresponding to A_i. Let e_i be an edge common to C and A_i ($i = 1, 2, 3$). By Lemma 1, e_i lies in a chordless cycle, say B_i, contained in the induced subgraph $\bar{C}$. Clearly, B_i is not equal to any cycle A_i. Let b_i be the vertex in $C(G)$ corresponding to B_i. Then a_i and b_i are adjacent in $C(G)$ (Figure 8). Since $\bar{C}$ is a block, $C(\bar{C})$ is connected by Theorem 2.

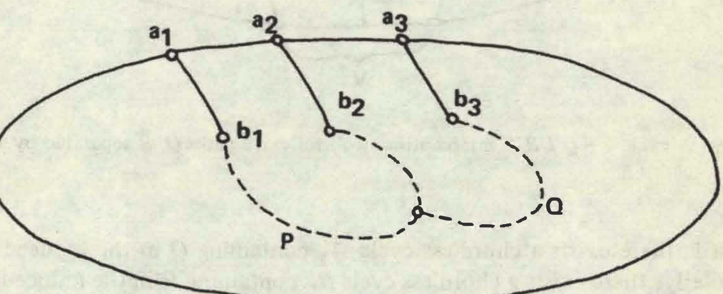

Figure 8. A cycle $a_1a_2 \ldots a_na_1$ in $C(G)$ and three outside vertices b_1, b_2, b_3 adjacent to a_1, a_2 and a_3 respectively.

Therefore there exists a path P in $C(\bar{C})$ joining b_1 and b_2. Also, there exists a path Q in $C(\bar{C})$ joining b_3 to P (Figure 8). The paths P, Q and the edges a_ib_i (i = 1, 2, 3) form a tree with three end vertices a_1 a_2, a_3, intercepted by the cycle $a_1a_2 \ldots a_na_1$. Our argument actually shows that for each positive integer n, $C^n(G)$ contains a cycle (intercepting two skew paths). Hence G is not cycle-vanishing.

A path of order at least two in a graph G is *reflexive* if its end vertices are adjacent in G otherwise it is *irreflexive*. Note that a path of order 2 is necessarily reflexive; an irreflexive path has order at least 3.

Theorem 4. *Let G be a graph composed of a cycle C and a family p of parallel intercepted paths. Then G is cycle-vanishing if and only if it has the following properties:*

(1) Any two irreflexive paths of ρ are separated by at least two chords in ρ.
(2) Any ideal of C consisting of at least 4 paths contains only reflexive paths.

Proof. First assume that G is cycle-vanishing. Let Q and R be two irreflexive paths in ρ, and suppose they are separated by at most one chord in ρ. Let U, V be the paths in C forming a cycle C' with Q and R. Then $C - C'$ consists of two edge-disjoint paths Q', R' such that $A = QQ'$ and $B = RR'$ are cycles (Figure 9). By

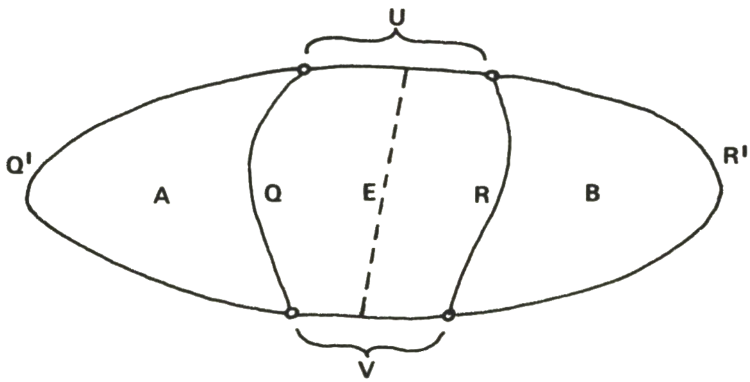

Figure 9. A cycle $C = Q'UR'V$ intercepting two irreflexive paths Q, R separated by at most one chord E.

Lemma 1, there exists a chordless cycle A_1 containing Q in the induced subgraph $\bar{A}$. Similarly, there exists a chordless cycle B_1 containing R in the induced subgraph $\bar{B}$ (Figure 10).

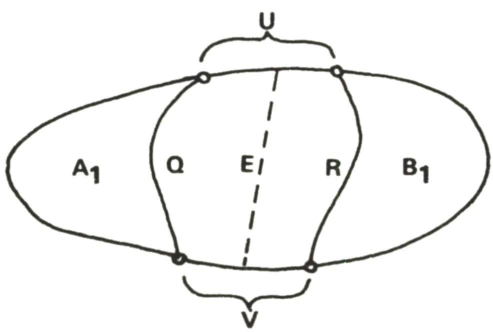

Figure 10. An induced subgraph consisting of two chordless cycles A_1, B_1 and a cycle $QURV$ with at most one chord E.

In case Q and R are not separated by a chord, then the induced subgraph in Figure 10 has a cycle graph of order 6 and is shown in Figure 11 (a) if U or V has order at least 2, and Figure 11(b) if both U and V have order 1. In either case,

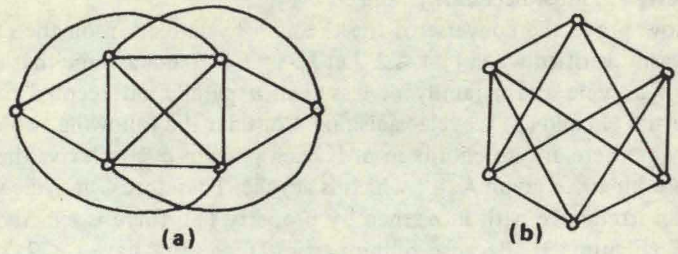

Figure 11. Cycle graph of an induced subgraph of G.

we have a cycle which intercepts two skew paths. It follows from Theorem 3 that G is cycle-persistent. In case there is a chord E which separates Q and R, then E lies in 4 chordless cycles. By Theorem 1, G is cycle-persistent.

Let $K = \{Q_1, Q_2, \ldots, Q_k\}$ be an ideal of C with k O $\geqslant$ paths. Let $R_1, R_2, \ldots, R_k$ be the edge-disjoint paths in C whose end vertices are those of $Q_1, Q_2, \ldots, Q_k$ respectively and let A_i $(i = 1, 2, \ldots, k)$ be the cycle Q_iR_i (Figure 12).

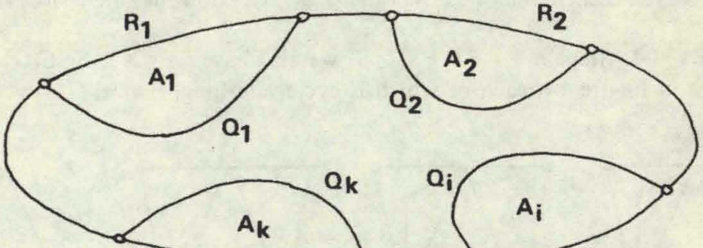

Figure 12. An ideal $K = \{Q_1, Q_2, \ldots, Q_k\}$ of C.

By Lemma 1, there exists a chordless cycle containing Q_i in the induced subgraph $\overline{A_i}$. We may then assume, without loss of generality that each A_i is a chordless cycle. Let the path S_i be defined as Q_i if Q_i is irreflexive, and otherwise it is the edge joining the end vertices of Q_i.

Now suppose that there is an irreflexive path in K, say Q_i. Let A be the cycle formed by $Q_1, S_2, S_3, \ldots, S_k$ and some paths in C; let B be the cycle formed by $R_1, S_2, S_3, \ldots, S_k$ and some paths in C. Then A, B are chordless cycles having some common edges. Let a, b be the vertices in $C(G)$ corresponding to A, B; let a_i

be the vertex in $C(G)$ corresponding to A_i ($i = 1, 2, \ldots, k$). Then a_i is adjacent to both a and b since the path S_i is common to A, B and A_i. Therefore we have at least 4 chordless cycles aba_ia ($i = 1, 2, \ldots, k$) in $C(G)$, each containing the edge ab. By Theorem 1, $C(G)$ is cycle-persistent, and so G is. This is a contradiction, and hence property (2) must necessarily hold.

We now prove the converse of the theorem by induction on the cardinality of ρ. It is easily verified when $|\rho| \leqslant 2$. Let $|\rho| = n \geqslant 3$ and assume that any graph consisting of a cycle and a family of less than n parallel intercepted paths satisfying properties (1) and (2) is cycle-vanishing. Consider the following two cases:

Case 1. There are no chords in ρ. If each path in ρ is reflexive then $C(G)$ is the complete bipartite graph $K_{1,n}$, which is acyclic. Therefore G is cycle-vanishing. If there is an irreflexive path in ρ, then by property (1), there is exactly one such path, say S (Figure 13). Because of property (2) we must have $r \leqslant 2$, $s \leqslant 2$ and

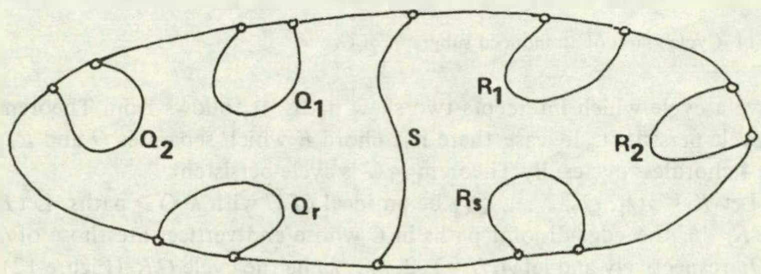

Figure 13. A cycle C intercepting reflexive paths Q_i, R_i and exactly one irreflexive path C.

hence $r + s \leqslant 4$. Since $n = r + s + 1 \geqslant 3$, we also have $r + s \geqslant 2$. So $C(G)$ is one of the graphs in Figure 14, each of which is cycle-vanishing. Hence, G is cycle-vanishing.

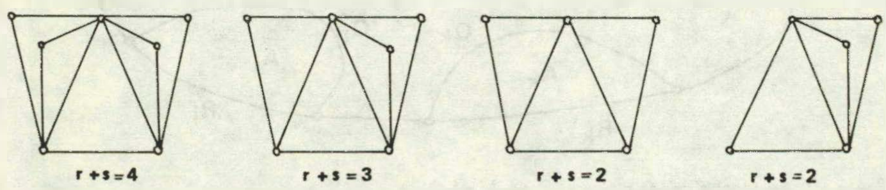

Figure 14. Cycle graph $C(G)$ for Case 1.

Case 2. There is a chord in ρ. Let E be a chord in ρ. Split G into subgraphs G_i ($i = 1, 2$), each consisting of a cycle D_i passing through E and a family ρ_i of parallel intercepted paths (Figure 15). Properties (1) and (2) are inherited by each ρ_i from ρ. By induction hypothesis each G_i is cycle-vanishing since $|\rho_i| < |\rho|$. By Lemma 1, each G_i contains at least one chordless cycle passing through E. By Theorem 1, each G_i contains 2 chordless cycles passing through E. Furthermore, if one G_i contains 2 chordless cycles through E, the other contains only 1.

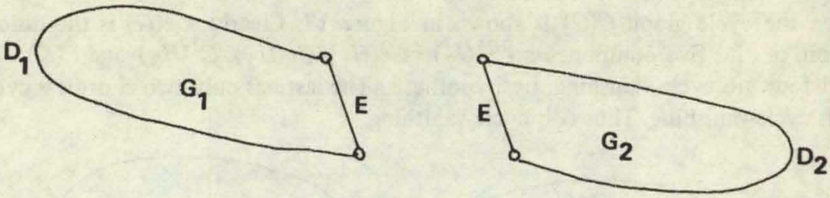

Figure 15. Splitting of G along the chord E.

If G_1, G_2 each contains only one chordless cycle through E then the cycle graph $C(G)$ is composed of $C(G_1), C(G_2)$ and one additional edge joining them. Therefore, $C^2(G) = C^2(G_1) \cup C^2)(G_2)$, the union being disjoint. By induction hypothesis, it follows that G is cycle-vanishing.

Suppose G_1 has 2 chordless cycles A, B which pass through E. Then we may assume without loss of generality that A contains an irreflexive path Q of ρ_1. If B contains any chord of ρ_1, at most one of them is in A, for E, Q and any such chords form an ideal of C and as Q is irreflexive, property (2) limits the size of this ideal to at most 3. If $A \Delta B$ denotes the chordless cycle which is the symmetric difference of A and B, it similarly follows that $A \Delta B$ contains at most two chords of ρ_1, for Q together with such chords forms an ideal of C. Let R represent a chord of ρ_1 in $A \Delta B$. Separate G_1 into subgraphs H_1, H_2, H_3 and G_0 such that G_0 is the subgraph containing B and Q while H_1, H_2, H_3 intersect G_0 in R_1, R_2 and R_3 respectively (Figure 16). In the general case, if any of the chords R_1 is absent, so is the related subgraph H_i.

Since R_i is already contained in two chordless cycles in G_0, then there is a unique chordless cycle Z_i in H_i passing through R_i. Likewise G_2 contains a unique chordless cycle X passing through E. Let K be the subgraph of the cycle graph $C(G)$ induced by the vertices corresponding to $A, B, A \Delta B, X, Z_1, Z_2, Z_3$.

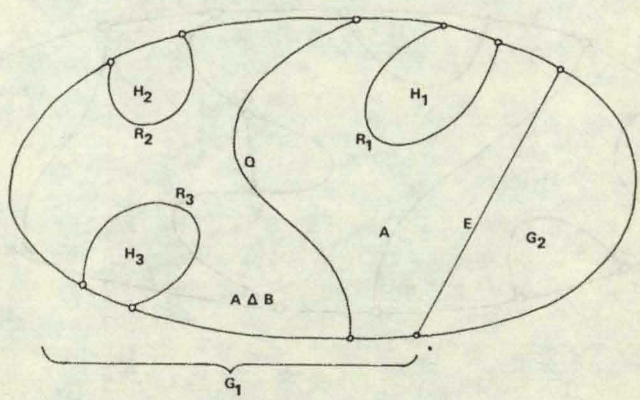

Figure 16. The graph G. Q is an irreflexive path while E is a chord.

Then the cycle graph $C(G)$ is shown in Figure 17. Clearly. $C^2(G)$ is the disjoint union of the five components $C^2(G_2)$, $C^2(H_1)$, $C^2(H_2)$, $C^2(H_3)$ and $C(K)$. The first four are cycle-vanishing, by hypothesis. The last has only two chordless cycles so is cycle-vanishing. Thus G is cycle-vanishing.

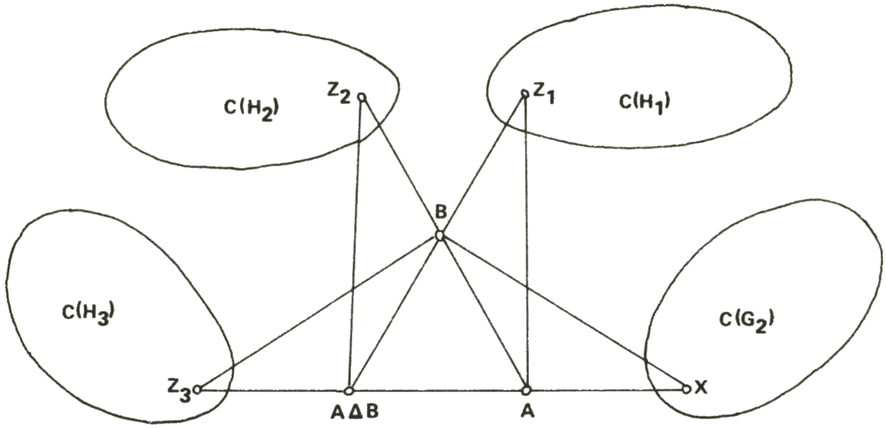

Figure 17. The cycle graph $C(G)$.

Corollary. Let G be a cycle-vanishing graph. The each subgraph of G consisting of a cycle and a maximal family of parallel intercepted paths satisfies properties (1) and (2) of Theorem 4.

Proof. Let G_0 be a subgraph of G consisting of a cycle C and a maximal family ρ of parallel intercepted paths. If x and y are vertices in G_0 which are adjacent in G but non-adjacent in G_0, then they must lie in only one path in ρ and at most one of the vertices x and y is an end vertex of this path (Figure 18). We add the edge

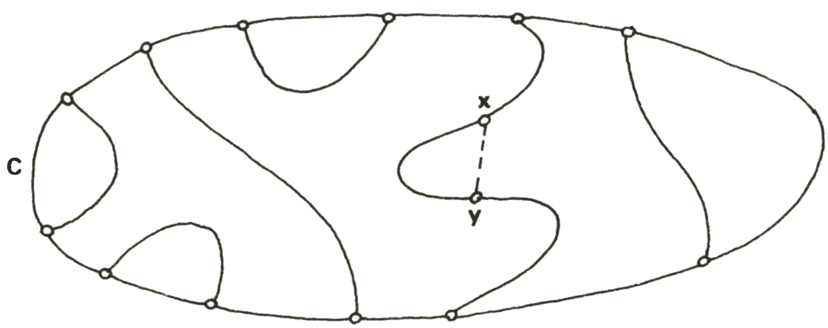

Figure 18. A subgraph G_o of G consisting of a cycle C and a maximal family of parallel intercepted paths.

xy and remove the corresponding portion of the path forming a cycle with xy. We keep on repeating this process until all the paths in ρ can no longer be shortened. Denote by G_1 the graph obtained from G_0 after completing the construction. Then G_1 is an induced subgraph of G consisting of a cycle C and a family ρ' of parallel intercepted paths which is in one-to-one correspondence with ρ. Furthermore, a path in ρ' is a chord if and only if the corresponding path in ρ is a chord. Hence, it suffices to prove that G_1 satisfies properties (1) and (2). Since G_1 is an induced subgraph of G, C_1 is cycle-vanishing by Lemma 3. By Theorem 4, G_1 satisfies properties (1) and (2).

Theorem 5. *If G is cycle-vanishing graph, then each chordless cycle in the cycle-graph $C(G)$ has length 3.*

Proof. Without loss of generality, we can assume that G is a block. We shall prove the theorem by induction on the number m of edges of G. The theorem is easily verified when $m \leqslant 5$. Let $m \geqslant 6$ and assume that the theorem holds when the graph has less than m edges.

If G does not contain any cycle with a chord then G either is a cycle or is composed of a cycle intercepting exactly one irreflexive path. In both cases, G is cycle-vanishing. So we may assume that G contains a cycle C intercepting a chord E. Let ρ be the family of all paths intercepted by C. Observe that $C \cup \rho = G$ and that there are no skew paths intercepted by C in view of Theorem 3. Split G into subgraphs G_i ($i = 1, 2$), each consisting of a cycle D_i passing through E and a family ρ_i of intercepted paths. By Lemma 1, there is at least one chordless cycle in G_i passing through E. By Theorem 1, each G_i has at most 2 chordless cycles passing through E. Furthermore, if one G_i has 2 chordless cycles passing through E, the other has only 1.

In case each G_i has exactly one chordless cycle passing through E, then $C(G)$ is composed of $C(G_1)$, $C(G_2)$ and an edge joining them. Therefore any chordless cycle of $C(G)$ either is in $C(G_1)$ or is in $C(G_2)$. By induction hypothesis, each chordless cycle in $C(G_i)$ or is in $C(G_2)$. By induction hypothesis, each chordless cycle in $C(G_i)$ has length 3. Hence, each chordless cycle in $C(G)$ has length 3.

In case G_1 has two chordless cycles A, B which pass through E, then G_2 has only one chordless cycle D passing through E. If a, b, d are the vertices of $C(G)$ corresponding to A, B, D respectively, then $C(G)$ consists of $C(G_1)$, $C(G_2)$ and the cycle *abda*. By induction hypothesis, each chordless cycle in $C(G_i)$ has length 3. Hence, each chordless cycle in $C(G)$ has length 3.

Corollary. If G is a cycle-vanishing graph, then $C^4(G) = \phi$.

Proof. If G is acyclic, $C(G) = \phi$. If G contains cycles and $C(G)$ is acyclic, then $C^2(G) = \phi$. If $C(G)$ contains cycles, then all chordless cycles of $C(G)$ have length 3. By Theorem 1, any edge in $C(G)$ can lie in at most 3 chordless cycles. Therefore, $C^2(G)$ either is acyclic or it contains chordless cycles of length 3 which have no edges in common. In the first case, $C^3(G) = \phi$ and in the second case $C^3(G)$ is acyclic and so $C^4(G) = \phi$.

We can now give the main result of this section, which is a characterization of cycle-vanishing graphs.

Theorem 6. *(Characterization Theorem). A graph G is cycle-vanishing if and only if it satisfies the following properties:*

(1) *G does not contain a cycle intercepting two skew paths.*

(2) *G does not contain an edge belonging to at least four chordless cycles.*

(3) *For every subgraph of G which consists of a cycle and a maximal family ρ of parallel intercepted paths, any two irreflexive paths in ρ are separated by at least two chords in ρ and any ideal of C with at least four paths contains only reflexive paths.*

Proof. First assume that G is cycle-vanishing. Then (1) follows from Theorem 3, (2) follows from Theorem 1 and (3) follows from the Corollary to Theorem 4.

Conversely, let G be a graph satisfying properties (1), (2) and (3.) Without loss of generality, we can assume that G is a block of order at least 3. We shall prove that G is cycle-vanishing by induction on the order n of G. This is easily seen to be true when $n = 3$ or 4. Let G be of order $n \geqslant 5$ and assume that the theorem holds for graphs of order less than n.

If G does not contain any cycle with a chord then G either is a cycle or is composed of a cycle intercepting exactly one irreflexive path. In both cases, G is cycle-vanishing. So we may assume that G contains a cycle C intercepting a chord E. Let ρ be the family of all paths intercepted by C. Then $G = C \cup \rho$ and there are no skew paths in ρ. Split G into subgraphs G_i ($i = 1, 2$), each consisting of a cycle D_i passing through E and a family pi of intercepted paths. Properties (1), (2), (3) are inherited by each G_i from G and hence G_i is cycle-vanishing by hypothesis. Just like in the proof of Theorem 5, G_i contains at least one and at most two chordless cycles passing through E and if one G_i contains two chordless cycles passing through E, the other one contains only one. By the same argument used in the proof of Theorem 4, G is cycle-vanishing.

Acknowledgement

I would like to thank Dr. Roger B. Eggleton for considerably improving this paper through his detailed comments, more appropriate terminology and simplified presentation of proof of many results.

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Norman F. Quimpo, Discussant

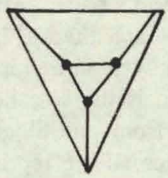
Counting Cycles. The main result in this paper arises from a natural classification of cycle graphs suggested by the definition itself of a cycle graph. That is, if we derive a graph from the cycles of a graph, how many cycles are produced in the new graph? The answer is that the number may decrease, remain the same, or increase.

The paper deals with the first situation.

Regarding the second situation it will be interesting to characterize graphs which reproduce themselves in their cycle graphs. Wheels reproduce themselves.

What other classes of graphs do?

An example of a graph whose cycle graph has more cycles than the original is the following:



How does the cycle count in the new graph relate to the configuration in the original? It seems like a big challenge to prove counting results here.

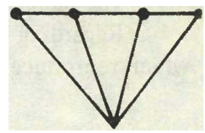
Verifying the Usual Properties. Now that a new way of defining a graph has been given, students of graph theory can have a heyday checking the usual properties of graphs. For example, what sort of graph produces a hamiltonian cycle graph? What conditions must be present in the original graphs for its cycle graph to be a tree, a bipartite graph, a regular graph? When does a graph have a graceful cycle graph? Etc., etc.

As more results about cycle graph pile up, and when the experts move in, we shall see the so-called "soft" results lead to "hard" ones. At some point, we can expect the key problems for cycle graphs arise.

Generalizations. The author imposes the restriction of *chordless* cycles in the definition of cycle graphs. Seeing the neat result that he obtained, we can see that it has been a good choice. The restriction is natural enough (a K_4 produces a K_4) strict enough to exclude a lot of graphs from the investigation and yet loose enough to yield a complex result.

However, we see the way to a generalized study. We can either (i) replace the chordless condition by another, or (ii) drop it entirely.

If we drop the chordless condition entirely, then the new cycle graph will have the same number of or more edges than the Gervacio cycle graph. It follows that any result on cycle-persistence will be preserved while any result on cycle-disappearance will have to be reviewed. For example, consider the following graph under chordless or non-restricted conditions. Under the Gervacio conditon, it is cycle-vanishing. With no restriction, it becomes cycle-multiplying.



Rolando E. Ramos, Discussant

Basically, Dr. Severino V. Gervacio's paper entitled "Cycle Graphs" is about cycles. Cycles are very important in graph theory. In fact, graph theory was developed from the problem of finding a cycle in a graph. Also, cycles have practical applications. One practical application is the so-called Chinese postman problem. From a post office, a postman goes from one block to another to deliver mails. Afterwards, he goes back to his office. If we represent the post office and the intersections by vertices, and the streets between them by edges, the postman's route turns out to be a cycle. Another application is the travelling salesman problem. Likewise, from a warehouse, a salesman travels from one town to another to sell his goods, then he goes back to his warehouse. Again, if we represent the warehouse and the towns by vertices, and the roads from one vertex to another by edges, the salesman's route becomes a cycle.

In this paper, Dr. Gervacio first defines two classes of graphs, namely, cycle-vanishing graphs and cycle-persistent graphs. Then he gives necessary and sufficient conditions for graphs to be cycle-vanishing or cycle-persistent. Most of the approaches in mathematics are of this type. A mathematician first defines a collection of objects then he finds objects that belong to the collection.

As pointed out by Dr. Gervacio, his study of cycle graphs was motivated by the concept of line-graphs. Line-graphs have theoretical applications and practical applications. They can be used in characterizing finite projective geometries, finite affine geometries and balanced incomplete block designs. They can be used also in solving coloring problems and self-avoiding walk problems. So, I am optimistic that mathematicians will be able to discover theoretical applications and practical applications of these cycle graphs.

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