TECHNICAL BULLETIN NO. 76 DECEMBER 1968

The Effect of Levels of Nitrogen, Phosphorus, and Potassium Fertilization upon Beef Production on Kikuyugrass

YUSUF N. TAMIMI
LLOYD B. SHERROD
STANLEY M. ISHIZAKI
and
TAKUMI IZUNO

HAWAII AGRICULTURAL EXPERIMENT STATION, UNIVERSITY OF HAWAII

CONTENTS

ACKNOWLEDGMENT

Grateful acknowledgment is made to Mr. Robert R. Martin, Farm Manager, Mealani Experimental Farm, and staff for assistance in the experiment; to Mrs. Elaine H. Shikuma and Mrs. Asako Tanaka for clerical assistance; and to Mrs. Anna Lindsey Perry-Fiske for the loan of the experimental steers.

THE AUTHORS

DR. YUSUF N. TAMIMI is Assistant Agronomist at the Hawaii Branch Station, Hawaii Agricultural Experiment Station, Hilo, Hawaii.

DR. LLOYD B. SHERROD was formerly Assistant Animal Scientist at the Hawaii Branch Station, Hawaii Agricultural Experiment Station, Hilo, Hawaii.

MR. STANLEY M. ISHIZAKI was formerly Junior Analyst at the Hawaii Branch Station, Hawaii Agricultural Experiment Station, Hilo, Hawaii.

DR. TAKUMI IZUNO was formerly Associate Horticulturist and Superintendent, Hawaii Branch Station, Hawaii Agricultural Experiment Station, Hilo, Hawaii.

The Effect of Levels of Nitrogen, Phosphorus and Potassium Fertilization upon Beef Production on Kikuyugrass[1]

YUSUF N. TAMIMI, LLOYD B. SHERROD, STANLEY M. ISHIZAKI, and TAKUMI IZUNO

The use of fertilizer is one of the major approaches to increased forage production. Several investigators reported an increase in beef production due to increase in forage production (*8, 9*). Yield of beef per acre also depends on stocking rate. Light stocking rate concurrently with high available forage and selective grazing usually gives higher animal and lower acre output than heavier stocking *(1, 4, 5)*. Riewe *et al. (7)* reported that when stocking rate was increased, gain per steer decreased. Peterson *et al. (6)* reported that, theoretically, gain per animal is constant as stocking rate is increased to a "critical point." Beyond this point, gain per animal is inversely related to stocking rate. They suggested that gain per acre increases linearly as stocking rate is increased to the "critical point," then decreases linearly with further increases in stocking rate. Hull *et al. (3)* concluded from a grazing study that maximum production per animal was not the proper measure and suggested that production per acre was more realistic. On factors other than stocking rate Gross *et al. (2)* reported that fertilized pure grass pastures supported a longer grazing period, higher stocking rates, and higher per-acre gain than grass-legume pastures. Yet, average daily gain and slaughter grade were lower on the grass swards.

Kikuyu *(Pennisetum clandestinum* Hochst.), a perennial, is one of the major grasses on Hawaiian pastures. It has a wide range of adaptability to elevation and rainfall. It grows from sea level to elevations over 6,000 feet and under annual rainfalls of less than 20 inches to over 150 inches.

The objective of this study was to determine the effect of fertilization with several rates of nitrogen, phosphorus, and potassium upon the performance of steers grazed on kikuyugrass.

---

[1] This study was conducted under Agronomy and Soil Science Project 108-A and Animal Science Project 204, in cooperation with Western Regional Project W-94, Range Livestock Nutrition.

EXPERIMENTAL PROCEDURES

The site of this experiment was the Mealani Experimental Farm of the Hawaii Agricultural Experiment Station in the Waimea area of the island of Hawaii. Soil analysis for the experimental pastures is reported in table 1.

The station is located at an elevation of 3,000 feet. The land is relatively flat with some small hills. The soil is of the Maile series, which is a member of the thixotropic isomesic family of Hydric Distrandepts (Latosolic Brown Forest). The soils have a silty clay loam texture and dehydrate irreversibly into fine aggregates. Rainfall is distributed throughout the year with November, December, January, and February usually being the wettest months (see Appendix). The area is occasionally foggy and sometimes windy.

Seven paddocks of kikuyugrass ranging in area from 9.0 to 9.4 acres were used in this study. All paddocks with the exception of the control (treatment 1) were limed with 2.5 tons of crushed coral per acre. All paddocks were disked, seeded with ladino (*Trifolium repens*) and crimson clover (*Trifolium incarnatum*), and fertilized according to the treatments listed in table 2. All field preparations were completed by the first week of August 1964 for treatments 2, 3, 4, 6, and 7. Liming, plowing, disking, and legume seeding, with the exception of fertilizing for paddock 5, were also completed during the first week of August 1964. Between August 1964 and May 1965 paddock 5 was grazed by non-experimental animals. On May 21, 1965, paddock 5 was fertilized according to table 2. The paddocks were allowed to recover, and when the growth was ample the experiment was initiated.

Two enclosures of 62 x 62 inches were placed in each pasture in representative areas of the paddock. The forage produced in these enclosures was harvested just before grazing started and occasionally during the grazing period to give an estimate of forage production. Forage samples from each enclosure and for each harvest were analyzed for total nitrogen, phosphorus, potassium, and calcium.

TABLE 1. Initial soil analysis of paddocks at Mealani Experimental Farm*

TREATMENT NO.	% ORGANIC MATTER	% TOTAL NITROGEN	C.E.C. ME./100 G.	pH	P PPM
1	28.56**	1.22	128.22	5.55	5.8
2	25.81	1.20	107.66	5.55	13.4
3	25.28	1.06	105.82	5.44	11.5
4	26.36	1.09	105.04	5.53	12.8
5	—	1.20	—	5.69	—
6	23.93	1.10	96.72	5.64	13.0
7	26.24	1.15	110.50	5.75	7.6

* Soil was sampled January 7, 1965.
** Values reported are average of 5 samples.

TABLE 2. Fertilizer treatments and their effect on forage yield, crude protein production, and beef production on kikuyugrass

TREATMENT NO.	FERTILIZER TREATMENT AND RATE LBS./A. N	P	K	FORAGE YIELD* (OVEN DRY) LBS./A.		CRUDE PROTEIN YIELD* LBS./A.	BEEF PRODUCED* LBS./A.
1	0	0	0	6176**	e	421.2	162.2
2	50	250	50	10164	d	931.5	341.1
3	100	250	50	11697	cd	1019.5	319.0
4	300	250	50	15260	a	1201.2	401.5
5	100	125	50	12913	abc	1102.2	272.2
6	100	250	100	12636	bcd	998.3	336.4
7	100	250	200	14326	ab	1250.7	390.6

* Data reported here represent 329 grazing days.

** Means within a column not followed by the same letter are significantly different at the 5-percent level.

During the experiment forage production declined, thus it became necessary to re-apply nitrogen and potassium to all fertilized paddocks at one-half the original rate. Treatments 2, 3, 4, 6, and 7 received this increment 10 months after the initial application, and treatment 5, 11 months after the initial application.

Grazing was initiated January 19, 1965, on paddocks 1, 2, 3, 4, 6, and 7 and June 28, 1965, on paddock 5. Fifty-five mixed steers were individually identified, drenched with phenothiazine, weighed and assigned into weight groups. The steers within each weight group were proportionally allotted at random so that 4, 7, 9, 10, 12, and 13 steers were assigned to treatments 1, 2, 3, 6, 7, and 4, respectively. Grazing intensity was maintained as nearly constant as possible in all pastures throughout the study. Periodic visual evaluations were made on each pasture and stocking rates were adjusted to maintain approximately equal grazing levels in all paddocks. The only adjustments in stocking rates necessary were the addition in June 1965 of one animal each in treatment 1 and 3 pastures, and two animals in treatment 2 pasture. Ten steers were allotted to paddock 5 and no adjustment was made in stocking rate.

All steers were maintained as treatment groups until the termination of the experiment. Grazing was continued with groups 1, 2, 3, 4, 6, and 7 until December 1965 and with group 5 until May 1966 for a total of 329 grazing days for all groups. All animals had free access to a mineral mixture containing 45 percent trace mineral salt, 45 percent dicalcium phosphate, and 10 percent soybean oil meal. Individual weights were recorded at 6-week intervals and a 16-hour shrink period preceded the initial and final weighings. Response criteria were total weight gains and average animal gains.

RESULTS AND DISCUSSION

Dry matter yield of kikuyugrass increased significantly with N-P-K fertilization when compared with the control (table 2). Increasing the rate of nitrogen (treatments 2, 3, and 4, table 2) increased the forage yield. Fertilization with 300 pounds N per acre increased the yield significantly over 50 or 100 pounds N per acre. The increase in yield was also accompanied by increase in total protein production (table 2). It is noted here that paddock 2 had about 30 percent legumes as compared with 5 to 10 percent in the other paddocks. Similar to data reported by Younge and Ripperton (*8*), increasing the nitrogen fertilizer rate decreased the percentage of nitrogen in the grass tissue (table 3). It is possible that this reduction in percentage of nitrogen in the tissue could be due to more vigorous growth with higher nitrogen rates resulting in a greater stem-leaf ratio, with stems being lower in nitrogen than leaves. To verify this point three samples of kikuyugrass with heights 6 inches, 1 foot, and 2 feet were collected. Stems and leaves were separated and analyzed separately (table 4). It seems that there is a large increase in stem-leaf ratio as kikuyugrass grows from 1 foot to 2 feet in height. Data reported in table 4 indicate that the stem at all heights has a lower nitrogen percentage than the leaves. It also appears that as kikuyugrass grows taller and/or older, the nitrogen percentage in leaves decreases (table 4).

Phosphorus and calcium levels at all growth stages of kikuyugrass were consistently higher in leaves than in stems. As the plant grew taller, the concentration of these two elements decreased. Potassium level in leaves and in stems was highest when plants were 1 foot tall. Magnesium percentage decreased in stems and increased in leaves as the plant grew taller (table 4).

There was no significant difference in forage yield between the treatment with 125 pounds P per acre and that with 250 pounds P per acre (treatments 5 and 3, respectively, table 2). Increasing the phosphorus rate was found to increase the level of phosphorus in the tissue (treatments 1, 5 and 3, table 3).

TABLE 3. The effect of fertilizer treatment on tissue constituents of kikuyugrass*

TREATMENT NO.	% N	% P		% K	% Ca
1	1.09	.186**	d	2.050	.438
2	1.47	.260	c	1.971	.610
3	1.39	.264	bc	2.598	.540
4	1.26	.185	d	2.202	.445
5	1.37	.245	c	2.070	.513
6	1.26	.284	ab	2.760	.450
7	1.40	.291	a	2.886	.510
	N.S.	P.01		P.10	N.S.

* Data reported are average analysis of all harvests.

** Means within a column not followed by the same letter are significantly different.

TABLE 4. Tissue analysis and proportion of stems and leaves of kikuyugrass harvested at different heights

HEIGHT	TISSUE	% OF TOTAL (DRY MATTER)	% N	% P	% K	% Ca	% Mg
6 inches	Stem	40.70	1.28	.33	2.72	.28	.27
	Leaf	59.30	2.78	.42	3.31	.38	.24
1 foot	Stem	40.56	1.52	.28	4.48	.24	.28
	Leaf	59.44	2.45	.30	3.49	.36	.31
2 feet	Stem	57.96	0.99	.16	3.51	.15	.18
	Leaf	42.04	2.32	.23	3.30	.35	.30

From table 3 it appears that there is an interaction between amount of potassium fertilizer applied and phosphorus uptake by kikuyu. With increasing rates of potassium fertilizer, the phosphorus content of kikuyugrass increased. This increase was significant between 50 pounds and 200 pounds K per acre (treatments 3 and 7, respectively). Yield of forage increased with increasing potassium rate (treatments 3, 6 and 7, table 2). This increase was significant only between 50 and 200 pounds K per acre. Tissue potassium also increased with increasing rate of potassium fertilizer (treatments 3, 6, and 7, table 3).

Steer performance data are presented in tables 2 and 5. These data indicate that total beef production increased substantially with all levels and combinations of N-P-K pasture fertilization when compared with the control group. The data also suggest that total beef production was increased with higher rates of application of the three elements.

Forage production correlated significantly with total beef production ($r = 0.869^{**}$, figure 1). Total crude protein production was found to correlate very highly with beef production with an $r = 0.889^{**}$, figure 2. A comparison of total beef production from 50 pounds and 100 pounds N per acre (treatments 2 and 3, respectively) shows that treatment 2 produced more beef per acre than treatment 3 (table 2). The relatively higher beef production from treatment 2 might partially be explained on the basis that paddock 2 contained a considerably denser stand of legumes (about 30 percent) than any of the other paddocks. Application of 300 pounds N per acre (treatment 4, table 2) resulted in the production of 401 pounds of beef per acre in 329 days, which is the highest for all paddocks. Total beef production was also increased by increasing the level of phosphorus fertilization, as indicated by comparing treatments 5 and 3 (table 2). Similar increases were noted for potassium levels (treatments 3, 6, and 7, table 2). Total yearly gain per acre followed trends similar to those of total beef production per pasture when the data were compared with levels of N-P-K fertilization (table 5).

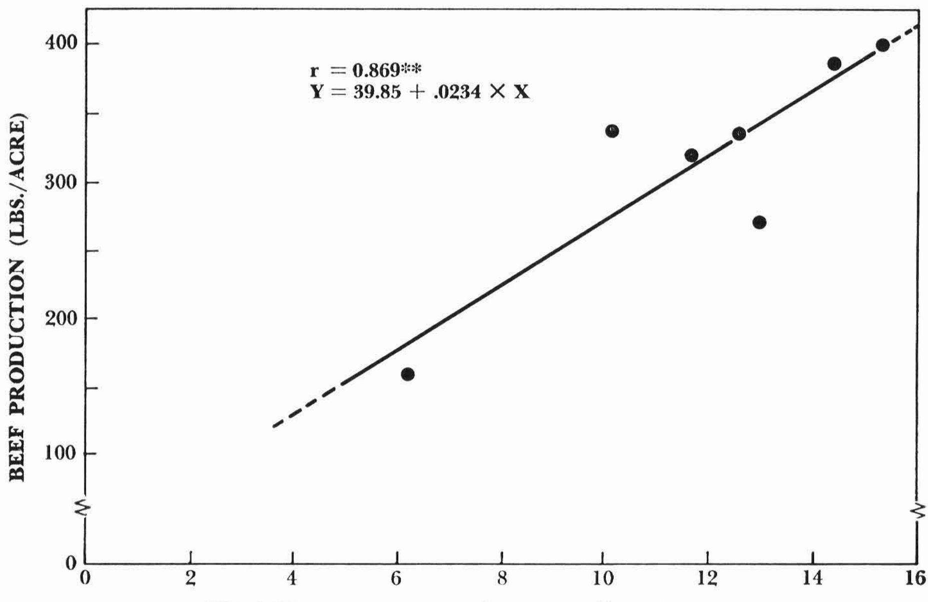

FIGURE 1. The effect of forage production on beef production.

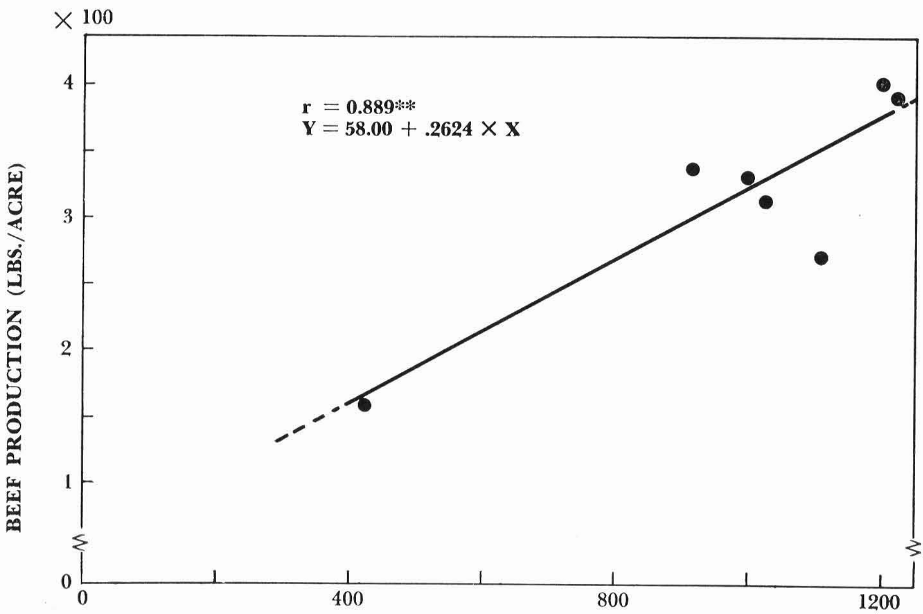

FIGURE 2. The effect of crude protein production on beef production.

TABLE 5. The effect of fertilizer treatments on stocking rates and steer performance on kikuyugrass

TREATMENT NO.	AREA ACRES	AVG. NO. STEERS	ACRES/ HEAD	AVG. INITIAL WT. LBS./HD.	AVG. FINAL WT. LBS./HD.	TOTAL GAIN LBS. (329 DAYS)	AVG. GAIN LBS./HD. (329 DAYS)	AVG. DAILY GAIN LBS./HD.
1	9.0	4.6	1.96	469	786	1460	317.4	0.96
2	9.4	8.2	1.15	485	876	3206	391.0	1.19
3	9.3	9.6	0.97	492	801	2967	309.1	0.94
4	9.3	13.0	0.72	500	787	3734	287.2	0.87
5	9.0	10.0	0.90	645	890	2450	245.0	0.74
6	9.4	10.0	0.94	488	804	3162	316.2	0.96
7	9.0	12.0	0.75	465	758	3515	292.9	0.89

The increase in total beef production appears to be a function of increased carrying capacity rather than increase in average animal performance. Average animal performance should be considered in pasture fertilization programs primarily because daily gain of beef cattle influences the quality and condition of the animal, which are criteria for determining both live animal and carcass grade (*2*). Average gains are similar when the control group (treatment 1, table 5, with .96 pound average daily gain) is compared with the average of all groups (treatments 2, 3, 4, 5, 6, and 7, with .93 pound average daily gain) on the fertilizer treatments.

There was an inverse relationship between average animal performance and levels of nitrogen fertilization (treatments 2, 3, and 4, table 5). The relatively high average gain for treatment 2 may have been influenced by the greater proportion of legumes in this paddock, as previously mentioned. The relationship between daily gain and nitrogen fertilization levels might also have been influenced by stocking rate (table 5).

Grazing intensity was maintained as nearly equal as possible in all pastures. These results suggest that stocking rates and levels of nitrogen fertilization were not proportional when considering average animal performance. The results reported in table 5 also indicated that average gain per animal decreased as stocking rates were increased beyond that which permitted near-maximum gain per animal. This is in agreement with results of grazing studies reported by other investigators (*6*).

Average animal performance increased as levels of phosphorus fertilization increased (treatments 5 and 3, table 5) and remained relatively constant with increasing levels of potassium fertilization (treatments 3, 6, and 7, table 5). These data indicate that increases in stocking rates were closely associated with increased forage quality and/or production, which was stimulated by phosphorus and potassium fertilization. This allowed average animal performance to remain almost constant, while total beef production increased.

SUMMARY

Pasture fertilization could have a very beneficial effect on beef production in Hawaii. With fertilization, beef production per acre per year (329 days) increased from 160 pounds on unfertilized pasture to 400 pounds on fertilized kikuyu pasture. This was accomplished by increasing the forage production, which allowed higher stocking rates. Nitrogen, phosphorus, and potassium fertilizers were all beneficial in increasing forage available to grazing animals. Both forage production and total crude protein production correlated very highly with beef production. Increasing nitrogen fertilizer rate caused a decrease in the percentage of nitrogen in the tissue. Increasing the increments of phosphorus and potassium fertilizer was found to increase tissue phosphorus and potassium, respectively. Increasing potassium fertilizer rate also caused an increase in phosphorus uptake by kikuyugrass. Under normal conditions, forage sample of a unit area for yield and protein content may be used to estimate beef that can be produced on that pasture. The following two formulas were obtained for beef production on kikuyugrass:

$$Y = 39.85 + .0234 \times X_1$$
$$Y = 58.00 + .2624 \times X_2$$

where

Y = beef produced, pounds/acre
X_1 = forage produced, pounds/acre (oven dry)
X_2 = crude protein produced, pounds/acre

APPENDIX

Rainfall record at the Mealani Experimental Farm

YEAR	MONTH	RAINFALL, INCHES
1964	August	2.76
	September	3.30
	October	7.86
	November	4.09
	December	8.97
1965	January	6.12
	February	7.00
	March	5.87
	April	3.63
	May	3.70
	June	2.03
	July	1.78
	August	2.25
	September	0.56
	October	4.21
	November	6.52
	December	7.53
1966	January	4.96
	February	5.59
	March	2.95
	April	5.13
	May	1.74

LITERATURE CITED

(1) BRYANT, H. T., R. C. HAMMES, JR., R. E. BLASER, and J. P. FONTENOT. 1965. EFFECT OF STOCKING PRESSURE ON ANIMAL AND ACRE OUTPUT. Agron. J. 57: 273–276.

(2) GROSS, H. D., LEMUEL GOODE, W. B. GILBERT, and G. L. ELLIS. 1966. BEEF GRAZING SYSTEMS IN PIEDMONT, NORTH CAROLINA. Agron. J. 58: 307–310.

(3) HULL, J. L., J. H. MEYER, and R. KORMANN. 1961. INFLUENCE OF STOCKING RATE ON ANIMAL AND FORAGE PRODUCTION FROM IRRIGATED PASTURE. Journal of Animal Science 20: 46–53.

(4) LAUNCHBAUGH, J. L. 1957. THE EFFECT OF STOCKING RATE ON CATTLE GAINS AND ON NATIVE SHORT-GRASS VEGETATION IN WEST-CENTRAL KANSAS. Kansas Agr. Expt. Sta. Bul. 394.

(5) LEWIS, JAMES K., G. M. VAN DYNE, L. R. ALBEE, and F. W. WHETZAL. 1956. INTENSITY OF GRAZING; ITS EFFECT ON LIVESTOCK AND FORAGE PRODUCTION. South Dakota Agr. Expt. Sta. Bul. 459.

(6) PETERSON, R. G., H. L. LUCAS, and G. D. MOTT. 1965. RELATIONSHIP BETWEEN RATE OF STOCKING AND PER ANIMAL AND PER ACRE PERFORMANCE ON PASTURE. Agron. J. 57: 27–30.

(7) RIEWE, MARVIN E., J. C. SMITH, JOHN H. JONES, and E. C. HOLT. 1963. GRAZING PRODUCTION CURVES. I: COMPARISON OF STEERS GAINS ON GULF RYEGRASS AND TALL FESCUE. Agron. J. 55: 367–369.

(8) YOUNGE, O. R., and J. C. RIPPERTON. 1960. NITROGEN FERTILIZATION OF PASTURE AND FORAGE GRASSES IN HAWAII. Hawaii Agr. Expt. Sta. Bul. 124.

(9) YOUNGE, O. R., D. L. PLUCKNETT, and PETER P. ROTAR. 1964. CULTURE AND YIELD PERFORMANCE OF DESMODIUM INTORTUM AND D. CANNUM IN HAWAII. Hawaii Agr. Expt. Sta. Tech. Bul. No. 59.