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Contents

A REVIEW ON AGROSTOLOGY AND ANIMAL HUSBANDRY UNDER COCONUT IN SRI LANKA

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Abstract

It had been identified that it was important to establish subsidiary industries such as animal husbandry and dairy farming on coconut lands not only to improve the land fertility but also to increase the milk production in order to save a considerable amount of foreign exchange spent on importing milk products. It had been observed that in certain estates where pasture was used to feed a herd of dairy, the palms were healthy and the yields were satisfactory. This paper reviews the published research work on the agrostology and animal husbandry under coconut was undertaken at the Coconut Research Scheme (Institute) starting from 1950s to date.

Keywords: *agrostology, animal husbandry, coconut*

History of Animal Husbandry under Coconut in Sri Lanka

A division called Animal Husbandry was started at the Coconut Research Institute in 1951. The objectives of this division were to study the effect of rearing livestock on the (i) production of coconut palms, (ii) production of manure (iii) maintenance of pasture under shade, (iv) development of secondary livestock industries as a source of additional income to smallholder farmers and (v) production of milk, meat and eggs under coconut estates. This division also participated in the livestock shows such as "All Ceylon Cattle Show", "Marawila Livestock Show" and "District Livestock Show" to inspire and encourage all livestock breeders in Sri Lanka. The different animal husbandry units shown in Table 1 were established as a mere stepping stone for agrostology and animal husbandry research activities.

Use of Pasture as a Source of Soil Rehabilitation

For the first time, the importance of having pasture under coconut had been discussed by the Schrader, (1950) in the Ceylon Coconut Quarterly 1950 questioning whether the "grass is good or bad for coconuts". According to the above Author when a single crop was grown for many years the soil conditions started to deteriorate and in order to maintain the crop yield, the land needed restoration with soil fertility. The earlier symptom of land deterioration was the inability of the soil to retain its soil moisture causing drought conditions even in small dry periods. It had been observed that the soil moisture could be retained if the humus content in soil was improved.

In other words, soil organic matter content needed to be increased. Naturally, the dead and decaying weeds in a cropping land would be the soil organic matter. Deep-rooted weeds would draw up the minerals from the deeper soil layers and deposit in the surface layers when decay. Similarly, leguminous plants would add nitrogen to the soil. When the animals were used to graze this vegetation, animal manure would also be added to the soil as a source of organic matter. As animals would not feed on every weed then the choice of vegetation would be limited to the weeds that only be eaten by the animals. These weeds were called the pasture.

Ley farming where the fields were left with pasture without cropping in alternate seasons was practiced as a measure of soil conservation. Fibrous roots of the grasses bind the soil particles and aggregated the soil, reducing the erosion. There were two types of grasses; grasses that were grazed and grasses which were cut and fed to animals called fodder grasses. It had been observed that the controlled grazing on cultivated grasses would benefit both animal and soil (Sanjari et al., 2007).

Rearing cattle under coconut

Cattle grazed on the low quality grasses called weeds that were available in the coconut lands produced neither high quantity nor the quality of manure (Schrader, 1951). Farmers practiced tethering two head of cattle per palm per night where the palm had a shallow trench cut so that the dung and urine would be deposited in the trench. After 10 days, the trench would be filled in and the cattle would be transferred to a new palm. This way 18 palms could be manured by a cow annually. This method was referred to as the "compost made in the foot of the palm" (Schrader,1950).

In some coconut lands the cattle were kept in a shed during the night. The floor was laid with straw and there was water for the cattle in the shed. The straw that was mixed with dung and urine were raked in the morning and collected to a pit outside the shed. The shed was laid with fresh straw again in the morning to be used for the night. The straw mixed with manure was sprinkled with water twice per week for effective decomposing. This was referred as the "pen manure" (Schrader, 1950). This way 10 tons of pen manure could be prepared per head of cattle annually which could be used to apply for 200 coconut palms. However, the nutrient content in this pen manure would depend mainly on the type of feed fed to the cattle.

Table 1: Establishment of different livestock units by the Animal Husbandry division

Livestock unit	Remarks
Dairy unit	Established in 1951 with a herd of black cross-bred Indigenous cattle. The initial herd consisted of one stud bull and 12 heifer cows. By 1952 average milk production was 1.4 litres per cow per day.
Poultry unit	Poultry unit was established in 1951 and maintained as free-range in potable pens and kept in the middle of coconut square. Every three days, it was rotated from one square to the other. The Australorp poultry species were introduced in 1953 from the Government farm at Ambepussa. Egg production was 125 eggs per bird per year in 1953 and these were sold to the staff of the Institute. Manure was applied to the coconut palms.
Pig unit	Pig unit was established in 1951 and maintained as a demonstration in potable pens and kept in the middle of coconut square. The breed was middle white and the stocking rate was one boar to three sows. Every seven days, it was rotated from one square to the other. Manure was applied to the coconut palms.
Bee keeping unit	This unit was established in 1956 and maintained for the purpose of pollination of coconut flowers in order to improve nut setting.

The author concluded that (i) application of farmyard manure (Pen manure and compost together) would increase the humus content of the coconut land (ii) the cost of farmyard manure production would depend on the cost of ingredients and labour (transportation and application) (iii) management and feeding good quality feeds to the Indigenous cattle would enhance the potential production of these cattle.

Grazing management

A grazing trial was undertaken at a coconut estate of 1000 ac to evaluate the best method of grazing using a herd of Indigenous cattle with two pure-bred Scindhi bulls (Gunasekera, 1951). The pasture consisted of indigenous grasses, herbs and legumes that were grown naturally under the coconut palms. Grasses that were at the estate included *Axonopus compressus* (carpet grass), *Chrysopogon aciculatus* (love grass), *Eleusine indica* (wild kurrakkan) and *Cynodon dactylon* (Bermuda grass). Legumes such as *Alysicarpus vaginalis*, *Desmodium* spp, *Calapogonium mucunoides, Pueraria phaseoloides* and *Centrosema pubescens* were also present.

Free grazing

In this method, animals were allowed to graze freely (free grazing) in the estate. The weed species *Bidens pilosa*, *Imperata cylindrica* and *Mimosa pudica* that were not grazed by the cattle were removed from the estate every six months either by handpicking or using a *mamoty*. Hence, there was selection and constant movement at the estate leaving coarser and less palatable herbage species at the field. Ultimately coconut palms were affected due to the competition for soil nutrients and moisture. In addition, the pasture growth was also depressed at the field due to the abundance of above mentioned weeds.

Controlled grazing

In controlled grazing, each animal was tethered to a palm allowing it to graze a radius of the length of the rope where it was similar to the distance between two palms (26 feet or 8 m in this instance). The field was evenly grazed and the animals were moved to a different palm when the pasture height was 4 inches (10 cm).

Rotational grazing

In this method a 1000 ac (approximately 415 ha) coconut land was divided into 150 ac (approximately 62 ha) blocks (paddocks) by using a fence made up of barb wire. The herd was allowed to graze in a particular paddock and rotated to the next paddock when the herbage height of the first paddock was 4 inches (10 cm). Depending on the season, the duration that the animals were kept in a paddock varied; such as 10 days or fortnight when the pasture growth was slow and 30 days during the rainy season. On average, it has been observed an overall forage allowance would be 2 acres (1.2 ha) per animal compared to 6 acres per animal overall forage allowance in other countries.

The palms were manured using the animal droppings. Also, artificial fertilizer was applied in alternate strips along the square. The strips were mulched using coconut fronds. Strip manuring was practiced as both coconut palm and pasture would be fertilized by this way. Once the animals were moved to a new paddock, the manure was disc harrowed using a tractor and disc. The pastures were harrowed once per year. Overall it was observed that the nut yields were increased in the rotational grazing method.

Feeding trials using cross-bred Indigenous cattle

Animal husbandry activities were started with a herd of black, cross-bred indigenous cattle including a stud bull and 12 heifers in 1951. The average milk production per ha was 3 pints (1419.6 mL) per day per cow. Initially, there was no knowledge on stocking rates, forage allowance, milk production vs type of feeding, quality of manure derived from different sources of pasture and animal body weight gains. However, it was noted even during the earlier days that clean and hygienic cattle sheds should be maintained with a standard milking room. Similarly, it was noted that for a cattle herd there should be a stud bull approved by the Veterinary Surgeon or else need to undertake Artificial Insemination. Simultaneously, extra male animals should be castrated. All animals should have an identification method; ear tags or ear tattoo markers or other branded marks to identify individually. Feeding trials using cross-bred Indigenous cattle were started to find the answers to the issues mentioned above.

First trial

A preliminary experiment was undertaken in 1952 to compare the effect of two feeding methods namely grazing vs grazing plus concentrate feeding on the quality of cattle manure. The two cattle groups were housed separately at night to facilitate the collection of manure separately. It had been observed that (i) the production, condition and size of the cattle which were supplemented with concentrate were superior to the cattle fed only through grazing, and (ii) manure derived from the cattle fed only through grazing were superior to the manure derived from the cattle supplemented with concentrates (Anonymous 1953 and annexure).

Second trial

The first-ever designed feeding trial was started in 1952 using cattle aged 2-3 years at the Bandirippuwa estate to find out the effect of feeding of coconut poonac on the performance of grazing animals. There were three treatments namely; (i) grazing + 3 lbs (1.35 kg) of poonac, (ii) grazing + 2 lbs (0.9 kg) of poonac and (iii) grazing only as the control using six cows per treatment. Poonac was fed at a rate of half of the portion during morning milking (6.30 am) and the other half during afternoon milking (1.30 pm) hours. The grazing time was from 7 am to 5.30 pm except during the milking hours. During the night time, cattle were flocked at the farmyard to collect the manure for coconut palms, to avoid unnecessary trampling and polluting of grasses due to manure. Data collected during this experiment included daily milk yield, body weight and profit from the enterprise. In addition, records related to general health, service records and calving records were also maintained.

It was observed that cattle grazed mostly during the daylight hours. Similarly, with proper feeding and management, a profit could be obtained from rearing Indigenous cattle as they yielded a higher milk production.

Third trial

Another gazing trial was initiated in 1954 by the coconut research institute to find out the correct population of cattle per acre (stocking rate), to observe the grazing habits in order to conserve the pasture and to study the effect of feeding coconut poonac, rice bran and pasture on the production of milk in Indigenous cattle. Unfortunately no results have been recorded.

Cattle breeding programme under coconut

According to Goonesekera (1958), there were two breeding methods adapted at CRI (i) selective breeding within a breed or upgrading among the existing breed (ii) cross-breeding indigenous animals using high yielding exotic breeds such as Ayrshire, Friesian and Jersey or Indian milk breeds i.e. Sindhi and Sahiwal. The latter practice was considered as a logical step forward where high producing progeny can be achieved within a few years. However, when this method was practiced in other tropical countries, where there were high temperatures, heavy rainfall patterns, low-quality roughages and pest and disease conditions, the resulting progenies did not perform to the expected standard. Even though the first progeny (F1) have shown a hybrid vigour, repeated back-crossing with exotic breed produced lower-yielding females, a higher rate of mortality etc. among the young stock. It was found out that the failure for this back-crossing was more due to effect on the heat-regulating mechanism or in other words the inability of the animal to tolerate the heat. Therefore, the climate in the tropical regions affects animal production directly and indirectly (depending on the growth of pastures). It has been found that Indigenous/native cattle breeds have a better mechanism to tolerate the heat than the exotic breeds (Goonesekera, 1958). Thus the Ceylon Department of Agriculture suggested using cross-bred animals to produce the F2 generation instead of back-crossing to the exotic breed.

Iberia Heat Tolerance Test was undertaken to find out adaptability to heat tolerance by measuring the rectal temperature after leaving the animal in the sun at 90^0 F during the day. According to the test, if the animal was able to maintain its normal body temperature (101^0F) the adaptability to heat was 100. The formula used was 100-10 (body temperature – 101^0 F).

Individual animals within a breed may have a different degree of special characteristics to tolerate heat i.e. body coat (smooth, glossy and short hair). It had been found that depending on the season, European breeds had a change in coat mainly due to the photoperiod. However, in the tropics, day length variation was negligible affecting these European breeds to tolerate the heat.

A calf subjected to more than 80^0F temperature showed signs increasing body temperature, pulse rate and breathing rate. Within a breed, calves of same conditions tolerate heat in different levels and by repeated exposures to high temperature could make calves acclimatize to that temperature. The 'comfort zone' for European cattle lies between 0-60^0F depending on the level of production. It had been found that the total skin thickness of Shorthorn and Zebu though same, the thickness of different skin layers vary between the two breeds. This difference may be associated with the ability of heat tolerance in Zebu compared to the Shorthorn. The small size of the animal (dwarfism) also helped to tolerate the heat. This may be due to the low metabolic rate. However, when the metabolic rate was low, intake would also be low affecting the level of production and growth rate (Goonesekera, 1958).

According to Ferdinandez (1978), "Indigenous cattle breed was a primitive breed crossed with Indian and other breeds indiscriminately". Even under well-managed conditions, average body weight of an Indigenous cow would be 250 kg producing 2.8 litres of milk per day during a 250 days lactation. The breeding programme of this Indigenous cattle with Indian (Sindhi) and temperate (Jersey, Friesian and Ayrshire) breeds had been practiced at CRI. The F1 generation was giving a higher milk yield mainly due to the hybrid vigour. However, subsequent generations and back-cross of F1 with parent breeds did not perform as expected. As a remedy, a three breed rotational cross-breeding programme was established in 1969 using Sindhi, Jersey and Friesian with Indigenous breed as the foundation. First-generation of Jersey x Indigenous cross-bred cows were crossed with Sindhi. The progeny produced 200% higher milk yield than the parents. Afterwards above progeny cows were again crossed with the Friesian and the resulting progeny showed heat tolerance ability (Ferdinandez, 1979).

Experiments on pasture management

The milk board had established its milk collecting centres in the coconut growing areas by 1955 encouraging coconut growers to increase milk production and establishment of improved pastures to feed the cattle. Thus, the importance of fertilizing both the pasture and the coconut palm came in view to avoid any competition from the pastures on the palm. Hence, a lot of manuring experiments were initiated to identify the nutrient requirements of different pastures, yield and their performances in different climatic conditions (Ferdinandez, 1979).

Grasses such as *Stylosnathesys, Brachiaria brizantha, Brachiaria milliformis, Panicum maximum, Setaria geniculata, Dactyloctenium aegyptium* (putu thana), *Allotcropsis cimicinas, Digitaria longiflora, Paspalum etziza, Echinochloa colonum, Lyperus zollingeri, Digitaria marginata, Paspalum commersonii and Ischaemum ciliare* had been cultivated under coconut in different periods since 1954 to test the palatability, effect on coconut yield and resistance to drought. Legume species such as *Mimosa pudica, Centrosema pubescens, Pueraria phaseoloides* and *Desmodium triflorum* were also cultivated for the same purpose (Ferdinandez, 1973).

Quadrat samples were taken to determine the botanical composition (grasses, legumes and weeds) and dry matter content. Weed species such as *Tridax procumbens, Urena lobate, Vel panela, Sida acuta, Mitrocarpum villosum* and *Coomera bengalensis* were observed in the pasture. It was observed that the *Paspalum* was grazed to ground level. As a result, the regrowth was very slow and weed content in the field was high (Ferdinandez, 1979).

A pasture trial was undertaken in 1955 using four treatments *B. milliformis*, *B. brizantha, P. commersonii* and *P. maximum* initially with the objectives of obtaining animal data (live weight, milk yield and economic returns), pasture data (botanical composition, herbage yield before and after grazing) and also evaluating the effect of pasture on the yield of coconuts (Ferdinandez, 1979).

The highest herbage DM yield was obtained from *P. maximum* (Santhirasegaram, 1966a). However, the data showed that there was a coconut yield decrease of 99 nuts per acre (0.41ha) per year from *P. maximum*. There was an increase in the nut yield from *B. brizantha* (13 nuts per ac per year) and *B. milliformis* (12 nuts per ac per year). It was observed that there could be a competition for light, soil nutrients and moisture between coconut palm and the grasses affecting the yield of coconut nuts. However, Santhirasegaram (1966b) stated that with adequate levels of manuring for both coconut palm and grasses, the negative effects on the palm could be eliminated. The above author also stated that the growth of grasses during the dry period may negatively affect the coconut yield. Salgado (1944) stated that when increasing the level of fertilizer applied to a fodder grass, negative effect on the coconut yield could be eliminated permanently suggesting that the fertilizer recommendations for fodder grasses should be higher than that of the grazing grasses.

Experiments on *Panicum maximum* (Guinea Grass)

Guinea grass was a native grass introduced from South Africa. It grew well in fertile well-drained soils. It was well adapted to a wide range of soil conditions.

Experiment 1: Effect of nitrogen on the yield

Four Guinea grass strains (Australian Commercial, Australian Blue, Jamaican Tall and Ceylon Commercial) were established in 1964 (Santhirasegaram et al., 1969) to evaluate the effect of four levels of nitrogen (0, 100 , 200 and 400 kg per ha per season of Ammonium Sulphate) on the yield. The grass plots were established using rooted stem cuttings. Herbage samples were collected to determine pre-dry matter content when the grass was in mid-bloom. Afterwards, the grass was grazed by a herd of cows for three days. Then again herbage samples were collected to determine post dry matter content and leaf: stem ratio.

The DM data related to three grazing occasions in six months showed that Australian Commercial was superior to the other three strains but the performances of the Ceylon Commercial was also satisfactory (Santhirasegaram et al., 1969).

Experiment 2: Planting distance of Guinea grass

Planting distance of Guinea grass using Ceylon Commercial strain was tested in this experiment (Santhirasegaram et al., 1969). Grass stem cuttings were planted in five spacing levels; 0.3 m, 0.9 m, 1.5 m, 2.1 m and 2.7 m apart. Hence, there were 25 combinations of spacing to test. All the plots were applied with 200 kg per ha Ammonium Sulphate, 100 kg per ha of Saphos Phosphate and Muriate of Potash each as the basal dressing at the time of planting. At every harvest, 200 kg per ha Ammonium Sulphate was applied. The grass samples were collected to determine the DM content on three occasions. The results showed that with the increasing spacing the DM yield per ha decreased drastically. Literature showed that when the plant density decreased the DM yield per ha of grass increased and came to a constant which was called the “ceiling yield” (Donald, 1963). However, in this experiment, that trend was not observed. The highest DM yield was obtained at 3 feet (0.9 m) distance planting under coconut and tend to decrease afterward with increasing spacing. When planting Guinea grass, the manure circle of the coconut palm kept free from the grass.

Experiment 3: Height of cutting Guinea grass

Height of cutting of Guinea grass was tested in this experiment in 1964 (Santhirasegaram et al., 1969). There were two cutting heights (i) at 15 cm and (ii) at ground level. The highest yield was obtained at 15 cm cutting height than the ground level.

It was observed that the optimum yields could be obtained at cutting when the grass was in mid-bloom. The regrowth of Guinea grass after defoliation at ground level was lower than the regrowth after defoliated at 15 cm. The insufficient carbohydrate reserves may have limited the regrowth after defoliation at ground level. Further, it was observed that during the monsoons, Guinea grass could be cut once in six weeks and during the off-season, it could be cut once in 9 weeks (Santhirasegaram et al., 1969).

Experiment 4: Frequency of nitrogen application, source of nitrogen and frequency of cutting

Effect of frequency of nitrogen application (single dose or split or no N application), source of nitrogen (Ammonium Sulphate, Ammonium Nitrate, Urea, farmyard manure) and frequency of cutting (3 weekly or 6 weekly) of Guinea grass were measured in 1964 (Santhirasegaram et al., 1969). Dry matter yield per acre (0.41 ha) at each cutting frequency was also measured.

Six weekly cutting in a given season gave the highest DM yield irrespective of the source of nitrogen. Data related to the frequency of nitrogen application showed that application of a single dose of Ammonium Sulphate gave the highest DM yield compared to the other sources. Meanwhile, a split application of other sources gave the highest DM yield compared to the split application of Ammonium Sulphate. There was a drop in grass yield when applied farmyard manure only, compared to three other sources of nitrogen (Urea, Ammonium Sulphate and Ammonium Nitrate).

It was concluded that for better management of Guinea grass under coconut, the following factors should be considered. Guinea grass should be fertilized with double the amount of fertilizer that is recommended for *B. milliformis*. The application of dairy washings and farmyard manure could cut down the amount of inorganic fertilizer applied for Guinea grass. Irrigation using dairy washings during the dry periods would be highly beneficial for both grass and coconut. When fodder grasses were established under coconut, palms should be applied with the recommended fertilizer mixture to avoid the competition for nutrients.

Sheep breeding and management under coconut

It had been identified that coconut lands with the grassland farming had a vast potential to establish sheep industry to cater to the demand of mutton in the country. According to the rainfall pattern, two distinctive coconut growing areas were considered for animal husbandry under coconut i.e. wet zone and intermediate zone coconut growing areas. The wet zone coconut growing areas either with natural grasses or improved grasses for grazing were already having a dairy industry. These areas also have the potential to expand it. The intermediate zone had a bimodal rainfall pattern which also coincides with the grass production. Thus it had been considered as best for the sheep industry. The high producing grasses such as *B. milliformis, B. brizantha* and *P. maximum* and legumes such as *P. phaseoloides* and *Centrosema pubescens* were recommended to be cultivated under coconut (Perera, 1972).

Stocking rate

Using the dry matter production data of the grasses and legumes stated above, it had been estimated that around 5-8 ewes could be reared per acre of coconut. By observing several sheep units established on *B. milliformis* cultivated under coconut it had been estimated that at least 4 ewes could be reared per acre (0.41 ha) of coconut.

Breeding

The main sheep breed available in the area was Jaffna local which was small in size and mainly reared to obtain manure for tobacco and vegetable. Therefore, as the foundation for breeding Indian breeds such as Red Madras, Merchein, Barnur and Bikeneri were imported and reared under coconut. These breeds and local breed were cross-bred with temperate breeds such as Whlishire Horn, Southdown and Dorset Horn and the resulting progenies showed promising results.

Management

Extra pastures from the surplus period could be preserved into hay or silage to be used for scarce periods. The stock should be monitored closely for parasites. When sheep were reared under coconut it was better to use rotational grazing for maximum herbage utilization. However, it would be difficult to harvest, collect and transport coconuts in a coconut estate when the paddocks were being fenced (Perera, 1972).

Housing

Sheep needed to be protected from the wet weather especially during the rainy periods. Thus a "thatched house" could be established in each paddock to protect the sheep from wet weather.

Shearing

Sheep needed to be sheared twice per year before the two rainy seasons and dewormed.

Lambing

Rams could be allowed to be in the paddocks with ewes during July-August. Then lambing would occur in January-February just after the heavy northeast monsoonal rains. There would be grasses available for the ewes to feed on and produce milk for the new season lambs. Then, by the time of weaning there would be lush grass available for the lambs from the southwest monsoon rains during April-May.

Integration of animal production into the coconut cropping systems in Sri Lanka

Rearing cattle using available pastures under coconut was practiced for a long period of time (Ferdinandez, 1978). The main objectives of rearing cattle were to control weeds under coconuts and to obtain manure for coconut palms. Extra cattle were sold for beef. However, with time the estate owners tend to cultivate high yielding pastures adding fertilizers. This method provided the facility to increase the carrying capacity of coconut land also giving opportunities to adapt different management systems of rearing cattle under coconut. The key to surviving a mixed farming system under coconut would be "the correct utilization of space and growth factors available under coconut" (Ferdinandez, 1978).

Pasture, animal and coconut mixed system depends on the individual sector's (pasture or animal or coconut) growth and the effect of individual sector on the growth of each other. Issues that would curtail this system are; (i) the effect of the pasture on the yield and life span of the coconut palm (ii) the effect of the coconut palm on the yield, persistence and nutritive value of the pasture (iii) the efficiency of the animal to convert the pasture into animal products.

Ferdinandez (1973) showed that naturally occurring pasture under coconut had a low yields, low quality and low response to added fertilizer. These natural pastures being isolated for a considerable period of time at the same place lacks evolution and genetically improvements. Thus, with the expansion of the animal husbandry activities under coconut, there was a need to improve the production capacity and quality of natural pasture or to introduce new pasture species. Research showed that cultivating new pasture such as *B. milliformis* and *B. brizantha* under coconut in favourable rainfall regions had no detrimental effect on coconut yield provided that both pasture and coconut palm are adequately fertilized with the basal fertilizer mixture and nitrogen (Ferdinandez, 1973). In addition, this system has advantages such as (i) efficient recycling of nutrients (ii) improvement of soil structure and (iii) better water percolation characters.

Light intensity is the main factor that affected the growth of pasture under coconut. Sunlight penetration through the coconut canopy depends on the (i) age of coconut plantation (above 30 years of age 50% less light intensity under the canopy compared to the open area whereas in older coconut lands light intensity could be more than 85%), spacing and system of planting of coconut (ii) soil factors such as fertility, soil type, etc. (iii) time of day, season of the year, cloudiness etc. In older coconut plantations there would be no competition for light between coconut and pasture as the crown of coconut is situated at a considerable height (Ferdinandez, 1973).

Animal production in this system would affect depending on the environmental temperature. Research had shown that temperate breeds reared in tropics had low voluntary intake and shorter grazing period above 24^0C whereas Zebu breeds reduced their voluntary intake only above 32^0C. The studies showed that under coconut plantations air temperature was 6^0C below the open area air temperature encouraging to rear even cross-bred animals under coconut.

Carrying capacity on naturally available pastures under coconut was one animal per 2.3 ha (Ferdinandez, 1978). Both *B. milliformis* and *B. brizantha* were evaluated under coconut. It had been found that *B. milliformis* was (i) less competitive with coconut palm than *B. brizantha* (ii) responded better to added nitrogen fertilizer (iii) withstood grazing and drought (iv) comparatively more selected by the animals. Therefore, *B. milliformis* was recommended as a better grass to be cultivated under coconut. Experiments undertaken at CRI had shown that *Digitaria decumbance* also responded to the added nitrogen. Carrying capacity on *B. milliformis* or *Digitaria decumbence* grasses under coconut was 3.3 animal units per ha.

Cultivation of grasses along with legumes provided more advantages than cultivating either alone. Legumes increased the nutritive value of the ration and digestibility and also added nitrogen to the soil by fixing atmospheric nitrogen. With maturity fibre content in grasses increased reducing the quality of the feed. Therefore, by feeding grasses and legumes together especially during the dry season could increase the quality of the feed. Research showed that legumes such as *Centrosema pubescens* fixed a considerable quantity of atmospheric nitrogen and could be grown together with *B. milliformis,* Pangola, *B. ruziziensis* and Guinea grass. *Centrosema pubescens* withstood heavy grazing and had a faster regrowth at post grazing. However, the dry matter production was comparatively lower than the grasses.

Outputs from the coconut, animal and pasture system were (i) milk (during the earlier days more than 80% of the milk was sold to the Milk Board. About 15% were sold the CRI staff and less than 1% of the milk were used to produce ghee) (ii) live animals (live animals were sold to the staff and National Livestock Development Board (iii) dung (sold on request to staff or other estates).

Low cost poultry production system

This experiment was started in 2001 introducing one-month-old chicks (Samarajeewa et al., 2001). There were two upgraded populations of poultry strains used in the experiment; (i) 50% indigenous blood level x CPRS (brown): CPRS stands for Central Poultry Research Station Kundasale, (ii) 75% indigenous blood level x CPRS (Samarajeewa, 2003). Three poultry strains including CPRS (brown), CPRS x 50% Indigenous, CPRS x 75% Indigenous were evaluated to assess the nutrient balance and profitability of this system. There were three replicates per each treatment altogether having 18 coconut squares per treatment. Each treatment had 75 birds. The management method used for rearing was called “restricted scavenging system”. There was 16 m^2 enclosed area per each replicate for scavenging. It was expected that the upgraded poultry crosses would have superior egg production and at the same time be able to maintain the ability to brood. The poultry was allowed to scavenge during the daytime and supplemented with a formulated ration of 50% of the daily need.

Growth rate and body weight of birds

The growth rate of both crosses (CPRS x 50% Indigenous, CPRS x 75% Indigenous) were lower than the CPRS birds. By the 45^{th} week, CPRS birds obtained a 4.82 g per day growth rate compared to CPRS x 50% Indigenous (4.37 g per day) and CPRS x 75% Indigenous (4.01 g per day) crosses (Samarajeewa et al., 2001).

Egg production

For the period of 68 weeks, CRPS birds produced 216 eggs compared to CPRS x 50% Indigenous (181 eggs) and CPRS x 75%

Indigenous (186 eggs) crosses. Average feed consumption during the 68-week period was lower in CPRS birds (78.7 g per day per bird) compared to CPRS x 50% Indigenous (81.6 g per day per bird) and CPRS x 75% Indigenous (81.6 g per day per bird) crosses. There were two lapse periods of egg production during the 25-30th week and 40th week.

Egg weight in CPRS birds was higher (53.8 g) than the other two crosses CPRS x 50% Indigenous (48.8 g) and CPRS x 75% Indigenous (45.9 g) (Samarajeewa et al., 2001).

Nutrient balance

There was a positive nitrogen (133-170 kg per year per ac) and phosphorous (27-77 kg per year per ac) balance in this system. However, the potassium balance was negative (-46 to -49 kg per year per ac) (Samarajeewa, 2003). By the second year of the experiment, it had been estimated that the poultry excreta supplied only 67% of the potassium requirement of the palm. Thus, if the nut production was 90 nuts per palm per year it had been recommended to supplement 1200 g of muriate of potash per palm per year with the poultry manure. Further, adding poultry manure enhanced the soil microbial activity.

Profitability

The research showed that rearing 75 poultry birds in ¼ acre (0.10 ha) coconut smallholding produced a net income of Rs 2000.00 for the 68 weeks period (Samarajeewa, 2003). The system needed 2 hours of labour per day which could be provided within the household.

Cultivation of CO3 (where “C” stands for Coimbatoor, India) *Pennisetum purpureum x Pennisetum americarnum* fodder under coconut to improve the productivity of coconut lands

An experiment was started in 2006 to evaluate the effect of cultivating CO3 on the coconut yield and to determine the optimum level of nitrogen for CO3 cultivation under coconut (Somasiri et al., 2006). The experimental design was Randomized Complete Block Design having 5 treatments (0 kg, 30 kg, 45 kg, 60 kg and 75 kg urea per ha) and each treatment had three replicates. There were 16 effective palms per replicate to obtain the nut yield.

The CO3 plants were established at 2x1 m^2 between and within row spacing. A basal fertilizer mixture (Urea 200 kg per ha, Triple Super Phosphate 120 kg per ha and Muriate of Potash 100 kg per ha respectively) was applied to each plant. The treatments were applied at *Maha* and *Yala* seasons. The coconut palms were fertilized using the recommended adult palm mixture. The plants were harvested at every six months at 15 cm above ground level. Herbage samples were taken to determine the dry matter yield and crude protein content.

The data showed that higher the rate of urea application, higher the dry matter yield and cultivation of CO3 had no effect on the coconut yield. It was recommended to cultivate three rows of CO3 in a coconut square considering the distribution of CO3 roots vertically and horizontally (Somasiri and Premaratne, 2013).

Development of leguminous leaf meal blocks for ruminants

Leaf meal block preparation

Research was undertaken in 2007 to develop a leguminous leaf meal block for the ruminants specially to be used during the feed scarce periods. There were four treatments (*Acacia mangium* (Acacia), *Gliricidia sepium* (Gliricidia), *Leucaena leucocephala* (Leucaena) and *Calliandra calothyrsus* (Calliandra) with 6 replicates planned to a Complete Randomized Design. There were nine leaf meal recipes to be prepared for each treatment. Leaf meal recipes were prepared using the dried leaves and twigs of the above treatments. These recipes were pressed into blocks using a hydraulic press briquette machine and stored for three months. Each month two blocks from each recipe were analyzed for nutrient content, free fatty acid and total plate count to determine the shelf life of the blocks.

The data showed that it was easy to prepare leaf meal blocks from Gliricidia and Leucaena leaf meals and also the nutrient content of these blocks were higher than the Acacia and Calliandra leaf meal blocks. The fresh leaf: dry leaf ratio was 5:1 for Gliricidia and 10:1 for Leucaena. Thus the cost of production of Leucaena leaf meal blocks was comparatively higher compared to Gliricidia leaf meal blocks. The FFA content was lowest in Gliricidia leaf meal blocks compared to other treatments. Therefore, Gliricidia leaf meal blocks were selected as the best considering the easiness to prepare blocks, cost, nutrient content and shelf life (Somasiri et al., 2010b).

Feeding Trial

To test the palatability of these selected two recipes a feeding trial was undertaken at Rathmalagara Estate using dairy cows. Findings show that there was no adverse effect on milk production when feeding these leaf meal blocks (Somasiri et al., 2010c).

Growth performances of the leguminous trees grown under coconut

This research was undertaken to study the performance and biomass productivity of four types of leguminous tree species *Acacia auriculiformis* (Acacia), *Gliricidia sepium* (Gliricidia), *Leucaena leucocephala* (Leucaena) and *Calliandra calothyrsus* (Calliandra). Height and girth parameters were measured in the seedlings from three months up to 15 months of age. Results show that Acacia had the highest basal stem girth and height followed by Calliandra, Gliricidia, and Leucaena (Somasiri et al., 2010a).

Recommendations published related to agrostology and animal Husbandry under coconut in Sri Lanka

Related to the fodder grasses cultivated under coconut

In order to cultivate pasture and fodder, the age of coconut plantation should be less than 5 years or more than 25 years considering the light transmission through coconut canopy. Then, it is required to provide adequate fertilization for both crops; fodders/grasses and coconut. When growing *P. maximum* (Guinea grass), optimum planting distance would be 75 cm between and within rows. It was recommended that *P. maximum* (Guinea grass) should be cut down to 15 cm above ground level when in mid-bloom for maximum benefit. Further cutting 6 weekly intervals would provide higher yields than 3 weekly intervals. It was recommended to apply nitrogen in two splits for better herbage yield.

Fodder grasses can be harvested at 6 weekly intervals during the wet weather and 9 weekly intervals in the dry weather. The maximum number of CO3 rows that can be established under coconut will be three rows having 1 m within a row and 2 m between row spacing.

Related to grasses cultivated under coconut

Brachiaria milliformis (cori grass) and *B. brizantha* (Signal grass) cultivated under coconut withstand drought and grazing. *Brachiaria milliformis* has been recommended as a suitable pasture species under coconut as it withstands shade. It grows fast within 1-2 months controlling weeds. From one acre of cori grass under coconut one milking cow of 250 kg producing 2.4- 3.8 litres of milk yield can be reared. In addition, *B. brizantha* and *Digitaria decumbance* were also recommended to be cultivated under coconut.

Fertilizer mixture for grass:legume mixture is urea + Saphos Phosphate + Muriate of Potash – 1:1:1 an equal amount (25 kg per ha) at the establishment. *Pueraria phaseoloides* and *C. pubescence* were superior to *C. calothyrsus* with regard to persistence and nitrogen fixation.

Rearing livestock under coconut

Carrying capacity should be one Indigenous cattle per 2 ha under natural pastures. Or it was recommended to rear 2-5 head of Indigenous cattle per ha supplementing 1.4 kg of coconut poonac per head. Carrying capacity on *B. milliformis* or *Digitaria decumbence* grasses under coconut was 3.3 animal units per ha. When the grazing frequency was less and intensity was high the herbage DM yield tends to increase in *B.*

brizantha. Tethering two head of cattle per palm per night where the palm had a shallow trench cut so that the dung and urine would be deposited in the trench. After 10 days the trench would be filled in and the cattle would be transferred to a new palm. Using this method 18 palms could be manured annually. This method was referred to the "compost made in the foot of the palm" (Schrader, 1951). Compost prepared using partially decomposed bedding material and cow dung (10 tons of pen manure per head of cattle per year) can be used to manure 200 coconut palms.

It is recommended half-bred Indigenous x Jersey cow would be suitable for the low country wet zone of Ceylon under grazing condition. Cattle should be rotated to a new paddock when the defoliating height (post grazing height) is 10 cm in grazing pasture. The number of days of cattle grazing in a single paddock depends on the pasture growth, stocking rate and season. Further, it may vary from 10 days to one month.

Alternative feed sources for livestock

Gliricidia leaf meal can be prepared into blocks using a hydraulic press briquette machine. Gliricidia leaf meal; having 75% Gliricidia + 25% coconut poonac or 75% Gliricidia + 12.5% coconut poonac + 12.5% rice bran can be used to feed dairy cows for better yields specially during the dry periods.

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Annexure

Laboratory Investigations

EXAMINATION OF FARMYARD MANURE

In continuation of the work reported last year two more half-yearly samples of farmyard manure were examined. Table V summarise all the results obtained up till now, for the manurial constituents nitrogen, phosphoric acid and potash.

TABLE V

(*a*) **Farmyard Manure from Pasture-fed cattle**

Sample No.	*Date of Sampling*	*Per cent. Moisture*	*Per cent. Nitrogen (AS N)*		*Per cent. Phos. Acid (AS P_2O_5)*		*Per cent. Potash (AS K_2O)*	
			Wet basis	*Dry basis*	*Wet basis*	*Dry basis*	*Wet basis*	*Dry basis*
I (*a*)	Dec. 51	—	—	—	—	—	—	—
II (*a*)	Jan. 52	6·31	1·50	1·60	0·67	0·72	1·25	1·33
III (*a*)	June 52	8·15	1·84	2·00	0·68	0·74	1·55	1·69
IV (*a*)	Dec. 52	7·94	1·21	1·32	0·48	0·52	1·75	1·90
V (*a*)	July 53	7·81	1·52	1·65	0·65	0·70	2·12	2·30
VI (*a*)	Dec. 53	4·34	0·79	0·83	0·63	0·66	0·87	0·91
VII (*a*)	June 54	2·91	0·71	0·73	0·49	0·50	0·83	0·85
VIII (*a*)	Dec. 54	3·62	0·11	0·12	0·34	0·36	1·17	1.22
Seven Samples		5·87	1·10	1·18	0·56	0·60	1·36	1·46

(*b*) **Farmyard Manure from Concentrate-fed cattle**

Sample No.	*Date of Sampling*	*Per cent. Moisture*	*Nitrogen Wet basis*	*Nitrogen Dry basis*	*Phos. Acid Wet basis*	*Phos. Acid Dry basis*	*Potash Wet basis*	*Potash Dry basis*
I (*b*)	Dec. 51	5·44	1·22	1·29	0·58	0·61	1·30	1·38
II (*b*)	Jan. 52	5·35	1·33	1·39	0·80	0·85	1·28	1·38
III (*b*)	June 52	5·41	1·52	1·61	0·63	0·67	1·07	1·14
IV (*b*)	Dec. 52	6·36	1·09	1·16	0·58	0·62	2·12	2·27
V (*b*)	July 53	4·80	1·09	1·15	0·41	0·43	0·87	0·92
VI (*b*)	Dec. 53	5·26	1·11	1·17	0·74	0·78	1·33	1·41
VII (*b*)	June 54	1·93	0·51	0·52	0·35	0·36	0·63	0·64
VIII (*b*)	Dec. 54	3·99	0·93	0·96	0·42	0·44	0·97	1·01
Eight Samples		4·82	1·10	1·16	0·56	0·60	1·20	1·27

The average figure still indicate that the manure from pasture-fed cattle, if at all, is a trifle superior to that from the concentrate-fed animals. However, as the composition of the individual samples shows wide fluctuations, the present average figures could not be regarded as being strictly representative.