GROWTH RESPONSE, CRITICAL PERCENTAGE OF PHOSPHORUS, AND SEASONAL VARIATION OF PHOSPHORUS PERCENTAGE IN *STYLOSANTHES GUYANENSIS* cv. SCHOFIELD TOPDRESSED WITH SUPERPHOSPHATE

R. C. BRUCE*

ABSTRACT

Superphosphate rates up to 625 *kg* ha^{-1} *were topdressed onto* Stylosanthes guyanensis *pastures in three field experiments in north Queensland. Yields of control plots ranged from* 36% *to* 84% *of the highest yielding plots. Critical percentages of phosphorus were established for two plant parts sampled at the time of first flowering. For samples cut about 25 cm back from the growing point of erect stems ("tips") the critical percentage was* 0.16%P *while for erect stems cut about 5 cm above ground level ("tops,,) it was* 0.12%P. *Tips were favoured for diagnostic use because of the slightly better relationship between yield and percentage phosphorus and because they are easier to recognize and sample in a grazed pasture.*

A marked fluctuation in phosphorus percentage during the two months prior to flowering was found and this emphasized the importance of rigid standardization on sampling time. The effect was more pronounced in tips than tops.

INTRODUCTION

Andrew (1965, 1968) has discussed some diagnostic uses of plant chemical analyses. Perennial tropical pasture legumes offer an opportunity of using plant chemical analyses to monitor maintenance fertilizer programmes of pastures. This approach depends upon establishing critical percentages of nutrients in each species (Macy 1936). Andrew and Robins (1969a, 1969b) have reported critical percentages of phosphorus and potassium for some tropical legumes.

Schofield stylo (*Stylosanthes guyanensis* cv. Schofield) is a valuable pasture legume in parts of Queensland north of the Tropic of Capricorn where rainfall exceeds 1524 mm (Grof, Harding and Woolcock 1970). Because Andrew and Robins (1969a) did not include this legume in their work a series of experiments was initiated to establish a critical percentage of phosphorus in stylo and to study the effects of time of sampling on this percentage. These experiments were located on established, grazed pastures on a commercial property so that the critical percentage concept could be studied under conditions similar to those likely to exist when it is used for monitoring maintenance fertilizer programmes.

METHODS

Three field experiments with rates of topdressed superphosphate were conducted during the years 1968 to 1970 inclusive on the property of the Warringha Pastoral Co. at Bilyana near Tully in north Queensland, to study the relationship between dry matter yield and chemical composition. To illustrate seasonal variation in plant chemical composition samples were taken from these experiments as well as from grazed pastures in 1968 and from ungrazed nursery plots in 1969 and 1970.

---

*Queensland Department of Primary Industries, Indooroopilly, 4068.

TABLE 1

Details of the three field experiments, pasture history and botanical composition

Experiment No.	Pasture history Planting date	Previous fertilizer ($kg\ ha^{-1}$)	Superphosphate† treatments ($kg\ ha^{-1}$)	Basal fertilizer ($kg\ ha^{-1}$)	Experimental design	Plot size	Commencing date*	Harvest date	Botanical composition % legume‡
1	January 1966	250 superphosphate†	0, 0, 250, 375, 500, 625	11 copper sulphate	6 × 6 Latin square with duplicate controls	10 m × 8 m	29.i.68	3.vi.68	75
				11 zinc sulphate				9.vi.69	53
2	January 1968	375 superphosphate	0, 250, 375, 500, 625	11 copper sulphate	5 × 5 Latin square	10 m × 8 m	10.ii.69	2.vi.69	93
				125 muriate of potash					
3	January 1968	375 superphosphate	0, 125, 250, 500	11 copper sulphate	4 × 4 Latin square	5 m × 4 m	31.iii.70	8.vii.70	100
				11 zinc sulphate					
				125 muriate of potash					

*Date treatment fertilizer applied.
†Single superphosphate (9.6%P)
‡Legume percentage is the mean for all treatments at the harvest date

Field Experiments

The field experiments were located on established commercial pastures of Schofield stylo at two sites on the property. Details of pasture composition, fertilizer history, treatments, experimental design, plot size and harvest dates are given in Table 1. The companion grass species in Experiments 1 and 2 was molasses grass (*Melinis minutiflora*) with traces of guinea grass (*Panicum maximum* cv. Coloniao) in Experiment 1. Experiment 1 is described in detail elsewhere (Bruce 1972).

The original native vegetation at both sites was grassy sclerophyll woodland (Teitzel and Bruce 1971) which had been cleared in the year prior to planting the pastures (Table 1). The soil at each site is derived from granitic parent material and fits the Gn 2.21 Principal Profile Form of Northcote (1971). The range of texture down the profile was sandy clay loam to sandy light clay at the site of Experiment 1 and sandy loam to sandy light clay at the site of Experiments 2 and 3. Chemical analyses for 0-10 cm depth of virgin soil were similar for each experimental site. Available phosphorus (Kerr and von Stieglitz 1938) was very low (<5 p.p.m.); pH was strongly acid (5.2 to 5.8); and exchangeable potassium was adequate (0.24 to 0.42 m. equiv./100 g).

For each experiment the pasture was slashed to a height of about 30 cm, plots pegged out, and basal and treatment fertilizers broadcast by hand. Yields were measured after 14-16 weeks, just after the stylo began to flower. At the first harvest of Experiment 1 a strip 4.4 m in length was cut with an autoscythe to a height of 10 cm. The green material was weighed and subsampled for botanical separation and dry matter determination. At all other harvests two quadrats 1m × 1 m were cut per plot with shears, botanically separated, dried and weighed.

Plant sampling

In 1968 plant material was sampled for chemical analysis at 4-weekly intervals from Experiment 1 and from two nearby grazed pastures of differing fertilizer histories. The grazed pastures had been planted at the same time and with the same establishment fertilizer as the pasture at Experiment 1 (Table 1), but had received no additional fertilizer. However, one of them was on a soil which had a history of fertilizer application for beans and was considerably more fertile.

In 1969 and 1970 the sampling frequency was fortnightly. Samples were taken from Experiments 1 and 2 and from two small nursery plots at the South Johnstone Research Station (S.J.R.S.) in 1969, and from Experiment 3 and two other nursery plots at S.J.R.S. in 1970. The soil at S.J.R.S. is a fertile alluvial soil with a previous history of superphosphate applications, but none had been applied to the nursery plots for at least 6 months prior to sampling.

Two types of plant samples were collected from the field experiments. Erect stems cut about 5 cm above ground level or above the woody basal branches will be referred to as "tops". The other plant part sampled was "tips", cut about 25 cm back from the growing point of erect stems. They were picked by hand and were an attempt to obtain a sample of more constant physiological age.

Sampling intensity was 20 samples per plot in Experiments 1 and 2, 10 samples per plot in Experiment 3 and in the nursery plots, with approximately 40 samples per paddock for the grazed pastures. In Experiments 1 and 2 the composite samples from each plot were analysed for phosphorus separately. Replicates were bulked before analysis in Experiment 3. All samples were dried at 95°C, ground and stored for analysis in screw top glass jars.

Chemical analyses

Plant phosphorus was determined by the colorimetric method of Cavell (1954) after dry ashing at 500°C, while nitrogen was determined by titration after steam distillation of a microkjeldahl digest. All analyses are reported on an oven dry (105°C) basis.

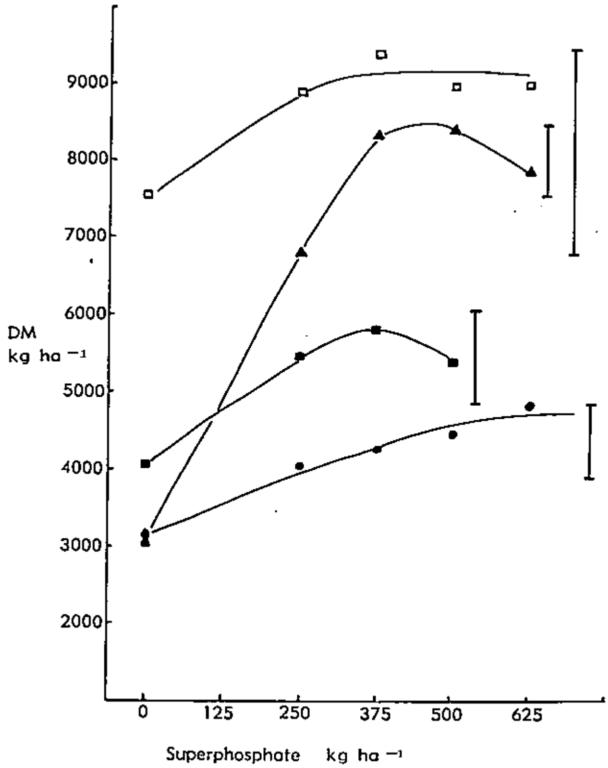

FIGURE 1
Effect of applied superphosphate on total dry matter yield in Experiments 1 (two harvests), 2 and 3.
● Expt. 1, 1968; ▲ Expt. 1, 1969; □ Expt. 2; ■ Expt. 3.
L.S.D's (P = 0.05) are indicated for each experiment.

RESULTS

Rainfall

Mean annual rainfall nearby at Murray Upper is 2,393 mm. Rainfall totals for the years 1968, 1969 and 1970 were 2,334, 2,060 and 2,156 mm respectively. Between 73 and 86% of the annual totals was received during the January to May periods.

Dry matter yields and critical percentages

Dry matter yields for harvests in the three field experiments are presented in Figure 1. Yield response decreased with increasing amounts of superphosphate. Yields near the maximum were achieved with the 250 or 375 kg ha^{-1} superphosphate treatments. Control plots yielded 64, 36, 84 and 69 per cent of maximum yields in Experiments 1 (1968), 1 (1969), 2 and 3 respectively.

The relationships between dry matter yields and percentage phosphorus in stylo tips and tops at the time of the first appearance of flowers are shown in Figures 2a and 2b respectively. Yields are plotted as a percentage of the asymptotic maximum yield for each harvest. Data from all harvests have been combined. Since tops were not sampled from Experiment 3, there are four harvests for tips and three harvests for tops. Exponential curves of the form $Y = A + Be^{Cx}$ have been fitted, where Y = percentage yield; A = asymptotic maximum yield; X = percentage phosphorus; and B and C are constants to be estimated. Coefficients of determination (R^2) have been adjusted for degrees of freedom to facilitate comparison of the two sets of data. The critical percentage of phosphorus is taken as the percentage corresponding to 90% of the maximum yield (Martin and Matocha 1973).

For stylo tips and tops R^2 values are 62.7% and 57.6% while critical percentages are 0.16%P and 0.12%P respectively.

Data from Experiment 1 give an indication of the precision of the phosphorus percentages reported. For stylo tips sampled on four occasions in 1968 the L.S.D's ($P = 0.05$) for comparison of fertilized plots ranged from 0.009 to 0.013%P (mean 0.010%P). For five samplings in 1969 the range was 0.010 to 0.017%P (mean 0.012%P). The corresponding means for stylo tops were 0.011%P in 1968 (only one sampling) and 0.010%P (range 0.007 to 0.014%P) in 1969.

Seasonal variation in phosphorus percentage

Phosphorus percentages in stylo tips during the two months prior to flowering are shown in Figures 3a, 3b and 3c. Stylo tops were sampled regularly only in 1969. These data are presented in Figure 3d. Not all results are presented as the pattern was similar for different superphosphate rates in any one experiment in any one year. For the field experiments the mean values of all superphosphate rates are plotted. In Figure 3b the S.J.R.S. results are the means of the two nursery plots while in Figure 3c the S.J.R.S. results are for single plots.

In stylo tips the phosphorus percentage reaches a maximum just before flowering and then declines rapidly. In stylo tops there is a gradual decrease in phosphorus percentage with time. Instead of a peak just before flowering there is a temporary decrease in the slope of the phosphorus percentage-time curve.

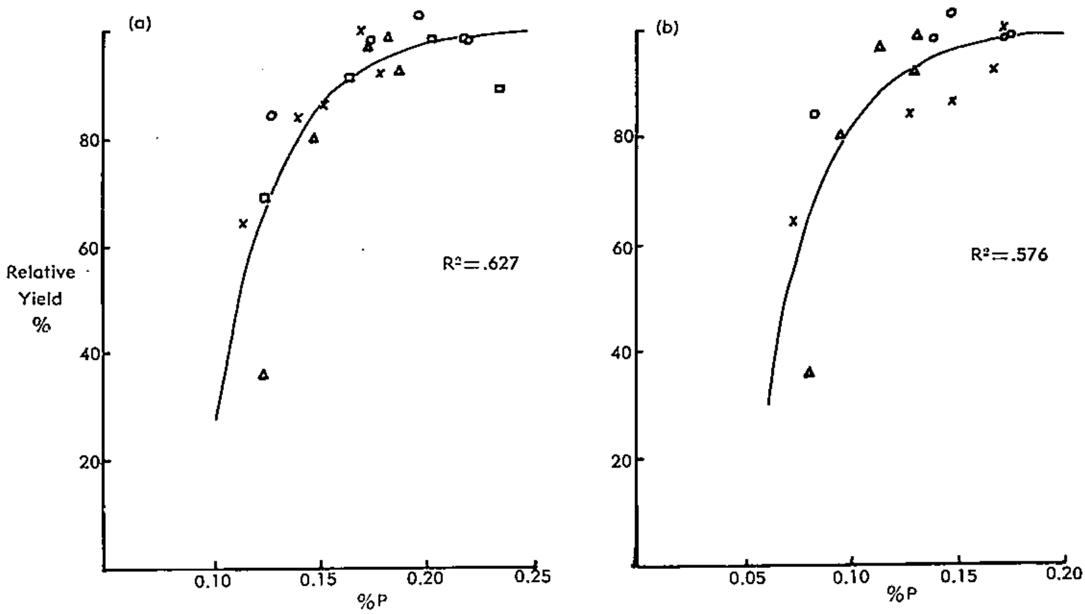

FIGURE 2
Relationships between dry matter yield and phosphorus percentage in stylo tips (a) and tops (b) at the time of first appearance of flowers. Yields are plotted as a percentage of the maximum yield for each harvest.

× Expt. 1, 1968; △ Expt. 1, 1969; ○ Expt. 2; □ Expt. 3.

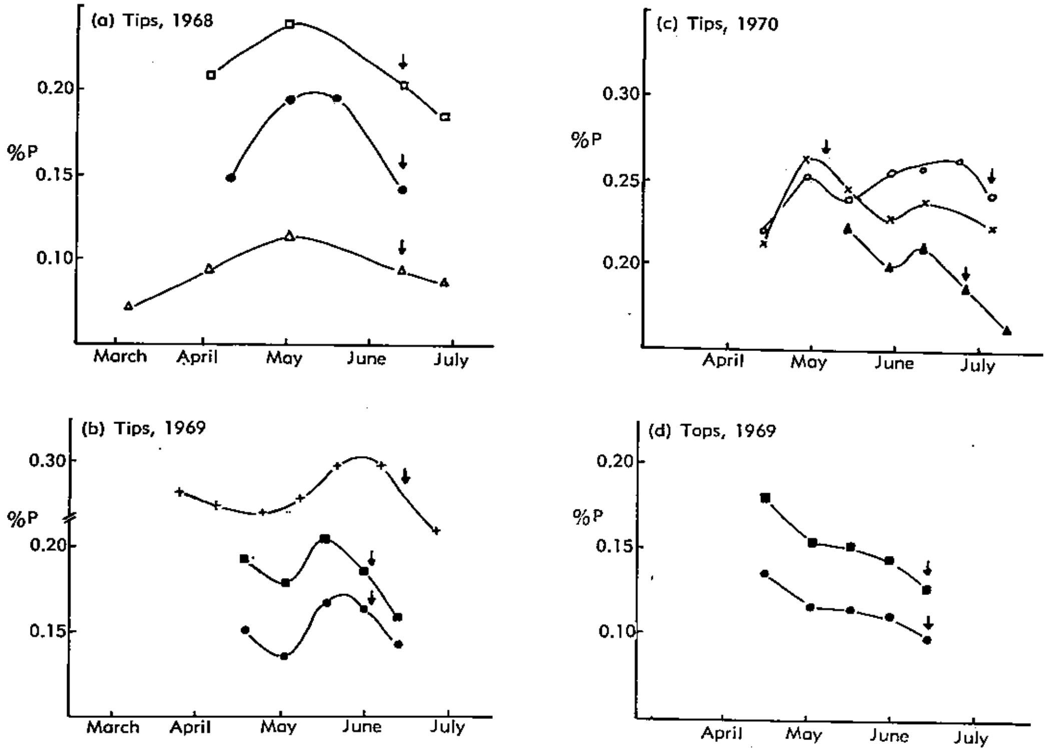

FIGURE 3
Seasonal variation in phosphorus percentage of stylo tips (a, b, c) and tops (d) sampled from field experiments, grazed pastures, and nursery plots. Flowering time is indicated by the arrow symbol. Other symbols are:—

● Expt. 1
■ Expt. 2
▲ Expt. 3
□ Grazed pasture
△ Grazed pasture
+ SJRS* Stylo 1969
○ SJRS* Schofield stylo 1970
× SJRS* Endeavour stylo 1970
(*South Johnstone Research Station)

Nitrogen percentage in tips followed a similar pattern to phosphorus percentage. Results are not presented in detail but as an example, in the pooled data from samplings in 1968 and 1969 in Experiment 1, the correlation coefficients between %N and %P were 0.939 and 0.854 respectively. Combining nitrogen percentages for all superphosphate rates and for all samplings gave mean values of 2.56, 2.58, 2.70 and 2.69%N for Experiments 1 (1968), 1 (1969), 2 and 3 respectively.

DISCUSSION

Dry matter yields increased markedly with applied superphosphate in each experiment (Figure 1). The relative yields of the control plots, although of limited number, indicate increasing yield response with increasing age of pasture and increasing time since last superphosphate application (Table 1). These responses to superphosphate are considered to be due to phosphorus component and not the sulphur. An experiment was conducted adjacent to and concurrent with Experiment 1 in 1968 to study the effects of phosphorus and sulphur. There was no response to sulphur but the response to phosphorus (relative yield 67%) was identical to the response to superphosphate in Experiment 1 (relative yield 64%).

The soil at the site of Experiments 2 and 3 was not considered sulphur deficient as it was similar to that at Experiment 1 and the pasture was younger and had not been as heavily grazed.

Stylo tips are recommended for diagnostic use because of the slightly better relationship between yield and percentage phosphorus (Figure 2a) and because tips are easier to recognize and sample in a grazed pasture. The critical percentage of 0.16% compares with 0.16 to 0.17%P reported for the above ground portion of Townsville stylo (*Stylosanthes humilis*) by Jones (1968) and Andrew and Robins (1969a). Their Townsville stylo samples would be more like Schofield stylo tips than tops, as tops can become lignified in older stands. The critical percentage of 0.12%P in stylo tops is lower than that in tips and tended to be more variable from one harvest to another. In a pasture grazing pressure would affect the amount of material sampled as tops.

Results presented emphasize some of the errors encountered when using the critical nutrient concentration concept. Critical concentrations derived from these experiments will not apply unless the same plant parts (tips or tops) are sampled very near the time of first flowering. The reasons for the seasonal pattern in phosphorus percentage (Figure 3) are not known. As flowering proceeds phosphorus is mobilized from leaves and transported to inflorescences (Fisher 1970; Bruce unpublished data). On the other hand, the dry weight of stylo tips sampled in Experiment 3 increased from 3.3 g/10 tips on 13th May 1970 to 5.1 g/10 tips on 8th July 1970 and the number of lateral shoots longer than 2.5 cm developed in axils of the tips' leaves increased from nil to 27/10 tips during the same period. These physiological and growth changes could be active in determining the changes measured.

The sampling intensity used in Experiment 1 (six replicates of 20 samples bulked per 10 m × 8 m plot) allowed the detection of small differences in phosphorus percentage between treatments. This high intensity was chosen so as to minimize sampling errors and is unlikely to be used in commercial pastures unless small fixed sites are sampled regularly in the manner suggested by Vallis (1973) for measuring soil nitrogen changes under grazed pastures. Using the stylo tips data and the formula quoted by Steyn (1961) it can be caluclated that three replicates of a 20-composite sample will be required to give a sample mean within 10% of a population mean. However it is likely that considerably fewer subsamples per composite sample would suffice but this cannot be derived from the existing data.

White and Haydock (1970) showed that the critical percentage of phosphorus in Siratro (*Macroptilium atropurpureum* cv. Siratro) varied with the rainfall recorded in the 28 days prior to sampling. Rainfall in excess of 150 mm was required during this period to achieve a fairly constant critical percentage. In the area where the present experiments were conducted, May and June are relatively dry months but rainfall during the 28 days prior to sampling varied from 222 mm to 342 mm so the effect noted by White and Haydock should not have been operative. In addition rainfall during the growing months of February to June was considered to be adequate each year and its distribution did not appear to be related to the variation in plant chemical composition.

It is of interest that in the cultivar Endeavour (Figure 3c) percentage phosphorus in the tips reached a maximum before flowering just as in the cultivar Schofield, even though flowering times differed by about eight weeks.

If close attention is paid to part of plant sampled, stage of growth at sampling, sampling intensity, and rainfall prior to sampling, phosphorus percentages in Schofield stylo will be useful in assessing the probability of a yield response and hence determining the adequacy of maintenance fertilizer programmes.

ACKNOWLEDGEMENTS

Technical assistance of Miss Barbara Allingham in the field and laboratory is gratefully acknowledged together with the cooperation of Mr. T. Pierce of the Warringha Pastoral Co.

REFERENCES

ANDREW, C. S. (1965)—Mineral nutrition of subtropical pasture species. *Journal of the Australian Institute of Agricultural Science* **31**: 3-10.

ANDREW, C. S. (1968)—Problems in the use of chemical analyses for diagnosis of plant nutrient deficiencies. *Journal of the Australian Institute of Agricultural Science* **34**: 154-62.

ANDREW, C. S., and ROBINS, M. F. (1969a)—Effect of phosphorus on the growth and chemical composition of some tropical pasture legumes. I. Growth and critical percentages of phosphorus. *Australian Journal of Agricultural Research* **20**: 665-74.

ANDREW, C. S., and ROBINS, M. F. (1969b)—Effect of potassium on the growth and chemical composition of some tropical and temperate pasture legumes. I. Growth and critical percentages of potassium. *Australian Journal of Agricultural Research* **20**: 999-1007.

BRUCE, R. C. (1972)—The effect of topdressed superphosphate on the yield and botanical composition of a *Stylosanthes guyanensis* pasture. *Tropical Grasslands* **6**: 135-140.

CAVELL, A. J. (1954)—A rapid method for the determination of nitrogen, phosphorus and potassium in plant materials. *Journal of the Science of Food and Agriculture* **5**: 195-200.

GROF, B., HARDING, W. A. T., and WOOLCOCK, R. F. (1970)—Effects of cutting on three ecotypes of *Stylosanthes guyanensis*. Proceedings of the XI International Grassland Congress. Surfers Paradise, Australia pp. 226-30.

JONES, R. K. (1969)—Initial and residual effects of superphosphate on a Townsville lucerne pasture in north-eastern Queensland. *Australian Journal of Experimental Agriculture and Animal Husbandry* **8**: 521-27.

KERR, H. W., and VON STIEGLITZ, G. R. (1938)—The laboratory determination of soil fertility. Bureau of Sugar Experiment Stations, Queensland, Technical Communication No. 9.

MACY, P. (1936)—The quantitative mineral nutrient requirements of plants. *Plant Physiology* **11**: 749-64.

MARTIN, W. E., and MATOCHA, J. E. (1973)—Plant analysis as an aid in the fertilization of forage crops. In 'Soil Testing and Plant Analysis' (Eds. L. M. Walsh and J. D. Beaton) Revised edition. (Soil Science Society of America, Madison, Wisconsin)

NORTHCOTE, K. H. (1971)—'A Factual Key for the Recognition of Australian Soils'. Third Edition. (Rellim Technical Publications, Glenside, South Australia)

STEYN, W. J. A. (1961)—The errors involved in the sampling of citrus and pineapple plants for leaf analysis purposes. In 'Plant Analysis and Fertilizer Problems' Volume 3 (Ed. W. Reuther) p. 409 (American Institute of Biological Sciences, Washington, D.C.)

TEITZEL, J. K., and BRUCE, R. C. (1971)—Fertility studies of pasture soils in the wet tropical coast of Queensland. 1. Soil-vegetation classification units. *Australian Journal of Experimental Agriculture and Animal Husbandry* **11**: 77-84.

VALLIS, I. (1973)—Sampling for soil nitrogen changes in large areas of grazed pastures. *Communications in Soil Science and Plant Analysis* **4**: 163-70.

WHITE, R. E., and HAYDOCK, K. P. (1970)—Phosphate concentration in siratro as a guide to its phosphate status in the field. *Australian Journal of Experimental Agriculture and Animal Husbandry* **10**: 426-30.

(Accepted for publication October 6, 1974)