THE ROLE OF SUPERPHOSPHATE IN THE ESTABLISHMENT OF OVERSOWN TROPICAL LEGUMES IN NATURAL GRASSLANDS OF WESTERN KENYA

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ABSTRACT

Four tropical legumes, Desmodium uncinatum, Desmodium intortum, Trifolium semipilosum *and* Stylosanthes guyanensis, *were oversown in the* Hyparrhenia/Combretum *grasslands of western Kenya in the presence or absence of 500 kg/ha superphosphate.*

In the absence of superphosphate the legumes were slow to establish. Fertilizer alone did not appreciably increase the quality and productivity of natural grassland. But the interaction between the oversown legumes and superphosphate was significant. Application of superphosphate doubled the total dry matter and almost trebled the total crude protein yields of D. intortum *and* D. uncinatum *plots in natural grasslands 16 months after oversowing.*

The implications of these results in relation to animal production potential in western Kenya are discussed.

INTRODUCTION

Vast areas of land in the medium altitudes of western Kenya with a high agricultural potential still lie in natural grassland (Brown 1963). These grasslands are dominated by tall low yielding fibrous grasses (Poultney 1959), which are low in quality (Dougall and Bogdan 1958, 1960, 1965). The carrying capacity of these grasslands is low. Bogdan and Kidner (1967) recommended 1.2 hectares for a 454 kg beast per year. Tropical legumes can be established in these grasslands by oversowing seed followed by topdressing with phosphatic fertilizers (Keya, Olsen and Holliday, in press).

A trial was initiated at Kitale to ascertain the role of superphosphate in the establishment of four tropical legumes oversown into these grasslands.

MATERIALS AND METHODS

The experimental layout used was a 2 × 5 factorial in a randomized complete block design. The plot size was 3 × 5 m^2 and there were four replications. The site had been closely grazed by Hereford steers prior to oversowing legume seed. Four tropical legumes were oversown in the presence or absence of 500 kg per hectare superphosphate. The fertilized plots received a further topdressing of 300 kg per hectare superphosphate in March 1970, at the start of the long rains. The fertilizer used was single superphosphate (21% P_2O_5; 10% S).

The seed used was scarified by rubbing between sandpaper. The seed was inoculated and pelleted with the appropriate inoculum and coating materials respectively (Keya, Olsen and Holliday, in press). The experiment was planted on June 11, 1969. Seeding rates were about double the normal rates for sown pastures. That for *D. intortum* was 4.0 kg per hectare pure germinating seed (p.g.s.) The

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seeding rates of the other legumes were calculated relative to *D. intortum* by proportions based on the means of five lots each containing 1000 seeds. The seeding rates for *T. semipilosum, S. guyanensis* and *D. uncinatum* were 3.0, 6.0 and 11.0 kg per hectare p.g.s., respectively. The calculations of the seeding rates, planting procedure and post-planting management were similar to those described by Keya, Olsen and Holliday (in press).

Legume establishment

The climate and soil types at Kitale have been described by Strange (1955). The mean monthly rainfall for a period of ten years (1958 to 1967 inclusive) and the rainfall during the period of the trial are presented in Table 1.

The first rains after planting averaged 4.4 mm per day and fell between June 15 and 18. Between June 24 and 30 a total of 15 mm was recorded. The first seedlings to germinate were observed on June 30, 1969. The first nine days of July received a total of 34 mm. The first seedling counts were taken on the July 7, 1969, almost four weeks after oversowing. The seedlings were counted at fortnightly intervals using the Frame Quadrat Method (Keya, Olsen and Holliday, in press). The final counts were taken 12 weeks after planting.

The establishment of oversown legumes was also assessed by analysing the botanical cover every two months. The first and final botanical analyses were carried out four and 16 months after oversowing. The inclined Point Quadrat Method was used for the botanical analyses. The final method of assessing legume establishment was by measuring the productivity and quality of the grasslands oversown with legumes. Four harvests were taken between December 1969 and September 1970. Harvests were taken at the early flowering stage of the oversown legumes. The sampling procedure, dry matter (DM) estimation and crude protein (CP) analysis have been described by Keya, Olsen and Holliday (in press). In addition, the P content in the plant tops was determined.

RESULTS

Germination counts

The legume seedling numbers four weeks after planting are presented in Table 2. There was a significant interaction between legume seedlings present and superphosphate applied. Whereas the application of superphosphate significantly increased the *T. semipilosum* seedlings four weeks after planting, the establishment of the other legumes was not affected by the presence or absence of fertilizer. *D. intortum* and *D. uncinatum* had significantly more seedlings than *S. guyanensis* four weeks after oversowing. In subsequent counts, the differences in seedling numbers present for the four legumes were not significant.

TABLE 1

Rainfall (mm) at Kitale during the period of the trial and monthly means over a ten year per period

Year	J	F	M	A	M	J	J	A	S	O	N	D	Total
1969	59	57	107	54	225	106	49	176	116	119	52	6	1126
1970	106	9	226	199	136	63	177	214	86	83	32	14	1345
10 years' mean	24	48	84	149	152	113	150	180	108	127	98	51	1284

TABLE 2

Legume seedling numbers four weeks after oversowing natural grassland in the presence or absence of superphosphate

Legume	Seedlings/m²		Mean
	Superphosphate (kg/ha)		
	0	500	
Desmodium intortum	31 a*	24 ab	28 A
Desmodium uncinatum	29 a	21 abc	25 A
Trifolium semipilosum	15 bc	26 a	21 AB
Stylosanthes guyanensis	14 bc	11 c	13 B
Mean	22	21	

S.E. of the mean = ± 3.5 seedlings   Coefficient of variation = 17.5%.

*Means followed by the same letter in the same column are not significantly different according to Duncan's multiple range test; capital letters denote a probability of 1%, small letters 5%.

Botanical composition

Four months after oversowing, *D. uncinatum* in the fertilized plots constituted 8% of the botanical cover and *T. semipilosum* and *D. intortum* constituted 2 and 3%, respectively. *S. guyanensis* did not contribute to the botanical composition.

The legumes oversown in natural grasslands in the absence of fertilizer started contributing to botanical cover eight months after planting. Initially, the seedlings of *D. intortum* and *D. uncinatum* in the absence of fertilizer were stunted and had red stems and small yellowish upright leaves. The botanical changes of the oversown legumes from the eighth to the 16th month after oversowing are presented in Table 3.

Application of superphosphate increased the botanical cover of oversown legumes significantly throughout the period of the trial. *D. intortum, D. uncinatum* and *T. semipilosum* in the fertilized plots established rapidly and covered 50 to 60% of the natural grasslands 12 months after oversowing. But the botanical cover of *S. guyanensis* in the fertilized plots did not exceed 35% throughout the period of the trial. In the absence of superphosphate, the cover of *D. uncinatum* and the other legumes did not exceed 34 and 17%, respectively, throughout the period of the trial.

Dry matter and crude protein yields

In the final harvest taken about 16 months after oversowing *S. guyanensis, T. semipilosum, D. intortum* and *D. incinatum* in the fertilized plots contributed 18, 26, 52 and 54%, respectively, of the total DM produced. In the absence of superphosphate, *D. intortum, S. guyanensis, T. semipilosum* and *D. uncinatum* constituted only 1, 2, 6 and 12%, respectively, of the DM in the final cut. The total yields for the establishment year (four cuts) are presented in Table 4.

Oversowing legumes in natural grassland without superphosphate increased DM yields by 13 to 30% over the control. Application of superphosphate alone increased the DM yield by 22% over the control and there were no significant differences in yields between the individual effects of superphosphate and legumes. But there was a positive interaction between legumes and superphosphate in DM production. In the presence of superphosphate, *S. guyanensis, T. semipilosum, D. intortum* and *D. uncinatum* increased the DM production by 58, 106, 109 and 124%, respectively, over the control in the establishment year.

TABLE 3

Percentage botanical composition of legumes oversown in natural grassland

Months after oversowing	8			10			12			14			16		
Superphosphate (kg/ha)	0	500	Mean	0	500	Mean	0	500	Mean	0	500	Mean	0	500	Mean
Legumes:															
Desmodium uncinatum	—	13A	4	3	25	13	17	61	37A	12	60	32A	33	50	42
Desmodium intortum	—	13A	4	4	26	12	3	54	22AB	7	53	27A	17	55	35
Trifolium semipilosum	2B	12A	6	6	43	21	11	51	29A	17	53	34A	14	51	30
Stylosanthes guyanensis	6AB	4AB	5	6	13	10	3	27	12B	4	27	13B	14	35	24
Mean	2 b	10a	—	5b	26a	—	17b	48a	—	9b	48a	—	19b	48a	—
S.E. of the mean for treatments	±0.34			±0.42			±0.67			±0.45			±0.62		
Coefficient of variation	25.6%			17.1%			15.9%			12.4%			13.0%		

* Means within each set followed by the same letter are not significantly different according to Duncan's multiple test.
Capital letters denote 5% and small letters 0.1% probability levels.
Data subjected to arcsine transformation prior to statistical analysis.

TABLE 4

Total dry matter production (kg/ha) 16 months after oversowing natural grassland with legumes in the presence or absence of superphosphate

Legume	Superphosphate (kg/ha) 0	500	Mean
No legume	3671 f*	4477 de	4074 c
Stylosanthes guyanensis	4303 e	5805 c	5054 b
Trifolium semipilosum	4781 d	7555 b	6168 a
Desmodium uncinatum	4150 e	8230 a	6190 a
Desmodium intortum	4763 d	7673 b	6218 a
Mean	4334 B	6748 A	

S.E. of the mean = ± 140.7 kg Coefficient of variation = 2.5%.
*Means followed by the same letter in the same column are not significantly different according to Duncan's multiple range test. Capital letters denote 0.1% and small letters 5% probability.

D. uncinatum in the fertilized plots had significantly greater DM yields than the other legumes. There were no significant differences between *D. intortum* and *T. semipilosum* topdressed with superphosphate, but these outyielded *S. guyanensis* topdressed with superphosphate.

The effects of oversowing legumes and topdressing with superphosphate on the CP yields of natural grasslands are presented in Table 5.

TABLE 5

Total crude protein production (kg/ha) of natural grassland 16 months after oversowing with legumes

Legume	Superphosphate (kg/ha) 0	500	Mean
No legume	266 b*	325 b	296 c
Stylosanthes guyanensis	274 b	423 b	349 bc
Trifolium semipilosum	316 b	695 a	506 ab
Desmodium intortum	306 b	749 a	528 a
Desmodium uncinatum	270 b	840 a	555 a
Mean	286 B	606 A	

S.E. of the mean = ± 54.3 kg Coefficient of variation = 12.2%.
*Means followed by the same letter are not significantly different according to Duncans' multiple range test. Capital letters denote 0.1%, small letters 1% probability.

Responses to superphosphate were very highly significant. Oversowing legumes in natural grassland without topdressing did not increase the CP yields over the control. Applying superphosphate to natural grassland alone or natural grassland oversown with *S. guyanensis* did not increase the CP yields significantly over the control. Oversowing the other legumes in natural grassland and topdressing however, increased the CP yields significantly. There were no significant differences in the CP yields among *D. uncinatum, D. intortum* and *T. semipilosum.* However these legumes significantly outyielded *S. guyanensis.* Where superphosphate was applied, *S. guyanensis, T. semipilosum, D. intortum* and *D. uncinatum* increased the CP productivity by 80, 196, 219 and 257%, respectively, over the control. The CP in the DM of the control plots was 6.3% in the final harvest. Oversowing natural grassland with legumes and topdressing increased the CP content in the DM. The DM from *S. guyanensis, T. semipilosum, D. uncinatum* and *D. intortum* plots contained 8.0, 9.6, 11.4 and 11.7% CP respectively.

P uptake by plants

The per cent P in the plant tops in the final harvest are presented in Table 6. Where superphosphate was applied, the P content in the plant tops was increased but the data were not subjected to statistical analysis. The increase in P content appeared to be less for *T. semipilosum* than for the other legumes.

TABLE 6

Percentage P on a DM basis in tops of four tropical legumes 16 months after oversowing in natural grassland in the presence or absence of superphosphate

Legume	Superphosphate (kg/ha) 0	500
Stylosanthes guyanensis	0.14	0.19
Desmodium intortum	0.14	0.19
Desmodium uncinatum	0.13	0.20
Trifolium semipilosum	0.20	0.21

DISCUSSION

Hall and Allen (1938) observed that where superphosphate was applied in natural grasslands of Kenya's high altitudes, wild white clovers became prevalent. This may explain the preponderance of *T. semipilosum* (Kenya white clover) in the farms around Kitale where phosphatic fertilizers are applied annually as part of the husbandry in pasture and maize production. There was a significant increase in the number of *T. semipilosum* seedlings in the fertilized plots four weeks after oversowing. It is postulated that the applied fertilizer encouraged the germination of sown as well as wild seed of *T. semipilosum* since this legume occurs naturally at Kitale.

The fertilizer in this study was single superphosphate (21% P_2O_5; 10% S). The applied fertilizer contained 50 kg S per hectare. Keya (1969) has shown that for a rapid establishment of *D. uncinatum* under Kitale conditions at least 60 kg P_2O_5 per hectare and 30 kg S per hectare were required as basal dressing. The quick establishment of legumes in the P plots in this study may have been partly due to the S content of single superphosphate.

The P content of the DM of the legumes was higher in the fertilized plots than in the plots not receiving superphosphate. This suggests that some of the fertilizer P was taken up by the legumes. Andrew and Robins (1969) using Samford soil from Queensland, Australia, worked out the critical P levels for some tropical legumes. For *D. intortum* and *D. uncinatum* on a DM basis, the P levels were 0.22 and 0.23% respectively. Dougall and Bogdan (1962, 1966) showed that *T. semipilosum, D. intortum, D. uncinatum* grown in the nursery at Kitale contained 0.28 to 0.33% P on a DM basis.

Analysis of soil samples from the site of the experiment described in this study prior to oversowing showed that the soil pH range was 5.6 to 5.8. The soil contained 2 to 10 ppm P. The low level of P in the soil may explain the significant responses to superphosphate in this study. P and S are required not only in plant growth but also in nitrogen fixation by pasture legumes. This may explain the positive interaction between superphosphate and the oversown legumes.

D. intortum and *D. uncinatum* are the most promising legumes for sown pastures in the medium altitudes of western Kenya (Thairu, Morrison and Keya 1968, Keya 1969). *Setaria sphacelata/Desmodium uncinatum* mixtures in the second and third seasons are capable of about 10,000 kg per hectare DM with a

CP content of 15 to 20%. The DM yields of natural vegetation oversown with *D. uncinatum* and topdressed with superphosphate in this study compared very favourably with the yields from sown pastures in the establishment year. When the oversown legumes become strongly established and increase the soil fertility grasses adapted to high fertility may volunteer, which may increase the productivity of these grasslands further.

At Te Awa, New Zealand, a five year old field trial was laid down to measure the effects of superphosphate and oversowing with clovers on hill pastures. By the end of the five year period, oversowing alone had increased yield by 22%, fertilizer alone by 36%, while clover seed and fertilizer together had doubled the yield (Suckling 1959). Although the trial reported in this paper has been going for less than two years, it is evident that the increases in productivity are much more rapid than was the case in New Zealand. This is especially the case for *D. intortum* and *D. uncinatum*. In 16 months, *D. uncinatum* alone increased the yield by 13%, fertilizer alone by 22% and *D. uncinatum* seed and fertilizer together increased the yield by 124%. It is likely that additional increases in both quality and yield of these grasslands will occur with time.

Apart from the lack of technical know-how, the lack of initial capital limits animal production in the areas of western Kenya with a high agricultural potential. Detailed costs of bush clearing and seedbed preparation for establishing improved pasture species in western Kenya are scarce. Oversowing legumes and topdressing with superphosphate may lower these establishment costs. Establishment by oversowing may also be relevant in hilly and unploughable areas which receive adequate rainfall for pasture growth.

CONCLUSION

The results of this study indicate that superphosphate was essential for quick establishment of tropical legumes oversown in the natural grassland of western Kenya. *D. intortum* and *D. uncinatum* were the most promising legumes in the improvement of these grasslands by oversowing.

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