EARTHWORMS AND THE FERTILITY OF PASTURE

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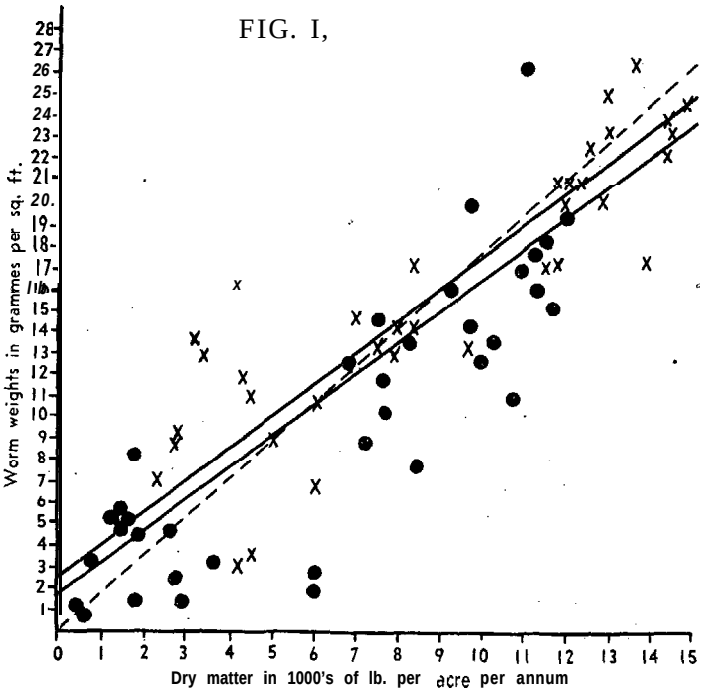
Research at Grasslands into earthworm activities dates from September 1947, when Sears and staff did a determination of the weight and number of earthworms per square foot in a series of 24 grass and clover plots at Palmerston North. Since then these; 24 plots under mowing have been sampled twice more, a series of 36 similar plots under grazing once, a corresponding 24-plot ***series*** at Gore once, and a corresponding 36-plot series at Gore once.

Twelve worm weights corresponding to the 12

FIG. I,



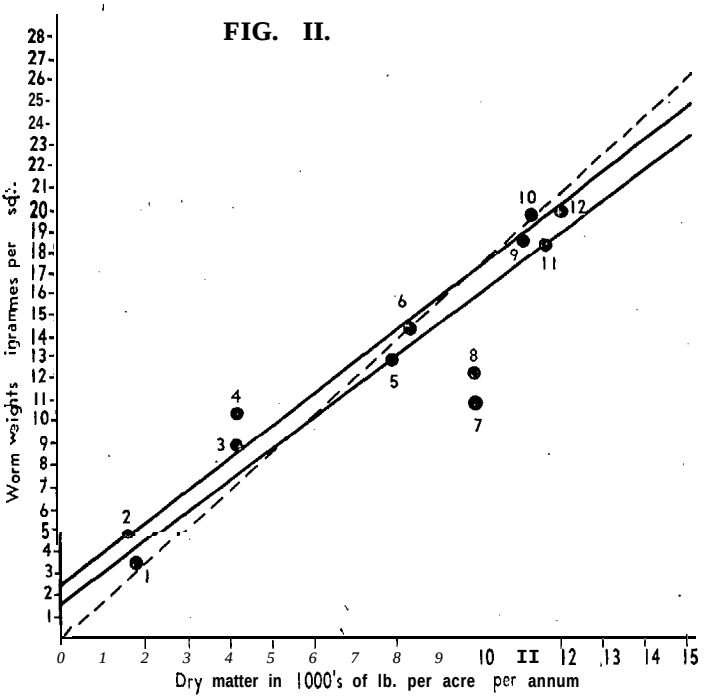
different fertiliser treatments were obtained from each count, giving, since there were 6 counts, 72 worm weights. The per acre production of each plot that had been sampled for earthworms was then worked out for the year before sampling, and from these figures 72 dry-matter production figures were obtained corresponding to the 72 worm-weight figures. The correlation between worm weights in grammes per square foot, and dry-matter production in thousands of pounds per acre per annum was 0.87, a value of 0.3 being required for significance.

A graph of earthworms in grammes per square foot against dry matter production in thousands of pounds per acre per annum was then prepared, 'and two regression lines plotted on it, one to show the relationship between the worm weights and the dry-matter production for the' plots as a whole, and the other to show the relationships between the worm weights and the dry-matter production of those plots that receive the dung and urine but no other fertiliser treatment. On this graph (Fig. 1) there are six points for each of the 12 different fertiliser treatments. In. order that the effect of each fertiliser treatment could be more readily seen, another graph was then prepared by averaging these six values, and plotting only one point for each fertiliser treatment. This is Fig. 2. (N.B. In Fig. 1 the values for plots receiving dung and urine are marked with a cross instead of a dot.)

It can be seen from the graphs that a pasture producing 14,000lb. of dry matter and receiving dung and urine in proportion to that production carries $23\frac{1}{2}$ grammes of earthworms per square foot or 1 ton per acre. Now a pasture will carry approximately $1\frac{1}{4}$cwt. of livestock per 1000lb. of dry matter produced, so that a 14,000lb. dry-matter-producing pasture should carry approximately 18cwt. of livestock. A 'pasture therefore carries a greater weight of earthworms beneath it than of livestock above it, and as can be seen from the graph, approximately $1\frac{1}{2}$cwt. of earthworms per 1000lb of dry-matter per acre.

The high correlation between worm weights in grammes per square foot, and dry matter yields in thousands of pounds, is sufficient proof, if proof were needed, that the earthworm lives directly or indirectly on organic matter derived from the pasture plant, yet in those plots which redeive no return of animal ex-

FIG. II.



creta neither the top growth nor its equivalent becomes available to the worm for food, since this is either grazed or mown off. Thus the only major source of organic matter remaining, to the earthworm is the accumulation of dead plant roots in the turf. It is upon this accumulation then that the earthworm subsists, and this is large enough in an 80001b. no-return pasture (see Fig. 2) to support 13.3 grammes of earthworms per square foot. A glance at the regression lime for the dung and urine no-fertiliser plots shows however that an 80001b. excrement-receiving pasture would support 14.3 grammes of earthworms per square foot, the extra, gramme per square foot being supported apparently upon the dung returned, the return of dung and urine increasing the earthworm-carrying capacity of a pasture by approximately 1 gramme per square foot or lcwt. per acre. The pasture worm feeds primarily, therefore, upon the, dead plant root,. and also to a small extent, it would seem, upon the dung. returned.

Fig. 2 also shows that the chief agents in raising

the yield of wormed pastures are clover, dung and urine, and that. in the absence of clover the yield can fall. as low as 4000lb. of dry matter per acre per annum, while in the absence of both clover and dung and urine, it can fall as low as 15001b. of dry matter per acre per annum, and this despite an earthworm population of $4\frac{1}{2}$ grammes, or approximately 18 earthworms per square foot. It is evident, therefore, that the earthworm cannot supply missing nutrients, though it may play a considerable role in increasing the availability of those already present. These facts need to be stated because of the exaggerated claims that have been made for the earthworm as an agent of fertility, and it cannot be sufficiently stressed that in the absence of an efficient clover and adequate return of animal excreta, no major improvement in pasture production can be expected.

Again it can be seen from Fig. 2 that certain treatments, such as the application of. lime, seem specially favourable to earthworms, while other treatments, such as the application of superphosphate in the absence of an adequate return of dung and urine seem unfavourable to earthworms.

In conclusion it is obvious that the main agents in increasing pasture production are plant nutrients and better plant species, and that if earthworms increase pasture production they .do so to a very much smaller extent, but whether we can grow high-producing pasture on an average soil in the complete absence of earthworms has yet to be determined.

Concurrently with the pasture counts various pot trials were undertaken, to determine (1) what earthworms feed upon, and (2) what effect earthworms have upon the growth of pasture plants.

The worms used in the feeding trials were mainly *Allolobophora caliginosa*. These worms, offered (a) dead grass root and (b) ground grass-and clover, fed at the surface of the soil, lost 11 per cent. and 14 per cent. of their weight respectively, but when fed at the surface on ground sheep's dung, gained weight by 32 per cent. showing that it was not the way in which the former foods were fed that made them unavailable, but something about the foods themselves. When, however, the ground grass and clover or ground dung was mixed into the soil, the weight of the worms was more than doubled.

Now it was noticed that when the ground grass

and clover was mixed into the soil, it soon became heavily attacked by fungal hyphae, whereas when it was fed at the surface, there was little fungal action *on* it. It was also observed that when fresh grass and clover were fed at the surface, both remained relatively untouched until they had reached the moist brown wilt stage, but that when this stage had been reached, they were attacked avidly, with a resultant gain in weight of up to 23 per cent.

It appears then from these trials that the earthworm feeds omnivorously on all pasture foods, but it seems probable that before some of them become available to the earthworm they must first have undergone some decomposition by the bacteria or fungi. It is also evident that foods fed beneath the ground are much more available to the earthworm than foods fed above it, so that it would seem likely that the earthworm is mainly a subterranean feeder, supplementing its diet of decomposing plant roots with small amounts of dung and fresh material from above ground.

In the first pot trial, undertaken'to determine the effect of earthworms on plant growth, the weight of dry soil placed in the pots (6000 grammes) and the weight of dry ground sheep's dung mixed into the soil (200 grammes) was kept constant, while the number of earthworms *(Allolobophora caliginosa)* was varied from pot to pot.

At the end of 2 months the worms were removed and the soil from each pot divided equally among three smaller pots, each of which was then planted with four ryegrass tillers of the same size, all tillers being taken from the same mother plant.

The following are 'some of the yields for the period 28.8.49-20.12.49.

Table I

Dry **Ryegrass Herbage** in Grammes per Pot

Treatment	No Worms	200 Worms	Increase
No Dung .	1.0	2.9	1.0
With Dung .	6.5	12.3	5.8*

The difference significant at the 5 per cent. level, i.e. that greater than 4.2 is marked with a-n asterisk. Numbers of earthworms less than 200 per pot gave proportionately smaller increases, but these increases were not statistically significant.

It can be seen from the table that compared with the treatment, 'fno worms plus dung," the treatment "200 worms plus dung" doubled the growth of the ryegrass, and that this increase was significant, whereas compared with the treatment "no worms no dung," the treatment "ZOO worms no dung" gave no significant increase.

It was concluded from this that earthworms can increase the growth of ryegrass, provided that dung, or probably any nutritive pasture residue, be present in the soil.

'Since the earthworms in the dung pots increased in weight during the experiment, and since there was in consequence no possibility of a manurial effect, it would seem from observations made on the structure of the soil at the time the ryegrass tillers were' planted, that the subsequent increases in growth produced by the earthworms were largely the result of improved soil structure, though the possibility that the increases may have been due to the secretion by the earthworms of special growth-promoting substances must not be overlooked.

The next pot trial was undertaken in an attempt to determine what effect earthworms have on the growth of ryegrass and white clover, (a) when grown separately, and (b) when grown together.

There were three replications, each consisting of eight pots.. The first pair in each. replication was sown to ryegrass, the second pair to white clover, the third pair to ryegrass and white clover intermingled, while in the fourth pair half the surface was sown to ryegrass and the other half to white clover, the grass being separated from the clover by a tin partition resting on the surface of the ground. When the grass and clover had established *24 Allolobophora caliginosa* were added to one pot in each pair.

The gains in yield and the nitrogen content of the herbage are given in the following table.

TABLE II

Treatment (+ W = + Worms)	Yields per Pot		Relative Yields		Relative N_2 Content	
	Grass	Clover	Grass	Clover	Grass	Clover
Grass	2.8		100		100	
Grass + W	5.0		177		111	
Clover		49		100		100
Clover + W		50		102		104
Grass + Clover Mixed	1.8	39	100	100	100	100
Grass + Clover Mixed + W	3.9	43	213	110	106	103
Grass + Clover Separate	3.2	36	100	100	100	100
Grass + Clover Separate + W	5.0	35	155	97	114	103

It was concluded:—

1. That the addition of earthworms produced a highly significant increase in the ryegrass yield, and where the ryegrass was not intermingled with the clover but grown alongside it a significant increase in the percentage of nitrogen.
2. That the addition of earthworms produced no significant change in either the yield or the nitrogen content of the clover.
3. That the most general effect of adding earthworms was to increase the yield and nitrogen content of the ryegrass;
4. That the most pronounced effect of adding earthworms was the prevention of the suppression of the grass by the clover.

Practically all the earthworms were recovered from the pots in all cases, but the loss in weight was up to 33 per cent. Whether therefore the increases in growth were due to aeration, or to special chemicals released by the earthworms, or simply to direct loss of nitrogen from their bodies as a result of loss of weight, is not known.

Since however it had been shown in a previous experiment that earthworms can effect an increase in the growth of ryegrass, the most interesting aspect of this experiment was that no increase was obtained in the growth of the white clover.

To see if the same results are obtained under pasture conditions an experiment is being set up consisting of eight pots, each 3ft. in diameter and 3ft. deep, with wire mesh bottoms. These pots are sunk 3ft. into the ground and have wire mesh upstands to prevent earthworms entering or leaving them. They will be sown, to grass and clover, and when these are established live earthworms will be added to four of the pots and dead earthworms to the other four. The conditions in these pots will be as near actual pasture conditions as can be obtained while still retaining control of the earthworm population.

In conclusion then, pot experiments at Grasslands have shown substantial increases in the growth of ryegrass as a result of earthworm activity, but little or no increase in the growth of white clover. Since, however, no attempts have been made anywhere to measure the effect of earthworms upon the growth of grass and clover under actual pasture conditions, it is not yet possible to say whether or not earthworms increase the growth of pasture, but it is hoped that an experiment now being laid down at Grasslands will provide this answer in the near future.