NITROGEN AND PHOSPHORUS RESPONSE OF *DESMODIUM UNCINATUM* ON SEED PRODUCTION AT MT. COTTON, SOUTH-EASTERN QUEENSLAND

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ABSTRACT

The effect of amount and timing of urea application and amount of calcium dihydrogen phosphate on the seed production of Desmodium uncinatum *cv. Silverleaf grown on a red-yellow podzolic soil at Mt. Cotton was studied. In two of three years good responses were recorded to high levels of phosphate, and to application of urea. These effects were mainly due to increased inflorescence density. Number of seeds formed per node and seed size showed seasonal variation, and reflect the unreliability of the climate of south-eastern Queensland for desmodium seed production.*

INTRODUCTION

Tropical pasture seed is a high value product, and it is usually profitable to remove soil nutrient limitations to seed production. Although a great deal of research effort has been directed to identifying fertiliser needs of grazed pasture, less attention has been given to the special requirements of seed crops. This paper reports three years' results of a fertiliser experiment on *Desmodium uncinatum* cv. Silverleaf grown for seed on a podzolic soil at Mt. Cotton, south-eastern Queensland. It was desired to define phosphate needs and to discover whether symbiotic nitrogen fixation provided an adequate level of nitrogen supply for seed production, especially in view of the reported autumn decline in nodulation (Whiteman, 1970), when flowering and seed maturation occur.

MATERIALS AND METHODS

The design of the experiment was a 4 × 3 × 3 complete factorial with three replications as randomised blocks, making 108 plots in all. The treatments were

(a) level of urea application: equivalent to 0, 56, 112, or 224 kg N/ha/year, designated N_0, N_{56}, N_{112} and N_{224} respectively;

(b) timing of urea application: applied all during vegetative stage (N_V, January 24, 1968, February 6, 1969 and 1970), or all during flowering (N_F, April 29, 1968, April 9, 1969, and April 2, 1970), or one half the level applied at each date (N_{V+F});

(c) level of calcium dihydrogen phosphate application: equivalent to 0, 22 or 89 kg P/ha in 1968, designated P_0, P_{22}, and P_{89} respectively, and applied at the time of N_V. Rates in 1969 and 1970 were one-quarter of the 1968 levels. Plot size was 4.6 m. × 4.6 m.

The experiment was done at the University of Queensland Farm, Mt. Cotton, ca 20 miles south-east of Brisbane. The site is a red-yellow podzolic soil (Beckmann, 1967) and major responses to phosphorus, nitrogen and sulphur, and lesser responses to potassium, molybdenum and calcium carbonate have been reported (Lee, 1969; Blunt and Humphreys, 1970) on an adjacent area. Nine p.p.m. available P (0.01 N sulphuric acid extraction) and total N 0.08 per cent were recorded in the 0-15 cm layer. During the 1966-67 summer, cowpeas were grown following application of 250 kg/ha single superphosphate. After thorough seed bed preparation, basal fertiliser at the rate of 31 kg each of copper sulphate and zinc sulphate, 125 kg potassium chloride and 146 kg calcium sulphate per ha was surface broadcast on January 24, 1968. Basal fertiliser at 125 kg/ha each of potassium chloride and calcium sulphate was again applied on February 27, 1970. *Desmodium uncinatum* seed inoculated with CB627 Rhizobium was drilled in rows 53 cm apart on January 25, 1968.

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The area was mechanically and hand cultivated intermittently to control weeds. In 1968 and 1969 weed control was satisfactory, but grass invasion (predominantly *Digitaria adscendens* and *Cyperus* spp.) was troublesome in 1970; weeds were hand painted with diesel distillate oil on February 25-27, 1970. The experiment was intermittently grazed with cattle during the July to December period each year, and cattle obtained accidental access from April 12-14, 1968. Tops were removed to 10 cm height with a forage harvester on January 5, 1970. The experimental area was sprayed with 0.1 per cent DDT on March 29 and June 10, 1968, and was misted with 0.5 per cent DDT on May 19, June 2, and June 16, 1969, March 18, April 13 and May 22, 1970 to control lepidopterous larvae. Supplementary spray irrigation was applied in 1968 (16 mm each April 6, April 9, 19 mm April 18, 10 mm May 1) and 1970 (6 mm April 3, 20 mm May 28).

Dissection of apices to determine date of floral initiation was carried out intermittently from March 9. Density and stage of development of inflorescences were determined on June 13, 1968, and on May 12-15, 1970. Seed harvesting was conducted on July 4, 1968, July 25-26, 1969 and June 16-18, 1970; inflorescence density, floral node number, seeds formed per node, and individual seed weight were determined from a single 2 m^2 quadrat in each plot. Seed material was dried at 60°C for 2 days, rubbed between ribbed surfaces, and winnowed. Plant density was estimated on March 15, 1968 and stem density was counted on May 8-11, 1970. Soil cores 15 cm deep and 19 cm diameter and central to plant crowns were excavated from four selected treatments on April 8, 1968 (five per plot) and on April 10-11, 1970 (four per plot); roots and nodules were recovered and dried. Samples of runners continuing eight nodes distal from the apex were collected on April 28, 1968 and analysed for nitrogen and phosphorus concentration. Dry weight of legume and of other species present was determined by clipping single 2 m^2 quadrats to ground level in each plot from June 22-29, 1970.

RESULTS

(i) *Weather conditions*

The seed yields reflect the unreliability of the south-eastern Queensland climate for desmodium seed production. The 1968 crop failed. This may have been associated with the accidental grazing at floral initiation, but was mainly due to very unfavourable weather conditions from May 7 to 17, at the peak of flowering. Conditions were wet and windy, and daily maximum/minimum temperatures decreased to 17°/7°C; bees were not active and seed set was very low. Rainfall (Table 1) was deficient during final crop maturation and may have limited seed development. No supplementary irrigation was used on the 1969 crop, which was produced following an unusually dry summer growing season. An abnormally wet May (248 mm rain) occurred; most of this fell during the main flowering from May 8 to May 16; harvesting was delayed to take advantage of the better seed set in late appearing inflorescences. Very wet conditions occurred in the 1970 summer; this made mechanical weed control operations difficult and some waterlogging was apparent, especially in the eastern plots. Weather conditions were generally satisfactory for flowering and maturation in 1970.

(ii) *Seed yield and its components*

Seed yields (Table 2) were low, and below the commercial Queensland average of 84 kg per ha suggested by Vicary (1970). In each year significant fertiliser effects occurred. The very low yields recorded in 1968 were unexpectedly further reduced at the 56 kg N per ha level and by late application of urea. The positive effect of phosphorus in 1968 did not reach significance, but in 1969 and 1970 good phosphorus responses were recorded. Urea also increased seed yield in these two years, but the response was not significantly affected by its level or timing; in 1969 and 1970 the late application of urea was made close to floral initiation rather than at the first external flower appearance stage.

TABLE 1
Monthly rainfall (mm) for Mt. Cotton Farm

Month	Year 1968	1969	1970
January	320	21	244
February	110	74	223
March	81	73	144
April	54	29	108
May	58	248	11
June	3	25	6
July	62	35	20
August	91	65	42
September	23	20	62
October	6	193	156
November	25	178	178
December	148	110	582
Year	981	1071	1776

TABLE 2
Fertiliser effects on seed yield (kg/ha)

Treatment	1968	1969	1970
N_0	5.9^b	15.1^a	36.5^a
N_{56}	3.7^a	23.9^b	62.0^b
N_{112}	4.7^b	26.0^b	47.9^b
N_{224}	4.3^{ab}	26.7^b	53.9^b
N_V	5.5^b	19.9	43.2
N_F	4.2^a	21.7	50.6
N_{V+F}	4.3^a	27.1	56.4
P_0	3.9	17.5^a	39.3^a
P_{22}	5.3	22.5^{ab}	46.8^{ab}
P_{89}	4.8	28.7^b	64.0^b
mean	4.7	22.9	50.0

* Figures followed by the same letter do not differ at the 5% level of significance.

Interactions between phosphorus level, nitrogen level, and timing of application were not significant. This meant that the main effects shown in Table 2 were to some extent additive e.g. in 1970 yield of the control N_0P_0 treatment was 42 kg per ha, relative to 79 kg per ha in the N_{56} P_{89} treatment.

Seed production may be considered in terms of the sequence of development processes which occur. Desmodium yield is the product of inflorescence density, the number of floral nodes differentiated on each raceme, the number of seeds formed and recovered from each node, and the weight of the individual seed formed. In this experiment inflorescence density was most sensitive to both seasonal and fertiliser effects, and number of seeds per node and seed size varied greatly from year to year. Seeds per floral node averaged 0.62, 1.54 and 1.52 in 1968, 1969 and 1970 respectively, whilst seed size averaged 2.8, 4.9 and 3.7 mg in the same years.

Positive responses to urea application in 1969 and 1970 were mainly associated with increased inflorescence density (Table 3). Floral initiation was detected on April 16, 1968, April 6, 1969, and March 31, 1970, and was unaffected by fertiliser treatment. There was a suggestion in the data that applied nitrogen extended subsequent flowering, and applied phosphorus hastened flowering, but these differences were not significant. In 1970 inflorescence density decreased 24 per cent from

TABLE 3
Fertiliser effects on inflorescence density (no./m²)

Treatment	1968	1969	1970
N_0	19.8	18.2[a]	64.5[a]
N_{56}	18.6	30.0[b]	99.4[b]
N_{112}	18.6	30.9[b]	85.0[b]
N_{224}	22.9	36.2[b]	93.1[b]
N_V	24.5[b]	24.1[a]	77.0
N_F	13.3[a]	28.4[ab]	85.4
N_{V+F}	22.0[b]	34.0[b]	94.1
P_0	12.5[a]	24.0[a]	69.5[a]
P_{22}	22.3[b]	27.5[a]	83.0[ab]
P_{89}	24.9[b]	35.0[b]	103.9[b]
Mean	19.9	28.8	85.5

May 12-15 to June 16-18, but this effect was not significantly affected by urea treatment. Early urea application produced fewer inflorescences than later urea application in 1969, but late urea application during flowering was unfavourable in 1968. A small decrease in number of floral nodes per raceme occurred in 1970 in the N_{224} treatment (8.5 relative to 9.4 in the control); node number per raceme averaged 13.9, 10.6 and 9.2 in 1968, 1969 and 1970 respectively.

The positive effects of phosphorus application were also due to increased inflorescence density. In 1970 stem density was quite independent of phosphorus supply, and raceme number per stem was 6.1, 7.3 and 13.6 in the P_0, P_{22} and P_{89} treatments respectively. A compensatory effect of reduced number of seeds per floral node (0.72 at P_0 relative to 0.54 at P_{89}) occurred in 1968, but applied phosphorus slightly increased seed size in 1970 from 3.5 to 3.8 mg.

TABLE 4
Fertiliser effects on plant yield, 1970 (kg/ha)

Treatment	Legume	Other species
N_0	371[a]	401[a]
N_{56}	636[b]	636[b]
N_{112}	600[b]	652[b]
N_{224}	631[b]	1200[c]
P_0	424[a]	604[a]
P_{22}	537[ab]	694[ab]
P_{89}	718[b]	869[b]

TABLE 5
Fertiliser effects on nodulation and root growth

Component	Fertiliser treatment			
	N_0 P_0	N_0 P_{89}	N_{V224} P_0	N_{V224} P_{89}
Nodule no./plant				
1968	5	27	Nil	Nil
1970	22	34	1.5	28
Nodule size (mg)				
1968	1.2	2.4	—	—
1970	2.9	3.7	3.3	3.2
Nodule wt (mg/plant)				
1968	6	65	Nil	Nil
1970	63	125	5	90
Root wt (g/plant)				
1968	2.2	4.3	2.5	4.6
1970	19.5	9.6	16.0	11.9

(iii) *Growth, nodulation and chemical composition.*

Dry matter production data are only available for the 1970 harvest (Table 4), when growth had been reduced by the earlier water logging. Yields were low, but legume growth was increased by applied nitrogen and phosphorus. Growth of other species was also responsive to fertiliser, and weed dominance was positively related to level of urea application. Applied phosphorus increased root growth (Table 5) in the establishment year of 1968, but decreased it in 1970.

Nodulation was suppressed by high nitrogen treatment in 1968 (Table 5), and this effect was also evident in 1970 in the absence of applied phosphorus. Phosphorus increased both nodule number per plant and nodule size.

Phosphorus concentration of terminal shoots on April 28, 1968 (when first flower bud appearance occurred) was 0.16, 0.19, and 0.25 per cent in the P_0, P_{22} and P_{89} treatments respectively. This should be considered in relation to the "critical" concentration of 0.23 per cent suggested by Andrew and Robins (1969). Increases in phosphorus concentration also increased desmodium nitrogen concentration (Y), according to the linear equation $Y = 2.86 + 5.04X$. Shoot nitrogen concentration was 3.5, 3.8, 3.9 and 4.3 per cent in the N_0, N_{56}, N_{112}, N_{224} treatments respectively, all values being above the suggested "critical" 3.3 per cent N.

DISCUSSION

The use of fertiliser nitrogen on perennial legumes is a controversial issue. In this study urea application at flowering was detrimental to seed production under the unfavourable conditions of the poor 1968 crop, but was consistently and economically beneficial in 1969 and 1970, and in an irrigated experiment at St. Lucia in 1971 (Gibson 1972). A relatively low level of urea application, equivalent to 56 kg N per ha (or 110 lb urea fertiliser per acre), was the most suitable rate under the conditions of the Mt. Cotton experiment. In the field very careful crop hygiene would be necessary, since high levels of urea increased weed dominance. Redrup (1965) referred to problems of declining second year sward vigour where rates of more than 112 kg N per ha were employed on tropical pasture legume seed crops. Timing of urea application did not significantly affect seed yield in 1969 and 1970, but the highest numerical values occurred where urea was applied as split dressings in the first weeks of February and of April.

Nodulation was suppressed in the establishment year by high urea application, and this effect continued if phosphorus was deficient. However, the key question is the adequacy of the rhizobial symbiosis to provide sufficient nitrogen for maximum production of high value seed, and clearly urea gave superior results in 1969 and 1970, even where high levels of phosphorus were also applied. Molybdenum, which is in marginal supply in similar soils of the area (Lee 1969) was inadvertently omitted from the basal fertiliser; the nitrogen concentration of 3.5 per cent in the N_0 plants on this poor soil suggests that nodulation was effective.

The whole experimental area received a basal application equivalent to 22 kg P per ha in 1967, and larger phosphorus responses would be expected on similar podzolic soils which had no previous phosphatic fertiliser history. The highest phosphorus level—equivalent to 8 cwt. single superphosphate in 1968 and 2 cwt per acre per year thereafter—gave the best yields in 1969 and 1970. The lower phosphorus rate equivalent to 2 cwt superphosphate at establishment had tissue concentrations of P below the suggested "critical" level (Andrew and Robins 1969).

Insect control posed a problem in the experiment, especially after flowering, since pollination is dependent upon bees. The number of seeds formed per floral node—0.6 in 1968 and 1.5 in 1969 and 1970 were very low, and contrast with the figure of 3.3 obtained in 1971 at St. Lucia (Gibson 1972). The results at Mt. Cotton point to the unreliability of the south-eastern Queensland climate for desmodium seed production, and the benefits of adequate nitrogen and phosphorus supply even under adverse conditions.

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