Improvement of Field System for Forage and Food Crop Production in Seasonal Drought-prone Area of Indonesia

I. Availability of three strata forage system*

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Abstract : In agricultural farming at Bukit Peninsula, Bali, Indonesia, cattle production has an important position as well as food crop production. However, the farmers very often experience shortage of forage for feeding Bali cattle because of seasonal drought. In order to solve this problem, Three Strata Forage System (TSFS) had been developed through the improvement of the traditional farming system (non-Three strata Forage System : NTFS) from the viewpoint of field system and selection of plant materials. In a TSFS-field, trees, shrubs, grasses and legumes were grown in the peripheral part and food crops were mixed-cropped in the inner part of the field ; while trees were grown only as a fence to protect food crops from animals in a NTFS-field. In this paper, the availability of TSFS for forage and food crop production was studied.

Though food-crop yield of a TSFS-field was 35% lower than that of a NTFS-field, forage yield was 96% higher, so that forage was available all the year round in a TSFS-field. Furthermore, the weight of a cattle on TSFS-field increased at almost the same rate as a cattle on NTFS-field even with about 10% less forages. Consequently, the net income from the TSFS-field was 24% more than that from the NTFS field. These results indicate that TSFS is more useful and profitable as a field system in seasonal drought-prone area of Indonesia.

Key words : Dry Farming, Field System, Forage Production, Indonesia, Three Strata Forage System.

インドネシア季節的乾燥地域における飼料および食用作物生産のための圃場生産様式の改善 第1報
Three Strata Forage System の有用性 : I.M. スアルナ・小合龍夫**・土屋幹夫**・I.M. ニティス・K. ラナ
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要 旨 : インドネシアの季節的乾燥地域、とくにバリ島のブキ半島等では、バリ牛の飼育を中心とした農業が営まれているが、乾季の飼料確保には著しく苦慮している。そのため、乾季には、約 30 km も離れた山野に自生する在来野草、木本類の枝葉を採取、供給している現状にある。そこで、乾季の飼料供給源を畑に隣接して設けた「Three Strata Forege System」による飼料と食用作物の圃場生産様式を提唱し、従来通り、周囲に垣根としてサボテン類のみを植えた同一面積の圃場との、飼料および作物の生産量、牛体重の増加、および年間収益の比較によって、その有用性を検討した。この生産様式は、圃場の周囲に飼料となり得る樹木類および灌木類を垣根状に植え、その内縁には牧草類を帯状に作付し、中央部には換金を目的とした作物類を混作するもので、作物の茎葉部も乾季の飼料として利用される。その結果、圃場当りの作物収量は作付面積の減少により 35% 低下したが、飼料生産量は 96% 増加し、一年間を通じた飼料の供給が可能となった。また、この様式で生産できる飼料では、供給量が約 10% 少なくとも牛体重の増加には差異がなく、年間収益においても、約 24% の増収となり、本圃場生産様式の有用性が明確になった。

キーワード : インドネシア、乾燥地農業、飼料生産、圃場生産様式。

Since olden times, farmers have raised Bali cattle as their own special product at Bukit Peninsula, Bali, Indonesia. At the same time, they have cultivated corn and cassava as their own food, and soybean as cash crop. Their fields are often on the slope of limestone hills, and the top soil is thin and infertile. Moreover, though the mean annual rainfall is 1700 mm,

it is concentrated during the period from November until February in the wet season and the rainfall in the dry season, which lasts from late March until October, is not enough to grow forages and crops without irrigation facilities (Fig. 1). Generally, around a field, a thorny shrub of cactus is planted as a fence to protect crops from animals, and some shrubs and trees are also planted arbitrarily along the fence. Though these plants are green even in

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Fig. 1. Monthly rainfall in 1986 (○) and 1987 (●) at the experimental site of Bukit Peninsula, Bali.

the dry season, these are useless for cattle feeds because of low quality and digestibility^{1,4}). Therefore, the farmers usually experience the shortage of forage, especially in the dry season. Consequently, the farmers have to go to lowland areas about 30 km far from their village and collect natural forages almost everyday.

In order to solve this problem, the authors have attempted to improve the traditional field system by altering planting pattern and introducing useful plant species. The improved field system is termed Three Strata Forage System (TSFS) and the traditional field system is called non-Three Strata Forage System (NTFS) in this paper. A TSFS-field consists of two parts, i.e. peripheral area for forage production and core area for food crop production (Fig. 2). In the peripheral area, forage crops, shrubs and trees were grown as 1st, 2nd and 3rd stratum, respectively. In the core area, corn, soybean and cassava were mixed-cropped.

The availability of TSFS for forage and food crop production was studied in this paper by comparing yields and income from TSFS- and NTFS-fields of a unit size.

Materials and Methods

The field experiment was carried out in Bukit peninsula 30 km far from Denpasar at 75–150 m above the sea level from 1984 to 1987, where the soil is Yellowish Red Mediterranean and the topography is undulated. The 16

Fig. 2. Scheme of TSFS.

Peripheral area (900m²) :

1st stratum : *Cenchrus ciliaris* (C), *P. maximum* (P), *S. guianensis* (Sg), *S. hamata* (Sh), *Centrosema pubescens* (Cp),

2nd stratum : *G. sepium* (○), *L. leucocephala* (△),

3rd stratum : *F. poacellie* (●), *L. coromandelica* (▲), *H. tiliaceus* (■),

Food crop area (1600m²) : corn, soybean, cassava.

ha land was divided into 64 plots. The plots were not all square in shape; some were rectangular, some trapezoidal. However, the areas of each plot were made equal (2500m² each). Among 64 plots, 32 plots were for TSFS-field and the other 32 plots for NTFS-field. Each of the five plots of TSFS- and NTFS-field was used to evaluate forage and food-crop productivity between the both types of fields. In the other plots, Bali cattle were stocked at the rate of one plot for one cattle of about 120 kg-body-weight in order to evaluate the availability of TSFS in supplying feed. The evaluation was started from 1985.

Along the circumference of a TSFS-field, *Ficus poacellie*, *Lannea coromandelica* and *Hibiscus tiliaceus* were planted at an interval of 5 m by using the cuttings of 3–7 cm diameter and 1.7–2.0 m length. Between two trees, either *Leucaena leucocephala* or *Gliricidia sepium* was planted at an interval of 10 cm. In planting *Gliricidia sepium*, the cuttings of 1–4 cm diameter and 1 m length were used, while *Leucaena leucocephala* seeds were directly drilled in the soil after being soaked in hot water. Therefore,

the field had 40 trees and 2000 shrubs along the circumference of the TSFS-field. The TSFS-field was divided into the peripheral area of 900 m² (5×180 m) for forage crops and the core area of 1600 m² (40×40 m) for food crops. The peripheral area was further divided into 20 lots, which were allocated to the grasses and legumes, i.e. *Cenchrus ciliaris* cv. Gayndah, *Stylosanthes guianensis* cv. Graham, *Panicum maximum* var. Trichoglume, *Centrosema pubescens* and *Stylosanthes hamata* cv. Verano in this order. Each lot was 5×9 m size. The trees and shrubs were planted in October 1984, while the grass and legume seeds were drilled at 10 cm spacing in December 1984. In the core area, corn, soybean and cassava were mixed-cropped according to farmer's practice, i.e. corn and soybean seeds were drilled in the soil at about 100×100 cm and 25×30 cm spacings, respectively, and cassava cuttings were planted at about 100×100 cm spacing, early in November every year. They were harvested in the middle of February, March and August of the following year, respectively.

On the other hand, in a NTFS-field, thorny shrubs of cactus sp. were grown as a fence along the circumference and corn, soybean and cassava were cultivated in the same way as in the TSFS-field.

All the individual plants of one crop in each food crop area of five TSFS- and five NTFS-fields were harvested at the harvest time. Yield and dry matter weight were measured in every field and their average values for TSFS- and NTFS-fields were calculated. Grass and legume productions were estimated by using a quadrat (0.5×0.5 m); i.e. samples were taken in nine quadrats for each species in every TSFS-field at the ends of wet and dry seasons. At the same time, to estimate the production of the 2nd and 3rd strata, the dry weight of leaves of eight plants in each shrub species, and those of seven plants of each tree species were measured individually in a TSFS-field.

The daily amount of forage given to a cattle was decided monthly according to body weight, in the dry weight of forage equivalent to 3% of body weight³⁾ and the availability of TSFS in feeding capacity was evaluated by comparing the increase of cattle weight in TSFS- and NTFS-fields.

Results and Discussion

Table 1 shows annual yields of food crop and forage produced in a TSFS- and NTFS-field with the average of yields in 1986 and 1987. As forage resources, a TSFS-field produced 96% more than a NTFS-field did. Particularly, in the dry season, forage produced in a TSFS-field was 75% more than that in a NTFS-field. Furthermore, forage produced in a NTFS-field only consisted of crop residue, while 33% of the total forage was obtained from crop residue and the remaining 67% was obtained mainly from grasses, legumes and shrub leaves in a TSFS-field. Among strata in a TSFS-field, 21% of total forage was obtained from grasses and legumes of 1st stratum, the other 45 and 1% were from shrubs of 2nd stratum and trees of 3rd stratum, respectively. In the production of 1st stratum, grasses produced more forage than legumes did. This may relate to the difference of photosynthetic mode, i.e. grass species selected as constituents of 1st stratum were all classified as C₄ plant, while legumes belonged to C₃ plant⁵⁾.

On the other hand, grain and tuber production of food crop in a TSFS-field was 35% smaller than that in a NTFS-field. This difference arose from the different size of food-crop area in a field, because, productivities of grain and tuber in both TSFS- and NTFS-fields were almost the same (0.47kg/m²). Therefore, this result shows that the improvement of field system to TSFS does not affect the productivity in food crop production.

Fig.3 shows the monthly amount of forage fed to cattle according to body weight during two years from January, 1986 to December, 1987. Contents of the ration to a cattle in a TSFS-field were determined by the seasonal pattern of forage production and crop residues were used as a store feed so as to fill up a shortage of forage, especially in the latter part of the dry season. A cattle on a TSFS-field was mostly fed with grasses and legumes of 1st stratum during the wet season, with shrubs of 2nd stratum in the early part of the dry season, and with shrubs, crop residues, particularly cassava residue and trees of 3rd stratum in the latter part of the dry season and the beginning of the wet season. On the other hand, a cattle on a NTFS-field was fed with

Table 1. Food crop and forage production during wet and dry seasons in TSFS- and NTFS-fields.

Effective species	Production (kg/field/season)					
	TSFS			NTFS		
	Wet	Dry	Total	Wet	Dry	Total
1. Food crop (grain and tuber) yield						
Corn	260	—		363	—	
Soybean	160	—		240	—	
Cassava	—	338		—	562	
Sub total	420	338	758 (65)	603	562	1165 (100)
2. Forage yield						
(1) Crop Residues						
Corn	277	—		413	—	
Soybean	231	—		359	—	
Cassava	—	186		—	291	
Sub total	508	186	694 (65)	772	291	1063 (100)
(2) 1st stratum						
<i>Cenchrus ciliaris</i>	94	66		—	—	
<i>P. maximum</i>	78	51		—	—	
<i>S. guianensis</i>	41	15		—	—	
<i>S. hamata</i>	57	16		—	—	
<i>Centrosema pubescens</i>	15	7		—	—	
Sub total	285	155	440			
(3) 2nd stratum						
<i>G. sepium</i>	734	147		—	—	
<i>L. leucocephala</i>	36	20		—	—	
Sub total	770	167	937			
(4) 3rd stratum						
<i>F. poacellie</i>	2	1		—	—	
<i>H. tiliaceus</i>	5	1		—	—	
<i>L. coromandelica</i>	4	0		—	—	
Sub total	11	2	13			
Total forage	1574 + (204)	510 = (175)	2084 (196)	772 + (100)	291 = (100)	1063 (100)
Total general	1994 + (145)	848 = (99)	2842 (128)	1375 + (100)	853 = (100)	2228 (100)

crop residues produced in a NTFS- field and natural forage which was collected by farmers outside the field, usually in lowland areas about 30km far from their village. However, the monthly amount of forage fed to a cattle on a NTFS-field was generally 15kg more than the ration in a TSFS-field. This was considered on the basis of the difference in contents of forages between TSFS- and NTFS -fields. Though the natural forage for a cattle on a NTFS-field also consisted of grasses and leaves of shrubs and trees, their species were different from those in a TSFS-field. Natural grass in tropical region is dominated by *Axonopus*, *Imperata*, *Panicum* and *Andro-*

*pogoneae*²⁾. If a cattle is fed with these grasses, it takes 5 years or more to reach market weight of 500kg live-weight, because of the low nutritive values and low nutrient digestibility^{1,4,6)}.

Fig.4 shows the increase of live weight of cattle on TSFS- and NTFS-fields. There was no significant difference between the two, though the cattle on TSFS-fields were fed approximately 10% less forages than those on the NTFS-fields. This point may be understood well with the results obtained by Nitis et al⁴⁾. They showed that the introduced grasses and legumes, and selected shrubs and trees which were used in TSFS-fields, contained more nutrients in leaves such as crude protein

Fig. 3. Monthly ration and composition of feeds offered to cattle which were started to be fed from 1986 at 120kg body weight to 1987 on TSFS- and NTFS-fields.

■ : 1st stratum, ▨ : 2nd stratum, ▩ : 3rd stratum,
▧ : crop residue, □ : natural forage collected from outside NTFS-field.

Fig. 4. Increase of cattle body weight fed by TSFS (—) and NTFS(-----).

and total digestible nutrient than the natural ones.

In the case of a common practice in cattle husbandry in this area, i.e. in a NTFS-field, live weight of cattle increased about 140kg in two years from 120 to 260kg. The result clearly shows that the traditional field system is able to be replaced by Three Strata Forage System and a TSFS-field can feed a cattle until the live weight reached at least about 260kg, judging from the total forage productivity of a TSFS-field.

However, it is necessary to evaluate the profitability of TSFS synthetically, on account of the low food-crop yield in a TSFS-field. According to the estimation of farmers' income and expenditure, income from food crop, forage or cattle and wages sector were Rp 506, 235 and Rp 443, 077/field/year for TSFS- and NTFS-fields, respectively, and expenditure for fertilizers, crop seeds and wages sector were Rp 27,600 and Rp 56,080/

field/year, respectively. Thus, the net income of farmers on TSFS was 23.7% higher than that on NTFS. Therefore, it is concluded that the Three Strata Forage System is more profitable and advantageous than traditional cattle farming and food-crop production methods of seasonal drought-prone areas in Indonesia.

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