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# NUTRITION OF GLASSHOUSE STRAWBERRIES WITH NITROGEN, PHOSPHORUS AND POTASSIUM

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## ABSTRACT

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A study was made of the fertilisation of glasshouse soil and nursery beds in the open for strawberries. The response of the crop to variations in fertiliser treatment was greater in the nursery beds than in the glasshouse. Only nitrogen dressings were of some importance under glass, but too much nitrogen proved to be harmful. The correct fertilisation of the nursery beds with nitrogen and potash is most important. Basic slag proved to be a suitable phosphate fertiliser for the nursery beds, but triple superphosphate cannot be recommended.

## INTRODUCTION

The river loam area situated between the main rivers in the centre of The Netherlands is an important area for the production of strawberries under glass. In this area about 150 ha of glasshouses are being used for growing strawberry, resulting in an annual turnover of about 12,000,000 Dfl.

The crop is grown as follows. Runnerplants are collected and planted out on a nursery bed in the open at the end of July. The plants remain on the spot where they root and develop. When necessary, the plants are watered by an overhead sprinkler system. At the end of November or the beginning of December the plants are lifted and brought, with their roots bare or hidden in clods of loam, into the glasshouse where they are planted out in the border soil. In the middle of February a black or white polythene sheet is placed as a soil mulch. The plants are then irrigated by perforated plastic tubes underneath the polythene sheet. The plants root and develop, and after flowering and pollination by bees, fruits can be picked. The fruit is harvested from early April until early June depending on whether the crop is grown with heat and artificial irradiation or not. Anonymous (1971) gives a description of the growing-system practised in the U.K.

Some of the trials to be described were performed during the propagation stage, viz. by various dressings of the nursery beds and subsequent determination of the yield of the plants brought into the glasshouse. Other trials were run under glass by varying the dressings of the glasshouse border soil.

There is very little literature dealing with the nutrition of glasshouse strawberries, as compared with that for the outdoor crop, and the latter will be of no help, as redistribution of minerals in October and November probably plays an important role. In unpublished experiments we found that of the total amount of nitrogen and sulphur the larger part was taken up in the first 3 months on the nursery bed.

Previously, the senior author studied the effects of organic fertilisers on the crop (Roorda van Eysinga, 1970), which investigation showed that the application of frosted black peat to the glasshouse soil had a favourable effect and that plants grown on nursery beds dressed with farmyard manure had a greater production capacity than plants grown without. The results obtained with nitrogen, phosphorus and potassium dressings in experimental plots will be discussed in this paper. For more detailed information the reader is referred to Roorda van Eysinga and Van Caem, 1976.

## MATERIALS AND METHODS

Most of the experiments were carried out on river loam. The glasshouse soils had a clay content varying between 12 and 22%, with an average of 18% and in the nursery beds it varied between 17 and 30%, with an average of 24%. The river loams are calcareous soils with 0.4 to 1.8% $CaCO_3$. The average pH-water in the nursery beds was 7.4 and in the glasshouses 7.1. The organic matter content of the nursery beds varied between 3 and 7%, with an average of 4.5%. The glasshouse soils in the river loam area are relatively rich in organic matter, because in the past, growers used a lot of frosted black peat and composted town refuse (60 : 40 v/v). The organic matter content of the glasshouse soils varied between 4 and 15%, with an average of 8%. The soil samples were drawn from the top 25 cm layer.

For soil analyses carried out before 1973 the samples were dried first and then extracted with water in the proportion of 1 : 5 w/v. After 1973, fresh soil samples were added to water in a 1 : 2 volume extract (Sonneveld and Van den Ende, 1971). With the old method, the analytical figures obtained were expressed as mg N, $P_2O_5$ and $K_2O$ per 100 g of dry soil. With the new method, the figures are expressed as mval N, mg P and mval K per litre extract. In order to characterise further the phosphorus and potassium contents of the soil, dried soil samples were used for the determination of P-AL and K-HCl which were expressed as mg $P_2O_5$ and mg $K_2O$ per 100 g dry soil (De Vries and Dechering, 1960).

The fertilisers used in the experiments were calcium ammonium nitrate (23% N, except in the final experimental year, 1975, when the N content was 26%), calcium nitrate (15½% N), triple superphosphate (about 43% $P_2O_5$), dicalcium phosphate (41% $P_2O_5$), basic slag (18% $P_2O_5$) and potassium sulphate (48% $K_2O$). In one experiment, sulphur coated urea (Gold-N, 38% N) was used. In 2 experiments (IB 1145 and IB 1585) nutrition of both the nursery beds and the glasshouse soil was studied in a factorial combination. Since no interaction could be found, both parts will be treated as separate experiments. The nutrient elements not subject to investigation, were supplied in optimum quantities as far as possible. Top dressings in the glasshouse were applied in liquid form via a Soluply lay-flat irrigation system. No top dressings were applied to the nursery beds. The strawberry cultivar used in almost all the experiments was 'Glasa'. In the nursery bed experiments — usually carried out with 5 replicates — plants which had received the same treatments were put together during lifting. Rogue plants — about 10% — were removed and discarded. After lifting, the batches were divided into the number of replicates — generally 3 or 4 — included in the glasshouse experimental design.

Leaf samples were collected for analysis in a number of experiments, in particular those in which the fertilisation of the glasshouse soil was being studied. The samples consisted of fully-grown leaves plus petioles collected at first flowering. In other tests whole plants were collected for sampling during lifting from the nursery beds. The plants were cut about 1 cm above the roots. After drying, the aerial and subterranean parts of the plants were analysed separately.

## RESULTS

*Nitrogen.* — Four experiments were carried out in which the nitrogen fertilisation of the glasshouse soil was studied in a normal crop, and 2 experiments were carried out with perpetual-fruiting strawberries which give a crop in autumn. Only 1 of these experiments (IB 1145) produced a statistically significant effect. The yields reacted to increasing quantities of nitrogen with an optimum curve Table 1. In mid-March the nitrogen contents of the soil (IB 1145) were 1.7, 2.2, 9.8 and 15.0 mg N per 100 g of dry soil, respectively. By mid-May, at the end of the harvest, the levels had dropped through repeated

TABLE 1

Yields in g per plant (10 plants per $m^2$) following the application of calcium ammonium nitrate to the glasshouse soil (IB 1145)

| | kg calcium ammonium nitrate per 100 $m^2$ | | | |
|---|---|---|---|---|
| | 0 | 7.5 | 15 | 30 |
| g per plant | 190 | 205 | 188 | 172 |
| Relative | 100 | 108 | 99 | 91 |

Statistical evaluation: linear N-effect $P = 0.01$; quadratic N-effect $P = 0.06$.

watering to 0.8, 0.7, 3.0 and 2.9 mg N, respectively.

At 2 experimental sites it was observed that the plants on unfertilised plots were lankier than those on fertilised plots. One of these trial sites was on marine sand at the Research Station at Naaldwijk, on which a normal crop was grown. The other site was at the Experimental Station at Zaltbommel (river loam) on which a crop of perpetual-fruiting strawberries of the cultivar 'Ostara' was grown. In both experiments different quantities of base dressings and topdressings of calcium nitrate were applied. Experimental data and yield results are shown in Tables 2 and 3. At the beginning of the harvest, at Naaldwijk, the N-water figures varied from 0.9 mg N per 100 g dry soil on completely unfertilised plots, to 3.0 mg on the heaviest fertilised plots. At the beginning of harvest on river loam (at Zaltbommel) the N-water figures varied from 1.9 to 14.0 mg N per 100 g dry soil, at the end of harvest from 0.6 to 4.7 mg N. The base dressing was reflected quite clearly in the analytical results, but the top dressing not at all.

In spite of the fact that on the untreated control plots at the 2 sites mentioned the plants were retarded, there was no great difference in yield. Compared with the averages of the fertilised plots, the yield differences were

TABLE 2

Yields in g per plant (7.3 plants per m$^2$) as a result of base dressings of calcium ammonium nitrate and top dressings of calcium nitrate in a glasshouse on marine sand

| Calcium nitrate (kg per 100 m$^2$) | kg calcium ammonium nitrate per 100 m$^2$ | | |
|---|---|---|---|
| | 0 | 2 | 4 |
| 0 | 131 | 145 | 138 |
| 2 | 139 | 139 | 140 |
| 4 | 134 | 144 | 140 |

Statistical evaluation: no significant effects.

TABLE 3

Yields in g per plant (8 plants per m$^2$) as a result of base dressings of calcium ammonium nitrate and top dressings of calcium nitrate with perpetual-fruiting strawberries in a glasshouse on river loam

| Calcium nitrate (kg per 100 m$^2$) | kg calcium ammonium nitrate per 100 m$^2$ | | |
|---|---|---|---|
| | 0 | 7.5 | 15 |
| 0 | 189 | 195 | 199 |
| 3 × 2 kg | 214 | 203 | 190 |

Statistical evaluation: effects of N top dressing treatments not significant; interaction significant ($P = 0.05$).

8% on the marine sand and 4% in the case of the perpetual-fruiting strawberries at Zaltbommel.

The conclusion must be that strawberries prefer a relatively low nitrogen content in the glasshouse soil. An N-water figure of 2 mg N per 100 g dry soil would appear to be adequate. According to the 1 : 2 volume extract method, this is equivalent to about 1 mval N per litre extract. For comparison, the optimum for tomatoes and cucumbers is considered to be 4 to 4.5 mval N.Excessive nitrogen dressing can be very harmful for strawberries. Too little nitrogen in the soil can result in a sparse stand of the crop, giving a yield loss of about 6%.

In one experiment sulphur coated urea was tried. Hindsight showed that the glasshouse soil in question was too rich in nitrogen to show any favourable effect of a fertiliser dressing. The coated urea produced a poorer grade (more small fruit) than the calcium ammonium nitrate (significant difference at $P = 0.05$) which is why the experiment was not repeated.

Nitrogen fertilisation of the nursery beds was studied on 1 trial site (IB 1145). Table 4 shows the quantities of nitrogen applied and the yield data. No irrigation was given initially and the heaviest fertilised plants were somewhat retarded in growth. Fungal diseases such as mildew occurred less, the more nitrogen was applied. From this experiment (Table 4) the conclusion may be drawn that the nursery beds for strawberries must be provided with quite a lot of nitrogen. On river loam at least 10 kg of calcium ammonium nitrate (2.5 kg N) should be applied per 100 m$^2$ and with irrigation 15–20 kg (3.75–5 kg N) is probably even better. On lighter soils such as sand, a considerably smaller dressing will be adequate. Because of its high moisture content, river loam has a strongly buffering-capacity which will help to prevent salt damage, while it probably also has ammonium-fixing properties.

TABLE 4

Yields in g per plant (10 plants per m$^2$) as a result of calcium ammonium nitrate dressings applied to the nursery beds (IB 1145)

| | kg calcium ammonium nitrate per 100 m$^2$ | | |
|---|---|---|---|
| | 0 | 10 | 20 |
| g per plant | 190 | 209 | 202 |
| Relative | 100 | 110 | 106 |

Statistical evaluation: 0 – (10 + 20) $P < 0.01$.

*Phosphorus.* — Two experiments were carried out in which the phosphate dressings of glasshouse soil were studied. The 2 trial sites were in different glasshouses on the same nursery (Table 5). The soil proved to be too rich in phosphate to show any clear effects. At the P-AL levels found, few crops will

TABLE 5

Yields in g per plant (10 plants per $m^2$) as a result of triple superphosphate dressings applied in 2 glasshouses

| Experiment | P-water | P-AL | kg triple superphosphate per 100 $m^2$ | | |
|---|---|---|---|---|---|
| | | | 0 | 5 | 20 |
| IB 1264 | 2.0 | 165 | 329 | 333 | 324 |
| IB 1265 | 1.9 | 120 | 267 | 272 | 255 |

Statistical evaluation: no significant effects.

show a response to phosphate dressings. As the 5 kg superphosphate dressing produced a slightly larger yield than the unfertilised plots in both cases, a dressing of about 2 kg $P_2O_5$ per 100 $m^2$ could probably be considered an optimum dressing for soils with low phosphorus levels, such as in a new glasshouse or one which is only a few years old.

Five experiments were carried out on nursery beds. In the first 2 experiments the investigation was concerned mainly with the effects of organic manure dressings, supplemented in some cases with 12.5 kg triple superphosphate per 100 $m^2$. Where the supplementary dressing had been applied, the average yields obtained at both experimental sites were slightly lower than where no superphosphate had been applied, but the differences were small and statistically not significant.

In experiment IB 1770 four levels of triple superphosphate dressings (0, 5, 10 and 20 kg per 100 m) applied to the nursery beds were compared. The experimental site was on a new nursery in a recently reclaimed area and, as expected, the phosphate levels in the soil were relatively low (P-water 1.1 and P-AL 49). Yields were reduced with increasing triple superphosphate dressings. This negative linear P-effect was statistically significant ($P = 0.03$).

In the ensuing years another 2 experiments were carried out under similar conditions on soil with low phosphate levels. In experiment IB 2019 the triple superphosphate dressings were combined with dressings of farmyard manure (750 kg per 100 $m^2$), or with mineral fertilisers only, or with mineral fertilisers plus trace elements. The latter were applied in the form of Sporumix Pg, a trace element fertiliser based on magnesium sulphate, and chelated iron Fe-EDDHA was also applied. The soil showed a P-water of 1.2 and P-AL of 47. Table 6 shows the results obtained.

In experiment IB 2269, other phosphate fertilisers besides triple superphosphate were tried on the basis of the same phosphorus contents. The soil had a P-water of 1.0 and P-AL of 52. The results are shown in Table 7.

It appears that triple superphosphate applied to the nursery beds has a negative effect on the production capacity of strawberry plants which are planted out in the glasshouse later on. An attempt was made in experiment IB 2019 to

TABLE 6

Yields in g per plant (10 plants per m$^2$) as a result of triple superphosphate dressings applied to the nursery beds in combination with farmyard manure or with fertilisers or fertilisers plus trace elements (IB 2019)

| | kg triple superphosphate per 100 m$^2$ | | |
|---|---|---|---|
| | 0 | 10 | 20 |
| Fertilisers | 178 | 166 | 161 |
| Fertilisers plus trace elements | 189 | 165 | 154 |
| Farmyard manure | 168 | 178 | 176 |

Statistical evaluation: interaction not significant, P-effect for mineral fertiliser and mineral fertiliser plus trace elements: $P = 0.04$.

TABLE 7

Yields in g per plant (10 plants per m$^2$) as a result of different quantities and types of phosphate fertilisers applied to the nursery beds (IB 2269)

| | kg $P_2O_5$ per 100 m$^2$ | | |
|---|---|---|---|
| | 0 | 2.15 | 8.6 |
| Triple superphosphate | 267 | 265 | 252 |
| Dicalcium phosphate | | 270 | 259 |
| Basic slag | | 278 | 280 |

Statistical evaluation: interaction not significant. Basic slag (triple superphosphate + dicalcium phosphate) $P = 0.01$.

prevent this negative effect by applying trace elements, but a mineral trace element fertiliser failed to achieve this. The use of farmyard manure for this purpose appears to be more effective. Basic slag proved to be an excellent fertiliser for use in nursery beds, but this could not be said for triple superphosphate or even dicalcium phosphate.

The reason for the negative effect of triple superphosphate was investigated by carrying out a chemical analysis of the plants from the nursery beds. Table 8 shows the contents of some trace elements which were found in the aerial and subterranean parts of the plants from the nursery beds on trial site IB 2269. The data shown were obtained by averaging the analytical figures obtained for the 3 controls and the 2 levels of 3 fertiliser treatments (2.15 and 8.6 kg $P_2O_5$ per 100 m$^2$). The average dry weight of the aerial and subterranean parts of the plants were 9.2 and 4.3 g respectively. The high iron and aluminium contents shown in the Table are remarkable. Triple superphosphate increased these contents, but basic slag had a similar effect which means that the explanation cannot be found in excessive iron and aluminium levels.

Of the trace elements investigated, the only one which could have a harmful effect is fluoride contained in triple superphosphate. It is known that fluoride taken up via the roots may cause damage to monocotyledonous bulbous and tuberous plants, particularly if they are grown in acid soils, resulting in excess symptoms, but sometimes also in growth inhibition only. The fluoride contents found (Table 8) seem to indicate this, but they do not prove the case. A fluoride content of 3—4 p.p.m. may not sound much, but it has proved to be excessive for certain sensitive crops such as freesias (Roorda van Eysinga, 1974).

*Potassium.* — Two experiments were carried out in which the effects of potash dressings of the glasshouse soil were studied. One of the experimental sites was low in potash (K-water 2.1 and K-HCl 16), whilst the other was rich in potash (K-water 14.2 and K-HCl 54). In spite of the fact that there were great differences in the amounts of fertilisers applied — varying from 0 to 40 kg sulphate of potash per 100 $m^2$ — no statistically significant differences in yields were found.

Potash fertilisation of the nursery beds was studied in 2 experiments. One trial site was relatively rich in potash (K-water 6.7 and K-HCl 36), whilst the other was low in potash (K-water 1.6 and K-HCl 21). Only the second trial site produced significant results (Table 9).

With potash as with nitrogen and phosphates, it is apparent that fertilisation of the nursery beds has a much greater effect on yields than fertilisation of the glasshouse soil. Where the potash level of nursery beds was low, a suitable

TABLE 8

Trace-element contents expressed as p.p.m. of dry matter in the aerial and subterranean parts of strawberry plants from nursery beds, comparing the effects of 3 phosphate fertilisers with an unfertilised control

| | Mn | Fe | Al | Zn | B | F |
|---|---|---|---|---|---|---|
| Aerial parts | | | | | | |
| No phosphates | 89 | 1,482 | 2,002 | 399 | 32 | 3.6 |
| Triple superphosphate | 102 | 1,892 | 2,443 | 399 | 34 | 4.3 |
| Dicalcium phosphate | 104 | 1,884 | 2,499 | 475 | 33 | 4.0 |
| Basic slag | 126 | 2,425 | 3,695 | 696 | 35 | 3.8 |
| Subterranean parts | | | | | | |
| No phosphates | 88 | 1,405 | 2,319 | 232 | 27 | 2.6 |
| Triple superphosphate | 103 | 2,338 | 3,340 | 177 | 27 | 3.2 |
| Dicalcium phosphate | 134 | 2,141 | 2,772 | 275 | 27 | 2.4 |
| Basic slag | 105 | 1,911 | 2,552 | 265 | 28 | 2.7 |

TABLE 9

Yields in g per plant (10 plants per m²) as a result of potash applied to the nursery beds

| | kg sulphate of potash per 100 m² | | | |
|---|---|---|---|---|
| | 0 | 15 | 30 | 60 |
| g per plant | 218 | 209 | 233 | 224 |
| Relative | 100 | 96 | 107 | 103 |

Statistical evaluation: (0 + 15) – (30 + 60) $P < 0.01$.

dressing proved to be 30 kg sulphate of potash (15 kg $K_2O$) per 100 m². The soil type — river loam with potash-fixing properties — is likely to have played a part in the results.

*Crop analyses.* — Leaf samples were examined in order to determine the critical values of the nutrient elements in the leaves. Because of the disappointing results obtained in the experiments with various fertiliser treatments under glass, this was not possible. A list of the contents found is given in Table 10. This Table shows the extreme values found in the samples taken from the experimental sites.

There is hardly any information in the literature about the nutrient contents of strawberries grown under glass. For a comparison of the data shown in Table 10, the literature survey of Van der Boon (1965) was therefore used. The figures quoted by this author refer mainly to strawberry plants grown in the open. The N contents in Table 10 (total N) are similar to the data in the literature, but according to Van der Boon no agreement could be found on the desirable content. According to the literature good growth is assured with phosphate levels above 0.28% P, but according to one author there is luxury consumption above a level of 0.30%. Optimum levels for potash are considered to be between 1.5 and 2.0% K and higher levels indicate luxury consumption. In the case of magnesium, 0.30% Mg is indicated for

TABLE 10

Nutrient contents of recently-matured strawberry leaves

| | |
|---|---|
| Dry matter % of fresh weight | 17.7 —25.7 |
| N % of dry matter | 2.94— 3.72 |
| $NO_3$—N % of dry matter | 0.11— 0.46 |
| P % of dry matter | 0.32— 0.63 |
| K % of dry matter | 1.97— 3.04 |
| Ca % of dry matter | 0.59— 1.33 |
| Mg % of dry matter | 0.26— 0.51 |
| Na % of dry matter | 0.00— 0.03 |

maximum growth and 0.40% for the highest yields. Compared with the figures given by Van der Boon, the potash and phosphate contents given in Table 10 almost all fall in the luxury consumption range, which is borne out by the absence of clear responses in the fertiliser experiments under glass. Some of the magnesium contents are also well above the optimum level.

Chemical analyses of the plants from the nursery beds were carried out in the hope that an explanation might be found for the negative effect of triple superphosphate dressings of the nursery beds. The matter was discussed in the relevant paragraph. Some trace elements contents were shown in Table 8.

## CONCLUSIONS

Strawberries show a greater response to the fertiliser treatments of the nursery beds than to those of the glasshouse soil. In older glasshouse soils which are enriched by fertiliser residues, phosphate and potash dressings may be omitted. A small nitrogen base or top dressing may be recommended, if the nitrogen level is less than 1 mval N per litre 1 : 2 volume extract (= about 20 p.p.m. water soluble nitrogen of dry soil). Depending on the nutrient status of the soil, it may be necessary to apply heavy fertiliser dressings to nursery beds on river loam, i.e. 2.5—4 kg N and on soil low in potash, 15 kg $K_2O$ per 100 $m^2$. Phosphates should be applied to the nursery beds in the form of basic slag.

## REFERENCES

Anon., 1971. Strawberries under glass must average a high price. Grower, 75: 1155.

Boon, J. van der, 1965. Bemesting en vochtvoorziening van de aardbei. (Literatuurstudie). Inst. Bodemvruchtbaarheid, Rapp. 17, 124 pp.

Roorda van Eysinga, J.P.N.L., 1970. De organische bemesting van glasaardbeien op rivierklei. Bedrijfsontwikkeling, 1: 40—45.

Roorda van Eysinga, J.P.N.L., 1974. De opname van fluoride door de wortel en de gevolgen daarvan voor diverse gewassen, in het bijzonder fresia. Versl. Landbouwkd. Onderz., 821: 83.

Roorda van Eysinga, J.P.N.L. and Caem, H.E. van, 1976. De bemesting van glasaardbeien met stikstof, fosfor en kali. Inst. Bodemvruchtbaarheid, Rapp. 6—76, 26 pp.

Sonneveld, C. and Ende, J. van den, 1971. Soil analysis by means of a 1:2 volume extract. Plant Soil, 35: 505—516.

Vries, O. de and Dechering, F.J.A., 1960. Grondonderzoek, 4th ed. Ceres, Meppel, 215 pp.