PRELIMINARY STUDIES ON CURING AND STORING NANDI SETARIA HAY

V. R. CATCHPOOLE*

ABSTRACT

Four preliminary haymaking trials were conducted with Nandi setaria in preparation for detailed studies to test the reliability of haymaking from improved pastures in the coastal districts of S.E. Queensland. The object of the preliminary trials was to select a practical method of haymaking suitable for experimental use. In addition the trials were necessary to reveal other problems requiring detailed study.

Under the conditions of the trials, severe conditioning of the swath (i.e. crushing and slashing) did not result in shorter curing periods than mechanical tedding. This was largely because the severely conditioned hay took up more water at night and during rain than the tedded hay. Tedding was therefore selected for the detailed trials. The frequency and timing of tedding are important. These trials confirmed the published data that hay should be tedded frequently on the first day, and if the weather is fine, once or twice on the following days.

Losses during curing of Nandi setaria hay were usually small (i.e. less than 10 per cent of the original dry matter and nitrogen) and appear to present no serious problems.

Detailed study is needed to determine water contents at which hay is safe (resists degradation) during storage under the sub-tropical climate of south-east Queensland. Knowledge of this water content is necessary before curing periods can be measured.

INTRODUCTION

The area of sown pastures is increasing in the coastal districts of south-east Queensland, and excess growth is available, in good seasons, for conservation. The silage fermentation of two tropical grasses has been tested (Catchpoole 1965, 1966, 1968), but experience with haymaking from improved pastures in this sub-tropical environment is very limited.

The main question in deciding between hay and silage for the coastal districts of south-east Queensland concerns the reliability of good haymaking weather during the growing season, particularly during the wet months of January, February and March. The reliability of haymaking weather could be assessed by a statistical analysis of existing meteorological records, provided one knew how long it takes to make hay under the various weather conditions encountered in this environment. Before trials were started to gather these data, the current preliminary trials were necessary to select a practical haymaking method suitable for use in experiments. These preliminary trials were necessary also to reveal problems in haymaking from pastures in south-east Queensland.

Four haymaking trials were conducted on a Nandi setaria pasture at Samford. Each trial included 2 or 3 swath conditioning treatments. The rate of drying and losses of dry matter and nitrogen during curing, and losses of these constituents during storage were measured.

MATERIALS AND METHODS

Plant material

The Nandi setaria pasture used in these trials covered 11 acres, and was planted in 1960. Since 1964 this pasture has been cut frequently for conservation and fertilized twice each year with 100 lb. of nitrogen as urea, 2 cwt. of superphosphate and 1 cwt. of potassium chloride at each application. When each of these trials was harvested the pasture regrowth was 5 to 6 weeks old; it followed a clearing cut to a 3 inch stubble and one of the above dressings of fertilizer.

* C.S.I.R.O. Division of Tropical Pastures, Cunningham Laboratory, St. Lucia, Queensland, 4067.

Experimental design

Swath conditioning treatments were applied to plots arranged in randomised blocks. There were 2 treatments and 4 blocks in trial 1, 2 treatments and 10 blocks in trial 2, and 3 treatments and 5 blocks in trials 3 and 4. The sizes of the plots were—Trial 1, 4 swaths wide and 92 ft. long; Trial 2, 1 swath wide and 54 ft. long; and Trials 3 and 4, 1 swath wide and 72 ft. long. Blocks within Trials 2, 3 and 4 were adjacent, but in Trial 1, Blocks 1 and 2 were 60 ft. from Blocks 3 and 4. The experimental sites were small and side effects were avoided by mowing 2 acres of pasture surrounding each site.

Conditioning treatments

The dates of the four trials and the conditioning treatments were as follows:

Trial	Date	Treatment
Trial No. 1 Raking V Tedding	9.2.66	(1) Tedded soon after mowing, then tedded 3 times a day for 2 days and tedded twice before baling on the third day. (2) Not touched for 3 hours after mowing, then turned with a side-delivery rake in the place of tedding in treatment 1.
Trial No. 2 Crushing V not crushing	12.12.66	(1) Crushed soon after mowing, then tedded 3 times a day for 2 days, and tedded twice before baling on the third day. (2) Tedded soon after mowing, then tedded as for treatment 1.
Trial No. 3 Slashing V Mowing	5.3.68	(1) Tedded soon after slashing, then tedded 3 times a day for 3 days, and tedded twice before baling on the fourth day. (2) Slashed only. (3) Tedded soon after mowing, then tedded as for treatment 1.
Trial No. 4 Frequency of Tedding	6.3.68	(1) Tedded soon after mowing, then tedded 4 times a day for 2 days, and tedded twice before baling on the third day. (2) Tedded soon after mowing, then tedded twice a day for 2 days, and tedded twice before baling on the third day. (3) Tedded soon after mowing, then tedded once a day for 2 days, and tedded once before baling on the third day.

Machinery

The sickle-bar mower used in Trials 1 and 2 cut a 7 ft. wide swath, and the one used in Trials 3 and 4 cut a 6 ft. wide swath. Both mowers were fitted with swath deflection boards, were fully mounted on a tractor, and set to cut 3 in. above the ground. The tedder, "Bamford Wuffler", had an "up and over" action and a working width of 5 ft. The swaths were wider than this and because most of the experimental plots were 1 swath wide, each swath was initially tedded twice to form one windrow on each plot. A "New Holland", fully trailed, ground-drive, side-delivery rake was used to turn the hay in Trial 1. The crusher, "New Holland 404", had one smooth steel and one fluted rubber roller, and a working width of 7 ft. The rotary slasher trailed the tractor and had a cutting width of 5 ft. This machine was not adapted for haymaking and it ejected very severely bruised grass out of the back of the chamber, and often threw this grass onto neighbouring plots. A second difficulty was that the slasher did not cut the grass flattened by the tractor wheels, so that when the hay was windrowed for baling some of this uncut grass was torn off and baled with the dry hay. Experienced operators can overcome these difficulties, but the original yields and losses during curing in Trial 3, in which some of the plots were slashed, could not be measured.

Field procedure

Pasture maturity was expressed as the proportion of flowering to vegetative tillers, of leaf to stem plus sheath, and as the height of vegetative tillers to the top of the youngest leaf, and of flowering tillers to the top of the seed head. The measurements were made on composite samples consisting of 25 to 30 small handfuls of grass cut at ground level and at random over each site.

Losses of dry matter and nitrogen during curing were measured by estimating their yields in the mown grass on each plot, and comparing these with the yields when the hay was baled. Losses of these consitiuents during storage were the difference between the amounts baled, and the amounts remaining after storage for 24 weeks in Trial 1, 33 weeks in Trial 2, and 20 weeks in Trials 3 and 4. Detailed sampling procedures were as follows: The original yields were estimated by cutting samples, 5 ft. long and one swath wide, from the mown grass on each plot. Three samples were cut from each plot in Trials 2, 3 and 4, and 12 samples were cut from the larger plots in Trial 1. The positions of these samples in the plots were selected by a stratified random sampling procedure. The samples were weighed, sub-sampled for water and nitrogen analyses, and the remaining grass was returned to its original position in the plot. The yields of dry matter and nitrogen after curing were the amounts baled plus the amounts in the samples taken before the hay was baled.

Changes in the water content of the hay during curing, and contents of water and nitrogen in the hay at baling, were determined by analysing composite samples, each being 10 to 12 grab samples, taken along each plot. These samples were taken 2 or 3 times each day, and those at baling were taken immediately in front of the baler.

Chemical analyses

Water contents were determined by drying samples at 100$\pm$2°C in a forced draught oven. All water contents were expressed on an oven dry basis. Samples for nitrogen analysis were digested by a salicyclic acid modification of the Kjeldahl method, and ammonia in the digests was determined by an automated colorimetric method. Nitrogen contents after storage were determined on ground samples of air dry hay, and corrected for water content by drying separate samples in the oven. All of the other samples were re-dried in the oven before they were analysed.

The temperature of the hay was measured at frequent intervals during the first 2 weeks of storage by inserting mercury in glass thermometers into the bales.

RESULTS

Characteristics of the plant material

The yields of dry matter were over 4,000 lb. per acre at the start of Trials 1, 3 and 4 and 3,080 lb. at the start of Trial 2 (Table 1). In Trial 1 the grass on Blocks 1 and 2 was leafier and not as tall as the grass on Blocks 3 and 4, and the results of this trial have been presented separately for these two types of grass. In Trial 2 the grass was at a young stage of growth; it had a low proportion of flowering to vegetative tillers, a relatively high nitrogen content, and was short. In Trials 3 and 4 most of the tillers were vegetative, and the proportion of leaf to stem plus sheath was relatively high. This grass was cut towards the end of the growing season when tillers of Nandi setaria remain vegetative longer than they do earlier in the season.

TABLE 1

Yield, Nitrogen content, and Maturity of the Nandi Setaria Pasture when Mown for Four Haymaking Trials

	Yield		Nitrogen Content		Maturity at Harvest		Height of Tillers in inches	
	Dry Matter (lb/ac)	SD and (No. in Mean)	Percent of Dry Matter	SD and (No. in Mean)	Flowering Tillers/ Vegetative Tillers (percent by No.)	Leaf Blocks/ Sheaths Stems (percent by Wt.)	Vegetative	Flowering
Trial 1								
Blocks 1 & 2	4250	643 (8)	1.56	0.05 (4)	31	53	17	31
Blocks 3 & 4	4340	764 (8)	1.32	0.05 (4)	38	29	28	38
Trial 2	3090	410 (20)	1.54	0.06 (20)	11	47	13	23
Trials 3 & 4	4780	668 (15)	1.51	0.13 (30)	5	62	17	30

TABLE 3

Losses of Dry Matter and Nitrogen During and Curing During Storage of Nandi Setaria Hay

	Trial 1		Trial 2		Trial 3			Trial 4		
	Tedded	Raked	Crushed	Uncrushed	Slashed	Slashed & Tedded	Mown & Tedded	Tedded 4 times/day	Tedded 2 times/day	Tedded once/day
Losses During Curing (% original amounts)										
Dry Matter	9	5	13	4				4	0	3
SD and (No. in mean)		5.7 (4)		8.5 (10)						14.2 (5)
LSD 5%		NS		8.6						NS
Nitrogen	13	6	14	11				6	9	14
SD and (No. in mean)		2.2 (4)		8.9 (10)						16.8 (5)
LSD (5%)		4.8		NS						NS
Losses During Storage (% amounts stored)										
Dry Matter	1	4	4	5	15	2	3	2	4	9
SD and (No. in mean)		4 (16)		4 (10)		3.2 (5)				2.1 (5)
LSD 5%		NS		NS		2.0				*
Nitrogen					9.4	0.7	1.7	3.2	1.1	8.4
SD and (No. in mean)							4.7 (5)			5.9 (5)
LSD 5%							5.4			NS

* Linear regression significant $P < 0.01$

Weather conditions

Meteorological measurements during the trials were recorded 600 yd from the experimental sites (Table 2). The weather during Trial 1 was fine, and net radiation values were high. Low net radiation values and 0·03 in. of rain corresponded with the first 24 hours of Trial 4, and with the second 24 hours of Trial 3. Trial 2 suffered persistent light rain and the hay was baled at a water content of 50% when a thunderstorm was imminent on the third day.

TABLE 2

Weather Conditions During Four Haymaking Trials

Date	Trial 1 1966			Trial 2 1966			Trials 3 & Trial 4 1968			
	Feb. 9	10	11	Dec. 12	13	14	March 5	6	7	8
Screen Measurements										
Temperature °F										
Min.	62	58	65	53	58	65	70	65	59	63
Max.	82	84	93	78	79	80	88	87	78	81
R H	57	69	74	63	63	60	67	60	70	59
Rain										
inches to 9.00 a.m.				0.02	0.01	0.10			0.03	
Wind										
Miles per day	17	15	22	45	54	34	12	81	45	85
Direction	S	Calm	NE	NE	NE	Calm	S	S	S	SW
Net Radiation										
Langleys per day	366	352	296	166	347	275	336	148	320	297

Changes in the water contents during curing

Grass in Trials 1, 2 and 3 (Figures 1(A), 1(B), 1(C) and 2(A)) lost water rapidly during the first day, but the first day of Trial 4 was dull and the grass lost a good deal of water during the second day (Figure 1(D)). However in all of the trials the amount of water lost during the first day varied with the conditioning treatments and in Trials 1, 2 and 4, although these treatment effects decreased, particularly in Trial 2, with time, they persisted throughout the second day and even into the third day. In Trial 3, the advantage established by the slashed grass during the first day was almost lost that night, and for the slashed grass that was not tedded, the initial advantage was reversed in favour of the mown grass during the second night.

Losses of dry matter in the field and during storage

Losses of dry matter during curing were usually well below 10% of the amounts in the grass at harvest. The largest loss of 13% was for the crushed treatment of Trial 2. Field losses of nitrogen varied between 6 and 14% of the amounts harvested. The dry matter and nitrogen losses, shown in Table 3, were mean values for each treatment; their standard deviations were wide, and differences between treatments were usually not significant. Losses of dry matter during storage in Trials 1 and 2 were less than 5% of the amounts stored, but in Trials 3 and 4 this loss increased from 2 to 15% when the water content of the hay at baling increased from 28 to 112%.

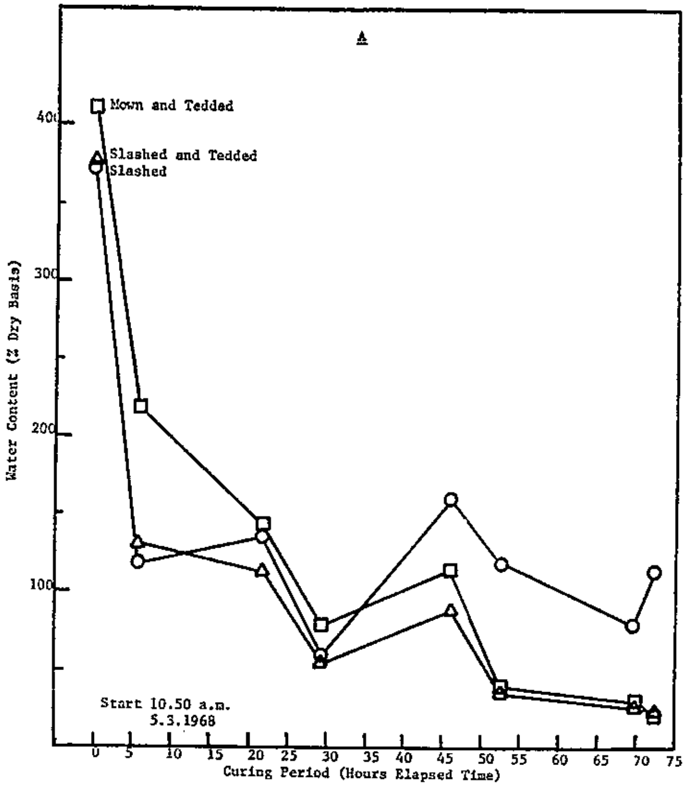

FIGURE 1

Changes in Water Contents During Curing of Nandi Setaria Hay
(A) Trial 1 Blocks 1 and 2
(B) Trial 1 Blocks 3 and 4
(C) Trial 2
(D) Trial 4

Temperature of hay during storage

The maximum temperatures recorded in the bales during storage were plotted in relation to the water contents of the hay at baling. This figure is not presented, but it demonstrated that temperatures above the ambient level were common when the water contents were above 30 to 35%.

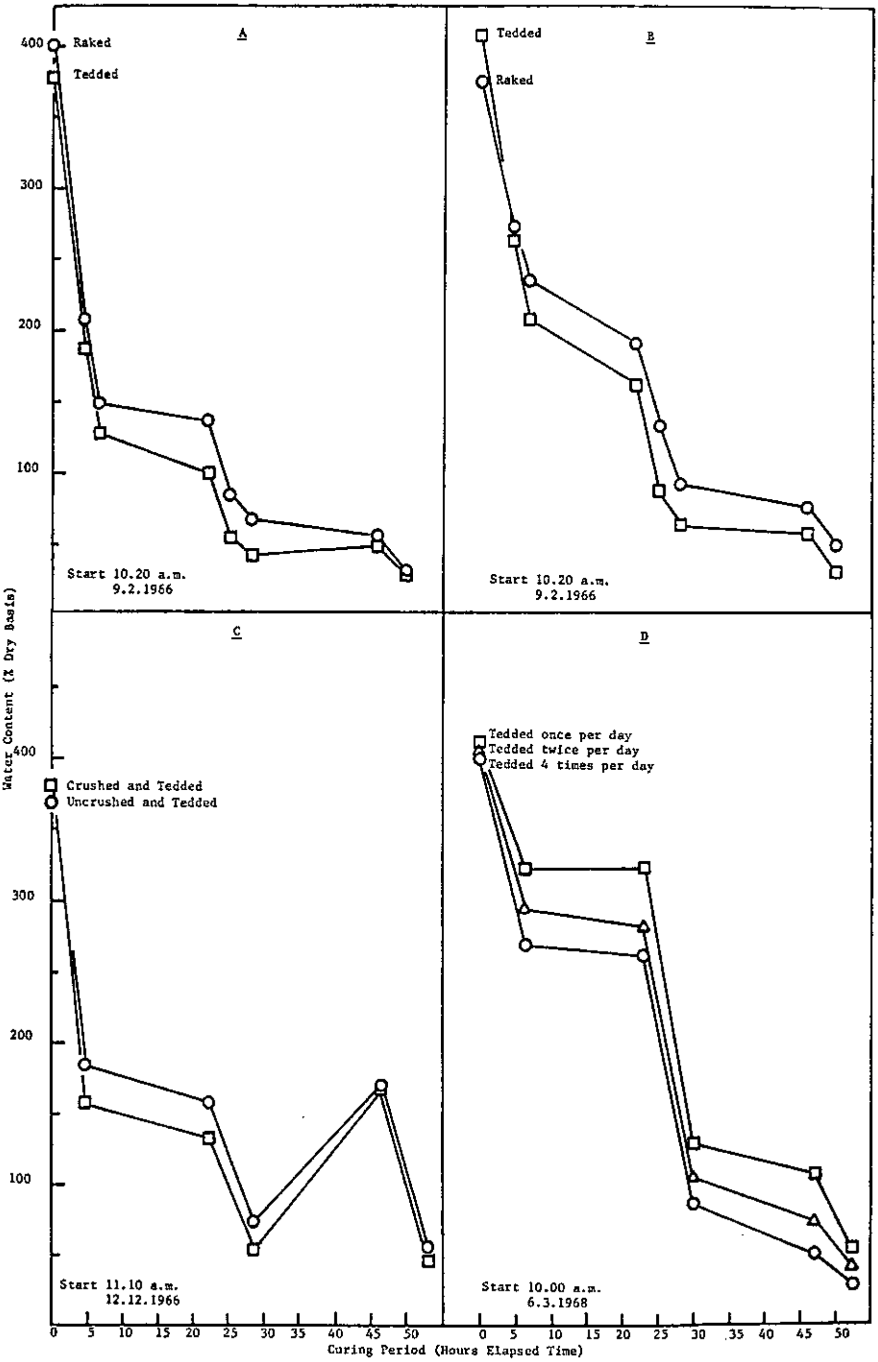

FIGURE 2
Changes in Water Contents During Curing of Nandi Setaria Hay
(A) Trial 3

DISCUSSION

These trials were not intended to assess the reliability of suitable haymaking weather in south-east Queensland, but the results were sufficiently favourable to justify the proposed trials that have this object. Tentative curing periods as short as 50-55 hours were, in fact, measured. These curing times were achieved by the tedded hay in Trial 1, and by the hay tedded four times a day in Trial 4. This result was encouraging because pasture yields were over 4,000 lb. of dry matter per acre, and during the first day of Trial 4 the weather was dull with 0·03 in. of rain. This dull weather corresponded with the second day of Trial 3, and here curing periods were 70-75 hours.

During the above curing periods the water content of the hay fell to near 25% (dry basis). The curing periods were tentative because hay baled at this water content may not be safe (i.e. resist degradation) during storage under the climatic conditions of south-east Queensland. Water contents of 25% are safe for hay made from temperate pastures (Shepherd, 1964) and the lower content of 22% is safe for Coastal Bermuda grass hay at Tifton, Georgia (Hellwig, 1965). Research to define safe water contents for hay in south-east Queensland is obviously needed, and it must take priority over research to measure curing periods, because curing periods cannot be measured until the safe water contents are known. Deterioration of stored hay was found by Greenhill *et al.* (1961), to increase with the temperature during storage, and with the water content of the hay. High temperatures are unavoidable in the sub-tropics, and hay may have to be baled at very low water contents to limit deterioration during storage.

The losses during storage measured in the study must be interpreted carefully because the hay was stored in small open stacks in a shed, and the hay lost heat and water during the first two weeks of storage. Under these storage conditions losses of nitrogen and dry matter were commonly below 5% of the amounts stored. These losses were not large, Lucerne/Meadow Fescue hay lost between 1·0 and 6·5% of its dry matter during storage for 35 weeks in England (Murdock *et al.* 1959), and in Victoria, subterranean clover/Wimmera ryegrass hay lost 8% of its dry matter (Cameron, 1966). Deterioration of hay stored in large stacks in the sub-tropics may be more serious. Miller *et al.* (1967) stored experimental lots of hay in insulated boxes, and as the water content of the hay increased above 23%, the temperature of the bales increased, and the feeding value of the hay was reduced.

Nandi setaria hay was not prone to heavy losses during curing, even when it was tedded frequently. Published losses vary widely but under conditions somewhat similar to those in the current trials (i.e. when pasture hay was made in fine weather, tedded and baled) dry matter losses were near 10% (Rice, 1966, and Kerr and Brown,1965) Dry matter losses in this study were below 10% of the amounts harvested except for the 13% loss from the crushed treatment of Trial 2. This grass was wet twice by rain during curing. Losses during curing of Nandi setaria hay apparently present no serious problems, but confirmation of this would be desirable because, as the wide standard deviations in Table 3 demonstrate, the losses were quite variable.

The four methods of conditioning the swath tested in this study were: turning with a rake; mechanical tedding; crushing; and slashing. The object was to select a practical method of haymaking for use in experiments. Comparisons between methods of haymaking require extensive trials covering a variety of weather and crop conditions. The current results, although very limited, were useful when considered in relation to published experience.

Mechanical tedding of the swath was selected as a suitable method of haymaking for future trials. Mechanical tedding promoted rapid and uniform drying during extensive trials in Ireland (Anon., 1963), and this was confirmed under local conditions by Trial 1 of this study. The frequency and timing of tedding are important. Hay should be tedded frequently on the first day, and if the weather is fine, once or twice on the following days. This procedure will be used in future experiments, because it has not only been recommended in England (Shepperson, 1965) and in Ireland (Anon., 1963), but its effectiveness was demonstrated also by Trial 4 of this study. Here the hay tedded 4 times a day dried faster during the first day than hay tedded less frequently, but on the second and third day, the rate of drying was not influenced by the frequency of tedding (Figure 1(D)). In future trials, primarily concerned with the effects of weather conditions on the rate of drying, certain field procedures will be standardised. All trials will be harvested at the same time of day (Mitchell and Shepperson, 1955), the hay will be tedded immediately following harvesting (Shepperson, 1965), and an attempt will be made to harvest all trials at equivalent yields of grass (Hart and Burton, 1967).

Slashing and crushing were not selected for further use because, during this study, they did not result in shorter curing times than mechanical tedding. The crushed grass (Trial 2) and the slashed grass (Trial 3) lost more water during the first day than tedded grass, but this advantage was lost when they took up more water at night and during rain than the tedded grass. As the capacity of partly-dry, damaged grass to take up water is well known (Watson and Nash, 1960) the use of conditioning machines that severely damage the grass is questionable under the humid conditions of the sub-tropics. Further testing of crushing and slashing machines may, however, be desirable because the weather was not entirely favourable when they were tested in this study. In addition, very short curing times have been published for these treatments. Fairbanks and Thierstein (1966) found that crushed lucerne was ready to bale 8 hours after it was harvested, and Jones and Dudley (1948) found that the water content of crushed and uncrushed Sudan grass fell to 20·5% after 27 and 72 hours respectively. Hellwig (1965) used a rotary slasher on Coastal Bermuda grass; 28 hours after harvesting the water content of the slashed grass was 14·0% while that of the mown grass was 20·9%. Further testing of haymaking machines with rotary cutting actions is also warranted because sickle-bar mowers do not cut a well defined swath in pastures containing the trailing tropical pasture legumes. Modern haymaking machines with rotary actions (Medling, 1966) could overcome this difficulty.

REFERENCES

ANON. (1963)—Haymaking machinery 1963. Test Report An Foras Ialüntais, Carlow No. 13.

CAMERON, I. H. (1966)—Dry matter and quality changes during and after making pasture hay. *Australian Journal of Experimental Agriculture and Animal Husbandry* **6**: 394, 401.

CATCHPOOLE, V. R. (1965)—Laboratory ensilage of *Setaria sphacelata* (Nandi) and *Chloria gayana* (C.P.I. 16144). *Australian Journal of Agricultural Research* **16**: 391-402.

CATCHPOOLE, V. R. (1966)—Laboratory ensilage of *Setaria sphacelata* (Nandi) with molasses. *Australian Journal of experimental Agriculture and Animal Husbandry* **6**: 76-81.

CATCHPOOLE, .V. R. (1968)—Effects of season, maturity, and rate of nitrogen fertilize on ensilage of *Setaria sphacelata* (Nandi). *Australian Journal of Experimental Agriculture and Animal Husbandry* **8**: 569-573.

FAIRBANKS, G. E., and THIERSTEIN, G. E. (1966)—Performance of Hay Conditioning Machines. American Society of Agricultural Engineers Transitions **9**: 182, 184.

GREENHILL, W. L., COUCHMAN, JEAN F., and DE FREITAS, J. (1961)—Storage of Hay. III. Effect of temperature and moisture in loss of drymatter and changes in composition. *Journal of the Science of Food and Agriculture* **12**: 393-397.

HART, R. H., and BURTON, G. W. (1967)—Curing Coastal Bermudagrass Hay: Effects of Weather, Yield, and Quality of Fresh Herbage on Drying Rate, Yield, and Quality of Cured Hay. *Agronomy Journal* **59**: 367-371.

HELLWIG, R. E. (1965)—Effect of Physical Form on Drying Rate of Coastal Bermudagrass. American Societyof Agricultural Engineers.Transactions **8**: 253-255.

JONES, T. N., and DUDLEY, B. F. (1948)—Methods of field curing hay. *The Journal of the American Society of Agricultural Engineers* **29**: 159-161.

KERR, J. A. M., and BROWN, W. O. (1965)—A comparison of nutrient losses in Baled Hay made from Forage—Harvested, Crimped or Tedded Swards with those in Barn Drying. *Journal of the British Grassland Society* **20**: 156-163.

MEDLING, P. C. (1966)—New Techniques in Haymaking. *Journal of the Department of Agriculture*, Victoria **10**: 437-445.

MILLER, L. G., CLAYTON, D. C., NELSON, L. F., and HOEHNE, O. E. (1967)—Nutritive value of hay baled at various moisture contents. *Journal of Animal Science* **26**: 1369-1373.

MITCHELL, F. J., and SHEPPERSON, G. (1955)—The effects of Mechanical treatment on the drying rate of Hay in the Swath. *Institution of British Agricultural Engineers Journal* **11**: 3-18.

MURDOCH, J. C., FOOT, A. S., HEAD, M. J., HOLDSWORTH, M. C., HOSKING, Z. D., and LINE, C. (1959)—Changes in the Chemical Composition and loss of Nutrients in Tripoded and swath-cured hay. *Journal of the British Grassland Society* **14**: 247-252.

RICE, B. (1966)—A comparison of six types of Haymaking machine. *Irish Journal of Agricultural Research* **5**: 43-53.

SHEPHERD, W. (1964)—Paths and Mechanisms of Moisture movement in Detached Leaves of White Clover (*Trifolium repens* L.): I. Losses of Petiole moisture direct from Petioles and via Laminae. Annals of Botany **28**: 207-220.

SHEPPERSON, G. (1965)—Quick Haymaking machinery and Methods. Outlook on Agriculture **4**: 259-269.

WATSON, S. J., and NASH, M. J. (1960)—The Conservation of Grass and Forage Crops. Oliver and Boys. Edinburgh and London.