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THE JOURNAL OF THE NATIONAL AGRICULTURAL SOCIETY OF CEYLON

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The Journal is published annually mainly to disseminate the results and trends of research in agriculture, horticulture, and animal husbandry in Sri Lanka. Articles of current interest in education, development, and management in agriculture, horticulture and animal husbandry may also be considered for publication.

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IN MEMORIAM

Professor

Reginald Rajakulasingam Appadurai

1928-10-01 TO 1978-02-03

It is with deep regret that we bring to the notice of our readers the sudden demise of Professor R. R. Appadurai who was the first Editor of the Journal. The Journal as conceived by him was intented to cover all phases of agriculture and to serve as an additional medium through which agricultural scientists of Sri Lanka would be able to contribute to the expanding body of scientific knowledge on agriculture. It was his hope that the Journal would receive recognition in Sri Lanka and abroad, both of which were realised soon after the publication of the early issues.

Against many odds and without a financial base, Professor Appadurai published the first volume in 1961, and guided its subsequent growth until 1969. All those years, he had to seek advertising support to meet the cost of publishing. Before he relinquished his role as Editor, the Journal had become one of the leading publications on agriculture in the country and continues to be a valuable periodical sought by agricultural scientists in Sri Lanka and abroad.

Professor Appadurai began his agricultural career in 1951 as a freshman undergraduate in agriculture in the University of Ceylon. After graduating with a First Class B. Sc. (Agriculture) degree in 1954, he joined the small staff of the Department of Agriculture of the University as an Assistant Lecturer and proceeded on a Smith-Mundt Scholarship to Texas Agricultural and Mechanical University where he obtained his MS (Agronomy) in 1956. He returned to Sri Lanka for a short spell of duty at the University and proceeded to Wye College, London where he obtained his Ph.D. in 1961. Since then, he has made a significant contribution to agriculture in Sri Lanka as a teacher, researcher and advisor. In recognition of his research on agrostology he was the first scientist from Sri Lanka to be awarded the coveted Sir George Stapledon Memorial Fellowship which allowed him in 1966 to undertake post-doctoral research at the Grassland Research Institute, Hurley, England. Through the years until his death, he contributed substantially by his research and writings to our knowledge on pastures and fodders and their role in the development of the livestock sector of Sri Lanka.

In 1968, Professor Appadurai was appointed to the Chair in Animal Husbandry. He served as the Head of the Department of Animal Husbandry from 1968-1975, a period during which he implemented a programme of staff and resource development to strengthen the teaching and research in this department. He was appointed Dean of the Faculty of Agriculture in 1972 and Director of a new institution, the Postgraduate Institute of Agriculture in 1975, which posts he held until his death. With the objective of making the Institute one of the leading institutions of postgraduate education on agriculture in the years ahead in the Asian region, he set the highest standards of academic administration so as to lay the foundation for a strong institution within the shortest possible time.

During the last few years, he served on several committees of the Ministries and Departments connected with agriculture and was a delegate to many international and regional conferences. His death has removed from the academic and scientific community one of Sri Lanka's most competent agriculturists. But the foresight he had in bringing out this journal will remind its readers, that his contribution to the advancement of agriculture has not ceased but would continue through its uninterrputed publication.

INTEGRATED RURAL DEVELOPMENT IN DEVELOPING COUNTRIES

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SUMMARY

Problem-ridden developing countries are sensitive about improving the lot of their peoples. Internal desire and axternal encouragement, particularly from donor international agencies/countries led to the pronouncement and adoption of IRD in these countries as an approach to the gigantic development problems of their masses who are invariably rural. This article aims at spelling out specifically the basic goals and components of IRD. Attempts are also made to work out key development strategies, and theirby a viable IRD methodology for achieving its basic goals. IRD offers a basis for improving the quality of life of people in rural communities through both production increases and general welfare. It is clear from the experience of the countries implementing IRD approach that political commitment and policy formulation with adequate redistribution of resources are sine qua non to achieve IRD goals. It also requires some practical steps to gradually build institutions and local leadership, to search for appropriate technologies, and finally to lay out a complex of research - action - evaluation - training cycle, continuously ensuring solutions to the day-to-day problems of rural communities. A development program evolved on this line will be meaningful to the common rural people. A lack o appreciation of these vital steps in realizing the IRD objectives could be regarded as the main reason for ineffectiveness of the development efforts in general and IRD in particular in the developing countries.

Introduction

The integrated approach or IRD, concerned with both production increases and general welfares, to some extent grows from a failure of the much publicized "Green Revolution" in the 1960's. Remarkable gains in production were sometimes possible, but were not necessarily accompanied by an improvement in the distribution of benefits from production increases. A change over from the production - oriented approach (exemplified by the preceding example) to a welfare-cum-production-oriented approach requires intensive research and careful planning to achieve the goals of IRD. The failure to accomplish these goals may invite the substitution of another untested approach as a reaction against IRD, thus intensifying further the existing problems in the developing countries.

The article intends to pinpoint common conceptual as well as operational bases for problems confronting an integrated approach to rural development. In analyzing these problems and the multiple socio-cultural forces that interact closely in the adoption of IRD, some acceptable solution may be suggested towards the success of this approach.

Another outcome of this article may be to broaden the scope for further research and useful deliberations on the topic to explore better design or framework for the adoption of IRD.

The first issue is the *selection of the goals of IRD*. How can these goals keep a balance between total economic growth and distributive justice in view of the conflicting national priorities?

The second issue is the *discovery of tools*, or methods for accomplishing the tasks specified under IRD framework.

The third issue is the *role of research and evaluation* in developing and testing rural development strategies and in developing a viable IRD methodology. Closely related to this is the introduction of technologies ecologically adaptable and economically efficient.

Last, but not least, is the *search for suitable institutional models*, dealing with the problem of institution building, management, and the attitude of bureaucracy.

Materials and Methods

The major goal of IRD is to improve the quality of life of people living in rural areas in a sustained fashion. Quality of life includes:

* social and economic justices to all rural people
* improvement in their educational and health conditions
* participation in political activities and
* satisfaction in their living.

To many, these goals may not appear to be unique, integration under IRD operational framework makes them unique. The term "integrated" implies the *interweaving* or interaction of various elements of rural development for the achievement for growth of agricultural production as well as for development of health, nutrition, education, recreation and institutions. Integration is sought as both the end and the means of rural development (Oshima and Rikken, 1975).

Integration of Agricultural Services: Agriculture is a key factor of the rural economy. Its development requires improvement in crop yield, land utilization, livestock production, fisheries, off-farm employment opportunities, return from investment and establishment of agro-based industries. Such improvements imply the need for proper design and implementation of the programs, availability of appropriate technology (cultural practices, better crop varieties, cheaper plant nutrients and efficient sources of power) and institutions, credit and other inputs, marketing facilities, managerial, technical and entrepreneurial skills, infrastructure construction, adequate water resources, and the motivation and active participation of the farmers.

Due to the complex nature of these services, a number of government agencies under different ministries and departments are involved in the delivery of these inputs. These agencies generally suffer from the following major problems:

* lack of coordination
* inter-agency friction and jealousy
* inter-agency suspicion and fear
* agency's own biases and priorities based on self-interests
* duplication of tasks and
* agency's involvement with local politics.

New technology and changing circumstances require more cooperation among agencies concerned to achieve desired goals.

For example, an irrigation agency needs the help of an extension agency and material inputs for its success. Similarly, a credit agency cannot have a successful livestock development program without the assistance of the veterinary surgeon and marketing facilities. This is one situation where each agency has a specific role to play but needs cooperation from others to achieve significant success, although its own fears, suspicion and interests prevent it from cooperating willingly with others.

The situation where there is duplication of tasks is one where ejalousy, competition, and strong resistance to outsiders becomes conspicuous in the servicing agencies. But it is difficult to avoid some duplication. Each country has its own political obligation towards its ministries and departments, and the strength of a ministry/department is measured control it has over various services.

Local politics may also inhibit departmental cooperation. Sometimes departmental workers/officers become aligned with local political factions, leading to their unwillingness to cooperate with others at the farm level.

So apart from the question of how efficiently those agricultural services by various agencies are managed and administered, the important and related issue is *how effectively these agencies integrate and coordinate their activities while approaching the actual users, the clientele.*

Farmers find themselves helpless to these confusing agencies. Their needs are not splintered like agencies. The implication therefore is that these agencies should be structured, and their programs designed, to meet the farmer's needs in his present situation We have examples from a few countries where a well-designed organizational structure helped to integrate required agricultural services to cater to the needs of farmers.

Welfare programs: Another very important component of IRD is the package of programs for development of modern amenities essential to improvement in the quality of life of the people living in rural communities. A significant increase in agricultural productivity requires healthy, educated, participative and satisfied producers. In developing countries, per capita rural incomes are so low that even a temporary increase in production and a relatively equitable system of distribution cannot guarantee the availability of essential services like health, education, recreation and transportation. The people in those countries consider provision of many of these services as the responsibility of the state. Therefore *it is rather difficult to expect* that the people themselves will help develop these facilities on a self-help, self-reliance basis by utilizing their own limited resources (labor or capital). A wider package of programs initially funded by the government may be more suitable at the outset to develop essential services for the area. These programs must be weighted towads outlining future interrelationhips between outputs within and between each program allowing gradually increasing dependence on locally available resources.

Since the goals of health, education, nutrition, family planning and manpower development programs interact so closely with one another, an appropriate organizational structure is needed to manage and administer these services efficiently as well as to deliver them in an integrated fashion. Ideally, a development center should encompass all the necessary agricultural and rural development services within a geographic area at a point easily accessible to the rural people. Such an integration of the physical location of the services may encourage changes in attitudes and behavior of those responsible for managing them (services), thus leading to qualitative changes for integration among specialized servicing agencies. The center must be linked with the village level organization and through it to the individual farmers for the purposes of inputs delivery.

Any organizational structure must suit the needs of the clientele and have the power to deal closely with the local problems. Institution building and farmers' organizations form a key issue in the subsequent paragraphs.

Institution Building and Farmer's Organizations:

Need: The complexity of rural development problems and the rural people's own limited capability to tackle them individually require formal organizations to achieve the goals of IRD.

Building of such formal organizations, especially at the village level, is essential to mobilize local resources, attract outside resources for investment, coordinate inputs, introduce appropriate technologies, induce innovations, and permit local populations to participate in planning and decision-making.

Not only must new organizational structures be built. Some old structures may be re-examined, re-constituted, and used to induce changes. Whether old or new, organizations are needed which are self-sustaining and capable of identifying and solving local problems.

Effectiveness: To be efficient and effective, organizations must have links with outside agencies which can train local leaders; provide marketing facilities, credit and other necessary inputs; audit accounts, disciplining those responsible for irregularities; provide technical innovations; and hold leaders accountable to beneficiaries (Rondinelli and Ruddle, 1976). Other political, social and cultural rural institutions can also give a moral boost to the efficient functioning of the cooperatives/associations.

Cooperatives and farmers associations are two types of "base level" local organizations that are particularly useful. They can enable small and medium-scale farmers to share in the economic and social benefits resulting from rural transformation. But other organizations may also be needed to mobilize different groups of people: women, youth, landless, and artisans.

Limitations: Some such local organizations have played important roles in bringing economic prosperity, social solidarity, and technological changes. But some aspects of the local social structure have impeded introduction of such organizations or have prevented them from being self-sufficient. The existence of wide economic and social inequities among the rural populations in developing countries, particularly in Asia, has created a rural elite which, because of its economically, socially and politically privileged position, dominate the rural power structure.

In India, Indonesia, Bangladesh, Pakistan and Sri Lanka, this minority of rich and influential people did control the management of the cooperatives, exert a preponderant influence over its administration and capture its resources, mainly credit and water distribution, for their own benefits. This can hardly be conducive to the spontaneous growth of rural organizations cooperatives/ associations. This exploitation is possible in many rural organizations because of the vulnerability of the poor.

The poor majority does not benefit adequately from the changes brought by the organizations due to their own weak economic position. They need more than others to have access to inputs required for technology transfer. Even if they have access to inputs they may not be able to utilize these inputs properly or may hesitate to utilize them at all. The small size of land holdings, the subsistence nature (sometimes below subsistence level) of the farmings, and the uncertainty of returns due to natural hazards and other related factors limit their capabilities to make use of available inputs.

The poor have another disadvantage: ignorance, lack of management skills and know-how to adopt proper technologies. Continuous training and education (both formal and informal) with obvious and immediate incentives can contribute to the development of their human resources and make them equal partners in development activities.

The basic remedy to the problem of elite domination of the poor may be beyond reach of individual organizations.

Remedy: Effective rural development for them requires just and equitable distribution of rural resources, particularly land and water. Sometimes, this suggests land reform to eliminate traditional tenurial systems and can give land and tenurial security to landless and near-landless farmers. But remedy must also be sought when land reform is not possible.

To avoid the chance of exploitation and clash of interest from inside the organization, it may be proper to organize small homogeneous groups under the cooperatives or other local organizations. Such groups must be more participative and capable of safeguarding their interests with minimum internal conflicts. They should not aim at creating hostile groups and reinforce the status quo. Rather they should work as functional groups within the same rural organization which works to protect group interest and encourage them to be complementary. An honest and conscious organization, like honest parents, can do justice to its different categories of beneficiaries and thus integrate them for the achievement of common goals, even if they differ in their outlook and capabilities. The organization with its careful and deliberate planning involving all interested parties can become effective in reaching specific institutional goals.

The provision of employment opportunities created by rural work programs, cottage industries and agri-business can also improve their economic position, thus increasing their capability to utilize inputs, and reducing their dependence economically on the elite.

Building Leadership: Effective leadership is very essential to carry out specific tasks of the organization. An appropriate organizational structure serving a fixed and manageable geographical area eases the problems of splintered and uncoordinated servicing agencies. Similarly, an effective leadership also encourages diverse agencies to integrate their activities.

Strong leadership with its honest, charismatic, and persuasive character has played a vital role in articulating the necessity and goals of rural development. *National leadership* helps generate national policies supporting IRD. *Local leadership* helps to implement those policies. In other words, the support of local leadership from government agencies, political groups and cooperative associations is a basic ingredient in planned development.

Although there is no substitute for effective formal leadership, technical assistance personnel can provide informal leadership to supplement deficiencies in local leadership. Technical assistance personnel and change agents should aim at building local leadership and making it technically and managerially strong enough to perform its tasks effectively. The local leaders have their own perception and motivation, but the association of the government agencies can make them more skilled and articulate.

One role of local organizations is to act as pressure groups to have their interests considered in the operation of government development programs. The rural organizations should express the perceptions and value orientations of the participants and should not become the instrument of a few men. The leadership should be dispersed and directed towards the organizations ends.

IRD emphasizes a comprehensive rural development through the involvement of all sections of rural population Thus, it is imperative to identify various forms of local leadership existing in the area and use them to stimulate over rural development.

3. *The Model*

Taiwan, for example, has made progress in nearly all aspects of rural development. It improved crop, irrigation, rural health, animal husbandry, forestry, fisheries, land reform, credit and farmers' organizations. When in 1949, Taiwan started its planned effort toward rural development, it had certain advantages, namely: extensive infrastructure, good roads, well-functioning railway, electricity, irrigation systems, and a motivated people with a high level of literacy. It also received American financial and technical assistance through the Joint Commission for Rural Reconstruction (JCRR) which served as a catalyst and a stimulus to all development efforts. Yet the organizational and administrative setup developed by Taiwan's model of rural development has a lesson for other countries.

The model demonstrates the importance of effective integration at the three levels of decision-making: (1) *that of the government which provides the social overhead, the infrastructure and capital investment;* (2) *that of the farmers through their organizations, which take care of cooperative marketing, water distribution, pest control and technical advancement;* and (3) *that of individual farmers who decide on the adoption of the available divisible inputs* (Hsieh, 1971).

On the other hand, Bangladesh (then East Pakistan) started its development programs from almost insignificant levels of development It had all the disadvantages, namely: lack of physical and institutional infrastructure, capital and new technology; widespread illiteracy, poverty, distrust and fear and natural hazards such as flood, drought and diseases. Amidst these general constraints the Comilla Academy for Rural Development started its development programs in one of the most problem-stricken areas of the country, Comilla Kotwali Thana.*

* Thana is a lower administrative unit and equal roughly to a county, having an average area of 150 sq m and a (average) population of 175,000.

The thana, previously served as a law and order enforcing agency, was established as the center from which development would extend to the villages. Prior to this, departmental officials and extension workers were scattered, and for farmers it was difficult to locate them.

> So, a thana council was created which became the nucleus for rural development work. It brought the nation-building departments and the local governments together and located them in one building called Thana Training and Development Center (TTDC). The thana council was conceived as the planning and coordinating body, particularly for programs of training and building physical infrastructure.
>
> However, even bringing all the government agencies together at a lower level was not considered enough to develop the villages. So another body was formed–the Federation of Cooperatives–and this organization, bypassing the local government unit, went directly to the village, which organized itself as a cooperate unit. The Federation would run a bank, a tractor station, an irrigation unit, a demonstration farm, processing industries and so on. This would be a powerful economic body which could stimulate increased productivity at the village level, train villagers in the art of business management, provide them with processing of facilities and market their produce, thus increasing production.
>
> (Chu and Rahim, 1976)

Since, unlike Taiwan, Comilla programs started from rudimentary levels, considerable investment by the government was needed in irrigation facilities, electrification, feeder roads, machinery and a credit system. The previous notion that villages could help themselves was considered hypocritical and false.

The development of such an organizational structure, with integration of the servicing agencies at a point accessible to villages, and mobilization of villages into village cooperatives strongly supported by the center make it possible to:

—bring institutional and technological innovations by streamlining and unifying flows of communication;

—pool resources - human, institutional, material and technical - from various sources including from farmers themselves for efficient distribution and utilization;

—undertake programs necessary for building a physical infrastructure, effecting technological transfer, rural administration, social activities, educational, and health and family planning activities with the involvement of all the villages and the support of integrated servicing agencies at the center; and

—develop rural capital formation, local leadership, manpower and employment opportunities by providing professional training and establishing agro-based industries.

(Webster, 1975)

Under Comilla system of IRD, which is being expanded throughout the country, the main thrust is on building a unified and identifiable entity of villages by organizing them into village cooperatives so that these village cooperatives can pass for and get all the necessary individual requirements. Equally important is a powerful supporting institution at a lower level (thana) which integrates all the nation-building departments, including the central cooperative federation, in order to channel or deliver goods - appropriate technology, inputs, infrastructure construction - to the villages for their development.

Thus integration takes place at three important levels: the *national level* where policy makers and planners decide to allocate funds for social overhead, infrastructure development and capital investment; *country/thana level* where farmers through their village cooperative and representatives along with the departmental p ofessionals (specialists) take care of distribution of inputs and water, diffusion of technologies, construction of infrastructure and provision of marketing and processing facilities; and the *farm level* where individual farmers decide to adopt innovations and inputs.

In Sri Lanka, integration among servicing agencies was hardly felt until 1972 when the government decided to establish the Agricultural Services Center (ASC) at the village council level, covering a total of roughly 100 villages for service. All the extension offices, including a branch of the national bank, were housed in one building, the ASC. The Agricultural Productivity Committee (APC) representing a total of 10 leading farmers from the area was formed. The APC served as a "pressure group" in order to avail of inputs from various agencies and institutions, and to exercise coordination-channelling those services, preparing a production plan and providing advisory services to the farmers. The APC was given power to increase productivity through proper utilization of rural resources, land and water. The farmers' representatives, the professionals (extension workers) and the banker were combined for the first time at a point easily accessible to the farmers, to plan, coordinate and execute the programs of agrarian development.

The Agrarian Research and Training Institute, a national research and training institute, selected one of the newly established APCs as its socioeconomic field laboratory to demonstrate how the goals of an APC could materialize. After intensive survey of the area, a number of pilot projects were undertaken, namely: institution building, rural credit program, group production, livestock development, home gardens and nutrition training, land development and crop diversification, population education and extension services (manpower development). The main thrust was on making the primary institution the cultivation committee (village level) more effective and receptive to the development programs, and the supporting institution, the APC, much stronger and conscious to pool all the necessary resources for the development of the areas. This was done by exploiting the resources locally available from the farmers as well as the agencies (Khan, 1976).

The execution and evaluation of these development programs had immediate impact on the neighbouring APCs and the APCs throughout the country in shaping and developing the newly established institutions as an agent for IRD.

Lessons: A few lessons may be learned from the three cases referred to above. These are:

—structural change in the institution or a proper institutional structure to suit the needs of farmers and rural development, to bring and promote processes of interaction among different governmental and non-governmental agencies, and to guide innovations;

—local planning, execution and coordination of development programs to involve the direct beneficiaries and their leaders, organization and servicing agencies;

—a particular manageable geographical area for integration of above partners and their activities to conveniently take place;

—constant flow of information both vertically and horizontally;

—political support and committment to encourage changes;

—local political awareness and participation in the development programs; and

—adequate resource allocation to rural development programs and its execution.

4. *Results and Discussion*

A comprehensive goal of IRD with particular emphaasis on integration as both means and end of rural development suggests a number of pragmatic steps for its fulfilment, rather than depending on abstract philosophy or ideology. It implies that IRD should be based on continuous *research, action programs, training* and *evaluation.* These steps - research, action programs, training and evaluation - should be oriented towards solving farmers' day-to-day problems, and promoting innovations and basic technological breakthroughs.

Research: No new approach to rural development can succeed unless it clearly reflects a thorough understanding of the local problems it intends to solve. Unfortunately, the dependence of planners and policy makers on macro-economic research studies and on large projects which might attract foreign aid, has neglected the "basic howework" necessary to define practical micro-level strategies for rural development. For IRD, therefore, is a need of primarily micro-socio-economic research studies.

Such research studies should include important topics such as problems of inter-agency relationships, institution building, effectiveness of the extension and servicing agencies, communication and diffusion of technologies, topography of the area, literacy, health, family planning, physical infrastructure, income distribution, agronomic trials (seeds, soils, fertilizers, etc.) cottage industries, and any other villagers' constraints to IRD.

These research studies may be carried out through both conventional and non-conventional methods. A careful appreach to such research studies may provide immediate benefits of using field workers and villagers as change agents who may gradually undertake more specific roles. The field workers or extension workers are trained to study carefully every aspects of village life, to know village life intimately and to help villagers solve their problems. Relatively better qualified/trained research workers will provide extension (field) workers with better techniques and knowledge to help villagers solve their problems effectively. So, they will have to work closely together (Oshima and Rikken, 1975).

The IRD must outline the need for appropriate technology adaptable to the local situation, which varies from country to country and from region to region, institutional change and their importance in facilitating and modifying technological change. The study of important issues such as these require new research procedures and techniques.

Action programs: While problem solving research strategy goes on, a number of action programs, both short-term, may be formalized as a result of intensive studies and experimentation. Action programming is preceded by a planning process that includes (a) identification of problems; (b) specification of objectives; (c) analysis of the causes of problems and the shortcomings of existing programs; and (d) an examination of possible action alternatives.

Evaluation: Evaluation of programs is necessery for further planning and program refinement. Although evaluation follows mplementation, it is desirable that evaluation activities begin prior to implementation or replication of programs on wider scale. Results of evaluation may be used to modify programs while they are in progress. These results may also provide the basis for further investigation and research. When evaluation is viewed apart of a process of planned change, the utilization of evaluation findings in decision making becomes a key concern (Caro, 1971).

Training: Training is an important vehicle for introducing change. Under IRD, it can be a mechanism for involving local people in the development process, providing skills in the adoption of technology, and for creating and managing modern institutions. To be effect ve, training must guide people to solve their problems, sensitize them to the needs of IRD, create a receptive local atmosphere, improve the technical and administrative performance of field staff and upper echelon administrative staff, and improve conditions to make implementation more effective. Such a training system should also exploit all the training resources locally available such as field workers and school teachers, as well as potential farmers (including their leaders) as training agents; reach maximum number of farmers in the shortest possible time; and form a link with necessary services and supplies.

Common approach: With the widespread concern for IRD, the importance of *applied research* and *social science research* is growing rapidly. There are examples in different countries where research institutions have contributed considerably to formulating rural development programs. A few of these research institutions to cite here are Comilla Academy for Rural Development in Bangaladesh, International Institute of Rural Reconstruction (IIRR) in the Philippines, Puebla in Mexico, and more recently the Agrarian Research and Training Institute in Sri Lanka. They have common features of bringing together many disciplines and facilities for discovery, experimentation, testing and improving of the development programs and technologies. The emphasis here is on micro-approach: collecting data at the village level, conducting interviews with field workers and villagers, and observing in a field laboratory situation.

Based on the experiences of those research institutions, a common approach to IRD may be suggested. First of all, there should be an agrarian research and training institution capable of carrying out interdisciplinary research surveys and guiding experimentation. It should be recognized from the outset that its (the institution's) success depends upon the team efforts of professionally trained individuals of different disciplines who have the the necessary skills, insights and attitudes to creatively formulate sound projects - research and development. An effective leadership with the participative consultative style rather than autocratic form is desirable to create an atmosphere of cooperative collaboration at the institution. The research institution should also play an effective role in coordinating research activities done by other agencies like universities, government departments, technical experiment stations, etc., in order to streamline more suitable research strategies with an objective of quick transfer of technology to villagers.

A geographically manageable area with its administratively defined boundary, which may be representative of a country's overall rural development problems, may be selected to serve as socio-economic field laboratory of an agrarian research and training institution. In case of Comilla, it is the thana, while in Sri Lanka, it is the Agricultural Productivity Committee area which serves this purpose.

The experimental area of the research and trainining institution will serve as a training ground for those responsible for duplication and expansion of the programs. After the development programs are carefully developed in the field laboratory, the government will undertake the responsibility of replicating them elsewhere in the country. The institution will take on the tasks of training recipients duplicating programs; guiding and influencing the government in policy formulation for extending the programs; and undertaking the evaluation of extended programs in collaboration with other research agencies.

The research-action programs-evaluation and training cycle as shown in Fig. 1 will be closely linked and will alternate with each other constantly in making a full cycle. Since development is a continuous process, the cycle may be repeated indefinitely, thus making improvement and refinement in the development programs to appropriately suit the needs of the time.

There may be one or two such institutions at the national level to lead the IRD programs. But, according to size and need of the country, a few sub-institutions with a much more modest capacity may be spread over the country to encourage research and evaluation continuously carried out in different ecological locations or regions.

5. *Policy Implications*

There are two contrasting views about the objectives of economic growth. One is to achieve total economic growth even if it means that distributive justice has to be delayed for quite some time. Another emphasizes enforcing distributive justice even if it means a temporary setback in the GNP. A rather moderate and realistic view, but not free from difficulties, is to emphasize distributive justice without any slowing down of growth.

Even if a country is vocal in launching development programs that stress social justice, internal forces who benefit disproportionately from the emphasis upon growth may resist it, and cause a program to fail. For example, when the Comilla Academy for Rural Development in Bangladesh introduced development programs with an emphasis on social and economic justice for the average villagers by organizing them into village cooperatives, by providing cheap institutional credit to protect them from the vicious circle of indebtness to private lenders, and by inviting villagers to participate actively in the development programs, the so-called rural elite opposed to the programs from outside. In the mid - 1960's the government encouraged the shift towards development of agricultural production by making available adequate capital and other resources for irrigation mechanization. Because of their large size of landholdings and other privileged positions, the rural elite stood to reap greater benefits from the program than their fellow farmers with average holdings. They got into and tried to subvert the initial objectives of the program, this time, from the inside. They occupied key positions in the cooperative society, took most of the loan money, and distributed credit and other benefits among their friends and relatives. They established contact with the bureacracy of the Central Cooperative Association, particularly the Cooperative Inspectors, and defied repayment of the loan (Khan, 1971). This did considerable damage to the programs and common villagers justifiably felt cheated.

In other countries, tenants have not been able to fully claim their tenancy rights from powerful landlords even after land reform apparently was initiated.

What emerges from these examples is the fact that *the rural rich, who form the socially, politically and economically privileged echelon of rural society, are capable of reaping the benefits of rural development for themselves at the cost of the rural poor.* A national policy must be sensitive to this fact. It must be geared toward minimizing gaps between different rural economic groups. Yet it must do so without causing any substantial reduction or delay in economic development.

The accomplishment of such a difficult task depends upon how *strongly the national policy is committed to it, and how conscientious the policy makers are* in making the people aware of the national goals and preparing them for sacrifice and commitment in the name of national growth. The national mass media and rural institutions have a major role to play in quickly and peacefully breaking down the resistance of the privileged minority. Accomplishment also depends on how *practical these policy makers are in* *giving high priority* to IRD and allocating adequate national resources to IRD programs. A more informed and politically-socially conscious majority of people will put pressure on those who resist change in status quo to change their attitude for common progress. This is only possible if national policy is formulated along the line of the new realities and implemented in true spirit.

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THE EFFECT OF STORAGE TEMPERATURE ON SEED GERMINATION IN SOYBEAN
GLYCINE MAX (L.) MERR.

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SUMMARY

The effect of storage temperatures viz. 5°C, 25°C and room temperature on the germination of 10 varieties of soybean (Improved Pelican, Hardee, Lee 68, Bragg, T. K. 5, T. E. 32, T. E. 26, T(R)-1, S. J.-2 and Pb-1) was studied.

Germination increased with an advance in the period of storage in Improved Pelican, Hardee, Bragg, T. E. 26 and Pb-1 until 60 DAS and in Lee 68, T. K. 5, T. E. 32, T(R)-1 and S. J. 2 until 75 DAS and then declined. At these stages, the percentage of germination ranged between 97 - 99%. The variety T. K. 5 maintained a germination of 58 - 99.75%, while other varieties maintained 41 - 99.83% throughout the period of storage.

There were no significant differences in germination due to temperature effects until 165 DAS. Beyond this stage, seeds stored at 5°C maintained a higher percentage of germination than those stored at other temperatures. Seed storage at 25°C was also superior to storage at room temperature.

Introduction

A major constraint in soybean production in tropical and sub-tropical countries of the world, is the poor storability of the seed (Delouche, 1973). The seed often drops in germination to the extent that it is worthless for planting within 2 - 3 months after harvest. The reason for the reduction in seed viability has been

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suggested to be due to climatic conditions which prevail from the time seed moisture percentage drops below 25% during the post maturation period until the seed is harvested. Since the seeds are physiologically mature, they are in effect "stored" in the field during this period (Delouche, 1968; Delouche *et al.*, 1973). Hot dry weather during harvesting adversely affects both the physical and physiological quality of seed (Green *et al.*, 1966, 1971; Harris *et al*, 1965). The viability of seed in storage is also influenced by the growth duration of the cultivar, (Delouche, 1972; Mondragon, 1972), quality of seed at the time it enters storage, temperature of the storage environment and moisture content of seeds (Grabe, 1965; Delouche, 1968 a, b, 1972; Harrington, 1972; Delouche, *et al.*, 1973).

The problem of poor soybean stands due to failure of seeds to germinate has been experienced in Sri Lanka but no studies on seed viability have been done probably as the cultivation of this crop is new. This paper reports the results of a preliminary experiment conducted to study the storability of seeds of 10 soybean varieties under varying temperatures to find out the optimum storage temperature and the period for which seeds could be stored.

Materials and Methods

The experiment was conducted at the Central Agricultural Research Institute, Peradeniya during September 1973 - September 1974. The treatments consisted of seeds of 10 soybean varieties namely, Improved Pelican, Hardee, Lee 68, Bragg, T. K. 5, T. E. 32, T. E. 26, T(R)-1, S. J. 2 and Pb-1, stored under 3 storage temperatures (5°C, 25°C and room temperatnre). The experiment was conducted in a single split plot design with varieties treated as main-treatments and storage temperatures as sub-treatments. The initial moisture contents of seeds of all varieties used ranged between 9.3 - 10.5%, while germination percentages ranged between 65 - 100% (Table 1).

100 seeds were kept in sealed polythene bags to maintain the initial moisture contents and were subjected to the storage temperatures. The seeds were subjected to germination tests at fortnightly intervals until 360 days after storage (DAS).

Table 1. *The initial moisture and germination percentages of soybean seeds.*

Variety	Moisture (%)	Germination (%)
Improved Pelican	10.5	98.00
Hardee	10.1	96.00
Lee 68	10.0	65.00
Bragg	9.5	97.00
T.K. 5	9.6	100.00
T.E. 32	10.00	99.00
T.E. 26	9.7	100.00
T(R) - 1	9.3	100.00
S. J. 2	10.1	96.00
Pb - 1	10.0	85.00

Results and Discussion

The initial percentages of germination in all varieties were 85% or over except in Lee 68 which was 65%. The varieties differed in the percentage of germination significantly at all periods of storage (Table 2). The percentage of germination increased with an advance in storage period in Improved Pelican, Hardee, Bragg, T. E. 26 and Pb-1 until 60 DAS and in Lee 68, T. K. 5, T. E 32, T(R)-1 and S. J. 2 until 75 DAS. All varieties maintained more than 85% germination until 105 DAS. Germination percentages in T. K. 5, T. E. 32, T. E. 26 and T(R)-1 at 150, 165 and 225 DAS; S. J. 2 and Pb-1 at 165 and 180 DAS; Improved Pelican T. K. 5 at 195 DAS, T. E. 32 at 180, 195 and 210 DAS and in T. E. 26 at 180 and 210 DAS were more than 80%. Beyond 225 DAS, germination in all varieties except T. E. 26 at 255 DAS and Lee 68 at 270 DAS, dropped below 80%. The germination in T. K 5 during 285 – 360 DAS ranged between 77 - 79%, while in other varieties, it ranged between 41 – 77%.

Storage temperatures had no significant effect on the percentage of germination until 165 DAS. The germination percentage of seeds stored at 5°C was significantly more than those stored at 25°C at 225, 285, 315 and 345 DAS and room temperature at 180, 225, 240, 270, 285, 300, 315, 330, 345 and 360 DAS. Seeds stored at 25°C were also significantly superior in germination to those stored at room temperature at 180, 195, 210, 225, 270, 300, 315, 330, 345 and 360 DAS.

Significant interactions between varieties and storage temperatures for germination percentages were observed (Table 3). Seeds of different varieties stored at 5°C had significantly higher percentage of germination than those stored at 25°C or at room temperature. Seed stored at 25°C was also superior in germination to that stored at room temperature. In general, T.K. 5, T.E. 32, T.E. 26, T(R)-1, S.J. 2 and Pb-1 stored at different temperatures significantly maintained higher percentages of germination than Improved Pelican, Hardee, Bragg and Lee 68 stored at the same temperatures at different stages of germination. Thus, the germination decreased as the storage temperature increased. This is similar to the result of Mukherjee *et al.* (1971), who reported that seeds stored at low temperatures (-2°C and 5°C) maintained a fairly high germination percentage as compared with room temperature. Similarly, Toole and Toole (1946) reported that soybeans maintained at 20° C with 8 - 9% moisture resulted in 90% germination after 5 years of storage,

The foregoing results show that there is no significant difference in seed germination of different varieties for the first 6 months after harvest whether the seeds are stored at 5° C, 25° C or at room temperature. Beyond 6 months after harvest, seeds stored at 5° C maintain a higher percentage of germination than those stored at 25° C or at room temperature. Seed storage at 25° C is also superior in germination to that stored at room temperature. The variety T.K. 5 maintained a fairly high germination percentage throughout the storage period compared with other varieties.

The results, suggested that there is no need to store soybean seeds at a cool temperature if planting is done within 6 months of harvest.

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SOME OBSERVATIONS ON THE GRAZING BEHAVIOUR OF MURRAH BUFFALOE IN THE DRY ZONE OF SRI LANKA

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SUMMARY

An observation carried out to acquire knowledge on the behaviour patterns of six Murrah buffaloe cows in the Dry Zone district of Polonnaruwa, Sri Lrnka, is described.

The average time occupied in grazing was 8.07 hr/day! over 65% of effective grazing being accomplished during the night. Animals spent 7.8 hrs/dry wallowing which occupied 53% of the total daylight hours. This constituted most of the time between 10.00 a.m. and 6.00 p.m.

Wallowing had a direct relationship between air temperature and relative humidity. It took place when the air temperature was over 79° - 84° F and relative humidity below 61 - 74%.

On the basis of these observations, it seems essential that buffaloes be provided with good quality grazing during the night. Wallowing facilities should be made available if the air temperature exceeds 80°F and the relative humidity falls below 60%. It may however be possible and could be to the advantage, to provide adequate shade and frequent sprinkling of water instead of providing wallowing facilities.

Introduction

Although adequate information is available on the grazing behaviour of exotic cattle, both under temperate and tropical climate (Castle, Foot and Halley, 1950; Castle and Halley, 1953; Hancock, 1950; Waite, Macdonald and Holmes, 1951; Payne, Lairy and Raivoka, 1951; Mugerwa, Chistensen and Ochetin 1973; and Goldson, 1963), information is lacking on the behaviour

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patterns of the buffaloe. Available information indicate that buffaloes generally spend around $7\frac{1}{2}$ hr per day grazing. They wallow to regulate body temperature and control external parasites, when water is available, especially during the heat of the day (Mason, 1974).

Behavioural studies with cattle have been successfully used in solving grazing management problems. Many workers (Johnstone–Wallace and Kennedy, 1944; Seath and Miller 1946; and Payne *et al*, 1951) have demonstiated the importance of night grazing of temperate cattle under tropical climate for maximizing production. Hughes and Harker (1951) showed how behavioural studies can be used to improve animal weighing methods when cattle are at grazing. Levy (1935) suggested that the knowledge of grazing habits could help to eradicate feed flavours in milk.

No grazing behaviour studies with buffaloes have been reported under Sri Lanka conditions Lack of information on behaviour patterns could therefore be one of the major factors limiting production by the buffaloe.

The investigation presented in this paper was therefore aimed at gaining some knowledge on the grazing behaviour of Murrah buffaloes under Dry Zone conditions of Sri Lanka.

The study was carried out duiing the month of March 1976, at the Government Livestock Farm, Polonnaruwa.

Experimental

Animals: Six dry Murrah buffaloe cows of average live weight 498 kg (1098 lb) were selected for these observations. Animals were familiar to being handled in the field without causing any disturbance.

Pasture: The paddock in which the six animals grazed measured approximately 0.4 ha (1 acre). It enclosed two large trees which provided shade to the animals and part of a stream measuring approximately 30 sq. metres which provided water for wallowing.

The pasture for grazing predominantly consisted of *Brachiaria brizantha* interdispersed with a few patches of *Brachiaria mutica*. The field was fertilized with urea at the rate of 336 kg N/ha (300 lbs N/ac), one month prior to the commencement of the experiment. A shed constructed at the center of the paddock was used for making the observations.

Weather: Dry conditions prevailed during both days of the experiment, However early mornings appeared to be densely foggy with a high relative humidity (96-97%) and a low ambient temperature (64–70° F). During the day temperature reached 93° F.

Hourly meteriological data for the 48 hr period is given in Appendix Table 1.

Observation Techniques: Observations commenced at 6 00 a.m. on day 1 and ended at 6 00 a.m. on day 3. The activities of each animal were recorded continuously at 5 minute intervals for 48 hrs. At night in addition to a pressure lamp in the observation shed a flash light was used to observe the activities of the animals.

The activities of the animals were classified as follows:

1. Grazing – time spent in selection, gathering or grazing of herbage.
2. Idling – time spent in standing, walking or lying down without grazing or ruminating.
3. Wallowing – time spent in water standing or lying down.
4. Ruminating – time spent in ruminating while standing or lying down out of water.

Ruminating activity while in water was not recorded. The distance walked by one labelled animal during the 48 hr period was also measured using the technique of Hancock (1950).

A pasture sample collected from the field before and after the experiment was analysed for dry matter, ash, crude protein and crude fibre by conventional methods.

Results

The mean chemical composition of the pasture before and after the experiment is given in Table 1.

The average time spent in various activities by buffaloe cows during the 48 hr period is presented in Fig. 1. Daylight hours was taken as the time period between 6.00 a.m. and 6.00 p.m.

Table 1. – *The mean chemical composition of the pasture grazed before and after experiment.*

	Percent Dry matter	Crude protein	Crude fibre	Ash
		(% in dry matter)		
Before experiment	26.3	6 96	29.28	8.12
After experiment	26.8	6 82	28.12	10 59

The average time occupied in grazing was found to be 8.07 hr/day and ranged from 7.70 hr to 8.44 hr. Animals spent 7.08 hr/day wallowing and 5.87 hr/day ruminating. During the rest of the period (2.98 hr/day) animals were found to idle.

The average time spent per animal in various activities during day and night is shown in Table 2. Grazing was largely during the night whilst daylight hours were mainly devoted to wallowing. Over 65% of effective grazing was accomplished during the night. Most of the night grazing occurred between mid-night and early hours of the morning.

During the day animals spent 6.37 hr wallowing. This represented 90% of the total time devoted to this activity, and occupied 53% of the total daylight hours. Most of the period between 10 00 a.m and 6.00 p.m. was used for wallowing with a little scattered grazing and ruminating around 12.00 noon. The rest of the wallowing occurred between 6.00 p.m. and 7.00 p.m.

Similar to the grazing habit most of the ruminating took place at night. Night ruminating accounted for 66% of the total ruminating time.

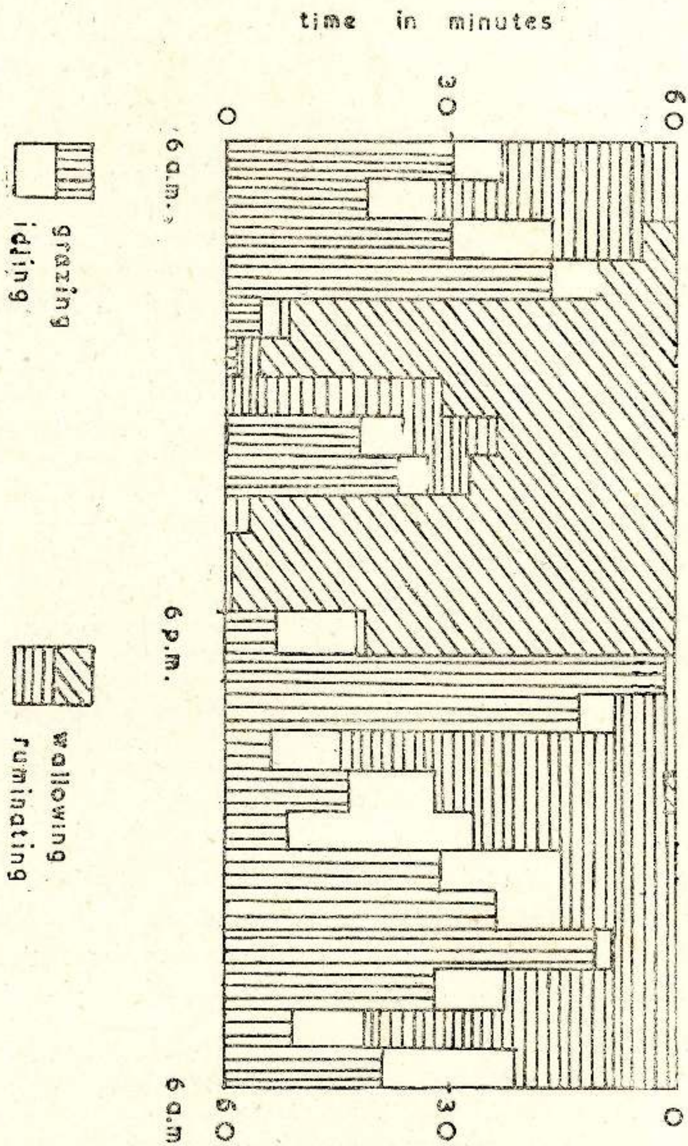


Fig. I. *Periodicity of grazing habits*

Table 2. *Average time spent (minutes) per animal in various activities during day and night.*

	Day	Night	Total
Grazing	168.6	315.6	484.2
Ruminating	120.0	232.2	352.2
Idling	49.2	129.6	178.8
Wallowing	352.2	42.6	424.8
Total	720.0	720.0	1440.0
Word/Leisure ratio (Idling and wallowing constitute leisure)	0.72	3.18	1.38
Ratio of grazing/ruminating (G/R)	1.405	1.359	1.375
Distance walked (meters)	642.4	693.1	1335.5

There was a significant difference between individual animals with regard to time spent in grazing, ruminating and idling. They also showed a marked tendency towards group activity specially in relation to grazing and wallowing.

The average distance walked by the labelled animal during a period of 24 hr was 1336 meters (1461 yds).

Discussion

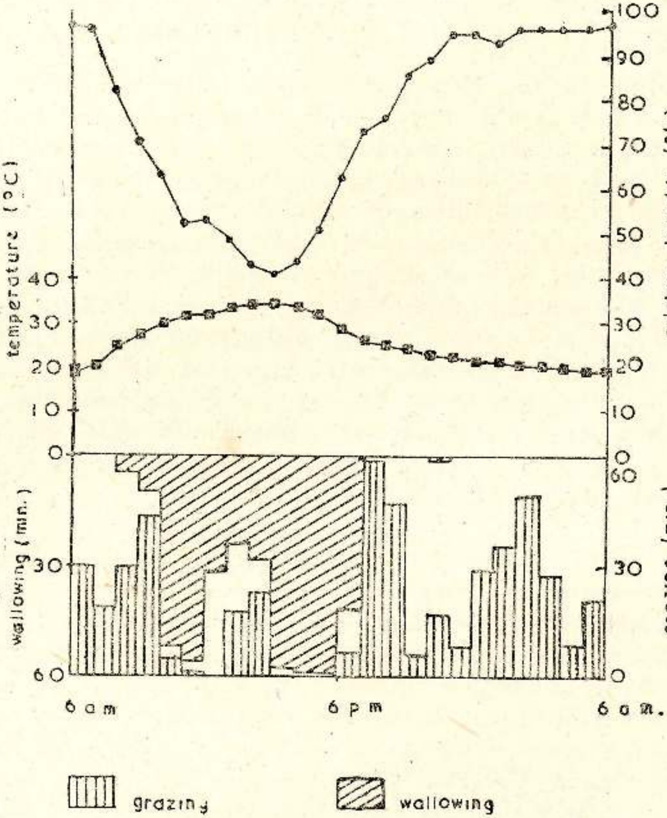
Lack of sufficient information on the behavioural patterns of buffaloes makes it difficult to analyse critically, the results of the present investigation. However the study brings forth certain important information that could be useful in improving present management practices.

The average time spent in grazing (8.01 hr/day) was in good agreement with available data on grazing activity of the buffaloe. Mason (1974) indicated that buffaloes generally spent around 7½ hr grazing. This however does not compare with the findings of many workers for grade cattle under tropical climate (Goldson, 1963; Mugerwa *et al*, 1973). In the present study although the pasture was of low quality in respect of the crude protein content, it was high in dry matter (Table 1). The reduced time spent in grazing as compared to neat cattle grazing under tropical conditions, could have been due to the hirh dry matter content of the pasture. Brumpy (1959) indicated that the time spent in grazing was governed by the weight of the dry matter eaten.

Studies on the behaviour patterns of grade cattle under tropical climate have indicated, that a greater proportion of effective grazing is accomplished during day light hours (Goldson, 1963; Harker *et al*, 1954; Musangi, 1965; Mugerwa *et al*, 1973 and Kashiwamura and Jayasuriya, unpublished da'a). However, evidence from the present study indicate that with buffaloes under tropical conditions, over 65% of effective grazing is during the night. Mason (1974) was also of the view that sometimes buffaloes tend to spend most of the night grazing. The high air temperature and the low relative humidity that existed during the day in the present study, affecting the poor heat regulatory mechanism of the buffaloes, could be the main factor responsible for this behaviour pattern. The buffaloes were observed to spend over 50% of day light hours wallowing in water.

The buffaloe is known to wallow for two main reasons; to regulate body temperature and control external parasites. Wallowing to regulate body temperature is important for the buffaloe because of its less efficient heat regulatory mechanism and the low heat tolerance as compared to neat cattle. Although there is some evidence to indicate that they can be maintained in the complete absence of wallows provided there is adequate shade, even under tropical climate (Cockrill, 1974). Studies on the relationship between air temperature and relative humidity by Alim and Ahmed (1966), Asker *et al*, (1953) and Bhatnagar and Chandhamy (1960) have indicated that 80-90% of the variation in body temperature and respiration rate can be attributed to changes in air temperature and relative humidity. Therefore these two climatic factors can be expected to play a major role in determining wallowing habits of the buffaloe. Evidence from the present study supports this view. Wallowing was found to take place only when the air temperature was over $79^\circ - 84^\circ$ F ($26^\circ - 29^\circ$ C) and relative humidity below 61-74% (Fig. 2). Mason (1974) also observed that buffoloes wallow when the air temperature was over 84° F (29° C).

Fig. 2. *Time spent grazing and wallowing in relation to temperature and humidity*



Mugerwa *et al* (1973) suggested that a certain level of reticulorumen fill must be reached before the process of rumination is initiated. The speed with which this level is attained depends among other things on the rate of herbage consumption which in turn is influenced by herbage quality. Thus the concept of grazing to ruminating ratio is an important parameter that reflects herbage quality and acceptability. The high grazing to ruminating ratio (G/R) of 1.375 (Table 2) in the present study is therefore indicative of the poor quality of the pasture and also explains the high degree of selectivity animals exhibited while grazing. Studies by Hughes and Reid (1951) and Castle *et al* (1950) with cattle in temperate regions have shown grazing to ruminating ratios ranging from 0.6 to 1.0.

In the present study buffaloes exhibited a high degree of group activity. This was particularly true of the wallowing habit where in at any one time over 95% of the animals were seen to wallow together.

The distance walked by a buffaloe during 24 hr period appeared to be about half of that reported by Hancock (1950) and Castle *et al* (1950) for grade cattle. It is generally difficult to interpret the factors that influence walking because of their very number and diversity but it is well known that grass of poor palatability increases the distance walked by animals. However this is contradictory to the observations made in the present study. It appears that factor or a factors other than quality of the herbage has influenced walking in the present study.

On the basis of these observations it can be tentatively suggested that good quality night grazing should be provided to ensure maximum milk production. In addition, during the dry months of the year when the day temperature is likely to rise above 80° F and relative humidity fall below 60%, buffaloes should be provided with wallowing facilities. When buffaloes have to be managed intensively, wallowing may be replaced by the provision of adequate shade and frequent sprinkling with water. This will not only help the animal to regulate body temperature but also eliminate the necessity of thorough washing before milking, thereby resulting in cleaner milk production.

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Appendix Table I – *Weather Data*

Day 1			Day 2		
Time (m)	Dry Bulb Temperature °F	Relative Humidity %	Time (m)	Dry Bulb Temperature °F	Relative Humidity %
6.00 a.m.	61.7	97	6.00 a.m.	66.2	97
7.00	66.2	97	7.00	69.3	95
8.00	75.2	84	8.00	77.0	80
9.00	79.7	76	9.00	81.5	66
10.00	85.1	61	10.00	85.1	64
11.00	87.8	50	11.00	89.6	54
12.00 noon	87.8	53	12.00 noon	89.6	54
1.00	89.6	53	1 00	93.2	44
2.00	93.5	45	2.00	93.2	40
3.00	91.4	43	3.00	95.0	39
4.00	91.4	42	4.00	92.3	45
5.00	87.8	50	5.00	88.7	51
6.00 p.m.	82.4	63	6.00 p.m.	83.3	63
7.00	78.8	73	7.00	78.8	73
8.00	77.0	76	8.00	77.0	75
9.00	76.1	88	9.00	74.3	84
10.00	73.4	88	10.00	72.5	90
11.00	71.6	93	11.00	71.6	96
12.00 night	69.8	95	12.00 night	70.7	95
1.00	69.8	96	1.00	70.7	91
2.00	68.0	92	2.00	68.0	100
3.00	68.0	95	3.00	68.0	97
4.00	68.0	95	4.00	68.0	96
5.00	67.1	95	5.00	68.0	97
6.00 a.m.	66.2	97	6.00 a m.	67.1	96

EFFECT OF AMMONIUM SULPHATE, UREA AND SODIUM CHLORIDE ON GERMINATION OF RICE SEEDS[1]

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SUMMARY

The effects of ammonium sulphate and urea, on the germination of seeds of nine rice varieties were tested in solutions whose concentrations ranged from 0.01M to 0.08M. Distilled water was used as the control. Percentage germination was generally less in urea than in ammonium sulphate of the same concentration. Pokkali had the highest percent germination while A 15-100 had the lowest.

In ammonium sulphate solutions percentage germination of vars A 15-100 and A 16-14 was less compared to other varieties. However, unlike with urea none of the concentrations of ammonium sulphate tested completely prevented germination. Pokkali showed 100% germination even in the highest concentration (0.08M) and A 15-100 showed the lowest.

With increasing concentration of urea percentage germination of vars A 15-100 and A 16-14 decreased rapidly and seedling vigour degenerated. There was no germination in solutions stronger than 0.04M. The vars Bg 34-6 and Bg 3-5 did not germinate in 0.05M and 0.06M solutions respectively. All other varieties tested ceased to germinate at concentrations above 0.07M; and seedling vigour gradually declined up to this concentrations. Increasing concentrations of sodium chloride showed no adverse effect on seed germination.

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1 Part of a paper presented at the 32nd Annual Session of the Sri Lanka Association for the Advancement of Science on 9th December 1976.

Introduction

Urea and ammonium sulphate are the two most widely used forms of nitrogenous fertilizers for rice. The main advantage of the former over the latter is the higher content of nitrogen. The presence of even small amounts of biuret in the urea, however, could also cause phytotoxicity.

Maxten (1927) has reported the effects of fertilizers on seed germination and reported rice plants to be more sensitive to fertilizers during the young seedling stage than during germination. Gasser (1965) has reported that increasing rates of urea decreased seed germination, growth and nitrogen uptake in some soils more than in others. For example, emergence was delayed more on calcareous soils than on others. Barley suffered decreased growth at all rates of applied urea, but with wheat urea did not increase growth although dry matter production decreased from the rate of 336 Kg N/ha, applied as urea. These results indicate that even small amounts of urea can cause problems if soils contain free ammonia that is liberated from urea on hydrolysis to ammonium carbonate. According to Low and Piper (1961) the principal factor in urea toxicity to seeds and seedlings appears to be ammonium formed during ammonification.

A reasonable proportion of rice land in the dry zone of Sri Lanka is "dry-sown", where seed is broadcast on to dry land, and seed germination and growth occur only when it rains. Under these conditions if fertilizers are also applied with seed and if the initial rains are scanty it is very likely that the seeds will germinate in an environment having a relatively concentrated solution of fertilizer. Even though not much nitrogen fertilizer is recommended by the Department of Agriculture, farmers tend to use more than the recommended quantities of nitrogen at the expense of phosphorus and potassium. Therefore this investigation was conducted with ammonium sulphate and urea to study the effects of these two fertilizers on the germination of rice seeds.

Materials and Methods

Laboratory experiments were conducted to study the effects of fertilizer grade ammonium sulphate (21%) and urea (46%N) on the germination of rice seeds. Sodium chloride was also used later to ascertain if there were any osmotic effects that limited seed germination. The molar concentrations of the two fertilizers used were 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07 and 0.08. Distilled water was used as a control. The rice varieties used were Pokkali, IR 8, Bg 90-2, Bg 3-5, Bg 34-6, A 16-14, A 15-100 and Mashuri.

Twenty seeds of each rice variety were placed in separate petri dishes each containing a solution of different concentration or distilled water. The petri dishes were kept closed at constant temperature (28° C) during the germination period of seven days. Loss of water due to evaporation was negligible. Each treatment was triplicated.

Germination was recorded after seven days when radicles and plumules were clearly visible. There was no further germination after this.

Sodium chloride was used instead of ammonium sulphate or urea in another set of experiments using the four rice varieties Pokkali, IR 8, Bg 3-5 and Mashuri. The concentrations of sodium chloride used were the same as that of ammonium sulphate and urea used, and the experimental procedure was also the same.

Results and Discussion

The varieties Pokkali, IR 8, Bg 90-2, Bg 3-5 and Mashuri germinated within the first four days while varieties Bg 34-6, A 15-100, A 16-14 and BW 78 were slow in germination. The latter group also had relatively poor germination percentage in the the control treatment. Therefore to facilitate comparison of the varieties in a particular solution the germination percentages in the treatment were all calculated on the basis of 100 percent germination in the control treatment. This gives the relative germination in the control treatment.

Ammonium sulphate

Results in Table 1 show that the relative percentage germination of Pokkali remained at 100 even in a 0.08M concentration of ammonium sulphate with the variety IR 8 following closely. Mashuri was the next best variety. Of the Bathalagoda varieties

Table I. *Effect of increasing concentration of ammonium sulphate on relative germination percentage of rice varieties.*

Variety	Concentration								
	Control	0.01M	0.02M	0.03M	0.04M	0.05M	0.06M	0.07M	0 08M
Pokkali	100	95	95	100	100	100	100	100	100
IR 8	100	100	90	100	100	84	100	105	95
Bg 90-2	100	100	85	80	85	90	107	85	80
Bg 3-5	100	100	96	107	85	100	100	75	80
Bg 34-6	100	82	67	105	119	75	97	97	90
A 16-14	100	91	53	38	46	38	99	61	30
A 15-100	100	87	77	87	77	167	106	39	39
BW 78	100	64	96	90	83	96	71	109	90
Mashuri	100	96	107	102	85	107	90	102	90

tested Bg 34-6 appeared to be the best while Bg 90-2 and Bg 3-5 were inferior to the former, and could both be ranked together. The last two varieties appeared to be affected at 0.07M concentration and beyond. The Ambalantota varieties A 16-14 and A 15-100 were very sensitive to increasing concentration of ammonium sulphate, being adversely affected beyond 0 06M concentration. The single variety tested from Bombuwela, BW 78, was inconsistent in behaviour to increasing concentrations of ammonium sulphate.

Although germination in the varieties Mashuri and Bg 90-2 was reduced with increasing concentration of the solutions, they were seen to possess more vigour than the other varieties with the exception of Pokkali and IR 8.

Urea

The effect of increasing concentration of urea on relative germination of rice varieties is seen in Table 2. Mashuri appeared to be the best as far as tolerence is concerned, being unaffected up to 0.03M. This was followed by Pokkali and IR 8. In general, germination of all varieties in urea was less compared to ammonium sulphate. The varieties Bg 90-2, Bg 3-5 and BW 78 were the next in tolerance to increasing concentrations of urea, while the varieties Bg 34-6 and the two Ambalantota varieties A 16-14 and A 15-100 were adversely affected even at 0.01M concentration.

In the case of Pokkali the 100% germination in 0.02M urea solution is noteworthy compared to that of A 15-100 which showed the lowest percentage germination.

From the data in Tables 1 and 2 it is clear that germination of rice seeds is suppressed by urea to a greater extent than by ammonium sulphate Urea is thus more toxic than ammonium sulphate, and the toxicity of urea has been ascribed to various reasons. Many workers have expressed differing opinions on the problem of toxicity of urea.

Table 2. *Effect of increasing concentration of urea on relative germination percentage of rice varieties.*

Variety	Concentration								
	Control	0.01M	0.02M	0.03M	0.04M	0.05M	0.06M	0.07M	0.08M
Pokkali	100	100	100	80	75	50	30	5	-
IR 8	100	95	90	73	62	58	43	31	-
Bg 90-2	100	90	75	48	53	43	27	5	-
Bg 3-5	100	96	90	21	11	16	-	-	-
Bg 34·6	100	53	22	29	15	-	-	8	-
A 16-14	100	46	-	23	-	-	-	-	-
A 15-100	100	29	-	29	-	-	-	-	-
BW 78	100	96	64	20	-	20	13	13	-
Mashuri	100	96	101	101	80	37	37	53	-

Sodium chloride

Table 3 shows the effect of varying concentration of sodium chloride on germination of rice seeds of the four varieties that performed best in ammonium sulphate solutions. This experiment was designed to ascertain if there were any effects due to excessive osmotic pressure on seed germination in the solutions of ammonium sulphate and urea used in the earlier study. The results indicate that even a 0.08M sodium chloride solution had no adverse effect on seed germination.

According to Metha and Desai (1955) this problem is one of salinity. However, the results of the experiment with increasing concentration of sodium chloride on the varieties that showed the best germination with ammonium sulphate ie. Pokkali, IR 8, Bg 3-5 and Mashuri, did not indicate any validity in the salinity theory.

Osmotic pressure has been considered to be the cause for poor germination of geed in salt solution (Unvits, 1946). Urea does not ionize, but is hydrolyzed to NH_4^+ and CO_3^- ions, while ammonium sulphate is ionized NH_4^+ and SO_4^- ions. As similar concentrations of both solutions have the same number of ions the adverse effect of urea over ammonium sulphate cannot be attributed to osmotic phenomena.

Biuret, a phytotoxic impurity in urea has been suggested as a cause for the problem with urea, by Widdowson and Penney (1960) but in this case the very dilute solutions of urea used cannot possibly contain such toxic proportions of biuret.

From laboratory and pot culture studies Low and Piper (1961) concluded that the toxic effects of urea on seed germinations was due to liberation of free ammonia during ammonification. In this investigation also it was observed that the pH of the solutions were in the alkaline range, those of 0.01M and 0 05M being 7.4 and 7.6 respectively, indicating the presence of free ammonia. The pH values of solutions of ammonium sulphate of similar concentration were 6.8 and 6 6 respectively.

Table 3. *Effect of varying concentrations of sodium chloride on relative germination percentage of four rice varieties.*

Variety	Concentration								
	Control	0.01M	0.02M	0.03M	0.04M	0.05M	0.06M	0.07M	0.08M
Pokkali	100	100	95	100	100	100	100	100	100
IR 8	100	105	105	100	105	105	105	100	105
Bg 3-5	100	90	100	95	100	100	90	95	90
Mashuri	100	105	100	105	105	95	105	105	105

In conclusion it may be stated that urea showed greater toxicity towards germinating rice seeds than ammonium sulphate, as indicated by the lower percentage of germination corresponding to increasing concentration. The suppression of germination by urea should probably be due to the effect of free ammonia that is liberated from ammonium carbonate, a hydrolysis product of urea. The hydrolysis of urea could be catalyzed by active urease produced by soil microorganisms (Alexander, 1961). Urease actively has been reported in plants also (Meyer and Anderson, 1952). Under the conditions of this investigation the only source of urease has to be the seed itself, but no experimental data is available to support this view. The only other possibility for the hydrolysis of urea in this experiment could be due to chemical reactions. Further investigations are necessary before a definite conclusion can be made.

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COMPARATIVE STUDIES ON THE COMPOSITION AND NUTRITIVE VALUE OF GREEN AND KING COCONUT WATER

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SUMMARY

Several samples of coconut water obtained from green and king coconuts were analyzed at three preferred beverage stages of maturity. Moisture comprised the major constituent of both coconut waters. Nutritive value was provided chiefly by the carbohydrate component which formed 78 and 83% of the total solids in green and king coconut water respectively.

There was no appreciable differenee in chemical composition between green and king coconut water except in total sugars. At any corresponding stage of maturity, king coconut water contained about 1% more total sugars than that of green coconut water. The content of non-reducing sugars was insignificant in comparision to that of glucose and fructose which constituted the main sweetnens of coconut water. The concentration of reducing sugars increased with advancing maturity reaching a maximum of 3.80 and 4.95% for green and king coconut water respectively at the ideal beverage stage.

Protein and crude fat parameters together form 9% of the total solids component in either green or king coconut water. Among the minerals, potassium and calcium are present in adequate amounts. On the average, king coconut water provides 4 Cal/g. higher than that of green coconut water.

Introduction

Water from unripe green and king coconuts is refreshing, sweet and hygienic, and thus constitutes a popular beverage in Sri Lanka. Socio-economic surveys indicate that consumers

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prefer king coconut water, since it is generally believed to be sweeter, and more nutritious. These characteristics and availability considerations probably accounts for the wide disparity in price of the king coconut which rates two or three times that of the green coconut. (Commodity Purchase Department, 1976).

Comparative studies on the composition of green and king coconut water have not been reported in the literature, except for results on the analysis of the sugar content of coconut water (Nathanael 1952). Child and Nathanael (1947) have reported that the sugar content of king coconut water is slightly higher than that of green coconut water at the maximum sugar content stage.

Considering the present coconut crisis and indiscriminate harvest and sale of young green coconuts, it was regarded opportune to ascertain the gross composition of green and king coconut water from a beverage standpoint. This paper reports the results obtained from a study of the chemical and nutrient composition of green and king coconut water at various stages of maturity.

Materials and Methods

Experimental work on green and king coconut water was conducted in the laboratories of the Department of Agricultural Chemistry, Faculty of Agriculture, University of Sri Lanka, Peradeniya Campus.

Green coconut *(Cocos nucifera var. typica)* and King coconut *(Cocos nucifera var. aurentica)* samples were obtained from Kandy, and suburban areas in the hill country of Sri Lanka. The nuts collected from different varieties and locations were analyzed over a two-year period to minimize seasonal effects and other variations which would alter the composition of coconut water. Identification of maturity of the coconut was based on the thickness of the endosperm. This parameter designated three categories of maturity as follows (a) Young (aged 2 mth): no endosperm (b) Medium (aged 3 mth): endosperm in the nature of a thin film less than 3mm in thickness and (c) Mature (aged 6 mth): depth of endosperm 5-8 mm.

At each stage of maturity 24 samples were analyzed in duplicate for each coconut variety. Thus, a total of 144 green and king coconuts were investigated, providing 288 individual analyses. Samples were collected in plastic containers. The time lapse between sample collection and analyses was minimal, usually within three days, to avoid deterioration of the coconut water.

Analytical methods

Determination of moisture, total solids, protein and ash contents were conducted according to Official Methods of the Association of Official Analytical Chemists (1970). The gravimetric procedure involving partial vacuum drying (90 mm Hg) at 70°C was employed for total solids determination. The micro-kjeldahl was used for protein analysis. Ash content was determined with a 'Hotspot' Muffle furnace FR-510, maintained at 525°C.

A modified Manuel Mata Method (Manuel 1948) was necessary to adapt the Soxhlet apparatus for obtaining the crude fat content. Coconut water accurately measured to 1 ml was soaked into defatted filter paper (Whatman No. 1; Diameter 12 cm.) and introduced into the Soxlet apparatus.

Carbohydrate was calculated by difference of the sum of all the other component (moisture, protein, crude fat and ash) from the total solids content. The non-stoichiometric volumetric copper reduction method was done for sugar analysis (Pearson 1970). Among the procedural techniques employed for mineral determinations, potassium and sodium was obtained by a flame photometer, calcium and magnesium were estimated by E. D. T. A. (ethylene diamine tetra acetic acid) titration and phosphorus was analyzed by the ammonium molybdate-sulphuric acid method (Association of Official Analytical Chemists, 1970). Specific gravity was estimated by means of a specific gravity bottle.

Results and Discussion

In accordance with the utility value of the product, it could be observed that moisture constitutes the predominant component in both coconut waters. However no appreciable variation was noted in moisture content with respect to varietal differences (Table 1).

Table I. *Comparison of the chemical composition of green and king coconut water*

Component	Stage of Maturity					
	Young		Medium		Mature	
	Green	King	Green	King	Green	King
(%)						
Moisture	96.00	95.17	95.32	94.54	94.90	93.97
Total Solids	4.00	4.85	4.68	5.46	5.10	6.03
Carbohydrate	3.14	4.04	3.81	4.63	4.11	5.10
Reducing Sugars	3.12	4.04	3.64	4.55	3.80	4.95
Sucrose	0.00	0.00	0.15	0.08	0.28	0.15
Protein	0.05	0.08	0.06	0.11	0.08	0.17
Crude fat	0.21	0.26	0.26	0.32	0.38	0.39
Ash	0.60	0.45	0.55	0.40	0.53	0.37
(ppm)						
Potassium	2680-2900	2670-2940	2450-2600	2400-2700	2190-2280	1900-2310
Sodium	65	72	48	51	35	44
Calcium	218-236	181-199	182-206	230-242	316-332	357-383
Magnesium	62-94	64-69	61-74	42-56	44-66	75-80
Phosphorus	57-67	58-65	58-62	60-67	41-55	37-58
Specific Gravity	1.0189	1.0209	1.0191	1.0222	1.0234	1.0254

*Statistical analyses of differences in components using a single-tailed 't' test revealed significant differences at the 0.01 and 0.05 levels for carbohydrates and reducing sugars only at various stages of maturity between **green and king coconut water.***

Morphologically, coconut water comprises the liquid endosperm of the fruit. As ripening proceeds the notable changes are variation in chemical composition and reduction in total volume of coconut water. In the unripe coconut with an underdeveloped endosperm, the entire cavity of the nut is filled with water. Physiological processes such as germination or ripening and prolonged storage result in a gradual reduction in total water while a more or less complete absorption of water occurs at the termination of these processes (Nathanael 1960). As a beverage 400 - 600 ml. of coconut water is available from each coconut depending on the variety, size and stage of maturity. The average 1.2% decline in moisture content during the maturity of the coconut may be further attributed to a concurrent increase in total solids content.

Nathanael (1952) has observed that the concentration of total solids in coconut water at the earliests stage of its appearance is about 2% which gradually increases with maturity reaching a maximum around seven months followed by a decline. The young coconut employed in this investigation, aged three months showed an average 4.4% total solids content with appropriate increases consequent to maturity of the nut. At the mature stage 5.1% total solids content was obtained for green coconut water and 6.0% for king coconut water. As indicated in Table 1, it could be seen that the total solids is comprised chiefly of carbohydrate, which form 78 and 83% for green and king coconuts respectively.

Although the values reported for the carbohydrate content are deduced from the gross composition, this premise is justified since essentially sugars form the carbohydrate component. This contention is also supported by earlier work (Nathanael 1952, 1960). Further, the minimal amounts of sucrose, the major non-reducing disaccharide, at the various beverage stages implies that glucose and fructose constitute the sweetners in coconut water. However with advancing maturity an increase in sucrose concentration is noticed. On a comparison basis, the sugar content of king coconut water is about 1.0% higher than that of green coconut water at any corresponding stage of maturity. As this difference is very small and coconut water is consumed essentially for sweetness, this is one instance wherein the disparity in price and demand for king coconuts presents no justification. The relative difference in sweetness of the two varieties is thus minimal from compositional and taste panel data and could thus be attributed to have variation of the total sugar content. The percentage composition of total sugars shows a distinct increase during the ripening of the coconut chiefly by the contribution of the reducing sugars and in a small measure by that of the higher sucrose content.

Fig. 1, illustrates the variation in total solids of both green and king coconut with four stages of maturity. A similar representation of the variation in per cent total sugars is given in Fig. 1. The marked linearity in the increase-phase can be observed from these illustrations. The mature stage represents the ideal beverage for both coconut waters since the highest concentration of total sugars are contained in the water. Further, at this stage of maturity, the endosperm too could be consumed as "hardening" of the meat has not been realized. The fully mature stage, designated by the deposition of hard meat results in a relative decrease in sweetness value, and especially in the case of green coconut indicates a preliminary phase in the utilization of the coconut as an essential ingredient in food preparation.

Analytical parameters such as protein, crude fat and ash contribute slightly towards the general composition of coconut water when compared to that of the percentage composition of total sugars. Protein forms only 1.7% of the total solids in green coconut water and 2.9% in king coconut water at maximum protein concentration, a marked difference was not observed in this parameters with respect to the two coconut waters. Appreciable quantities of crude fat were not found in either green or king coconut waters. Further, no changes were detected with maturity of the coconut. This observation is realized since the lipid component is absorbed almost in full measure in the formation of coconut

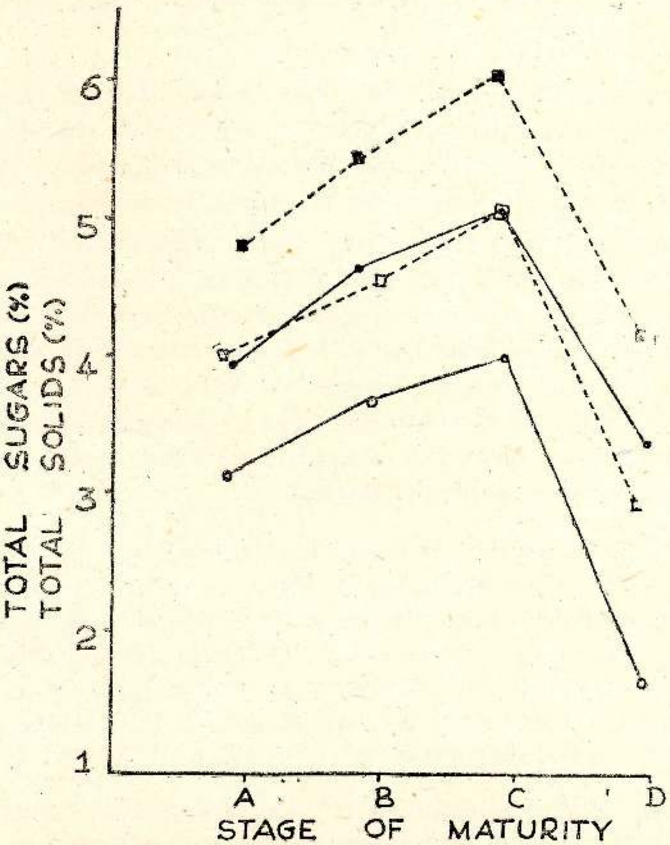

Fig. 1. *Variotion in total solids (● —— ● green, ■ - - - - - ■ king) and total sugars (○ —— ○ green, □ - - - - □ king) of coconut water with stage of maturity – A: Young, B: Medium, C: Mature, D: Fully mature.*

water (Nathanael 1960). Noticeable differences do not occur in total ash content either with stage of maturity or variety of coconut. An average value of 0.56% and 0.41% could be assigned to the total ash content of green and king coconut water respectively.

Detail determinations were conducted for five major components namely, potassium, sodium, calcium and phosphorus. Potassium and calcium comprised the chief mineral constituents of ash in both coconut waters (Table 1). In many instances, coconut water obtained from young king coconuts is used as a substitute for saline in the medical field since it is sterile, isotonic with body fluids and contain valuable electrolytes, especially the high potassium content which ranges from 2,670-2,940 ppm. The calcium content of 182 - 332 ppm. for green coconut and 181 - 383 ppm. for king coconuts could also be considered as an important dietary constituent There was no distinct change in mineral content either with stage of maturity or variety of coconut.

The single physical parameter analyzed was for the specific gravity. The minor difference of this parameter for the two coconut varieties is of no consequence in the physical characteristics of coconut water. In the realm of vitamins, random determinations for vitamin C content gave values ranging from 0.85 to 3.75 mg./100 ml. However the majority of samples realized values at the lower range of the scale, from 0.85 to 1.12 mg./100 ml.

The proximate composition of coconut waters was utilized to ascertain the nutrient and energy requirements provided by the beverage. Total calorific values supplied by coconut water was calculated on the accepted basis of 4 Cal/g for carbohydrate or protein and 9 Cal/g for fat. These results are summarized in Table 2, Which depicts the calorific status of both coconut waters. On the average, king coconut water provides 4 Cal/g higher than that of green coconut, at the same stage of maturity. For calculation purposes, if 500 ml. of cooonut water is taken as a norm, then about 100 Cal and 123 Cal are obtained from the consumption of the entire contents of a mature green and king coconut respectively.

Table 2. *Total calorific value obtained from a single beverage* [1] *of green and king coconut water.*

Stage of Maturity	Green Coconut (Cal)	King Coconut (Cal)
Young	72.85	92.10
Medium	88.70	105.00
Mature	100.30	122.95
Fully Mature	76.50	81.20

[1] Volume of coconut contents : 500 ml.

With respect to the nutritional aspects of coconut water, the provision of readily assimilable sugars merits consideration. The amounts of protein and crude fat (9% of total solids) are appreciable. Regarding the mineral composition, the concentrations of potassium are noteworthy. However, a deficiency of potassium rarely occurs in human nutrition and this element is widely distributed in most foods. As a source of calcium, the daily requirement could be obtained from the water of four green or king coconuts. The contribution of calcium is however only of academic interest, since it is not intended to advocate coconut water to furnish this element considering the coconut crisis and the availability of other foods such as dried sprats which could effectivily supply generous amount of calcium in the diet.

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THE ROOTS OF PINEAPPLE *ANANAS COMOSUS (L) MERR cv. KEW* UNDER PLANT COMPETITION AND MOISTURE VARIATION.

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SUMMARY

In a pineapple trial which was established in the midland intermediate agroclimatic zone of Sri Lanka (emsl 450 m), to study the influence of plant densities ranging from 30,000 to 61,500 plants per hectare, characteristics of root growth of the mother crop were measured at maturity, 20 months after planting. Measurements were taken on the total number of roots, the numbers of live, dead and branched roots, root length and root dry weight. For all plant densities the average numbers of total roots per plant were 79.16 and 76 49 under irrigated and rainfed condions respectively, but the numbers of true roots were 49.64 and 50,67 respectively. The proportion of dead roots of the total roots was 38% under irrigation and 31% under rainfed conditions. The average numbers of branched roots were 5.73 and 7.91 in the irrigated and rainfed treatments respectively. Root length was about 15 cm, the average lengths of the longest root was approximately 34 cm and the dry weight of roots was approximately 12 g. All treatment combinations were non significant (P = 0.05). These studies show that densities higher than 61,500 plants could be used before and competitive effect on root growth could be recognised and that supplementary irrigation had no beneficial influence on this character under local conditions.

Introduction

In studies of pineapple under different plant densities, the emphasis has been directed on studies of the yield and quality of fruits (Dodson, 1968; Chadha *et al*. 1974). Root growth under competition has not received the attention it deserves. Previous

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studies in other countries have either examined the morphological characteristics of roots (Godfrey, 1936; Gwynne, 1962: Krauss, 1949) or their distribution in soil in single density plantings (Black, 1962; Gwynne, 1962). Poor root health and retardation of root growth as causes of poor plant growth and fruit development in Queensland have also been reported by Black (1962).

In Sri Lanka there has been no study on the root growth of pineapple, in field plantings. The present study was made on plants obtained from a field trial which was established to study the influence of different densities of plants on the growth and productivity of the mother plants of pineapple under rainfed conditions and under supplementary irrigation in the midlands of Sri Lanka.

Materials and Methods

The trial was conducted on the University Farm, Kundasale (*emsl* 450 m) which is located in the midland intermediate rainfall zone. The soil of the experimental site was a red yellow podsol. Six plant densities, 30,000, 36,000, 43,000, 48,000, 57,500 and 61,500 plants per hectare (approximately 12,500, 15,000, 17,500, 20,000, 22,500, and 25,000 plants per acre) were established under 2 soil moisture regimes, one rainfed and the other which in addition received supplementary irrigation. A randomised block experiment was used with the treatment combinations replicated 3 times. The row bed plots were established with one plant per hill.

Each plant received the following fertilizers. At planting 7.14 g P_2O_5 as concentrated superphosphate (42% P_2O_5) and 5.2 g K_2O as Potassium sulphate (50% K_2O). At 2 months and 6 months after planting 5.96 g and 11.93 g Nitrogen respectively as ammonium sulphate. At 9 months and 12 months an additional 14 g K_2O. Weeding was done manually with a mammoty and the plots were not mulched.

The trial was conducted from May 1973 to January 1975. During this period the rainfed plots received 581.99 cm rainfall. The plots which received supplementary irrigation water were irrigated on 16 days during the 20 months experimental period. These irrigations were done during rainless periods. The additional water supply to the irrigated plots was equivalent to 66.59 cm rainfall. The experimental site was well drained throughout the experimental period. The data on rainfall and irrigation are shown in Table 1.

Data were recorded on number of total roots, live, dead and branched roots, root length and root dry weight in 10 bed row plants per plot selected at random.

Results

The results of all the treatments were not significant (P = 0.05) for all parameters recorded. They are reported to draw attention to certain trends.

Total root number

The highest number of roots per plant was 90.27 at the lowest plant density of 30,000 plants per hectare under irrigation (Table 2). It was 13.4 per cent more than in the rainfed treatment. There was no recognisable relationship between the total number of roots, availability of soil moisture and increasing density of plants. The total number of roots was higher in the irrigated treatments only at densities of 30,000, 36,000 and 61,500 plants per hectare. The pooled average root number under irrigation at all densities was 79.16 which was 2.5 per cent higher than under rainfed conditions.

Number of live and dead roots

The number of live roots per plant at maturity was highest in the 30,000 plant density treatment at both soil moisture levels. It was lowest in the irrigated treatment of 61,500 plants. With the

Table I. *Rainfall data and number of irrigated days per month. (Figures in parenthesis denote, *highest rainfall on a day and **number of rainy days.)*

	1973		1974		1975	
	Rainfall cm.	Days irrigated	Rainfall cm.	Days irrigated	Rainfall cm.	Days irrigated
January	—	—	0	1	11.96	0
				(0)	(3.33)	(7)
February			29.37	2		
			(10.32)	(6)		
March			28.67	2		
			(2.82)	(1)		
April			52.65	0		
			(10.98)	(16)		
May	1.76	0	41.93	1		
	(0.88)*	(2)**	(8.29)	(17)		
June	11.30	0	14.97	1		
	(2.32)	(11)	(4.52)	(9)		
July	16.63	3	35.65	0		
	(11.42)	(9)	(6.53)	(13)		
August	22.86	0	33.46	0		
	(5.65)	(9)	(7.28)	(9)		
September	12.99	3	43.62	0		
	(4.91)	(5)	(10.04)	(15)		
October	18.47	1	17.69	0		
	(4.02)	(13)	(11.24)	(6)		
November	53.45	0	21.09	1		
	(8.60)	(14)	(7.09)	(7)		
December	76.45	0	37.04	1		
	(13.36)	(20)	(8.60)	(13)	—	—
Total	213.89	7	356.14	9	11.96	0

Table 2. *The influence of treatments on the average root number per plant at maturity.*

	Plants per hectare						Pooled average
	30,000	36,000	43,000	48,000	57,500	61,500	
A. Total roots							
Irrigated	90.27	79.10	76.37	76.10	78.03	75.10	79.16
Rainfed	79.60	69.00	81.14	79.33	79.37	70.47	76 49
B. Live roots							
Irrigated	59.20	52.60	48.90	44.03	50.67	42.47	49.64
Rainfed	56.07	43.63	53.63	55.07	49.53	45.60	50.67
C. Dead roots							
Irrigated	31.07	26.50	29.47	32 07	27.36	32.63	29.85
Rainfed	23.53	25.37	27.50	23.67	25.37	24.87	25.07
D. Branched live roots							
Irrigated	4.55	7.88	6.69	5 25	4 85	5.15	5.75
Rainfed	4.67	8.10	8 33	10.10	7.58	8.68	7.91

exception of the 57,500 plant population, there was a reduction of live roots with increasing density under irrigation. In rainfed plots however there was no such discernible relationship. There was no difference in the pooled average live root numbers in the irrigated and rainfed treatments.

There were more dead roots at all plant densities in the irrigated treatment compared with the rainfed one. No relationship could be drawn between the number of dead roots and plant density at both levels of soil moisture. A comparison of the data on pooled averages show that the proportion of dead roots of the total roots was 38% in the irrigated treatment and 31.5%, in the rainfed one.

Number of branched roots

There were more branched roots at all plant densities in the rainfed treatment when compared with the irrigated one. The difference was lowest with 30,000 plants and highest with 48,000 plants. A comparison of the pooled averages shows that the proportion of branched roots of the total roots was 7 per cent in the irrigated treatment and increased to 10 per cent in the rainfed one.

Root length

There was no difference between the irrigated and rainfed treatments in either the root length or the length of the longest root at all plant densities (Table 3). The pooled average length of a root was approximately 15 cm in both treatments and the longest root was approximately 34 cm.

Root dry weight

The pooled average dry weights of the roots were almost alike in the railfed and irrigated treatments being 11.94 and 12.35 respectively (Table 4). The dry weights were slightly higher in the

Table 3. *The influence of treatments on the average root length per plant at maturity.*

	Plants per hectare						
	30,000	36,000	43,000	48,000	57,500	61,500	Pooled average
A. Live roots (cm.)							
Irrigated	15.67	14.51	14.79	14.38	15.66	15.58	15.10
Rainfed	16.23	14.41	14.89	14.50	15.05	15.37	15.08
Average	15.95	14.46	14.84	14.44	15.36	15.48	
B. Longest root (cm.)							
Irrigated	32.94	32.48	35.74	29.45	38.92	33.98	33.92
Rainfed	38.96	50.47	33.66	35.81	35.01	33.86	34.57
Average	35.95	31.48	34.70	32.63	36.97	33.92	

Table 4. *The influence of treatments on the average root dry weights (g) of a plant at maturity.*

	Plants per hectare						
	30,000	36,000	43,000	48,000	57,500	61,500	Pooled average
Irrigated	14.03	11.29	12.39	11.50	12.52	9.90	11.94
Rainfed	13,29	10.69	12.41	13.39	12.97	11.37	12.35
Average	13.91	10.99	12.40	12.44	12.75	10.64	

irrigated treatements at the two lower densities of 30,000 and 36,000 plants but at increasingly higher densities, the dry weight was slightly greater in the rainfed treatments.

Discussion

Even though the *Kew* variety used in this trial was the same as that grown in all pineapple growing countries, comprisons of root growth have to be made with reservation because plant age, soil characteristics, climatic conditions, management and plant densities could influence root characteristics.

Krauss (1949) reported that pineapple had a radiating root system of about 100 main roots. The highest number of roots for any treatment in the present study was 10 per cent lower and the average for the experiments was 22 per cent less. Competition did not inhibit root production at densities from 36,000 to 61,500 plants per hectare which suggests that even higher densities may be tolerated by the plant under our conditions before a suppresive effect would be evident.

Irrigation showed a slight advantage in root production but its influence was nullified by the fact that it caused more root death at all plant densities. Thus the effective root number was higher in the rainfed treatment. This response confirms the need for selecting well drained land for pineapple cultivation in new localities.

Root branching in pineapple has been reported by Godfrey (1936). An interesting feature in our study was the formation of more branched roots under rainfed conditions. This was perhaps a response to moisture stress, whereby, the plants were able to increase the absorbtive root area in order to utilise the lower moisture supplies, since the root lengths under rainfed and irrigated treatments were similar. The need for root branching would therefore be less where moisture is adequate under supplementary irrigation.

With respect to root length, Gwynne (1962) reported on a study in East Africa that pineapple plants have a dense cluster of roots 22 - 30 cm long and another group 60 - 120 cm long which penetrated deeper. In another study made in Queensland the longest root in a sandy loam at 17 months was 131 cm (Black, 1962). In the present study the root length was much shorter, suggesting that the plants would have obtained their water and nutrients within a distance of 15 cm from the base. This result has different implications under local conditions. Firstly, pineapple has a compact root system which could effectively exploit shallow soils in marginal land. Secondly, in mixed cropping systems where the soil is deep, pineapple could be used as a surface feeding crop and thirdly a rational use of fertilizer could be made by judicious timing of applications in relation to the weather and by proper placement.

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POTENTIAL OF ORGANIC MANURES AND PLANT RESIDUES IN CROP PRODUCTION

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SUMMARY

Field studies were conducted in Iran, Philippines and Sri Lanka to evaluate the efficiency of organic manures and plant residues as alternate sources or supplements to NPK fertilizers in crop production, using potato (Iran) and rice (Philippines and Sri Lanka) as test crops. Potato showed no response to organic manures in one experiment, possibly due to the residual effect of manures and fertilizers applied to the previous crop. In the second experiment on potato, poultry dung increased tuber yield over other types of organic manures due possibly to its higher NPK content. Plant height, tillers / hill and grain yield of rice increased with poultry dung application in both Philippines and Sri Lanka experiments. Rates of organic manure application showed an inconsistent trend, in terms of plant growth, but the higher rate of application increased grain yield in Sri Lanka experiment only, probably associated with poor soil conditions. In the Philippines experiments organic manure at higher rates of application had a slight effect on grain yields probably due to the formation of harmful organic substances during their decomposition under anaerobic conditions in flooded rice culture. Both potato and rice showed a positive response to NPK fertilizers. It is concluded that judicious use of organic manures can increase crop yields. Its use, both alone as well as in combination with inorganic fertilizers, should therefore be encouraged.

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Introduction

Organic manures have been known to farmers since early agriculture for their favourable effect on soil physical condition and crop growth. However, the availability of high analysis, cheap and easy-to-use inorganic fertilizers, has brought about a significant reduction in their use, with a corresponding increase in the use of fertilizers. This phenomenon has also been witnessed in most developing countries, where there is a dominant dependence on foreign resources for both food and fertilizers, and where, as a result, fertilizer prices usually remain high, and supplies, erratic. This leads to the use of sub-optimal fertilizer levels, resulting in a reduction in crop yields. Ironically, organic manures and other plant residues which are available at the farm, continue to remain underutilized. While there may be practical limitations such as handling and distribution, it has been recognized that organic residues could still be used to supplement inorganic fertilizers, and thereby reduce the latter's requirement for crop production. In view of the current situation of energy scarcity and high prices, this factor becomes important.

The current study was therefore designed to re-examine the potential of organic residues usually available at farm locations. The study was undertaken as part of the *INPUTS* (Increasing Productivity Under Tight Supplies) project of the East-West Center (Ahmed, 1974).

Materials and Methods

Locally available organic manures and crop residues were tested at rates of 5 and 10 t/ha, with and without incorporation of the locally recommended rates of NPK fertilizers. Approximate nutrient content of the organic materials used is given in *Table 1*. The study was conducted in three countries, with two locations each in Iran and Philippines and one in Sri Lanka (Gunasena, 1976). The locations were within a latitude of 7-34°N with an annual precipitation ranging from 289 mm. in Iran, to 2032 mm in the Philippines. Crops tested were potato, *var* Alfa in Iran, and rice, *vars*: IR 26 and BG 11-11, in the Philippines and Sri Lanka respectively. The fertilizer rates used for different crops varied widely from country to country. NPK rates on potato were much

Table I. *Approximate nutrient content of organic manures*

Organic manures	Nutrient content, %			Estimated nutrients supplied by 10 t/ha application of material, kg/ha		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Poultry dung	1.3—1.5	0.8—1.0	1.0—1.5	130—150	80—100	100—150
Farmyard manure	0,7—1.0	0.3—0.6	1.0—1.5	70—100	30—60	100—150
Cattle dung	0.7—1.0	0.4—0.7	0.6—1.0	70—100	40—70	60—100
Compost	0.6	0.3—0.6	0.2—0.8	60	30—60	20—80
Pig dung	0.5—0.6	0.5—0.6	0.4—0.5	50—60	50—60	40—50
Paddy straw	0.20	0,1—0.2	1.5-1.6	20	10—20	150—160
Wheat straw	0.20	0.1—0.2	1 5—1.6	20	10—20	150—160

higher than those on rice; the recommended N rate for lowland flooded rice in Sri Lanka was four times than that in the Philippines, although improved varieties were grown in both locations *(Table 3.)* The Philippine soils, however, had a high CEC, indicating a higher level of soil fertility than in the Sri Lanka soils

All organic materials were incorporated into the soil at first ploughing, approximately 3 weeks prior to planting NPK fertilizer applications and other cultural practices were followed as per local recommendation. All treatment combinations were arranged in randomized blocks, replicated four times. Experimental locations, soil characteristics and other details are given in *Table 2 and 3.*

Results and Discussions

Potato experiments (Iran)

Tuber yield – In experiment *A*, potato tuber yields were not affected by treatments, but the yields observed for all treatments were comparatively higher than the corresponding yields in experiment B (*Table 4).* The previous crop at site *A* was alfalfa, which had received 20t/ha of farm yard manure, in addition to the recommended rates of NPK fertilizer. The lack of response to treatments at site *A* may therefore be attributed to this reason, indicating the importance oj site selection when conducting manurial field experiments. According to Cooke (1967), one third of nitrogen, half of phosphorus and most of potassium in organic materials are released under field conditions in the first season of cropping, the balance persisting in the soil to become available to subsequent crops. The residual nutrition available could therefore have raised the yield of potato as it would have been possible to obtain adequate nutrients from the reserves distributed throughout the cultivated zone of the soil more effectively.

In experiment *B*, poultry dung significantly increased tuber yields over cattle dung, compost and farmyard manure, the differences being 8.7, 9.7 and 10.4, respectively. Although it outyielded wheat straw treatments also, the difference was not statistically significant. The greater effect of wheat straw over other organic materials could be explained on the assumption that the major role of straw was to supply potassium, a much needed nutrient for potato. Results of 18 years' work on potato and sugarbeet

Table 2. *Experiment locations and soil characteristics.*

Location	*Iran* Hamadann	*Philippines* Mauresa Expt. Stn.	*Sri Lanka* Peradeniya
Altitude	..	90 M	450 M
Latitude	34°N	15°N	7°N
Longitude	48°E	125°E	80°E
Texture	sand	light clay	light clay
pH	8.3	7.2	5.3
Organic Carbon (%)	3.2	1.9	2.7
Total (N%)	0.90	0.16	0.24
Available P (me/100g)	7.98	8.46	2.99
Available K (me/100g)	0.27	0.22	0.40
Available Ca (me/100g)	20.8	18.5	2.34
Available Mg (me/100g)	10.8	9.96	0.60
Available Na (me/100g)	0.37	0 35	0.06
CEC (me/100g)	28.6	25.62	10.15
Extractable Al (me/100g)	..	5.39	9.25
ECe × 10^6 (micro mhos/cm)		319.0	101.0
Mean annual rainfall (mm)	289	2022	1990
Rainfall during cropping season (mm)	0	674	279

Table 3. *Experimental details*

Experiment	Iran		Philippines		Sri Lanka
	A	B	A	B	
Crop Tested	potato *var.* Alfa	potato *var.* Alfa	rice *var.* IR 26	rice *var.* IR 26	rice *var.* BG 11-11
Date of planting (1975)	Apr 6	Apr 9	Jun 6	Jun 6	Jun 9
Date of harvesting (1975)	Nov 3	Nov 5	Oct 9	Oct 9	Oct 31
Seed rate (t/ha)	1.7	1.7	—	—	—
Spacing (cm)	30 × 30	30 × 30	20 × 20	20 × 20	20 × 20
Plot size (m^2)	25	25	9.3	9.3	9.3
Harvested area (m^2)	20	20	7.5	7.5	7.5
Seedlings / hill	—	—	2-3	2-3	2-3
Age of seedlings (days)	—	—	20	20	21
Depth of water at transplanting (cm)	—	—	10-20	10-20	10 20
Fertilizer rates used, kg/ha					
N	240	240	30	30	120
P_2O_5	180	180	30	30	30
K_2O	120	100	30	30	45

summarized by Patterson (1960) suggest that straw have a "minus nitrogen" and "plus potassium" effect. The yield differences in the above crop could therefore be explained on the basis of differential immobilization of nitrogen and supply of potassium: the crop benefited more from potassium supply in the straw than it suffered from its loss of nitrogen, as it has a high requirement for potassium. The positive response to poultry dung in both experiments may be due to its higher nutrient content, having twice as much N and P as farmyard manure, paddy straw and wheat straw *(Table 1)*. The rate of organic matter used had no effect on tuber yield in both experiments. On the other hand, NPK fertilizer used at the recommended rate increased yield by 17% and 15% in experiments *A* and *B* respectively, the latter being highly significant. The lack of significant response to fertilizer use in experiment *A* can also be explained on the basis of its higher nutrient status due to the management practices used on the previous crop. Interactions between treatments were not significant, probably due to high variability of data as indicated by the coefficient of variation (*CV* = 16.3 - 19.7%).

Table 4. *Main effect of treatments on potato tuber yield.*

Treatments	Yield, t/ha	
	Expt *A*	Expt *B*
Organic manures		
poultry dung	22.1	15.5
compost	21.3	14.2
farmyard manure	20.7	14.1
cattle dung	20.3	14.3
wheat straw	19.8	14.7
LSD (P=0.05)	*N.S.*	1.0
Fertilizer		
with fertilizer	22.5	15.6
without fertilizer	19.1	13.5
LSD (P=0.05)	*N.S.*	1.2
Rate of organic matter		
5 t/ha	21.0	14.3
10 t/ha	20.6	14.8
LSD (P=0.05)	*N.S.*	*N.S.*
CV (%)	16.3	19.7

Rice experiments (Sri Lanka and Philippines)

Plant height – In all the three experiments, plant growth, as represented by plant height and tiller number per hill, was increased to the largest extent by poultry dung; farmyard manure was intermediate in its effect while paddy straw and cattle dung had the lowest effect *(Table 5)*.

In the Philippines experiment, poultry dung increased plant height of *var.* IR 26 over cattle dung and rice straw by 8.6% – 9.6%, the difference being highly significant; in the Sri Lanka experiment poultry dung also increased plant height (*var.* BG 11-11) by 5.5% and 2% over cattle dung and rice straw respectively, although the differences were not statistically significant. Rao and Mikkelsen (1976) found a significant reduction in plant height with the incorporation of paddy straw due to N transforming into organic N forms, unavailable to the rice plants, resulting in N deficiency in early stages of growth. Although the immediate effect of paddy straw is to depress growth as reported above, the long-term response has been to increase both plant height and tiller number due to increased N, *P* and *K* contents in the soil (IRRI, 1975). The rate of organic matter application used in our study increased plant height from 1 to 3% in all experiments, the effect being significant only in the Philippines experiment *D*. NPK fertilizer application increased plant height in Sri Lanka and Philippines experiment *D* by 10% and 3%, both increases being significant. Increase in height of rice plant due to NPK application has also been reported by others (Bhattacharyya *et. al.*, 1970; Wells, 1969), apparently associated with internode elongation and mutual shading due to fertilizer application.

Tillers/hill – In all except the Sri Lanka experiment, poultry dung significantly increased tillers / hill over all other organic manures. The positive effect of poultry dung could be associated with its N content, as high concentration of this nutrient favours vigorous tillering (IRRI, 1964). The rate of organic manure increased tillers / hill in Sri Lanka experiment by a significant 12%; in the Philippines there was a slight positive effect, but the difference was not significant. The greater response in Sri Lanka may be a reflection of poor soil fertility compared with the Philippines soils, as evident by the soil analysis data *(Table 2)*. Incorporation

Table 5. *Main effect of treatments on rice plant height and tiller number.*

Treatments	Plant height, cm			Tiller number/hill		
	Philippines		Sri Lanka	Philippines		Sri Lanka
	Expt *C*	Expt *D*		Expt *C*	Expt *D*	
Organic manure						
poultry dung	114	104	96	12 8	11.5	13.6
farmyard manure	107	102	95	11.2	9.4	12.3
pig dung	105	99	95	11.0	10.0	13.1
rice straw	105	98	94	11.2	9.6	11.1
cattle dung	104	98	91	10 8	9.2	12.4
LSD (*P* = *0.05*)	6.1	1.2	3,0	0.25	0.32	0 83
Fertilizer						
with fertilizer	107	102	99	11.5	10.4	13.2
without fertilizer	106	99	90	11.3	9.5	11.8
LSD (*P* = *0.05*)	*N S.*	0 82	6.88	*N.S.*	0.64	1.19
Rate of organic matter						
10 t/ha	108	101	96	11.5	10.2	13.2
5 t/ha	106	100	93	11.3	9.7	11.8
LSD (*P* = *0.05*)	*N S.*	0.82	*N.S.*	*N S.*	*N. S*	1.19
CV (%)	6.0	6.9	7.9	12.0	18.5	20.1

of organic manures have been reported to increase the available N, P, K and CEC in soils (Sahu and Nayak, 1971). NPK fertilizer application increased tiller / hill in Sri Lanka experiment by 12% and in the Philippines experiment *D* by 9%, both being highly significant. The varietal variablity in tillers / hill was less as both varieties belong to the medium tillering group. Generally, increasing N levels increased tillers/hill, whether N was supplied through organic manures or inorganic fertilizers. Kumura (1956a) reported that there was a positive correlation between the number of tillers and N content at tillering stage. This correlation has been confirmed by Sekiya (1963b). Thus the N contents of both organic manures and fertilizers could be used to interpret the variations in growth attributes observed in the present investigation.

Straw yield – Straw yield was measured in Sri Lanka experiment only *(Table 6)*. The higher rate of organic manure application was found to significantly increase straw yield by 13%. NPK fertilizer application had a slightly positive effect on straw yield, Enyi (1964) reported high straw yields due to fertilizer application, while IRRI (1964, 1965) reported high straw yields, due to both fertilizer and organic manure application.

Grain / straw ratio – The grain / straw ratio in Sri Lanka experiment ranged from 0.78 – 0.90, conforming with those of improved rice varieties (IRRI, 1964). As evident above, both straw weight and grain / straw ratio were only slightly affected by organic manures and NPK fertilizers. Generally, both grain and straw yields increase with fertilizer applications up to a certain level, after which grain yield decline with further additions of fertilizer, while straw yield remains unchanged. For this reason, grain straw ratio generally decreases with fertilizer application (Tanaka, *et. al*, 1958). Lack of such responses, in the above parameters may reflect the use of sub-optimal levels of NPK and a re-evaluation of the recommended rates may be justified.

Percentage of filled grains – Percentage of filled grains in Sri Lanka experiments varied from 90.1 – 92.9%. Farmyard manure increased the percentage of filled grain significantly over rice straw, while the higher rate of organic manure was significantly superior to the lower rate of application. Generally, under heavy NPK

Table 6. *Main effect of treatments on yield components and grain yield of rice.*

Treatments	Philippines			Sri Lanka				
	1000-grain wt (g) at 13% moisture Expt *D*	Grain yield (at 13% moisture content) (t/ha) Expt *C*	Grain yield (at 13% moisture content) (t/ha) Expt *D*	1000-grain wt (g) at 13.5% moisture	straw yield t/ha	grain/straw ratio	% filled grain	grain yield t/ha (at 13% moisture content)
Organic manures								
farmyard manure	27.1	3.94	6 24	14.6	5.05	0.87	92.9	4.40
pig dung	27.5	3.78	6.68	14.6	5.55	0.83	92.3	4.55
cattle dung	27.6	3.87	6.51	14 5	5.14	0.89	91.6	4.56
poultry dung	28 0	4.85	7.47	14.4	5.53	0.87	91.5	4 72
rice straw	28.2	4.15	6.54	*N.S.*	5.64	0.85	90.1	4.11
LSD (P = 0.05)	*N.S.*	0.19	0.17	*N.S.*	*N.S.*	*N.S.*	1.64	0.32
Fertilizers								
without fertilizers	27.8	4.09	6.64	14.4	5.22	0.78	91.9	4.04
with fertilizers	27.6	4.15	6.74	*N.S.*	5.55	0.90	91.9	4.90
LSD (P = 0.05)	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	0.28
Rate of organic matter								
5 t/ha	28.0	4.02	6 64	14.5	5.06	0.83	91.0	4.13
10 t/ha	27.4	4.21	6 74	14.6	5.71	0.85	92.3	4.81
LSD (P = 0.05)	*N.S.*	0.06	*N.S.*	*N.S.*	0.39	*N.S.*	1.16	0.28
CV (%)	7.9	15.3	9 2	4.5	17.6	26.3	3.4	21.6

fertilization the percentage of filled grains decreases (IRRI, 1964). As suggested for grain / straw ratio, the lack of response to applied NPK fertilizer may be due to its use at sub-optimal levels.

1000-grain weight – Varietal variations were observed in 1000-grain weight. In Sri Lanka, var. BG 11-11 had a 1000-grain weight of 14.4 – 14.6g, while for IR 26 in the Philippines it varied from 27.1 – 28.2g. At both locations, treatments had no effect on 1000-grain weight. Evidence indicates fertilizers to have little effect on this yield component (Baba, 1961). However, varietal differences due to rate of application (IRRI, 1964) and timing of N have been reported (Wilson, 1965).

Grain yield – Organic manures had a significant effect on grain yield in all experiments. In Sri Lanka, poultry dung had the highest effect and increased yield by 15%, 7% and 4% over rice straw, cattle dung and pig dung respectively. The Philippine experiments showed a greater response to poultry dung, although there was no definite trend in the yield response to the types of organic manures. Poultry dung had the highest increase over pig dung (28%) in experiment *C* and over farm yard manure in experiment *D* (20%) Paddy straw showed a moderate response in both experiments, due perhaps to the lower K status in the soil (0.22 me K/100g) and lower levels of K application (30 kg K_2O/ha), as indicated in *Table 2*. In many experiments reported by IRRI (1964), K demand appears to have been met by the application of straw, as its K is presumably in available form. The response to straw may thus be regarded as normal under Philippine conditions.

Rate of organic manure application had a significant effect on grain yield in Sri Lanka only, where a 16% yield increase was noted. Similarly, NPK fertilizer application also increased yield by a significant 21%. In the Philippines experiments, response to the higher rate of application of both organic manure and fertilizer varied from 2 – 5%. The effectiveness of inorganic fertilizers in increasing rice yields have been reported by many (Baba, 1961; IRRI, 1964; Sahu and Nayak, 1971; Subbiah and Morachan, 1976). The lack of response to applied fertilizer in the Philippine experiments may be explained on the assumption that recommended rates of NPK may have been sub-optimal. From the results of a series of experiments conducted in the Philippines, De Datta *et. al.*, (1976) concluded that *var.* IR 26 could respond even up to 100 kg N/ha. In both Philippine experiments, 30 kg N/ha had been used, and more yields may have been possible if higher rates of fertilizers had been applied.

Significant interactions between rate of organic manure and fertilizer were observed for both Philippine experiments. In experiment *C*, organic manure at the lower rate of application (5t/ha) with NPK enhanced yield by 7%, while at the higher rate, yield was reduced by 8%. Similarly, in experiment *D*, organic manure at 5t/ha with NPK increased yield by 5%, the response being negative at the higher rate of organic manure application (10t/ha). As evident from both experiments organic manure at higher rates of application with recommended NPK fertilizers had an adverse effect on grain yields. This may probably be associated with the production of undesirable substances during their decomposition under anaerobic conditions in flooded rice culture. These substances are known to weaken respiration and nutrient uptake, or at high concentrations, directly poison rice plants (Yamane, 1958; Motomura, 1962a). Sahu and Nayak (1971) in studies where inorganic fertilizers were used in combination with farmyard manure also reported low grain yields at high rates of application. In their study, the best combination for high grain yield was 45kg N/ha as inorganic fertilizer with organic manure to supply 45 kg N/ha, approximately equivalent to the lower rate of organic manure (5t/ha) used in the present studies. Based on evidence, two possible reasons for the yield reduction at high rates of organic manure could be suggested. Firstly, the formation of organic substances during their decomposition under anaerobic conditions causing physiological damage to rice plants (Yamane, 1958; Motumura, 1962a) and secondly, the temporary immobilization of N due to transformation into organic forms causing severe N deficiency in early stages of growth (Cooke, 1967). The latter explanation may not hold in the present studies as NPK fertilizers may have supplied the nutrients during early stages of growth. Therefore, application of high rates of organic manure seem not only impractical due to limited availablity, but could result in reduced grain yield of rice, particularly when the recommended rates of fertilizers are used.

Conclusion

The use of judicious levels of locally available organic manures and crop residues appears to be beneficial for high crop yields, both when used in conjuction with sub-optimal levels of NPK fertilizers. In view of the high fertilizer prices and their erratic supplies at the farm level in developing countries, it would be advantageous to popularize the use of such renewable resources in crop management systems. The rapidly decreasing availability of non-renewable resources even in the developing countries may lead to the reintroduction of organic materials in farming in the near future. Over application of some materials could be harmful and further field investigations may have to be conducted in various countries to establish yield response patterns under different agroclimatic zones.

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GINGELLY *(SESAMUM INDICUM D. C.)* OIL MEAL AS A PROTEIN SOURCE FOR BROILER CHICKEN

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SUMMARY

Results of five experiments suggest that sulphur amino acid imbalance is the major deficiency in locally produced gingelly meal. This is because of the destruction of cystine in expeller extracted gingelly meal due to high heat evolved during oil extraction.

The sulphur amino acid deficiency caused reduction of growth response and a slight decrease in feed conversion efficiency as the gingelly meal levels were increased in the rations of broiler finisher as well as broiler starter chicks. These two problems were overcome completely by addition of 50 g, DL-Methionine to 50 kg of gingelly meal containing rations. The results suggest that locally produced gingelly meal could be used without any growth inhibitory effect only up to 5 percent level with meat meal in broiler rations if methionine is not incorporated.

Introduction

Gingelly meal is the residue of the gingelly oil industry. It is fairly rich source of protein. Even though foreign data indicates that gingelly meal has about 45% protein (Almquist, 1937), the local samples analaysed by us yielded a mean value of only 30 65 (Table 1). This low value of protein may be due to the introduction of chopped paddy straw to gingelly seeds during the milling process to increase the oil yield out of the mechanical expeller. Further, the expeller extraction procedure adopted in Sri Lanka increased the temperature to about 160°C during the milling process and the heat generated is sufficient to lower the protein quality.

Gingelly meal is reported to be fairly deficient in lysine. (Manuel and Dunde, 1967; Smith and Scott, 1961; Ewing, 1963). This deficiency may be aggravated by the high heat generated in the expeller during milling as lysine is reported to be made unavailable at this temperature (Ewing, 1963). Also the gingelly meal is claimed to be a rich source of sulphur amino acids (Manuel and Dunde, 1967). It is possible that the same effect may not be there in the local gingelly meal due to destruction of cystine which is reported to be more heat labile than lysine during the milling process. (Beuk, 1948). This causes methionine to function as the sole methyl donor and the only source of sulphur amino acids of the protein in the gingelly, thus causing a deficiency of sulphur amino acids in gingelly meal. Therefore the object of this study was to evaluate the quality of locally produced gingelly meal as a protein source for broiler chicken.

Materials and Methods

Expeller extracted gingelly meal was obtained from the feed dealers and analysed for crude protein value before using in the experiments.

Five experiments were conducted in this study where gingelly was substituted for coconut meal. The experimental rations were carefully balanced to be iso-protein and iso-caloric within the experimental limits. The results of the experimental rations were compared with the performance of control rations balanced to carry all the nutrients required for broilers according to the recommendations of the National Research Council of U.S.A 1966. All the rations were fortified with a commercial vitamin supplement "Zoodry" according to the recommendation.

Cornish × White Rock cross broiler chicks were used in all the experiments. The treatments of all the experiments were replicated twice to include ten chicks in each replicate. They were housed in electrically heated brooders, so that no two replicates of a treatment were adjacent to each other. Feed and water were available to them at all times, Initial weights of chicks in each replicate were recorded at the commencement of the experiment. Thereafter weekly group weight gains and feed consumption were recorded for individual replicates during the entire experimental period. From the data thus obtained feed conversion efficiency was calculated by using the following formula.

$$\text{Feed Conversion Efficiency} = \frac{\text{Feed Intake}}{\text{Weight Gain}}$$

Table I. *Crude protein content of different samples of gingelly meal.*

Sample	Crude Protein (%)
I	27.04
II	28.05
III	32.50
IV	35.00
Mean	30.65

Experiments 1-3:

Experiments 1-3 were designed to study the effects of gingelly meal as a protein source in *broiler finisher rations.* The broilers used in these experiments were 6 weeks of age. Experiment 1 was planned to carry 5%, 10%, 15%, and 20% gingelly meal in order to study the effects of increasing the level of gingelly meal in rations. Experiment 2 was designed to study the possibility of improving the biological value of protein in gingelly meal by supplementing it with methionine. This experiment consisted of 4 treatments of which 2 carrying 10% and 20% gingelly meal were incorporated with methionine. The results of these rations were compared with two control rations, one carrying no gingelly meal and the other carrying 10% gingelly meal (Table 2).

Experiment 3 was a repetition of the experiment 2 where the performance of broilers that were fed 10% and 20% gingelly meal without methionine were compared with rations carrying similar levels of gingelly meal supplemented with methionine. The level of methionine used in all these experiments was 50*g* per 50 *kg* of feed. (Table 2).

Table 2. *Average gain in weight (G), average feed intage (F) and feed conversion efficiency (FE) per bird (g).*

TREATMENT	EXPERIMENT 1			EXPERIMENT 2			EXPERIMENT 3		
	G	F	FE	G	F	FE	G	F	FE
CONTROL	1039.0^{a}	4026.9	3.92	786.1^{a}	2938.1	3.74	1005.54^{a}	3941.9	4.17
5% Gingelly	1061.1^{a}	4095.1	3 95	—	—	—	—	—	—
10% Gingelly	930 4^{b}	3986.9	4.33	591.3^{b}	2811.4	4.77^{b}	899.15^{b}	3741.96	4.99^{b}
10% Gingelly + Methionine	—	—	4.09	754.1^{a}	2925.5	3.90^{a}	952.0^{ab}	3734.87	3.78^{a}
15% Gingelly	900.3^{b}	3923.6	—	—	—	—	—	—	—
20% Gingelly	884.3^{b}	3894.5	4.44	—	—	—	906.23^{b}	2825 31	4.48
20% Gingelly + Methionine	—	—	—	712.0^{a}	2896.1	4.06^{a}	924.7	3755.79	4.10^{a}

Statistical significance at 5% level is denoted by a different letter.

Experiment 4 and 5 :

Experiments 4 and 5 were designed to study the effects of gingelly meal as a protein source in *broiler starter rations*. The birds used in these experiments were one week old. The experiment 4 was a repetition of experiment 1, where the effects of the levels of gingelly meal on the performance of the starter chicks were studied. Experiment 5 was designed similar to experiment 3 with the only exception that methionine was incorporated up to 30% level of gingelly meal in rations. Thus the experiments consisted of rations containing 10%, 20%, and 30% levels of gingelly meal, supplemented with methionine and their results were compared with a control ration carrying no gingelly meal (Table 3).

Results

Increasing the level of gingelly meal from 5% to 20% of broiler finisher rations in experiment 1 caused progressive significant growth depression, beyond 5% level. However, the increase in feed intake and feed conversion efficiency were statistically not significant.

When methionine was incorporated into rations containing 10% and 20% gingelly meal in experiment 2, the growth inhibitory effect was corrected. But the ration with 10% gingelly meal without added methionine produced a significantly lower growth response than the control ration and confirmed the results of experiment 1 (Table 2). The feed intake of all the rations were not statistically significant. But the feed efficiency of the ration with 10% gingelly meal without added methionine was significantly lower than the other rations.

In experiment 3, growth response of the treatment supplemented with methionine did not differ statistically from the control. But the growth responses of the two rations that did not carry

Table 3 *Average gain in weight (G) average feed intake (F) and feed efficiency (FE) per bird (g).*

TREATMENT	EXPERIMENT 4			EXPERIMENT 5		
	G	F	FE	G	F	FE
CONTROL	408.55	1329.37	2.86	560.75	1779.12	3.56
5% Gingelly	434.14[a]	1276.88	2.66	—	—	—
10% Gingelly	357.98[b]	1208.77	2.83	—	—	—
10% Gingelly + Methionine	—	—	—	599.54	1845.34	3.11
15% Gingelly	346.80[b]	1059.81	2.53	—	—	—
20% Gingelly	344.75	1122.23	3.25	—	—	—
20% Gingelly + Methionine	—	—	—	637.02	1957.88	3 05
30% Gingelly + Methionine	—	—	—	668.21	1993 35	2 96

Statistical significance at 5% level is denoted by a different letter.

added methionine were significantly inferior to the control rations. The feed intake did not show any difference among the treatments. However there was a significant lowering of the feed efficiency in treatment that did not contain added methionine. This confirmed the results of experiment 2.

In experiment 4, the growth response, feed intake and feed efficiency of broiler starter chicks were similar to that of the experiment 1 where broiler finisher chicks were used.

When gingelly meal at 10%, 20%, and 36% levels were fed to broiler starter chicks with added methionine in experiment 5, the growth inhabitory effects of gingelly meal was overcome completely. There was no adverse effect on feed intake and feed efficiency also. This confirms the results of experiment 3.

Discussion

Progressive increase of gingelly meal from 5% to 20% in experiment 1 caused a steady decrease in the growth response of broiler finishers beyond 5% level, due to the deficiency of methionine more than lysine, the reasons being, that the lysine content of the type of rations used in this experiment carrying 18% good quality meat meal could sustain normal growth in broiler chicken (Rajaguru, 1970). Further, gingelly meal is a better source of lysine than its substitute coconut meal used in these rations (Almsquist, 1957). Thus as the gingelly meal content was increased in the experimental rations, the lysine value too should have been increased. On the contrary, methionine deficiency could be expected in these ration due to the total destruction of cystine in gingelly by the high heat evolved in the expeller extraction process (Beuk, *et. al*, 1948). Thus even though gingelly meal is considered to be a rich source of methionine (Ewing, 1963), destruction of cystine could lower the sulphur amino acid value. Also it was evident from this experiment that gingelly meal did not cause any detrimental effects on feed intake but the feed efficiency was slightly lowered though statistically not significant. This may be due to the limiting action of sulphur amino acids on growth response demanding more food per unit gain.

When gingelly meal was supplemented with methionine in experiment 2, the growth inhibitory effect observed in the experiment 1 was corrected. This suggests the possibility that the local expeller process used to extract oil from gingelly destroys the cystine content leading to the lowering of methionine potency (Table 2). The reduction in the growth response in treatment 4 where no methionine was added, confirms the possibility of sulphur amino acid deficiency of local gingelly meal.

The identical results obtained in experiment 3 which is a repetition of experiment 2, confirmed further that sulphur amino acid is the major deficiency in locally produced gingelly meal. Also it was observed that this deficiency caused no-ill-effects on the feed intake but reduced the feed efficiency significantly This further confirms the possibility that the sulphur amino acid imbalance of these rations must be leading to lower protein synthesis, demanding more feed per unit weight increase.

The fact that gingelly meal, when incorporated into rations of broiler starter above 5% level in experiment 4 caused growth depression (upto 20% level) confirms the results of experiment 1. Also it proved that the amino acid imbalance in the gingelly meal affects growth responses of broiler starter chicks as well as broiler finisher chicks. This indicates that the amino acid requirement for growth in the two stages of the life of the broiler chick is fairly similar. Gingelly meal had no ill-effects on the feed intake of broiler starter chicks too. The slight lowering of the feed efficiency of the broiler finisher chicks observed when the gingelley meal level was increased without added methionine could not be repeated with the broiler starter chicks in this experiment. The reason for this difference in the behaviour of the two groups under similar treatments is difficult to explain.

Correction of the growth inhibitory effect of gingelly meal for broiler starter chicks in experiment 5 fed at 10%, 20% and 30% levels in rations supplemented with methionine confirms further that sulphur amino acid deficiency in the local gingelly meal is more acute than that of lysine. This further confirms the possibility of the destruction of cystine during the expeller extraction process. Also it suggests that the amino acid requirement for growth of broiler starter chicks is fairly similar to that of broiler finisher chicks indicating that the protein efficiency for growth of the two groups is similar. The lack of significance of the feed efficiency data of this experiment confirms further that methionine had been the major factor that interfered with the feed efficiency of the experiments that were not supplemented with methionine.

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SHORT COMMUNICATION

HEVEA (RUBBER) SEEDS FOR HUMAN FOOD

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That the seeds of *Hevea brasiliensis*, the Para rubber tree, and other species of *Hevea*, have been and still are used for human food is amply attested by both literature and the testimony of living people. Seeds of *Hevea* are poisonous and somewhat imperfectly balanced nutritionally but so are the starchy roots of cassava or manioc *(Manihot esculenta Crantz)*, yet millions of people in the tropics of both hemispheres eat cassava regularly. They have learned how to prepare cassava so that it can be eaten safely. Detoxification of the seeds of *Hevea* can be done in the home without any special equipment thereby making available this food which is relatively high in protein.

It has been known for over two centuries that humans can eat seeds of *Hevea*. The earliest record of this was published in 1775 Aublet) who recorded that the aborigines of French Guiana utilized them for food. Richard Spruce, during his epic trip up the Amazon River on his way across from the Atlantic to the Pacific Coast also observed that the aborigines of Amazonia ate seeds of *Hevea* (Bentham, 1854). Further information on use of seeds of *Hevea* for food by the aborigines of South America is given by Seibert (1948) and Schultes (1956). The type of preparation used in Amazonia as recorded by Spruce (Bentham 1854) and Schultes (1856) is soaking and/or long boiling.

Outside of Amazonia there is some use of seeds of *Hevea* for human food: Ochse (1931) gives very complicated directions for preparing the seeds as practiced in southeast Asia, and Nur (1974) gives simpler methods used currently in Java which involve steeping in water and prolonged boiling. It is possible to prepare the seeds for eating by simply roasting the whole seed in an open fire. This method of preparation was used successfully by Kostermans

(1974) while he was a prisoner of war in Java during World War II, and is reported (Danture-Bandara, 1976) to be in current use among the low income people of Ratnapura District, Sri Lanka.

The requirement for preparation before eating is due to the presence of hydrocyanic acid and its readily hydrolyzable precursor, the cyanogenetic glucoside phaseolunatin (=linamarin) (Gorter, 1912). Soaking in water for 24 hours with several changes of water will allow the enzymatic digestion of the linamarin to yield HCN. Subsequent boiling for a half hour or longer in an open pan will evaparate the HCN to a tolerable level according to Giok *et. al.* (1967).

There are also unidentified growth-depressant and probably antifertility factors as shown by the results of feeding trials with poultry (Rajaguru, 1971) and cattle. Also Mcduski (1976), in feeding trials with rats, found that stunting resulted from raising rats with *Hevea* seeds in their diet. The antifertility factor, in addition to its demonstrated effect on poultry, is believed to effect humans also (Nur, 1974).

The protein content of the seeds of *Hevea* is relatively high, though of course, being of plant origin, is somewhat unbalanced in its amino acid profile. Giok *et. al.* (1967) report that the untreated seed (presumably the "kernel" i.e. embryo and endosperm minus the "shell" i.e. the seed coat) is 27% protein on a dry basis. According to Grist (1929) "Rubber seed consists of approximately 37 per cent of shell, and 63 per cent of kernel". As for the content of essential amino acids, the principal deficiency is a low content of methionine (Giok et. al. 1967).

There is a possibility that there may be toxalbumins (poisonous lectins referred to in early literature as phytotoxins) (Brocq-Rousseu & Fabre, 1947). These subtle but potentially deadly poisons are well-known in other Euphorbiaceae, but no mention of their occurrence in *Hevea* has been found.

There may also be potent allergens in the seeds of *Hevea*. Therefore anyone who is going to play gastronomic Russian roulette by experimenting with eating rubber seeds should, even after preliminary boiling or roasting, eat only a little at first and gradually increase the amount with an interval of at least a day, or preferably three days, to allow time for any unfavorable reactions. Just because some poineer in this worthwhile project of experimenting with eating seeds of *Hevea* suffers no ill effects, others nevertheless should start cautiously with a small amount. It is possible to become tolerant to allergens and to euphorbiaceous toxalbumins by ingesting small gradually increasing doses. This has been known long in the case of the deadly toxalbumin ricin of *Ricinus*, the familiar castorbean (Kobert, 1906)

The potential production of *Hevea* seeds in Sri Lanka is large. Reliable estimates (Nadaraja *et. al.*, 1973) indicate that over 7000 metric tons of rubeer seed meal left after the extraction of the oil could be harvested from plantations producing a yield of seed sufficiently high to warrant gathering them on a commercial basis. This is not to be construed as suggesting for use as human food the rubber seed meal resulting from commercial extraction of the oil by expellers, because this meal contains over 40% of finely ground seed coats.

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