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ASSOCIATION INTERNATIONALE
DES FABRICANTS DE SUPERPHOSPHATE (I.S.M.A.)

COMITÉ AGRONOMIQUE

1 Avenue Franklin D. Roosevelt, Paris 8e

JOINT TECHNICAL AND AGRICULTURAL MEETING

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Subject : 2 C

EFFECT OF PARTICLE SIZE ON THE EFFECTIVENESS OF FERTILISERS

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The improved physical characteristics of granular fertilisers in respect of handling, storage and distribution in the field has focussed attention on the problem of whether granulation has at the same time conferred any agronomic advantage or disadvantage.

The work carried out on this subject has been concerned in the main with phosphorus, since it has been assumed that differences in the agronomic effects are likely to involve phosphorus rather than N or K. Perhaps this assumption is unwise and more work is needed on this point. Further, much of the work has been concerned with water-soluble phosphorus, since earlier work showed that - in respect of insoluble phosphoric fertilisers, such as ground mineral phosphate and basic slag -fineness of particle size was related to effectiveness.

In 1950, Sherman and Hardesty (1) reviewed the experimental work on agronomic effects of particle size of superphosphate and of mixed fertilisers containing superphosphate or other water-soluble phosphate. This review covered work carried out in U.S.A., Canada, England, Scotland, France, Netherlands, Germany, Sweden and the Soviet Union. They concluded "that the experiment showed no marked difference in effects of granular and non-granular fertilisers on crop yields, though, on the other hand, some of the results have been decidedly favourable to the granular products". This was particularly true of the work conducted by Franck in Sweden. They emphasise, however, that in the U.S.A. "only little attention has been given to such factors as degree of water solubility of the P_2O_5, fertiliser placement, soil type, "phosphorus fixing" power and plant characteristics in relation to the respective crop-producing efficiencies of granular and non-granular fertilisers".

The review by Sherman and Hardesty has been summarised by Staroetka as follows :

> "Localised vs. mixed placement (23 experiments) : ('mixed placement' is taken to refer to the practice of broadcast distribution of fertilisers with subsequent cultivation into the soil.)

No significant differences in crop yields were shown between localised and mixed placement in 50 % of the experiments.

Almost 50 % of the experiments showed that localised placement caused an increase in yield over mixed placement. Not all of the results were statistically

analysed.

Size of particles within localised treatments
(47 experiments)

About 50 % of the experiments showed no significant differences due to size of particle.

About 25 % of the experiments showed an increase in crop yield due to use of large granules (2 mm and over) or briquets. Most of these experiments were on podzolic, lateritic, or low P_2O_5 soils.

About 10 % of the experiments favoured a medium sized granule (2.00 - 0.42 m Most of the experiments were on loamy soils.

About 15 % of the experiments favoured either a powder or very fine granules (0.4 - 0.1 mm). Most of these were on sandy or sandy loam soils or in pot experiments. Not all of the results were statistically analysed.

Size of particles within mixed placements (22 experiments)

No significant differences in crop yield due to particle size were shown within mixed placement in 65 % of the experiments.

About 35 % of the experiments favoured a large particle size. All of these were either in pot experiments or podzolic soils. Not all of the results were statistically analysed.

Granulated dicalcium and tricalcium phosphates

One experiment dealing with these materials indicated that "granulated dicalcium phosphate produced a poor crop yield and granulated tricalcium phosphate produced a very poor crop in comparison to the powdered material."

Some of the American experiments can be criticised on the grounds that the levels of P_2O_5 applied per acre were so high that differences in responses could not be expected. For example, in several of the trials, 2,000 lb per acre of a 4 : 8 : 7 fertiliser were applied. In other cases, it has not been possible to interpret the value of the results since the composition of the fertiliser, rates of application and size of granule, were not quoted.

The following selected items from experiments reviewed may be of interest :

"The differences in yield data as regards particle size were without statistical significance, but, with Cecil soil, the phosphorus-uptake data showed an interesting trend. With band placement, the particle size of the superphosphate had no influence on the percent. of phosphorus in the plants that was derived from the applied phosphate. However, when the phosphate was mixed with the top third of the soil, the percent. of phosphorus derived from the fertiliser increased with increase of particle size from 69% for the regular superphosphate to 92% for the granular material of 4.8 - 3.4 mm. With the large granules the 'mixed' placement was as effective as the 'band' application."

"Pellets of 'soluble phosphates' were compared with powdered phosphates in bands when mixed with the soil. The pellets gave a greater yield the year when mixed with the soil but a lesser yield than the powdered phosphate when applied in bands".

"There is no significance difference in the effectiveness of granulated and powdered triple superphosphate in the present experiments. The maximum size of the granule was, however, only 4.7 mm and larger granules might prove more effective. Granulation is generally associated with water-soluble forms and it is noteworthy, therefore, that granulated steamed bone tends, if anything, to be slightly superior to ordinary steamed bone flour. This indicates that some water-insoluble phosphates of this type might probably be granulated without any adverse effect on their manurial value. Since granular products are convenient to handle and distribute, this possibility is of practical interest."

"The assimilability of granular $CaHPO_4$ is appreciably reduced as compared with that of superphosphate or pulverulent $CaHPO_4$, irrespective of the nature of the soil. Granular $Ca_3(PO_4)_2$, gives even less satisfactory results. The larger the grain, the less satisfactory the results given by granular $CaHPO_4$. This phenomenon is absent in the case of water-soluble phosphates (superphosphates). Addition of the latter to fertilisers containing insoluble phosphates, or finer granulation, reduces the disadvantages due to the granular state."

SUMMARY OF SOME EXPERIMENTAL WORK CARRIED OUT AT THE I.C.I. RESEARCH STATION, Jealott's Hill, Berkshire, on the effect of particle size on the agronomic efficiency of phosphatic fertilisers (2)

SUPERPHOSPHATE

Experiment I

The recovery of P_2O_5 from superphosphate, pelleted and powdered, was compared in a box experiment using oats and wheat as test crops.

Soils : Oat crop - a sandy soil, pH 5.7
Wheat crop - a heavier soil, pH 6.5

Treatments :
Superphosphate pellets - 3.2 mm, 4.8 mm, 6.4 mm, all drilled.
Powdered superphosphate drilled.
" " broadcast.
Control - No phosphate applied.

Results :
(1) In no case did superphosphate pellets drilled with the seed lead to significantly greater uptake of phosphorus than powdered superphosphate drilled with the seeds.

(2) Superphosphate pellets drilled with the seed gave a significantly greater uptake of phosphorus than powdered superphosphate broadcast on oats but not on wheat.

(3) There were no significant differences in uptake from pellets of different sizes.

(Although the recovery from the pellets did not differ significantly from the powdered superphosphate - both drilled with the seed - there were slight indications that the pellets might, in some circumstances, be superior to the powder.)

Experiment II

In the following year, the above experiment was repeated in the field using micro-plots with two crops - spring oats and swedes - on a phosphate

deficient soil.

Treatments and rates of application were as described in expt. I above, a basal dressing of 1 cwt/acre potassium chloride being applied to all plots. The oats were drilled in contact with the fertilisers. The swedes and fertiliser were drilled separately, the latter being 3.8 cm to the side and 2.5 cm below the seed, which was sown 2.5 cm deep.

Results :

On a soil deficient in phosphate and of average fixation capacity, the recovery of phosphorus by oats and swedes from pelleted superphosphate was not differen from powdered superphosphate, both drilled with or near the seed. In the case of swedes only, however, the crop yield was higher from the powdered form.

SUPERPHOSPHATE AND NITROPHOSPHATE

Experiment III (Pot culture)

To compare the availability to Italian ryegrass on a range of soils of granular and powdered superphosphate, granular nitrophosphate and the same product ground to pass a 1 mm mesh.

Treatments :

Granular supers. 2.4 - 3.3 mm.
Powdered supers. passing 1mm mesh.
Nitrophosphate granular.
" fines passing 1mm mesh.

Soils : (1) A calcareous soil, pH 7.9
(2) A neutral soil, pH 6.9
(3) An acid soil, pH 5.5

Rate of application - equivalent to 60 lb/acre P_2O_5.

Results :

Granular vs. powdered superphosphate.

Recovery of P_2O_5 :

The uptake of phosphorus was significantly less from the granulated superphosphate on the neutral and acid soils but not significant in the case of the calcareous soil.

Yields :

The powdered superphosphate gave a higher dry weight than granular superphosphate on all soils but the difference was only significant in one case - on the acid soil.

Nitrophosphate :

The uptake of phosphorus from the fines was significantly greater than from the granules on two out of the three soils, and greater (but not significantly so) on the third (the calcareous soil).

Taking superphosphate as a standard, the best over-all response to nitrophosphate (as measured both by uptake of phosphorus and by dry weight increase over control) was on the acid soil, slightly poorer on the neutral soil, and much poorer on the calcareous soil.

Experiment IV (Pot culture)

To compare the availability to Italian ryegrass on a range of soils of nitrophosphate (granules and fines) and superphosphate (two samples).

Soils used and rate of application were as for expt. III above.

Recovery of P_2O_5 : Uptake of phosphorus from both nitrophosphate granules and fines significantly less than from superphosphate. On the calcareous soil, the nitrophosphat (both granules and fines) did not have an uptake significantly greater than control. There was a relationship between the recovery of phosphorus from nitrophosphate and the pH of the soil, the lower the pH the better recovery.

Yields : A difference between nitrophosphate granules and fines was found on comparing their respective dry weights with those from the two superphosphates. With nitrophosphate granules the dry weights were significantly less than with the two superphosphate except in one case, whilst with the nitrophosphate fines, the differences from the two superphosphates were not significant, except in one case (6 possibilities of difference).

DICALCIUM PHOSPHATE DIHYDRATE - $CaHPO_4 2H_2O$

Experiment V (Pot culture)

To compare the availability to Italian ryegrass on a range of soil of the phosphorus in dicalcium phosphate dihydrate of varying aggregate sizes and in superphosphate.

Treatments :

$CaHPO_4 . 2H_2O$ aggregate size 2 - 1 mm
" " " 1 - 0.126 mm
" " " <0.126 mm
Superphosphate.

Rate of application - equivalent to 60 lb/acre P_2O_5 .

Soils : As for expt. III

Influence of degree of aggregation of $CaHPO_4.2H_2O$ crystals on yield (dry weight) :

The differences are summarised in the following table :

Soil	Aggregate sizes compared: 2 - 1 mm vs. 1 - 0.126 mm	2 - 1 mm vs. <0.126 mm	1 - 0.126 mm vs. <0.126 mm.
A. (pH 7.5)	Not significantly different in dry weight	<0.126 significantly greater dry weight	Not significantly different
B. (pH 6.9)	1 - 0.126 mm Significantly greater dry wt.	<0.126 mm significantly greater dry weight	Not significantly different
C. (pH 5.5)	Not significantly different	Not significantly different	Not significantly different

Influence of aggregation of $CaHPO_4.2H_2O$ crystals on total uptake of P_2O_5 :

Soil	Aggregate sizes compared		
	2 - 1 mm vs. 1 - 0.126 mm	2 - 1 mm vs. <0.126 mm	1 - 0.126 mm vs. < 0.126 mm.
A. (pH 7.5)	Not significantly different	<0.126mm significantly greater uptake	Not significantly different
B. (pH 6.9)	1 - 0.126 mm Significantly greater uptake	< 0.126 mm significantly greater uptake	Not significantly different
C. (pH 5.5)	Not significantly different	Not significantly different	Not significantly different

Experiment VI (Pot culture)

To compare the availability to Italian ryegrass of superphosphate and of dicalcium phosphate dihydrate, of varying aggregate size.

The tests were done on two phosphorus deficient soils - one pH 5.5 and the other pH 7.7.

Rate of application - equivalent to 60 lb/acre P_2O_5

Material used :

$CaHPO_4.2H_2O$ aggregate size 2 - 1 mm
" " " 0.5 - 0.25 mm
" " " <0.126 mm
Superphosphate

Yields : On the acid soil, the dry weight increased with increasing aggregate size but the differences were not significant. On the calcareous soil, the dry weight decreased with the increasing size, the difference being significant between the largest and the two smaller sizes. Compared with superphosphate, on the acid soil all samples of dicalcium phosphate resulted in a higher dry weight, though the differences were not significant. On the calcareous soil, the two smaller aggregate sizes gave a greater dry weight than the superphosphate treatment, though the differences were not significant.

Availability : On the acid soil, the greatest uptake was of P_2O_5 from the 0.5 - 0.25 mm treatment but none of the differences was significant.

On the calcareous soil, the uptake from the 2 - 1 mm treatment was significantly less than from the two smaller aggregate sizes, which, however, did not differ significantly from one another.

Experiment VII (Pot culture)

To compare the availability to Italian ryegrass and mustard of anhydrous dicalcium phosphate and dicalcium phosphate dihydrate, powdered and pelleted anhydrous dicalcium phosphate alone and mixed with ammonium nitrate.

Tests were done on two phosphorus deficient soils : one pH 5.0 and the other pH 7.6.

Materials used :

(1) $CaHPO_4$ - all passing 0.15 mm mesh
(2) $CaHPO_4$ - pelleted 3.2 mm
(3) Fertiliser (1) mixed with NH_4NO_3
(4) do. pelleted 3.2 mm
(5) $CaHPO_4 . 2H_2O$
(6) Superphosphate

Earlier work showed that the response to $CaHPO_4.2H_2O$ in terms of crop growth decreased with increasing sizes of aggregates.

In expt. VII, powdered $CaHPO_4$ (less than 0.15 mm sieve) compared with pelleted material (3.2 mm), both dry weight and P_2O_5 uptake were definitely less from the pelleted material.

In comparison between pellets of $CaHPO_4$ alone and of $CaHPO_4/NH_4NO_3$, the pellets of the mixture resulted in greater yields (both treatments had the same amount of fertiliser N).

The difference in effectiveness may, possibly, be accounted for by the fact that the pellets of $CaHPO_4$ alone disintegrated very slowly, while the mixture disintegrated very quickly in water.

SUMMARY

The Jealott's Hill experiments summarised above reveal no significant differences in efficiency, as assessed by yields and uptake of P_2O_5, between granular and powdered superphosphate over a range of soil types.

In the experiments reviewed by Sherman and Hardesty (1950), the results do not show any clear cut and consistent pattern, and though the balance of advantage - if any - may tend to rest with the granular product, the results conform fairly closely with those obtained in the Jealott's Hill experiments.

This is contrary to the findings of Franck in his experiments on Swedish soils, where granulation of superphosphate was held to confer agronomic advantage.

There is some evidence to indicate that soil characteristics and plant characteristics (type of crop plant employed) may have an important bearing on the relative crop-producing efficiencies of granular and non-granular water-soluble phosphatic fertiliser.

In the case of nitrophosphate and dicalcium phosphate (Jealott's Hill experiments), there was a tendency for the response to these fertilisers - in terms of yield and uptake of P_2O_5 - to decrease with increasing particle size. Not unexpectedly, the pH of the soil appeared to have a marked effect on efficiency, these fertilisers being much less efficient on calcareous than on acid soils.

CONCLUSIONS

It is concluded that, over a wide range of arable soils, particle size (within the normal range) has little effect on the agronomic efficiency of water-

soluble phosphatic fertilisers or on mixed fertilisers based on water-soluble phosphates, but that the balance of advantage, if any, rests with the granular product

At the same time, there may be soil types where granulation of these fertilisers does effectively increase their agronomic efficiency. In no case, however, does granulation exert such a marked effect on efficiency as band placement.

REFERENCES

(1) Plant-Food Memorandum Report No.20 - "Review of Experimental Work on the Agronomic Effects of Particle Size of Superphosphate and of Mixed Fertilisers containing Superphosphate or other Water-Soluble Phosphates", by Mildred S. Sherman and John O. Hardesty, Division of Fertiliser and Agricultural Lime Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U.S. Department of Agriculture, Beltsville, Maryland, 1950.

(2) Imperial Chemical Industries Ltd., Research Station, Jealott's Hill, Berkshire.
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