STUDIES ON A SPEAR GRASS PASTURE IN CENTRAL COASTAL QUEENSLAND—THE EFFECT OF FERTILIZER, STOCKING RATE, AND OVERSOWING WITH STYLOSANTHES HUMILIS ON BEEF PRODUCTION AND BOTANICAL COMPOSITION

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ABSTRACT

Liveweight changes of Hereford steers were recorded on five paddocks over seven years. Introduction of S. humilis *(Townsville stylo) and application of molybdenized superphosphate both increased beef production from native pasture which was* Heteropogon contortus *dominant. Both treatments increased weight gain per head and allowed for increased stocking rates, and the biggest effect on both parameters was when the two treatments were combined. Heavier stocking of untreated native pasture severely reduced weight gain per head, and resulted in severe overgrazing and big changes in botanical composition. These detrimental effects of overgrazing on botanical composition were prevented by fertilizer or by over-sowing with* S. humilis.

INTRODUCTION

In a previous paper Shaw (1961) reported that on a native pasture dominated by black spear grass (*Heteropogon contortus*), oversowing with Townsville stylo (*Stylosanthes humilis*)+ plus application of fertilizer (superphosphate, potassium chloride, and molybdenum) increased carrying capacity and gain per head to give a five-fold increase in beef production per acre. Subsequent studies which are reported in this paper were designed to separate the effects of fertilizer, stocking rate, and *S. humilis,* and to follow long-term changes in botanical composition of the native pasture.

EXPERIMENTAL

For seven years from June 1959 to July 1966 animal weights and botanical composition were recorded from five paddocks at Rodd's Bay, near Gladstone (latitude 24°S, longitude 151° 30'E, elevation < 100 feet) which were subjected to the following treatments:—

Control—untreated native pasture grazed at the normal stocking rate for the district (area 45 acres).

NH—untreated native pasture grazed at a higher stocking rate (area 12 acres).

NHF—as for *NH* but with fertilizer as described below (area 12 acres).

TH—native pasture oversown with Townsville stylo and grazed at a higher stocking rate than *Control,* but not fertilized (area 12.7 acres).

THF—as for *TH* but fertilized as described below (area 16 acres).

Descriptions of the climate and soils of the experimental area at Rodd's Bay were given by Shaw (1961). It is gently undulating country with solodic to prairie-like soils derived from granite, where *Eucalyptus crebra* (narrow-leaved ironbark) was the dominant tree species before ringbarking. *Control* and *THF* were described in more detail previously (Shaw 1961), where the latter was referred to as *T.L. Paddock;* Townsville stylo in *THF* developed from an original sowing in 1952. *TH*

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+ Formerly known commonly as Townsville lucerne and botanically as *S. sundaica.*

was oversown with Townsville stylo seed at 2 lb an acre in December 1949 by surface broadcasting without cultivation; when included in the trial in 1959, the legume had been well established for some six years over which period the stocking rate had been about 0.25 beasts an acre. The other two treatments, *NH* and *NHF*, were fenced off from a large paddock in June 1957; experimental grazing started in 1958 but was interrupted by failure of the stock water supply and consequently animal live-weight records are available only from June 1959.

NHF paddock was fertilized with 3.4 cwt/ac superphosphate and 0.5 cwt/ac potash (KC1) in 1957 and 1958 plus 3 oz/ac sodium molybdate in 1958. From 1959 onwards it received molybdenized superphosphate (0.03%Mo) annually at 1 cwt/ac, plus potash at 0.5 cwt/ac in 1959, 1960, and 1961.

From 1954 to 1959 *THF* received a total of 10.5 cwt superphosphate and 1.5 cwt potash an acre, plus sodium molybdate (5 oz/ac) in 1954 (Shaw 1961). After 1959 it was fertilized as for *NHF*.

The pastures were continuously grazed, except for short periods between changes of animal groups, with grade Hereford steers which had previously been on unimproved native pasture. New groups of steers were introduced each year in June or July. They were 2½ years old in the first five years and 1½ years old in the last two. Animals were ranked on live-weights and divided among the paddocks at random according to weight classes. They were weighed at approximately monthly intervals after 16 hours without feed or water. Between 1960 and 1963 some of the steers in *THF* reached marketable condition (live-weight about 1100 lb) before the end of their 11 month grazing period; they were sold for slaughter and replaced by steers of the same age that had been grazing on unfertilized Townsville stylo pastures. Actual stocking rates for the whole experimental period (Table 1) were mostly held constant; however for *THF* the rate was increased in 1961-62 as the pasture improved, but had to be reduced in 1965-66 following severe overgrazing during two drought years.

TABLE 1

Stocking rates in the 5 paddocks during the experiment expressed as beasts an acre

Period	*Control*	*NH*	*NHF*	*TH*	*THF*
1959–60	0.11	0.25	0.25	0.24	0.25*
1960–61	0.11	0.25	0.25	0.31	0.31
1961–62	0.11	0.25	0.25	0.31	0.31°
1962–63	0.11	0.25	0.25	0.31	0.50
1963–64	0.11	0.25	0.25	0.31**	0.50
1964–65	0.13+	0.25	0.25	0.31	0.50
1965–66	0.13	0.25	0.25	0.31	0.31

* 0.37 from November 23 to end of period
° 0.44 from January 18 and 0.5 from March 13 to end of period
** 0.40 from January 17 to end of period
+ increased because younger stock were used

Botanical composition was determined as percentage frequency of all herbaceous species in 4 dm.[2] quadrats in each of the paddocks in the years 1960 to 1966 inclusive. On each occasion there were 200 observations in each paddock located on a stratified random sampling basis. In addition, starting in 1965, estimates of botanical composition on a dry matter basis were made in the same quadrats using the dry weight rank method of 't Mannetje and Haydock (1963).

After July 1966 two paddocks (*NH* and *NHF*) were used for other purposes but treatments in *Control* and *TH* were continued until 1968 and in *THF* until 1969. Supplementary botanical analyses were made in these three paddocks in 1967 and in *THF* in 1969. However animal weights for these three years are not presented because groups were not replaced annually and the results are not strictly comparable.

Seasonal Conditions

Rainfall at Rodd's Bay for the period under review is shown in table 2. Total rainfall was below average in five of the seven years, and severe drought prevailed in 1963-64 and 1964-65 when summer rains failed; rainfall for the three summer months had only been lower on one occasion in the previous 34 years. The years 1960-61 and 1965-66 were also dry but in both there was effective rain in summer. 1962-63 was a good year, although dry in the first six months, and 1961-62 was a very good year with exceptional spring rain and continued good rains up to the end of autumn. The winter rain of 1964-65 is also noteworthy.

TABLE 2
Rainfall records for Rodd's Bay in inches

	"Winter" June, July, August	"Spring" Sept., Oct., Nov.	"Summer" Dec., Jan., Feb.	"Autumn" Mar., April, May	Total
1959–60	1.61	6.45	15.78	5.60	29.46
1960–61	1.79	4.34	19.10	1.61	26.84
1961–62	1.42	17.65	11.91	15.62	46.60
1962–63	3.02	3.81	18.59	10.75	36.17
1963–64	1.48	1.73	7.17	7.24	17.62
1964–65	9.59	7.60	5.47	4.24	26.90
1965–66	0.22	5.95	11.51	3.45	21.13
34-year Mean	3.18	5.81	14.38	8.69	32.06

RESULTS

Animal production

Animal performance was strongly affected by treatment and by seasonal conditions (table 3). Gains per head were much higher in the two Townsville stylo treatments than in *Control* in all except the drought years 1963-64 and 1964-65. Furthermore, gains were higher in *THF* than in *TH* in five of the seven years. Gains in *NHF* gradually improved with time, relative to *Control,* but there was an opposite trend for *NH,* and steers in this treatment suffered severe stress in the drought. The very small gains by *NH* and *NHF* in 1960-61 were almost entirely due to bigger weight losses in winter (see Fig. 1).

An unweighted analysis of variance of the mean gains per head for treatments for all seven years was carried out, and treatment effects were tested against the treatment x years interaction. This indicated highly significant differences ($P < 0.01$) between treatment means. It is true that treatment effects and site effects are confounded in this analysis, but from past grazing history on this property it is known that differences in animal performance of the magnitude recorded do not occur even between different types of country, let alone different areas of the one type.

The cumulative liveweight changes in figure 1 show differences between treatments in winter and spring with a tendency for the Townsville stylo treatments to lose less weight. The main period of weight gain generally started at the same time in all treatments (within the limits of monthly weighings), and gains through to late February tended to be similar on all treatments, except *NH* after 1961-62. The biggest differences between treatments occurred after February when both fertilizer and Townsville stylo increased the rate of gain, and the combination of the two was outstanding in all except the second drought year (table 4).

TABLE 3

Live-weight gains per head and per acre for each treatment

Period	No. of days	Mean Initial weight	Live-weight gain per head (lb)					Live-weight gain per acre (lb)				
			Control	*NH*	*NHF*	*TH*	*THF*	*Control*	*NH*	*NHF*	*TH*	*THF*
1959–60	364	730	127	136	158	278	309	14	35	40	66	110
1960–61	367	740	128	64	92	304	307	14	16	23	95	96
1961–62	326	630	182	173	237	317	493	20	44	59	99	194
1962–63	370	630	263	198	313	334	464	29	50	78	105	236
1963–64	355	660	168	—9	196	127	161	19	—2	49	56	80
1964–65	349	550	257	57	291	265	185	34	14	73	83	92
1965–66	345	430	157	108	254	241	377	21	27	64	76	118
		Means	183	104	220	267	328	22	26	55	83	132
L.S.D.* (P = 0.05)					70 lb/head					27 lb/acre		
L.S.D. (P = 0.01)					95 lb/head					37 lb/acre		

* Least significant difference.

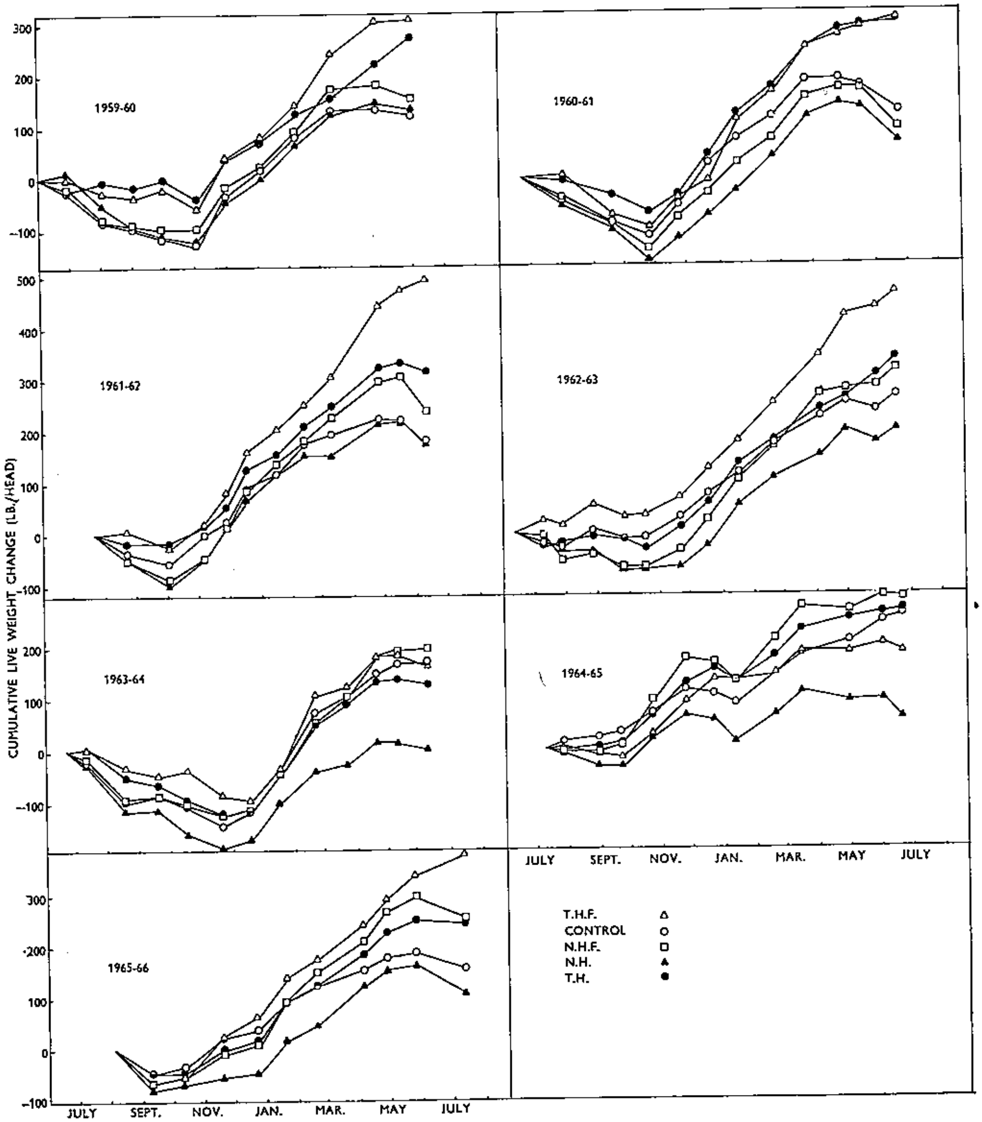

FIGURE 1

Mean cumulative live-weight changes for each group of steers in each treatment.

None of the steers in *Control* or *NH*, and only one of those in *NHF*, reached marketable condition at the end of their period on the experiment. However, in the years 1959-60 to 1962-63 inclusive, 7 steers out of 15 which grazed in *TH*, and 25 out of 27 which grazed in *THF* reached marketable condition and were sold, which meant a saving of about one year in age of marketing. This advantage was not achieved in 1963-64 or 1964-65 because of drought. In 1965-66 the steers were a year younger and were not finished; however those in *THF* remained in that paddock until January 1967 when they were sold about 1½ years earlier than normal.

TABLE 4

Rate of live-weight gain (lb/head/day) after mid-February in each year

Period	*Control*	*NH*	*NHF*	*TH*	*THF*
9.2.60–31.5.60	0.38	0.62	0.56	1.35	1.47
22.2.61–23.6.61	0.10	0.23	0.16	1.07	1.18
14.2.62–12.6.62	0.05	0.16	0.47	0.89	2.03
19.2.63–16.6.63	1.30	1.34	2.24	2.23	3.01
21.2.64–10.6.64	0.85	0.28	1.23	0.66	1.39
19.2.65– 2.6.65	0.99	0.27	0.83	0.80	0.54
19.2.66–27.5.66	0.66	1.15	1.46	1.29	1.65

The combination of higher gains per head with Townsville stylo, fertilizer or both, plus higher stocking rates led to very big increases in gain per acre (Table 3). The biggest increases were in 1961-62 and 1962-63 when *THF* produced 9.7 and 8.1 times as much live-weight gain as *Control*. Higher stocking alone (*NH*) gave increased production initially but this effect was counteracted in later years by poorer animal performance.

Botanical Composition

Percentage frequency

The general problem of analysing data consisting of sites specified by species recorded on successive occasions has been examined by Williams *et al.* (1969), and the method used is the one there recommended. Each site on each occasion on which it has been recorded is regarded as a separate individual and the total set of site-occasions is then classified with reference to the recorded species. Examination of the configuration of the resulting classificatory groups will disclose whether the major pattern is spatial or temporal, or a mixture of both. The classificatory model adopted was that of "information analysis" (Williams, Lambert and Lance, 1966; Lambert and Williams, 1966), modified to permit the use of frequency, instead of presence-or-absence, records.

Ninety-nine species were recorded and identified during the samplings (see Table 5 and Appendix) but many were of rare occurrence. The analysis described above was performed on 61 species, these including all native legumes recorded plus all other species which attained 10 per cent frequency for at least one site-occasion. All native legumes were retained because preliminary examination of the data indicated that they might be important in differentiating between site-occasions. Townsville stylo was omitted from this analysis because it was a treatment. With recordings in 5 treatments for 7 years plus additional analyses in *Control, TH* and *THF* in 1967 and in *THF* in 1969 there were 39 site-occasions. The results are shown in Fig. 2.

The analysis indicated that the major differences were between treatments rather than years. The yearly recordings for *Control* combined into a single group at a high level of similarity, as did those for *TH,* indicating little change in botanical composition. However while *NH* and *NHF* were very similar in 1960 and 1961, from 1962 onwards the two paddocks were in distinct groups indicating considerable changes in botanical composition. The recordings for *THF* showed much greater heterogeneity than those for other treatments.

While overall differences between years were less than overall differences between treatments, nevertheless examination of changes over time within treatments is of interest to detect responses of individual species to both treatment and seasonal conditions. The general pattern of seasons was that conditions were good from 1960 to 1963, dry in 1963-64 and 1964-65 and better again in 1965-66 and 1966-67.

Examination of all the data has indicated that the main trends can be detected from examination of results from 1960, 1965 and subsequent years. The percentage frequencies for these years are shown in Table 5, species being restricted to those reaching 10 per cent on at least one occasion.

Heteropogon contortus was strongly dominant in all treatments in 1960. The other main grasses were *Chrysopogon fallax, Eremochloa bimaculata, Digitaria longiflora* and *Eragrostis* spp.* but differences in the frequencies of these species

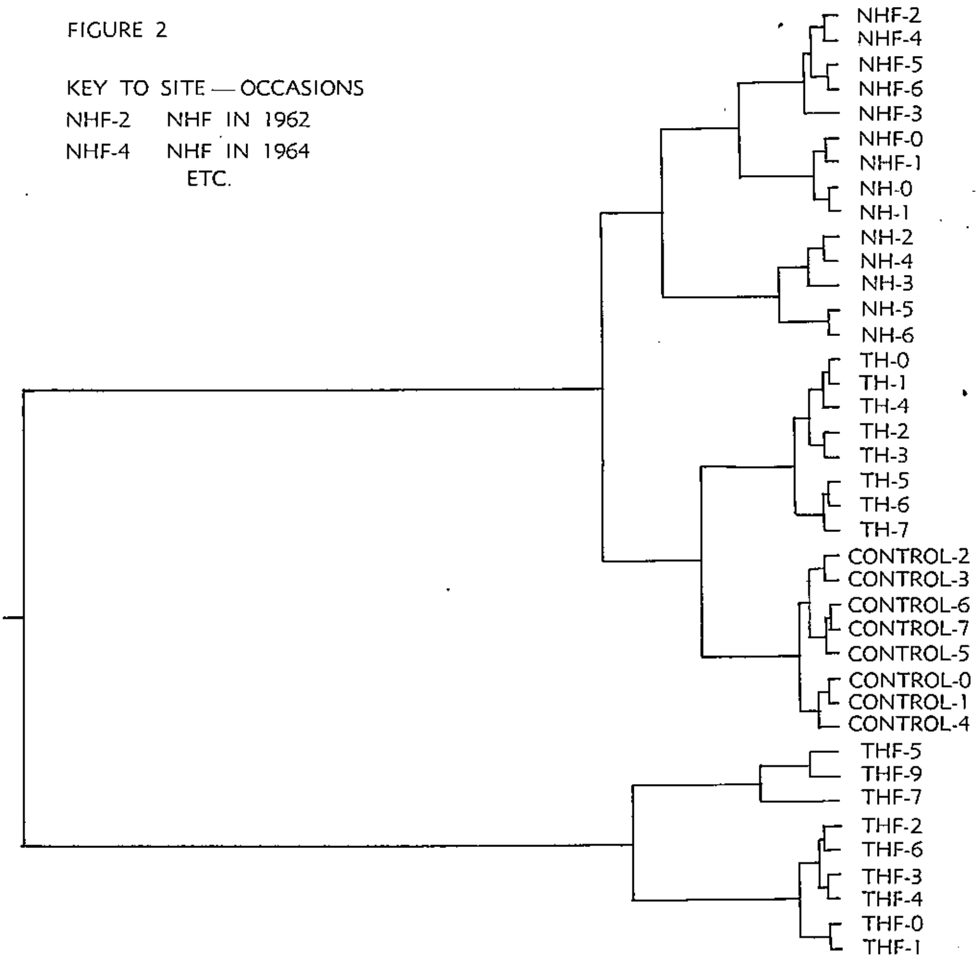

FIGURE 2
Grouping of site-occasions as a result of information-analysis.

account for much of the differences between the paddocks. *Fimbristylis dichotoma* was common in all treatments although less so in *TH* and *THF* than the others. *Glycine tabacina* and *Desmodium triflorum* were the main native legumes, and *S. humilis* was prominent in *TH* and *THF*. Forbs were generally minor components although *Helichrysum apiculatum* was common in *Control* and *NH*.

* Mainly *E. sororia, E. elongata,* and *E. leptostachya*—these were difficult to distinguish on vegetative characters when closely grazed and so were grouped.

TABLE 5

Percentage frequencies of the more prominent species in each treatment in the years 1960, 1965, and subsequent years
(Other species are listed in the Appendix)

Species	*Control* '60	'65	'66	'67	*NH* '60	'65	'66	*NHF* '60	'65	'66	*TH* '60	'65	'66	'67	*THF* '60	'65	'66	'67	'69
Heteropogon contortus	100	94	86	88	95	52	58	100	77	86	94	86	80	87	94	88	78	58	78
Eremochloa bimaculata	10	6	6	4	50	63	64	42	27	26	0	0	1	0	2	1	1	1	0
Chrysopogon fallax	44	61	64	70	24	48	42	26	44	42	14	48	32	46	8	16	13	16	26
Eragrostis spp.	30	18	14	31	18	23	18	6	12	10	16	12	12	34	14	14	8	22	24
Bothriochloa decipiens	2	5	4	4	1	2	1	1	18	14	2	30	14	16	4	4	1	2	1
Brachiaria miliiformis	0	0	3	0	0	1	8	0	0	1	0	2	5	8	4	22	18	26	54
Digitaria longiflora	6	3	5	10	19	14	8	12	3	4	4	6	3	10	10	27	14	40	6
Dactyloctenium aegyptium	0	0	1	1	1	0	1	0	1	2	1	1	2	0	4	10	6	8	20
Chloris divaricata	0	0	0	1	0	1	3	0	2	4	0	4	14	14	6	18	20	48	36
Tripogon loliiformis	0	12	18	19	0	26	34	0	4	3	0	0	4	6	0	0	1	0	0
Sporobolus indicus	0	2	4	6	0	0	0	1	6	8	2	10	12	8	5	4	6	6	6
Fimbristylis dichotoma	94	78	76	80	96	80	72	86	78	82	70	62	54	49	46	18	11	10	7
Desmodium triflorum	2	1	1	1	4	14	10	4	16	19	2	2	1	6	1	2	0	1	0
Glycine tabacina	15	16	13	16	5	10	8	14	23	14	10	16	8	8	2	2	1	0	1
Alysicarpus bupleurifolius	2	1	1	0	0	1	0	0	8	14	2	2	3	0	1	0	0	0	0
Stylosanthes humilis	0	1	1	1	0	5	13	0	1	4	47	61	90	92	77	92	99	89	95
Helichrysum apiculatum	28	10	5	9	22	8	4	7	1	0	0	1	0	0	1	0	0	0	1
Phyllanthus minutiflorus	12	3	14	14	10	34	27	6	4	7	3	2	2	9	1	2	0	0	1
Epaltes australis	10	2	3	1	1	12	10	0	2	0	1	2	1	1	1	1	1	2	1
Aporuellia australis	14	16	22	10	8	16	16	15	24	14	8	31	18	22	0	3	1	2	0
Gomphrena celosoides	0	1	1	1	1	1	1	0	2	1	2	4	2	4	9	23	4	34	48
Alternanthera nana	0	1	2	0	0	1	1	1	0	2	0	0	1	1	0	0	0	77	5
Portulaca oleracea	1	1	1	0	0	2	1	1	1	2	3	5	2	5	2	50	1	12	68
Erigeron canadensis	0	0	1	1	0	1	0	0	0	1	0	2	1	0	0	62	1	2	65
Portulaca filifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	11	36
Euphorbia australis	0	5	4	4	0	2	1	0	10	20	0	6	3	6	0	0	0	1	0

The botanical composition of *Control* did not change very much over the period of observations (Fig. 2 and Table 5), nor did that of *TH* apart from a doubling of the frequency of *S. humilis* between 1960 and 1967. *C. fallax* and *Tripogon loliiformis* increased in both treatments, although it seems very probable that the latter species was present but not recognized in 1960.

Changes in *NHF* were greater than in *Control* and *TH* although the pasture remained *H. contortus* dominant. There were fluctuations in some of the other grasses, notably *E. bimaculata, C. fallax,* and *Bothriochloa decipiens,* and increases in the native legumes *D. triflorum, G. tabacina,* and *Alysicarpus bupleurifolius.*

Much more pronounced changes occurred in *NH* and *THF*. In the former *H. contortus* decreased between 1960 and 1963 despite good seasons and in the subsequent drought years the decline was so pronounced that by 1965 it was no longer the dominant species. This decline was a combination of fewer plants and smaller plants, many being reduced to one or two tillers. There were associated increases in the frequency of *E. bimaculata, C. fallax, T. loliiformis* and *Brachiaria miliiformis.* However the major change was that the vegetative cover was severely decreased; bare ground increased, the total grass cover decreased, and there was an increase in forbs, notably *Phyllanthus minutiflorus, Epaltes australis,* and *Aporuellia australis.*

The pronounced changes in *THF* were associated with severe overgrazing during and following the drought years 1963-64 and 1964-65. *H. contortus* declined and there were big increases in *B. miliiformis, D. longiflora, and Chloris divaricata,* while *F. dichotoma* decreased. There were also big increases in forbs, mainly *Erigeron canadensis, Gomphrena celosoides, Alternanthera nana, Portulaca oleracea* and *P. filifolia.* These forbs, many of which are annuals, were not prominent in 1966 and this probably accounts for the fact that this year is not grouped with 1965, '67 and '69 in Fig. 2. After 1967 it was observed that *H. contortus* had started to recover and the extra analysis in 1969 confirmed this. *S. humilis* maintained a very high frequency throughout the whole period.

The increase in native legumes in *NHF* mentioned above is more clearly shown in Table 6 where the frequency of occurrence of 1, 2 and 3 or more species of native legumes per quadrat has been tabulated. Legumes were more prominent in *NHF* than in other treatments in 1960 but the increase to 1963 was most pronounced and this increase was largely maintained in succeeding years.

TABLE 6

Percentage frequency of occurrence of one, two, and three or more species of native legumes per quadrat in 1960, 1963, 1965 *and* 1966

Treatment	1960			1963			1965			1966		
	1 sp.	2 spp.	3 or more spp.	1 sp.	2 spp.	3 or more spp.	1 sp.	2 spp.	3 or more spp.	1 sp.	2 spp.	3 or more spp.
Control	18	3	0	30	4	1	24	2	0	20	2	1
NH	20	3	0	34	4	0	24	2	0	26	2	1
NHF	32	8	1	44	32	15	36	12	1	36	14	3
TH	14	2	0	32	16	4	16	1	0	12	1	0
THF	6	1	0	10	0	0	4	1	0	1	0	0

Percentage dry-matter yield

The results for the years in which percentage contribution to dry-matter yield was measured are shown in Table 7. *H. contortus* was the highest yielding single species in all treatments except *NH,* and this is further emphasised when the results

TABLE 7

Percentage contribution to dry matter yield of main species or groups of species

Year and Treatment		*H. contortus*	*C. fallax*	*E. bimaculata*	Other* Grasses (A)	Other+ Grasses (B)	*F. dichotoma*	Forbs	Native Legumes	*S. humilis*
		%	%	%	%	%	%	%	%	%
1965	*Control*	59	15	2	tr**	9	9	4	1	0
	NH	17	12	39	3	9	5	11	3	1
	NHF	50	11	12	tr	14	8	3	2	tr
	TH	40(51)°	11(14)	0	2(3)	15(19)	4(5)	5(6)	1(1)	21(0)
	THF	44(56)	3(4)	tr(tr)	17(22)	6(8)	1(1)	7(9)	tr(tr)	22(0)
1966	*Control*	47	24	2	2	8	10	5	1	tr
	NH	20	11	39	4	9	7	6	2	2
	NHF	52	10	9	2	12	9	2	3	tr
	TH	45(66)	6(9)	0	2(3)	10(15)	3(4)	2(3)	tr(tr)	32(0)
	THF	39(65)	1(2)	tr(tr)	12(20)	6(10)	1(2)	1(2)	tr(tr)	40(0)
1967	*Control*	49	25	2	2	11	8	2	1	0
	TH	42(54)	9(12)	0	5(6)	17(22)	2(3)	2(3)	1(1)	22(0)
	THF	26(30)	4(5)	tr(tr)	43(49)	10(11)	1(1)	4(5)	0	12(0)
1969	*THF*	39(51)	5(7)	0	14(18)	8(11)	tr(tr)	10(11)	0	24(0)

* Other Grasses (A) = *B. loliiformis* + *C. divaricata* + *D. longiflora* + *D. violascens*
\+ Other Grasses (B) = Grasses other than those in other columns
** tr = <0.5%
° Values in parentheses are percentage contribution to yield excluding *S. humilis*

for *TH* and *THF* are put on an equal basis with other treatments by excluding *S. humilis*. In *NH*, *H. contortus* was largely replaced by *E. bimaculata*. The increased contribution by *B. miliiformis*, *C. divaricata*, *D. longiflora* and *D. violascens* (Other Grasses—group A) in *THF* is also worthy of note. S. humilis made a substantial contribution to the yield of *TH* and *THF* in all years.

DISCUSSION

Townsville stylo, fertilizer, and stocking rate all influenced the level of beef production achieved on these pastures. In *Control* there was a large carry-over of uneaten herbage in each year so that animal performance was limited by feed quality and not by the amount on offer. Heavier stocking of untreated native pasture (*NH*) led to a gradual deterioration of animal performance and of pasture condition, with serious effects on animal production in the drought years when it was quite obvious that quantity of herbage had become limiting. It must be concluded then that the improvements in rate of gain per head in the paddocks with fertilizer and/or Townsville stylo, which were all grazed more heavily than *Control*, were not simply the consequence of this heavier stocking but must have resulted from an improvement in the quality of the feed on offer. The fact that it was possible to sustain higher stocking rates in these paddocks is a strong indication that there was also an increased quantity of feed on offer, and observations support this conclusion.

Highest production was recorded with the combination of Townsville stylo and fertilizer (*THF*). This paddock was stocked more heavily than the others but higher production was not purely because of this since production per head was also highest in this paddock. This effect is attributable both to Townsville stylo and to fertilizer. The legume obviously had an effect by itself (*TH*) and from the data in figure 1, table 4 and table 7, it is reasonable to ascribe much of this effect to the fact that the legume provided higher quality feed in autumn and winter.

Some of the fertilizer effect in *THF* can be ascribed to a direct effect on the Townsville stylo. Concurrent experiments at Rodd's Bay (Shaw, Gates and Wilson 1966) showed that applications of molybdenised superphosphate greatly increased the yield and the nitrogen and phosphorus content of Townsville stylo, and similar effects for Townsville stylo in mixed pasture have been observed subsequently (Shaw, unpublished data). Observations in this experiment indicated that fertilizer produced similar yield increases and that it increased the amount of legume available to the grazing animals. It is also probable that the fertilized Townsville stylo was of higher feed quality; this suggestion is supported by later work at Townsville in which Little (1968) using cattle, and Playne (1969) using sheep, showed that phosphate supplements increased the feed intake and live-weight gains by animals fed unfertilized Townsville stylo.

It is also probable that some of the fertilizer effect in *THF* was through the native pasture, since fertilizer alone increased production in *NHF*. It is tempting to suggest that the increase in frequency of native legumes in this latter paddock (Table 6) might explain some of the animal response, but the data in table 7 show that these species made only a very small contribution to pasture yield. Alternative possibilities are that the fertilizer increased the nutritive value and intake of the grass, and that the fertilizer enabled the native pasture to make better use of soil nitrogen and water.

The treatments also had a big effect on botanical composition. Some differences between treatments were recorded in the first analysis in 1960 but *Control*, *NH*, and *NHF* had considerable similarities, while *TH* and *THF* formed a second group. In this connection it must be remembered that both these latter treatments had been operating for some years before this experiment started. However because of these initial differences, and because the treatments were unreplicated, major consideration must be placed on changes over time within treatments.

The composition of *Control* was quite stable despite the wide range of seasonal conditions experienced. Heavier stocking (*NH*) produced big changes and since these started in good seasons it is clear that a stocking rate of 0.25 beasts/acre for untreated native pasture represents severe over-grazing. However these detrimental effects of a higher stocking rate did not occur in the treatments with fertilizer or Townsville stylo (*NHF* and *TH*). The composition of *TH* apart from Townsville stylo was quite stable, and it appears that this legume formed an addition to the pasture rather than a replacement of other species. Change occurred in *NHF* but since much of this was an increase in the frequency of native legumes the change can hardly be described as representing instability.

The effect of the *THF* treatment was more complex. From 1960 to 1963 there was little change in botanical composition and in these years there was also a considerable carry-over of uneaten herbage at the end of winter despite the fact that the stocking rate for this treatment was higher than for others. However in the drought years 1963/64 and 1964/65 grazing pressure became very high in this paddock and over-grazing effects ensued. These consisted of a reduction in the frequency of the grasses, an increase in annual forbs, and an increase in bare ground. The major changes in this treatment are therefore ascribed to the combination of high stocking and drought, whereas in *NH* the over-stocking effects started in good seasons. It is of interest to note that in both these paddocks recovery occurred after the experiment ended with a reduction in stocking rate and a return to better seasons.

One of the most obvious effects of overstocking was a reduction in the frequency of *H.* contortus. In the *NH* treatment there was an associated increase in frequency of other grasses (mainly *E. bimaculata, C. fallax,* and *T. loliiformis*) and forbs. Not only did this represent a reduction in basal cover but the main replacement of *H. contortus* in terms of dry-matter yield was *E. bimaculata* (Table 7). This species does not have the same yielding ability as *H. contortus* and the productivity of the pasture was accordingly lower. In the *NHF* treatment, however, much of the replacement of *H. contortus* was by *B. loliiformis, C. divaricata,* and *D. longiflora* (Tables 5 and 7). There was some increase of these species also in the *TH* treatment and it is possible that they had reacted to nitrogen contributed by Townsville stylo. Unpublished work by I. Vallis has recorded a considerable build up in nitrogen in *THF* paddock. These three grasses also appear to be more productive than *E. bimaculata* so that the change of grasses in *THF* was not necessarily detrimental to overall productivity.

The results of this experiment show that pasture improvement with Townsville stylo and fertilizer can give big increases in beef production. Benefits accrued from higher carrying capacity, higher gains per head, and earlier marketing. Equally important is that the improved pasture proved to be safe in drought. It is true that production was greatly reduced in the two drought years but weight gains per head were still comparable with those on untreated native pasture and no deaths resulted; furthermore production quickly improved with better rainfall and lighter stocking. In commercial practice it would have been possible to reduce stocking rate earlier in the drought, and in this connection it is of interest that steers were fattened in both drought years on a nearby Townsville stylo pasture (on a different type of country) which was stocked at 0.31 steers/acre.

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APPENDIX

Species recorded in the native pasture additional to those listed in Table 5

Alloteropsis semialata
Aristida calycina
Bothrichloa bladhii
Brachiaria whiteana
Capillipedium parviflorum
Chloris barbata
Chloris unispicea
Cymbopogon refractus
Cynodon dactylon
Dichanthium sericeum
Dichanthium sp. nr. tenuis
Digitaria adscendens
Digitaria violascens
Eriochloa pseudo-acrotricha
Panicum effusum
Paspalidium radiatum
Paspalum dilatatum
Paspalum orbiculare

Themeda australis
Tragus australianus

Cyperus cyperoides
Fimbristylis monostachyos

Alysicarpus vaginalis
Cassia concinna
Cassia mimosoides
Crotalaria linifolia
Desmodium filiforme
Desmodium varians
Galactia parviflora
Glycine clandestina
Glycine tomentosa
Indigofera australis
Indigofera linifolia
Moghonia parviflora

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Neptunia gracilis
Pycnospora hedysaroides
Rhynchosia minima
Swainsona oroboides
Tephrosia juncea
Vigna lanceolata
Zornia dyctiocarpa
Zornia muriculata

Aneilema gramineum
Boerhavia diffusa
Boraria brachystema
Commelina lanceolata
Convolvulus erubescens
Emilia sonchifolia
Evolvulus alsinoides
Glossogyne tenuifolia
Gnaphalium sp.
Goodenia glabra
Hedyotis galioides
Helichrysum ramosissimum
Hybanthus enneaspermis
Justicia procumbens
Lindernia crustacea
Myoporum debile
Oxalis corniculata
Phyllanthus simplex
Polygala japonica
Polymeria calycina
Pterocaulon sphacelatum
Richardia brasiliensis
Sida acuta
Sida corrugata
Solanum nodiflorum
Trianthema portulacastrum
Tricoryne elatior
Vernonia cinerea
Vittadinia brachycomoides
Wahlenbergia gracilis
Waltheria indica