METHODS OF APPLYING FERTILIZERS FOR HERBAGE CROPS

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(With Plate 7)

INTRODUCTION

Where temporary grass and other herbage crops are grown in an arable rotation, fertilizers may be applied at different stages in the cultivations which precede sowing. Satisfactory establishment may require a high concentration of phosphate near to the seed, particularly on deficient soils. Stewart & Reith (1945) showed that phosphate fertilizers drilled in contact with grass and clover seeds promoted better establishment than the same quantity of phosphate broadcast before sowing, but the value of phosphate fertilizers afterwards depended very much on management practices. The later needs of the crop may be met by fertilizer broadcast before sowing and incorporated deeply with the soil or by bands placed several inches deep. Such dressings may promote deep rooting and maintain growth during dry periods.

The drills used to sow herbage crops on narrow rows (4–7 in. apart) can be adapted to place fertilizer only in contact with or directly below the seed. Germination may be injured when any fertilizer other than a light dressing of phosphate is applied. With crops grown on wider rows there is an opportunity to introduce an extra coulter so that fertilizer may be sown in bands at a safe distance to the side of the seed and, if necessary, below its level. Such methods of 'sideband' placement have advantages for some arable crops (Cooke, 1949) and are easily applied to lucerne or grasses grown on wide rows. Two experiments on lucerne were laid down in 1950 to test whether placing fertilizer in bands at the side of the seed was superior to the usual practice of broadcasting. A further experiment on lucerne was laid down in 1952 to test the value of a 'starter-dose' of superphosphate placed directly beneath the seed and to compare phosphate and potash ploughed in with similar dressings worked shallowly into the seed-bed.

For an established crop the only alternative to the present practice of broadcasting is to cut grooves in the sward and place bands of fertilizer below the surface. In the work described here experiments on sainfoin, temporary leys and permanent pasture compared such localized dressings with broadcast dressings. In early work in the United States, Midgley (1931) showed that superphosphate applied in grooves 6 in. deep and 4 in. apart gave much higher yields of dry grass than similar dressings of superphosphate broadcast on the surface. Later American experiments are discussed by Jones & Rogers (1949), who state that subsurface placement of fertilizer for herbage crops does not show consistent advantages over surface broadcasting. Dodd (1950), from a survey of the Middle-West and North-East of the United States, states that placement of phosphate below the surface of the sward is about 15 % more effective than applications on the surface; there was no difference between placing nitrogen and potash fertilizers on or in the soil. Fertilizer cannot be placed below the surface of a sward with equipment used at present in this country. Implements commonly used to aerate and 'rejuvenate' old pastures rarely penetrate more than an inch, and to use such tools to incorporate fertilizer deeply may seriously damage the sward. New methods of applying fertilizer might be of interest in attempts to increase the productivity of poor grassland.

SCOPE OF THE EXPERIMENTS

Established crops

Experiments on several crops were laid down in 1950 and 1951, using a special drill built originally for experiments on row crops (Cooke, 1949). There were two experiments on sainfoin, one on winter oats undersown with sainfoin, three on permanent grass and one on a lucerne-cocksfoot ley. The methods of application tested were:

Fertilizer broadcast.

Fertilizer placed in bands 3 in. below the soil surface and (generally) 10 in. apart.

Each method of application was tested at two rates of dressing, 3·25 and 6·5 cwt./acre of a granular fertilizer containing 16 % P_2O_5 and 13 % K_2O. The four fertilized plots, together with two plots without fertilizer, were arranged in a randomized block, with threefold replication at all centres. In each block one unfertilized plot was completely untreated, on the other plot grooves were cut with the drill (but no fertilizer was applied) to assess any damage to the sward.

Lucerne

The methods of fertilizer application tested in experiments laid down in 1950 were:

Placed in one band 2 in. to the side of the seed and 3 in. below the soil surface.

Broadcast on the seed-bed and harrowed in.

Half the dressing placed beside the seed in spring 1950 and half beside the rows of lucerne in spring 1951.

Half the dressing broadcast on the seed-bed in spring 1950 and half broadcast on the surface in 1951.

Each method of application was tested at two rates, and the eight treatments, together with four unfertilized plots, were arranged in a randomized block. There were two blocks in an experiment near St Albans and three blocks at Rothamsted. A granular compound fertilizer containing 10 % P_2O_5 and 20 % K_2O was used. The rates of dressings were 2·5 and 5·0 cwt./acre at Rothamsted, and 5·0 and 10·0 cwt./acre at St Albans, where the soil was poorer.

Fertilizer was placed in a band 2 in. to the side of the seed; earlier experiments (Cooke, 1949) showed this lateral separation of seed and heavy dressings of fertilizer was necessary to avoid injury to germination. Other plots having broadcast fertilizer provided a straightforward comparison between broadcasting and placing. As lucerne grows slowly in the early stages and does not yield heavily until the second year smaller quantities of nutrients are required in the first than in subsequent years. Good use of fertilizer might be achieved by splitting the dressing, applying part in the first year and the remainder in later years. This method was tested in the experiments by introducing further plots having broadcast or placed fertilizer with half the dressing broadcast or drilled beside the seed in spring 1950 and the remainder applied in spring 1951 broadcast or drilled beside the rows of the crop.

The lucerne experiment laid down in 1952 at Rothamsted tested:

Superphosphate at 1·0 cwt. P_2O_5/acre.

Muriate of potash at 1·0 cwt. K_2O/acre.

Superphosphate (1·0 cwt. P_2O_5/acre) plus muriate of potash (1·0 cwt. K_2O/acre).

Each fertilizer treatment was applied in two ways:

Broadcast on stubble and ploughed in.

Broadcast on the seed-bed immediately before drilling.

The six treatment combinations, together with two unfertilized plots, were duplicated, half the plots receiving a 'starter-dose' of 2 cwt./acre of granular superphosphate placed 2 in. directly below the seed. The sixteen treatments were arranged in two blocks of eight plots by confounding a high-order interaction. There were eight blocks in the experiment.

METHODS OF LAYING DOWN THE EXPERIMENTS

Established crops

The plots used were 22 yd. long and 10 ft. wide. The experiments were marked out and fertilizer was broadcast by hand on appropriate plots. A special drill (Cooke, 1949), designed and constructed at the National Institute of Agricultural Engineering, was used to apply fertilizer in bands. Although built primarily for arable crops, it was used for this work on established crops without any modification, except that the seed coulters were removed. The fertilizer coulters pulled into work immediately and maintained the desired depth without difficulty; they were not deflected by stones or compacted soil. As the coulters are narrow, there was generally little disturbance of the sward. Plants uprooted by the fertilizer coulters were replaced by the rear rollers on the seed units; these rollers also closed the grooves in the sward which were completely obliterated in a few weeks. The drill was entirely satisfactory for placing bands of fertilizer below the surface on heavy moist soils. On lighter and drier soils the coulters did not cut through the root mat cleanly and many plants were torn up. In the experiments on sainfoin the drill passed over the area once and the bands of fertilizer were placed 20 in. apart; drilling the bands more closely uprooted an excessive proportion of sainfoin. In all other experiments the bands were placed 10 in. apart by going over the area twice. A string set beside the plot boundary guided the tractor driver, for the second treatment of each plot the guiding strings were offset so that the fertilizer was placed midway between the first bands. The drill was stopped on plot boundaries while adjustments were made to the gearbox governing delivery rates and to the fertilizer coulters. Pl. 7 (*a*) shows the drill being used to cut grooves and place bands of fertilizer 20 in. apart in an established crop of sainfoin.

A basal dressing of 3 cwt./acre of sulphate of ammonia or 'Nitro-Chalk' was applied by hand to all plots of the experiments on permanent grass.

Lucerne

Two experiments were marked out in spring 1950. The plots were 22 yd. long at both centres and were 10 ft. wide at St Albans and 5 ft. wide at Rothamsted. There were twelve plots in each block arranged side by side. Fertilizer was broadcast by hand on appropriate plots and harrowed into the seed-bed. The special drill was used to sow seed on all plots and to place fertilizer beside the seed as desired. As the drill has a fixed spacing of 20 in. between seed coulters the area was drilled twice so that the rows of lucerne were 10 in. apart.

Plots having split applications of fertilizer were

dressed again in spring 1951. Broadcast fertilizer was applied by hand on appropriate plots. On other plots the drill was used to place bands of fertilizer beside the rows of lucerne.

In all experiments on herbage crops the whole produce of each plot was cut by motor-driven scythe and weighed. Samples were taken for determination of the percentages of dry matter.

Table 1. *Yields (in cwt./acre) of dry hay given by different rates and methods of applying fertilizer for established herbage crops*

Rate of fertilizer (cwt./acre)	Without fertilizer		Fertilizer	
	Uncultivated	Cultivated	Broadcast	Placed
	Leguminous crops (4 experiments)			
3·25	—	—	39·6	37·4
6·50	—	—	40·2	38·6
Mean rate	37·6	37·8	39·9	38·0
	Permanent pasture (3 experiments)			
3·25	—	—	35·3	31·7
6·50	—	—	36·2	32·1
Mean rate	31·1	28·6	35·8	31·9

Table 2. *Comparisons of broadcasting and placing fertilizer for established herbage crops*

(Significant effects are marked ** for $P<0{\cdot}01$, * for $P=0{\cdot}05$–$0{\cdot}01$)

	Without fertilizer (cwt./acre)	Increase (cwt./acre) in yield from: Cultivation	Broadcast fertilizer	Placed fertilizer	Placing *over* broadcasting	S.E. per plot
No. of plots ...	6	3–3	6–6	6–6	6–6	
Oats undersown with sainfoin Meldreth, Cambs						
1950 Oats Grain	21·7	0·8	1·2	2·3	1·1	5·04
1950 Oats Straw	36·8	−3·4	5·3	2·8	−2·5	6·53
1951, Sainfoin hay	38·4	−0·2	−2·6	−0·9	1·7	4·80
Sainfoin (dry hay)						
1950, Meldreth, Cambs						
First cut	31·3	0·3	2·2	−0·6	−2·8*	1·96
Second cut	23·7	−0·1	3·0*	−0·7	−3·7*	2·28
1951, Royston, Herts	40·0	3·1	6·1*	0·8	−5·3*	3·76
Lucerne-cocksfoot ley (dry hay)						
1951, Rothamsted, Herts	41·1	−2·4	3·1	2·0	−1·1	2·89
Permanent grass (dry hay)						
1950, Rothamsted, Herts						
First cut	24·4	−1·7	4·9**	2·3	−2·6	2·26
Second cut	11·7	0·1	0·4	0·2	−0·2	1·36
1951, Ridge, Herts	37·2	−4·8	5·8**	0·6	−5·2*	3·13
1951, Rothamsted, Herts	27·9	−1·0	7·1**	3·3*	−3·8*	2·48

In the experiment laid down at Rothamsted in spring 1952 the plots used were 10 ft. wide and 90 links long and contained six rows of lucerne spaced 20 in. apart. Broadcast dressings were applied to the appropriate plots and the whole area was ploughed 10 in. deep with a one-way mounted plough. The seed-bed was prepared and dressings were broadcast where necessary immediately before drilling. The special drill was used to sow the seed and to place granular superphosphate below the seed as desired.

RESULTS OF THE EXPERIMENTS

Experiments on established crops

There were two classes of herbage crop in the experiments, temporary leguminous swards and permanent pasture. Mean yields for all experiments on each type of crop are given in Table 1. (Where more than one cut was taken, only the yields of the first cut have been used to prepare these averages.)

On the average of three experiments on sainfoin

Table 3. *Comparisons of broadcasting and placing fertilizer for lucerne in experiments laid down in* 1950

(Significant effects marked ** for $P<0{\cdot}01$, * for $P=0{\cdot}05$–$0{\cdot}01$.)

	Yields of dry hay in cwt./acre				
	Rothamsted			St Albans	
	Yields obtained in 1950				
	1st cut	2nd cut			
Without fertilizer	22·0	15·2		11·7	
Increase from broadcast fertilizer	3·8**	0·6		2·7	
Increase from placed fertilizer	−0·4	0·3		4·7**	
Increase from placing over broadcasting	−4·2**	0·3		2·0	
S.E.	±0·99	±0·46		±1·34	
	Yields obtained in 1951				
	1st cut	2nd cut	3rd cut	1st cut	2nd cut
Without fertilizer	50·8	21·2	25·3	9·4	5·9
Increase from broadcast fertilizer	1·2	−0·8	0·6	5·6**	5·8**
Increase from placed fertilizer	3·2*	0·5	0·2	4·7**	6·2**
Increase from placing over broadcasting	1·9	1·3	−0·4	−0·9	0·5
S.E.	±1·20	±0·97	±0·98	±0·93	±0·61
Gain from cultivating in absence of fertilizer	−1·6	2·7	1·2	1·3	0·9
Gain from splitting fertilizer dressing					
Broadcast	−1·9	−1·6	−0·8	0·4	1·8
Placed	−3·3	1·0	−1·0	−1·6	−1·1
S.E.	±1·70	±1·37	±1·39	±1·32	±0·86

Table 4. *Comparisons of different methods of applying superphosphate and muriate of potash for lucerne sown in* 1952

(Significant effects marked ** for $P<0{\cdot}01$; * for $P=0{\cdot}05$–$0{\cdot}01$.)

	Yields of dry hay in cwt./acre			
	First cut		Second cut	
	Without 'starter'	With 'starter'	Without 'starter'	With 'starter'
Yield without broadcast fertilizer	6·8	12·0	18·8	21·9
S.E.	±0·42		±0·63	
	Increase from broadcast fertilizer			
Increase from phosphate				
On seed-bed	0·9	−1·3	0·7	−0·3
Ploughed in	2·2**	0·2	0·6	−0·3
Increase from potash				
On seed-bed	−0·3	0·5	−0·2	0·3
Ploughed in	0·8	0·2	−0·2	0·3
Increase from phosphate and potash				
On seed-bed	2·2**	0·9	1·8	−0·5
Ploughed in	3·3**	1·2	1·8	0·4
S.E.	±0·71		±1·09	
	Increase from 'starter' dose of superphosphate drilled beneath seed			
Without broadcast fertilizer	5·2**		3·1**	
S.E.	±0·59		±0·89	
With phosphate broadcast				
On seed-bed	3·0**		2·1	
Ploughed in	3·2**		2·2	
With potash broadcast				
On seed-bed	6·0**		3·6**	
Ploughed in	4·6**		3·6**	
With phosphate and potash broadcast				
On seed-bed	3·9**		0·8	
Ploughed in	3·1**		1·7	
S.E.	±0·78		±1·26	

and one on lucerne-cocksfoot ley broadcast fertilizer increased yields, but there was very little increase from placed fertilizer. In three experiments on permanent pasture there were large responses to broadcast fertilizer; dressings placed in bands gave smaller increases in yield. Cultivating the sward without applying fertilizer had little effect on yields of leguminous crops but depressed yields in the experiments on permanent pasture.

Unmanured yields, increases from broadcast and placed fertilizer and comparisons of broadcasting and placing are set out in Table 2 for each centre, averaging the two rates of dressing. Fertilizer dressings had no significant effects on oats undersown with sainfoin at Meldreth and on lucerne-cocksfoot ley at Rothamsted. In all other experiments broadcast fertilizer produced significant increases in yields of hay. The only significant increase from placed fertilizer was given in the 1951 experiment on permanent grass at Rothamsted. Broadcasting fertilizer gave significantly more hay than placing the same dressing in two experiments on sainfoin and in two experiments on permanent grass.

Damage caused by cutting grooves in the sward was assessed by comparing yields from unmanured plots which were cultivated by the coulters with yields from uncultivated, unmanured plots (Table 2). In experiments on sainfoin yields were not reduced by cutting grooves 20 in. apart. For permanent grass and lucerne-cocksfoot ley grooves cut 10 in. apart caused decreases in yield which were not significant.

Experiments on lucerne laid down in 1950

One cut of hay was taken at each centre in August 1950 and a further cut was taken at Rothamsted in October. In 1951 three cuts of hay were taken at Rothamsted and two cuts at St Albans. Unmanured yields, increases given by placed and broadcast fertilizer, together with comparisons of broadcasting and placing, are set out in Table 3, averaging rates of dressing and times of application.

At Rothamsted in 1950 broadcast fertilizer increased the yield of the first cut significantly; placing fertilizer beside the seed gave significantly less hay than broadcasting. Placed and broadcast fertilizer gave small increases in yield of the second cut which were not significant. At St Albans placed fertilizer gave a significant increase in yield; the difference between broadcasting and placing was not significant.

In 1951 unmanured yields at Rothamsted were high, yields from the St Albans experiment were very low. At Rothamsted placed fertilizer gave a significant increase in the yield of the first cut. At St Albans broadcast and placed fertilizer increased yields of each cut significantly. There were no significant differences at either centre between the yields given by placed and broadcast fertilizer. Cultivating with the fertilizer coulters on unmanured plots in 1951 produced small, non-significant increases in yield of all cuts except the first at Rothamsted. Table 3 also sets out the effects of splitting the fertilizer dressing, applying half at sowing-time in spring 1950 and half in spring 1951. There was a general tendency for the divided dressings to give slightly lower yields than dressings applied wholly at sowing, though none of the differences was significant.

Experiment on lucerne laid down in 1952

Two cuts were taken in 1952. Table 4 sets out for each cut unmanured yields, increases from dressings of broadcast superphosphate and muriate of potash and increases from the 'starter-dose' of superphosphate drilled beneath the seed.

All dressings of broadcast fertilizer except seed-bed dressings of potash applied without the 'starter-dose' of superphosphate increased yields of the first cut. The increases given by ploughed-in phosphate and by the phosphate-potash mixture applied in both ways were significant. When the 'starter-dose' was applied increases in yields from broadcast fertilizer were smaller and there were no significant effects. There were no significant increases in yield of the second cut from any of the dressings of broadcast fertilizer.

The 'starter-dose' of superphosphate drilled beneath the seed made the lucerne grow very vigorously in the early stages: this effect is illustrated on Pl. 7(*b*). It gave significant increases in yield of the first cut when applied alone, and also in the presence of each dressing of broadcast fertilizer. At the second cutting there were significant increases from the 'starter-dose' when applied alone and also when applied with dressings of muriate of potash. For both cuts superphosphate drilled as 'starter' gave the highest increases in yield on plots having muriate of potash ploughed in or applied in the seed-bed.

Comparisons of ploughing-in phosphate and potash with the same dressings broadcast on the seed-bed were made. At the first cutting there were small increases in yield from ploughing-in all three dressings of broadcast fertilizer when no 'starter' was applied. When the 'starter-dose' of superphosphate was drilled beneath the seed, there were no worth-while gains in yield of either cutting from any of the dressings of broadcast fertilizer. There were no significant differences between the yields given by ploughing-in and broadcasting any of the fertilizer dressings at either cutting.

DISCUSSION

Broadcast fertilizer produced more hay than fertilizer placed in bands below the surface in six of the seven experiments on established herbage crops in 1950–1; the differences were significant at four centres. In experiments on permanent pasture yields were decreased on unmanured plots by cutting grooves with the fertilizer coulters 10 in. apart. For sainfoin the bands were placed 20 in. apart and yields on unmanured plots were not reduced by 'cultivation'. Since broadcast fertilizer nevertheless produced higher yields of sainfoin than fertilizer in bands, poorer yields from banded fertilizer are not wholly due to disturbance of the sward by cutting grooves. In the year of application, fertilizers broadcast on the surface and washed in by rain are more efficient than dressings placed in bands below the surface and 10 in. or more apart. The advantage of an equal supply of nutrients to all the plants in a sward outweighs any disadvantage of surface application.

The experiments reported here show no reason for introducing equipment to place fertilizer in bands below the surface of established swards. Machines needed for subsurface placement would be costly and very liable to break on stony soils; they would serve no other purpose on most farms.

For crops such as lucerne fertilizer is usually applied before sowing, and its effects may be considered separately as effects on establishment and on production in later years. In the two experiments laid down in 1950 there were no improvements in establishment and early growth from fertilizer drilled in bands 2 in. to the side of the seed. Lucerne is a deep-rooting crop, and plants excavated from the experiments about 8 weeks after sowing had long straight tap-roots and very few lateral roots; no roots were detected near to the fertilizer band. With such a root system young plants may be unable to use fertilizer placed in a band at the side of the seed. Haynes & Thatcher (1950), from the results of experiments in Ohio, state: 'Accurate placement of legume seed over the fertilizer bands is important to success of the band method—alfalfa seedlings as much as 0·5 in. to one side of the fertilizer bands perform as unfertilized plants.' They report much more rapid establishment when superphosphate was drilled directly below the seed than when it was broadcast.

A further experiment on lucerne was laid down in 1952 to test the value of a small dressing of superphosphate drilled directly beneath the seed and to compare broadcast superphosphate and muriate of potash ploughed in to a depth of 10 in. with the same quantities of fertilizer worked shallowly into the seed-bed. The 'starter-dose' of superphosphate gave much better growth of lucerne than any of the dressings of broadcast fertilizer throughout the spring and early summer, an effect which is illustrated in Pl. 7 (*b*). In general, the 'starter' gave larger increases in yields of both cuts than broadcast phosphate and potash. Broadcast fertilizer ploughed in tended to give higher yields of the first cut than seed-bed dressings, particularly in the absence of the 'starter-dose' of superphosphate. At the second cutting there was little difference between yields given by ploughed-in and seed-bed dressings.

This experiment will be continued in 1953. It has shown that where lucerne is sown on phosphate-deficient soils a dressing of superphosphate drilled directly beneath the seed gives very vigorous early growth and higher yields in the first year than broadcast superphosphate. Since dressings of fertilizers containing soluble salts are likely to damage germination when placed beneath the seed, 'starter-doses' must be restricted to modest dressings of superphosphate. It is not necessary to use specially built drills to place superphosphate beneath lucerne seed. Haynes & Thatcher (1950) have described simple modifications to an ordinary combined seed and fertilizer grain drill which allow a band of fertilizer to be placed beneath the seed of herbage crops grown in narrow rows.

There are no advantages in using special drills to place fertilizer at the side of lucerne seed. This method did not promote rapid early growth which is most important in establishing the crop and obtaining a stand free from weeds.

SUMMARY

Phosphate-potash fertilizer was drilled in bands 20 in. apart and 3 in. below the soil surface and compared with similar dressings broadcast on the surface for established crops of sainfoin. On unmanured plots yields were not reduced by cutting grooves for the fertilizer bands. Broadcasting fertilizer on the surface produced consistently more sainfoin hay than dressings placed in bands. In similar experiments on permanent grass broadcast fertilizer also gave consistently more hay than bands of fertilizer placed 10 in. apart. In the absence of fertilizer small decreases in yields of grass were caused by cutting grooves. The advantages of an equal supply of nutrients to all the plants in an established sward, obtained by broadcasting fertilizers, outweighs any disadvantage from confining the application to the soil surface.

Two experiments on lucerne in 1950–51 compared broadcast dressings of phosphate-potash fertilizer harrowed into the seed-bed with the same quantities of fertilizer placed in one band 2 in. to the side of the seed. Side-band placement did not give better early growth than broadcasting. Broadcast fertilizer gave higher yields of hay than placed fertilizer at one

centre in the first year. There were no significant differences at either centre between yields of hay given by broadcast and placed fertilizer in the second year. When the dressings were divided, half being applied at sowing-time and the remainder in the spring of the following year, slightly lower yields were obtained than from dressings applied wholly at sowing.

A further experiment on lucerne was laid down in spring 1952. Superphosphate, muriate of potash and a mixture of the two fertilizers were compared both when broadcast and ploughed in and when broadcast on the seed-bed. All the dressings of broadcast fertilizer were tested in the presence and absence of a 'starter-dose' of superphosphate drilled directly beneath the seed. The 'starter-dose' gave much better early growth and higher yields of lucerne than any of the dressings of broadcast phosphate and potash. Broadcast fertilizer ploughed in tended to give higher yields at the first cutting than seed-bed dressings. At the second cutting there was little difference between yields given by ploughed-in dressings and dressings broadcast on the seed-bed.

There is no case for introducing special equipment to place fertilizer in bands below the surface of established swards. For establishing lucerne and other ley crops, where fertilizers may be applied at or before sowing, there are no advantages from using special drills to place the full dressing of fertilizer at a safe distance to the side of the seed. Where combine-drills are used for sowing herbage crops they should be modified to place a small quantity of superphosphate directly beneath the seed and the remainder of the fertilizer should be broadcast before sowing.

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DESCRIPTION OF PLATE 7

(*a*) Special drill being used to place fertilizer in bands on an established crop of sainfoin.

(*b*) Rothamsted lucerne experiment in June 1952 showed improved early growth (left foreground) on plots receiving a 'starter-dose' of superphosphate. Plots with broadcast fertilizer grow more slowly (right foreground). There are similar comparisons in the background.

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(*a*)

(*b*)

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