Soil Conditions in Typical Lamsiekte and Styfsiekte Soils, as Revealed by Pot Cultures.

By J. P. VAN ZYL, B.A., Ph.D., Research Officer, Onderstepoort.

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§1. INTRODUCTION.

THAT a disease in cattle called "Lamsiekte" was already known in certain districts of the Cape (e.g. Piquetberg) well over a hundred years ago is evident from the report of the "Sheep Commission" appointed in the days of Commissioner van der Mist. According to Thael[1] they reported in 1805, *i.a.* that—

> "Het veld is daaromstreeks . . . onderhevig . . . aan Lamziekte."

and—

> "De plaatsen langs de Berg rivier . . . zijn geschikt . . . jaarlijks . . . enkelde maanden te worden gebruikt als een preservatief tegen lamziekte."

In referring to these early observations, Theiler[2] states:—

> "That the disease is identical with our lamziekte can be recognized from notes of the famous naturalist, Dr. Lichtenstein."

In the same article Theiler gives a very useful historical sketch of the early observations and work on lamsiekte and styfsiekte, and pays particular attention to the findings and views of Hutcheon[3], former Colonial Veterinary Surgeon to the Cape Government. It is very evident from Hutcheon's publications during the period 1880 to 1903 that, although he did not anticipate the existence of all the "links of the lamsiekte claim,"[4] nor indeed interpret the nature of the disease correctly[5], he was very definite in his view that *deficiency of available phosphorus in the soil and the resulting phosphorus deficiency in the vegetation* lay at the root of both lamsiekte and styfsiekte, which he erroneously regarded as different forms of one and the same disease.[6] Already in his report for the year 1882, the observation is recorded that styfsiekte is usually associated with a *great craving for bones* and is more prevalent in *dry seasons*.[7] His subsequent reports and writings abound in references to the relation between these diseases and the phosphorus content and water-holding capacity of the soil and the climate, as the following extracts show:—

> (1)[8] "In Griqualand West it (lamsiekte) is most prevalent along that elevated plateau called the Kaap Range, (where) the soil is principally calcareous . . . intermixed . . . with a red sandy loam, (whereas) . . . along the valleys of the Harts River . . ., where the soil is more of a clay loam, the disease is rarely seen; and when animals which are affected with the disease are removed to such localities, all symptoms of the disease disappear very rapidly . . . There are clear indications that

the vegetation which grows upon such soil (calcareous, silicious, red sandy loam) during the prevalence of the disorder is deficient in one most essential ingredient of a complete food, viz., phosphates. . . . I have hitherto found these diseases to prevail most on dry porous soils, such as the calcareous and the silicious, which have little power of retaining moisture, and on such soils they are most prevalent during dry seasons . . . and during the winter and spring months (refers to areas of summer rainfall), after the grasses have ripened and shed their seeds. . . . When the grass grows up luxuriantly after good rains . . . the disease suddenly disappears."

(2)[9] "Further inquiries . . . have tended only to confirm the opinion . . . that this disease is due to the defective nutrition . . . (which) arises principally from a deficiency of phosphates in the food . . . Young growing animals . . . for their bones . . ., cows . . . to manufacture milk, require . . . food rich in phosphates; hence . . . are the first to feel the deficiency."

(3)[10] "They (styfsiekte and lamsiekte) occur principally in districts in which the soil is light, sandy, or on porous limestone formations, such as cover a great part of Bechuanaland, Griqualand West, and many districts along the coast divisions, both east and west."

(4)[11] "The experiment (on bone-meal feeding to cattle, conducted by V. S. Borthwick[11a]) was a complete success and has clearly established the fact that a liberal allowance of bone-meal given to cattle where Lamziekte prevails acts as an effective preventive. . . . Where I have studied the disease, whether in Griqualand West, the East and West Coast districts . . . the main and constant conditions . . . are a *craving for bones*. . . . The disease is always associated with a deficiency of phosphates. . . . The contrast between the two lots of cattle . . . was distinctly in favour of those which received bone-meal."

(5)[12] " . . . I regard Lamziekte and Styfziekte as simply different phases of the same disease, arising from the same primary cause, a deficiency of phosphates. . . . It is quite possible also, that there are certain plants which, when eaten largely by cattle, may have a tendency to act as an exciting cause in hastening the development of the disease (i.e. producing the "lamsiekte form" of the disease). . . . But the main cause of the prevalence of this disease is undoubtedly due to the deficiency of phosphates in the food, and it disappears when that deficiency is supplied."

The views of Hutcheon are further summarised by Theiler[13] in the following words:—

"Styfsiekte and lamsiekte are two different forms of one and the same disease; the common factor in both, as the primary cause, is a want of phosphates in the system; this want may tend to produce styfsiekte, but when another exciting cause, possibly a plant, is present, lamsiekte may occur. The practical outcome of this view was Hutcheon's recommendation of feeding bone-meal as a preventive for both styfsiekte and lamsiekte."

That phosphorus deficiency was presumably the predisposing cause of lamsiekte and styfsiekte received further support from the chemical studies of Juritz[14] who, in the course of investigations into the composition of crops and soils from various divisions of the Cape Colony (now Province), during 1890 and subsequent years, was able to quote several instances where the soils from healthy farms were found to be relatively rich in phosphorus, but soils and crops from lamsiekte areas extremely poor in that constituent. Also Henry[15], in discussing certain diseases occurring in different parts of Australia, draws an analogy to S.A. lamsiekte, pointing out that the Australian diseases appear mainly during droughty seasons, are prevalent in areas where bone-chewing is marked, can be prevented by feeding skim milk to the cows and that phosphorus deficiency is presumably the cause.

After Theiler, Viljoen, Green, du Toit and Meier's[16] more recent investigations into the cause of lamsiekte had firmly established the importance of phosphorus as an " indirect " causal factor (thereby reconciling various earlier conflicting[17] opinions) and Green[18] had made a study of the variation of the phosphorus content of the Armoedsvlakte grazing (typical lamsiekte) throughout a period of 18 months, a so-called " Pica survey " was initiated by the Division of Veterinary Education and Research, with the object of obtaining a more thorough insight into the relation between osteophagia and the phosphorus content of soil and vegetation on the one hand, and osteophagia and the incidence of lamsiekte and styfsiekte on the other hand. Unfortunately this survey had to be abandoned whilst still in its initial stages; nevertheless considerable further data in support of the already available evidence relating to the important rôle of phosphorus was obtained. A report by Green, Marchand and van Zijl has still to be published, but in the popular article " Beenmeel as Beestevoer in Suidafrika "[19] in tables 1 and 3, a few average figures for P_2O_5, obtained in the course of this investigation, are already quoted, viz.:—

TABLE I.

Showing Differences between Pica and Pica-free Areas.

Designation.	Pica Soil.	Pica-free Soil.
	% P_2O_5.	% P_2O_5.
Soil phosphorus, soluble in strong HCl...............	0·033	0·045
Soil phosphorus, soluble in 1 per cent. citric acid......	0·0009	0·0060
Phosphorus-content of veld vegetation...............	0·12	0·31

Further, it was demonstrated by actual bone-meal feeding[20] that cattle, grazing over veld that was considered by practical farmers to be typical of lamsiekte or styfsiekte, benefited considerably by the additional phosphorus and rapidly lost their craving for bones; whereas on veld known to be free from lamsiekte and styfsiekte, pica was usually absent and bone-meal feeding had little or no effect.

§2. Purpose of Pot Experiments.

At this stage it was considered advisable to undertake a more detailed laboratory study of the influence of soil phosphorus, and possible other soil factors, on the phosphorus content of the crop. A fairly comprehensive pot culture experiment was therefore planned, for which three typical soils, about which definite knowledge had already been obtained in pica tests and field observations, were selected. Fairly large culture pots, holding about 30-35 Kg. each of dry soil, were used, as it was intended to use the same soil for several seasons. The experiment was arranged so that the influence of lime, phosphorus and full fertiliser could be followed and compared with controls receiving no fertiliser or full fertiliser without phosphorus; whilst a further set of pots was included with a view to following up the influence of the factor water content of the soil.

The objects aimed at in this investigation were in the main:—

(*a*) To see in how far the results of chemical analysis of samples of vegetation and soil from the field, on the one hand, and the results of actual pica-testing[21] on the other are borne out or capable of interpretation by comparison with the results of carefully controlled pot experiments.

(*b*) To obtain an idea of the extent to which the phosphorus content of the crop is influenced by factors such as physical nature, water content and acidity of the soil, excess of nitrogen-potassium, as apart from the influence of a varying phosphorus content of the soil.

(*c*) To study the relative rate at which the natural soil phosphorus, as well as the added fertiliser P., is removed from these three classes of soil by various crops, under various conditions and during several seasons.

(*d*) To be able to estimate roughly the relative amounts of water necessary for the production of unit weight of plant material on the different types of soil, kept at different degrees of moisture and subjected to different manurial treatment.

§3. Plan of Experiment.

The following Table II gives a general plan of the nature of the experiments finally decided upon:—

TABLE II.

Showing Plan of Experiment finally adopted.

Soil.	Water Content.	Differential Fertiliser Treatment.				
Armoedsvlakte. Sandy, shallow, on dolomite (lamsiekte)	High..........	Ca	CaKNP	O	CaKN	CaP.
	Low...........	Ca	CaKNP	—	—	—
	Minimum......	Ca	—	—	—	CaP.
	Varying.......	Ca	—	—	—	CaP.
Shepstone. Fine-grained loam from vlei, acid, deep (styfsiekte)	High..........	Ca	CaKNP	O	CaKN	CaP.
	Low...........	Ca	CaKNP	—	—	—
Verona East. Alluvial, clayey, deep (healthy)	High..........	Ca	CaKNP	O	CaKN	CaP.
	Low...........	Ca	CaKNP	—	—	—

It was the original intention to make the experiment fairly complete and to have for each treatment three parallel pots. Owing to the fact, however, that our institute had initially no equipment for work of this nature and that the "glass house" in which it became necessary to house the experimental pots was of limited size, it was impossible to include any more sets than those shown in the above plan (e.g. no K or N series) and on proceeding with the work it was further found necessary to reduce the O, CaP, and CaKN sets to two pots each for each soil. The Ca and CaKPN sets were composed of 6 pots for each soil for high and low water content respectively, as it was intended to grow two different crops on these sets simultaneously. Owing to a shortage of soil, it became necessary at the last moment to limit the two CaKNP Verona series to 5 pots each.

§4. PREPARATION FOR THE EXPERIMENT.

The soils were obtained from representative small areas from each of the three farms under examination. A small spot was shovelled superficially to clear away plant-growth and other foreign matter and about 50-60 Kg. then removed by digging to a depth of 20-25 cms. with an ordinary spade. A few yards further on the same process was repeated, and so on till a sufficient quantity of soil had been collected. The soil was dug out during winter, when it was fairly dry and forthwith bagged and despatched to the Onderstepoort Laboratory. Here the various bags of soil from the same farm were emptied into a large heap on a clean floor of boards in the open sun and mixed by throwing three times through a coarse sieve (6-7 mm. square mesh), which also served to remove stones and roots. Finally the soil was put through a fine sieve (2-3 mm. square mesh) and further mixed by shovelling into a new heap several times. Armoedsvlakte soil gave no trouble whatsoever and appeared to be very uniform. Shepstone soil contained a fair amount of root material and, judged by the colour, three distinct varieties of soil went into the mixture. A special effort was therefore made to obtain a uniform soil mixture in this case. The Verona soil consisted to a large extent of very hard lumps. To break these up successfully it was necessary to spray the lumps left on sifting and at the right moment, reduce them to a sufficiently fine state by beating with a spade. After final sifting this soil was then shovelled backwards and forwards several times during the next two days to ensure a proper air-dry state.

The circular pots, which were about 44 cms. deep and 30 cms. across, were fitted with the usual appliance for ensuring proper ventilation[22], after having previously been given a thick internal coating of so-called bitumen paint. A sufficient layer of clean granite chips to cover the base of the " ventilator " was put in and all the pots tared out to the same weight (12 Kg.). A quantity of soil sufficient to fill the pot nearly to the required level was taken from various parts of the soil heap, weighed out, and transferred to a large bin, where the fertiliser was thoroughly incorporated with it by hand mixing during several minutes. No filling appliance of any sort was available, but an attempt was made to ensure fairly uniform packing by transferring the soil of the pots in three approximately equal amounts and compacting the soil each time by slightly raising the pot and letting it drop to the ground three times. Finally 2 Kgs. of the same unfertilised soil was spread out on the top, so that the germinating seeds could have a " salt free " bed in which to grow for the first week or so.[23] The Armoedsvlakte pots ultimately contained 33 Kg. dry soil when filled to within $\pm$ 6 cms. from the top, whereas the Shepstone and Verona pots were sufficiently filled by 31 Kg. of soil.

The form in which the various fertilising elements were supplied and the amounts used per pot were as follows:—

Ca: 30 gm. pure calcium carbonate. As this quantity was distributed evenly over 31 to 33 Kg. it corresponds to a dressing of about 5.25 *gm. CaO per* 10 *Kg. dry soil.* Calcium carbonate was included in the fertiliser as it was known that Shepstone soil was " sour." For the sake of uniformity the other soils were given the same treatment.

P: 20 gm. pure monocalcium phosphate ($CaH_4P_2O_8 \cdot H_2O$), corresponding to about 0.9 *gm. N per* 10 *Kg.*, no nitrogen was given was added in the form of a fine powder. With it was introduced a further 1.4 gm. CaO into each 10 kg. soil.

K: 20 gm. pure potassium nitrate. This was first dissolved in 250 c.c. water before being added to the soil. The quantity corresponds to about 3 *gm.* K_2O *per* 10 *Kg. soil.*

N: Apart from the nitrogen contained in the KNO_3, corresponding to about 0.9 *gm. N per* 10 *Kg.*, no nitrogen was given initially. But it was intended to supply a further 15 gm. NH_4NO_3 (=1.6 gm. N per 10 Kg. soil) in the form of several top dressings in the course of the experiment, as required.

In addition to the above, all pots (including the O series) were given a basal dressing of 10 gm. $MgSO_4 \cdot 7H_2O$, dissolved in 250 c.c. water, i.e. 0.5 gm. MgO and 1 gm. SO_3 per 10 Kg. of dry soil.

As the soil was very dry and dusty, it was found advisable to moisten it slightly while mixing in the fertiliser and it was moreover thought possible that a slightly damp soil would pack better into the pots. For this reason the soluble fertilisers were given in the dissolved state, but apart from that, so much extra water was given that each pot got in all 1,000 c.c. Pots receiving only the basal dressing, therefore, got 750 c.c. water extra (added in small quantities at a time whilst stirring up the soil by hand), whereas pots getting potash as well, received 500 c.c additional water.

The order of magnitude of the above quantities of fertiliser is similar to that used by many European[24] investigators.

§5. Nature of the Soils.

Before proceeding to the discussion of details in connection with the first cultural experiment, a few words should be said about the nature of the three types of soils used. To the general remarks in Table II the following should be added:—

Armoedsvlakte soil.—" Armoedsvlakte " is a typical lamsiekte farm, situated in a part of Bechuanaland where lamsiekte has been very prevalent for years. The farm was taken over by the Division some 14 years ago with the object of studying lamsiekte under the best natural conditions. Styfsiekte, however, does not commonly occur there, although pica is very pronounced during the greater part of the year. The rainfall occurs in the summer, but is fairly low and irregular, and the climate is dry (average 15 in.) and the vegetation very sparse. The temperature shows a considerable range not only from winter to summer, but also from night to day. The soil over the major part of the farm is very shallow, overlying a dolomitic formation, is of a light sandy character and deficient in phosphorus and plant food generally. The soil used for the pot experiment was collected in what is known as the " permanent fallow " camp, which has (as far as is known) never yet been cultivated or manured. It is shallow and contains small pebbles of the underlying rock. Chemical and mechanical analysis of several samples from various parts of this farm have been done by Marchand,[25] but for the purpose of this study, the writer also examined three samples of the actual soil used in filling the pots (taken from different parts of the heap of thoroughly sun-dried soil after 5, 15 and 25 pots respectively had been filled). An average of six determinations showed the residual moisture content to be 0.8 per cent. ($\pm$ 10 gms. heated 4-6 hours in an electrical oven at 102-105°). The same samples gave a loss on ignition of 2.5 per cent. (mostly organic matter; in electrical furnace at $\pm$ 700° for $\pm$ 20 minutes). The amount of "total " phosphorus extracted by boiling with strong hydrochloric[26] acid (10 gm. soil with 20 c.c. strong HCl in covered Kjeldahl flask kept boiling one hour over a bare flame) was found to be .027 per cent. P_2O_5 (average of three determinations; determined by the coeruleo-molybdate method[27]). Available phosphorus, extracted by 1 per cent. citric acid was .0014 per cent. P_2O_5 (above colorometric method; 3 hours in rapid horizontal shaker). A sample of the soil was also tested with litmus paper but gave a neutral reaction, though the colorometric pH value was 6.6-6.7. The " apparent density " of this soil determined by filling a litre measure, compacting the soil by tapping and levelling with a scraper, was 1.47 gm. per c.c. Its water-holding capacity was determined by filling three pots with the sifted soil in precisely the same way as described above, weighing, saturating with water and determining the increase in weight. Water was added to each pot in small quantities, partly through the air-tube, partly on the surface. As soon as all the water had drained into the soil, more was added.

This was continued till finally water applied to the surface disappeared only very slowly, and a fair quantity of free water had collected at the bottom of the pot. After a few hours this was removed (pipetted out) and subsequently, at half-hour intervals, a pipette was lowered to the bottom of the pot, through the air-tube, to remove any excess water that might in the meanwhile have drained through the soil. When this quantity became negligibly small, the pot was weighed, the difference giving the amount of water necessary to saturate the soil fully, i.e. its maximum water-holding capacity under the conditions of the experiment. Further readings were taken during the next day or two adding more water on the surface and draining away the excess water percolating through the soil. The average was then taken. It is felt that the water-holding capacity of a soil under culture would probably vary as it settles down more or as plant roots accumulate. Nevertheless the figure determined in this empirical way seems to be more serviceable than that found by ordinary laboratory methods.[28] The author became acquainted with this method in 1913, in the course of pot culture work in the agricultural chemical institute of the Göttingen University. Armoedsvlakte soil had a water capacity of 9.05 Kg. per pot of 33 Kg. sun-dried soil.

Shepstone soil.—In certain parts of the Highveld of the Transvaal, styfsiekte is very prevalent (though lamsiekte may be rare). The area in question receives a sufficiently heavy rainfall (in the summer months) to give rise to a soil that is more or less leached out. A large portion of the grazing veld consists of low-lying, so-called "vlei" areas, where the soil is of acid character, carrying a thick vegetation of "sour" grasses and consequently fairly well supplied with humus. The climate is colder than that of Bechuanaland. Shepstone is situated in the east of the Ermelo district and is a typical styfsiekte farm. This trouble latterly became so bad that cattle farming was practically abandoned.[29] At this stage (1922) the Division of Veterinary Education and Research started a series of bonemeal feeding experiments on the farm, with markedly successful results. The soil used for the pot experiments was taken from a supposedly uniform small area, but on arrival at the laboratory it was noticed that about half was dun-coloured, the rest being chocolate and black (though the physical nature did not seem to vary much). The soil was very fine-grained and neither clay nor sand seemed to be important constituents of it. Samples taken and examined in a similar manner to that recorded under Armoedsvlakte soil gave the following:—

> Residual moisture, 1.0 per cent.; loss on ignition, 7.8 per cent.; total P_2O_5, .051 per cent.; available P_2O_5, .0027 per cent.; reaction to litmus paper acid, pH 4.8-5.0; apparent density, 1.27 gm. per c.c., water-holding capacity, 12.37 Kg. per pot (of 31 Kg. sun-dried soil).

Verona East soil.—Already Hutcheon had recorded the observation that very often an alluvial soil carried a vegetation of such quality that an outbreak of lamsiekte originating elsewhere would cease if the animals were transferred to it. He specifically mentions the area of the Harts River,[30] in which also Verona East is situated. It is a general experience of practical farmers that soil of this type[31] is free from lamsiekte and that bone-eating (osteophagia) hardly occurs.

A noteworthy point is that pica-free soils are usually of a clayey nature and that "ganna" (salsola aphylla) very often forms a large percentage of the vegetation. This is also the case at Verona East and in the course of the last few years several pica tests carried out by officers of this Division confirmed the absence of osteophagia. Conditions of climate, rainfall, and sparsity of veld are very similar to those of Armoedsvlakte The soil used in the experiment was a fairly stiff clay of a slightly reddish brown colour and showed the following:—

Residual moisture, 2.5 per cent.; loss on ignition (presumably including some combined H_2O), 4.8 per cent.; total P_2O_5, .065 per cent.; available P_2O_5, .011 per cent.; reaction to litmus alkaline, pH 7.6-7.8; apparent density, 1.30 gm. per c.c.; water-holding capacity, 11.41 Kg. per pot (of 31 Kg. sun-dried soil).

§6. Details of the First Experiment.

The pots were ready by the end of August, 1923. The final arrangement of the experiment gave a hundred pots in all. They were brought under shelter in a small glass-roofed room, attached to the north side of another building. A low brick wall (0.8 m. high), supermounted by glass on the two narrow sides (3.4 m. long) and mosquito netting on the north side (8 m. long) enclosed the available space, which just admitted of a somewhat crowded arrangement of the pots and left a small side space free for manipulating the decimal balance used in weighing.

For the first experiment, which had also to serve the purpose of showing up any difference between parallel pots, the same plant was used throughout. Although winter was already over, barley was selected, as being a fairly hardy plant that could be expected to give an even stand and produce sufficient growth even on the pots with very unfavourable conditions. The barley was moistened and only selected seeds, beginning to germinate, carefully planted out (30 seeds; lightly covered with soil). Unfortunately it was not possible to plant all the pots on the same day. Armoedsvlakte pots were planted on the 1st and 3rd September and were all well up by the 4th; Shepstone pots were planted on the 3rd and 4th and were all well up by the 5th; Verona East pots were planted on the 5th and 6th and were all well up by the 7th. During the first few days the 3 or 4 days' difference in the age of the plants prevented a comparison between the three soils; but in about a week's time after the plants appeared on the Verona soil, it ceased to be a factor worthy of particular consideration.

Immediately after planting about 500 c.c. water was sprayed gently over the soil surface and till the plants were about a week old, all pots were watered once or twice daily by means of a fine spray, receiving about 300 c.c. each daily, or if watered twice, about 100 to 200 c.c. at a time, i.e., just enough to moisten the top soil layer sufficiently. Verona soil had a tendency to crack badly on drying, but under the conditions of the experiment this seemed to be of no consequence. Shepstone soil on the other hand, did not crack but formed a compact layer which was markedly impervious to water and through which the young sprouts could only penetrate with great difficulty. In many cases it was noticed that the plant had grown more or less horizontally underground for several cms. before being able to find its way to the surface, and sometimes it did not succeed in breaking through at all. The stand on the Shepstone pots was therefore somewhat uneven.

Owing to the cramped space of the pot house and the size of the pots it proved impossible to weigh every pot regularly, but by a judicious selection of pots representative of the various soils and series for weekly weighing and a careful estimation of the probable water requirements of the parallels for the ensuing week, it was found possible in most cases to keep the variation of the *actual* water content from the *desired* water content within reasonable limits (cp. tables III, IV and V for typical figures). As is evident from table II, the majority of the pots were intended to be kept at a high water content (H.W.C.). This was arbitrarily fixed at about 80 per cent. of the full water-holding capacity, a figure which is probably not far from the optimum[32]. Neglecting the traces of moisture retained in the thoroughly air-dry soil as being of no consequence for the plants (and probably even correcting to some extent for the difference in hygroscopicity[32a]), this meant that the Armoedsvlakte H.W.C. pots had to receive 7.5 Kg. water (quantity rounded off, actually only 7.24 Kg.), the corresponding Shepstone pots 10 Kg. (9.9) and the Verona pots 9.5 Kg. (9.13). The low water content sets (L.W.C.) were adjusted to contain half the above quantities of water, i.e., ± 40 per cent. of the full water capacity. After the plants were about a week old (11.IX.23), the requisite quantities of water to bring to the correct L.W.C. level were added, half by repeated gentle spraying, the rest through the tube. As it was not considered advisable to adjust to the H.W.C. level at once, these pots initially got the same amount of water as the corresponding L.W.C. sets, but were gradually brought up to the 80 per cent. level during the next fortnight. In the case of the Armoedsvlakte soil a short series of minimum water content was included as well. During the first 8 or 10 days of growth (up to 11.IX.23) they received the same treatment as all the other pots. It was then found that they were at a water content of just over 20 per cent. of the total water-holding capacity. The pots were then weighed and all adjusted to exactly the same level, which was maintained for a further 14 days. Thereafter the degree of moisture was determined empirically by taking the wilting point of the plants as indicating definite deficiency of soil moisture. The pots were examined daily between 12 and 3 o'clock and those showing signs of wilting given 250-500 c.c. water, half on the surface, half through the tube. The "varying water content" series (Armoedsvlakte) was brought to a 50 per cent. level on the 11th September. The intention was to follow from this date the actual rainfall as far as possible. As the distribution and amount of the rainfall during the first two months proved completely unsuitable for the requirements of the growing plants, this series was practically reduced to a minimum water content too. Only after 6.XI.23 did it become possible to raise the moisture level appreciably.

In *watering* the pots the general practice, which was followed to the end of the experiment, was to give the necessary water by means of the air tube. In many cases, however, this procedure could not be strictly adhered to. During the early stages of growth (till 25.IX) all the low water content series received about half their water on the surface, and for the sake of uniformity the high water content pots also received roughly the same amount on the surface. It was soon found, however, that on the Shepstone soil 40 per cent. of the water-holding capacity seemed to be not far from the moisture limit for growth, particularly on the fertilised but also on the unfertilised series, so that it was now considered necessary, in order to counteract the effect of drought, not only to apply practically all the necessary water to the surface, but also to keep these pots at a somewhat higher level of soil moisture, i.e., at a weight of 49 Kg. (instead of the initial 48.5 Kg.), or about 45 per cent. of the water-holding capacity. To a certain extent the Verona East low water content series also showed signs of water shortage on hot dry days, but growth was sufficiently good to adhere to the 40 per cent. level, and, except on days when the plants were badly wilted, to continue the practice of giving half the water through the ventilating tube. On a few pots these tubes unfortunately leaked or were partially clogged up, so that some of the water unavoidably spilled over on to the soil surface. Armoedsvlakte soil absorbed water readily and there was usually no trouble in giving these pots as much as 2,000 c.c. water through the tube at a time, if required. Also on the Verona pots quantities of 1-1½ litres could be given at a time, and absorbed, if a little care was taken. Shepstone soil, however, did not readily absorb water and on several occasions, where the amount to be given to some S.H. pots was about a litre or more, some of the water generally ran over on to the surface.

The pot weights recorded in the tables were obtained prior to watering for that day. On pots with a high water requirement, especially after a spell of hot dry weather, these weights therefore frequently show a water shortage of 1 to 1½ litres. As this quantity, however, represents the accumulated deficit over a week or more and as it often does not exceed the water consumption in a single day this difference from the theoretical cannot be considered of too much consequence, although it is regretted that a closer agreement could not be maintained. On the other hand it was sometimes the case with pots with a low water requirement, or after a few days of cooler weather, that a surplus of about a litre was revealed on weighing. After each weighing (at *least* half the pots were selected for the regular weekly weighing, on several occasions all being weighed), a careful estimate of the water requirements for the ensuing week was made. If the water requirement was large (i.e., 3½ litres or more per week), daily watering was resorted to; where it was smaller five to two waterings per week proved sufficient. Any determined or estimated shortage was made good on the day of weighing. In the case of "overweight" pots no more water was given until the surplus was considered to be wiped off (except in individual cases on S.L. and V.L. when a little water was sprayed on if the plants were wilted, no matter if the pots were correct weight or not).

Table III.

Showing water consumption on Armoedsvlakte *soil. Normal wt. f. L.*=49·0; H.=53·0 Kg.

Series.	Pot No.	To 25.9.23.		To 16.10.23.		To 6.11.23.		To 27.11.23.		To 18.12.23.		To 8.1.24.		General.
		Wt.	Water.	Wt.	Water.	Wt.	Water.	Wt.	Water.	Wt.	Water.	Wt.	Water.	
		Kg.	Litre.	Kg.	Litre.	Kg.	Litre.	Kg.	Litre.	Kg.	Litre.	Kg.	Litre.	
II	43	48·1	4·6	48·6	9·8	—	—	48·3	19·5					
Soil: A	44	—	—	48·7	9·4	—	—	48·5	19·4					
Wat. Cont.: L	48	—	—	48·4	9·6	48·9	14·6	48·6	19·1					
Fert: Ca	45	48·6	5·5	48·6	10·4	49·0	15·8	48·7	20·5	49·9	24·3	48·2	26·0	
III	46	48·3	4·7	48·4	10·0	—	—	48·7	19·8	49·7	23·8	48·0	25·8	
	47	48·1	4·6	48·4	10·0	48·7	15·5	48·8	20·5	49·5	24·7	47·8	26·9	
II	61	48·3	4·4	48·0	10·2	48·5	24·9	47·1	38·4					Mildew.
	62	48·2	4·5	47·7	10·6	—	—	46·7	40·8					
A.L.	64	—	—	48·1	10·6	47·9	26·4	46·7	41·5					
CaKNP	59	—	—	47·8	10·7	47·9	26·5	48·1	43·2	49·1	56·0	46·7	59·9	
III	60	48·4	5·0	47·6	11·3	48·8	25·8	48·3	42·6	48·6	56·2	46·7	60·1	
	63	48·4	4·4	47·8	10·7	48·1	25·8	49·2	42·4	50·0	51·3	48·4	54·3	Mildew.
	50	—	—	52·5	10·8	—	—	52·3	25·3					
II	53	—	—	52·6	12·0	53·9	18·3	52·3	25·0					
A.H.	54	52·5	5·2	52·0	12·8	53·6	21·5	51·8	29·8					Better than parallels. Why?
Ca	49	—	—	52·1	11·3	—	—	52·9	26·7	53·4	35·0	50·6	40·7	
III	51	—	—	52·6	11·2	53·5	17·7	52·4	24·2	53·5	31·2	50·9	36·3	
	52	52·9	4·8	52·2	11·6	—	—	52·0	25·5	53·4	32·6	51·7	36·8	
	67	52·6	5·6	52·1	20·9	52·8	44·5	51·7	62·0					Mildew bad.
II	65	—	—	51·6	18·3	53·6	33·3	52·2	46·5					Tube clogged up.
A.H.	68	52·6	4·8	52·2	17·9	52·4	41·9	51·0	63·1					
CaKNP	66	—	—	52·0	18·5	52·5	45·3	52·7	69·9	53·9	76·6	52·6	79·6	
III	69	—	—	52·2	19·0	53·7	42·0	53·7	60·6	53·3	67·1	51·9	70·6	Mildew.
	70	52·5	4·9	51·6	19·7	52·8	46·2	54·0	64·8	53·5	70·5	52·6	73·4	Mildew.
A.H. III	41	52·9	4·8	52·6	12·7	52·7	20·7	52·4	26·8	52·2	32·1	51·9	35·9	Distilled water.
O	42	52·7	5·0	53·2	12·3	53·7	18·8	52·6	23·7	53·6	27·1	52·1	30·6	Distilled water.
A.H. III	58	53·3	4·4	53·0	11·0	—	—	52·3	24·5	52·2	33·0	51·2	38·0	
CaKN	57	53·3	4·4	52·9	10·9	53·2	17·7	52·6	24·9	53·7	32·1	51·6	36·7	
A.H. III	55	51·9	5·8	51·3	22·3	53·7	40·3	52·6	55·0	52·8	67·0	50·4	73·1	
CaP	56	52·2	5·5	51·6	22·0	53·4	38·6	52·1	51·5	53·8	58·9	52·2	62·9	Mildew.

Table IV.

Showing water consumption on Shepstone *soil. Normal wt. f. L.*=48·5; *later* 49·0; *H.*=53·5 *Kg.*

Series.	Pot No.	To 25.9.23.		To 16.10.23.		To 6.11.23.		To 27.11.23.		To 18.12.23.		To 8.1.24.		General.
		Wt.	Water.	Wt.	Water.	Wt.	Water.	Wt.	Water.	Wt.	Water.	Wt	Water.	
		Kg.	Litre.	Kg.	Litre.	Kg.	Litre.	Kg.	Litre.	Kg.	Litre.	Kg.	Litre.	
II	77	—	—	48·6	6·6	49·0	9·4	49·0	10·1					Many plants dead early; sprayed.
Soil: S.	75	48·7	4·3	48·7	6·8	—	—	49·1	9·8					
Wat. Cont.: L.	78	—	—	48·6	6·7	—	—	48·8	10·6					
Fert.: Ca.	74	48·5	4·9	48·5	7·5	49·1	10·1	48·6	11·2	48·9	12·5	48·8	13·2	Many plants dead early; sprayed.
III	73	—	—	48·6	6·6	49·3	9·0	48·8	9·8	49·0	11·0	48·8	11·7	
	76	—	—	48·5	6·9	—	—	48·8	10·4	49·3	11·3	48·7	11·9	
	89	48·5	4·3	48·8	6·8	—	—	48·7	12·1					Many plants dead early; uneven stand, esp. 94; sprayed; often wilted, esp. 90.
II	90	48·5	4·2	48·8	6·8	—	—	48·8	11·2					
S.L.	94	—	—	48·7	6·9	49·2	10·1	48·5	13·2					
CaKNP	93	—	—	48·5	6·8	49·0	10·4	49·0	14·5	49·0	20·5	48·0	24·4	Many plants dead early; uneven stand, esp. 93; sprayed; often wilted, 93 least.
III	91	48·5	4·2	48·6	7·0	—	—	48·6	13·5	49·4	17·0	49·0	19·0	
	92	48·6	4·1	48·6	6·9	48·5	10·6	48·8	14·1	49·2	18·0	49·2	19·4	
	80	—	—	52·8	9·8	—	—	52·8	18·7					
II	82	52·8	4·0	52·9	9·7	53·9	14·4	53·1	18·8					
S.H.	83	52·7	3·8	52·7	9·7	53·6	15·2	52·9	20·6					Better than parallels. Why?
Ca	84	52·6	3·9	53·1	9·4	53·6	14·3	53·4	18·0	54·0	22·4	52·2	25·8	
	79	—	—	53·0	9·6	—	—	53·1	18·2	53·9	22·6	52·1	26·4	
III	81	52·9	4·5	52·9	10·2	—	—	53·4	17·7	54·3	21·4	52·6	24·6	
	99	—	—	52·5	14·0	54·4	24·4	52·5	33·0					Mildew.
II	97	52·8	4·0	52·4	14·2	54·2	23·8	52·2	33·4					
S.H.	100	—	—	52·1	14·5	53·1	24·4	52·8	33·2					
CaKNP	98	—	—	52·2	14·2	53·7	26·8	53·1	37·7	53·9	45·2	52·6	48·3	
III	95	—	—	51·9	15·2	53·6	26·9	53·0	37·5	54·1	44·9	52·1	48·4	Uneven stand.
	96	53·1	39·	52·7	14·3	53·8	24·8	53·2	35·6	54·1	43·2	51·8	47·0	
S.H. III	71	52·8	4·1	52·9	9·3	—	—	53·0	17·0	53·6	20·7	51·9	23·9	Many plants dead early; dist. water.
O.	72	52·5	3·9	52·9	8·9	53·5	13·0	53·3	16·1	54·1	19·4	52·0	22·7	
S.H. III	87	52·8	3·7	52·5	9·6	54·4	13·6	53·6	16·7	54·2	20·4	52·7	23·4	
CaKN.	88	—	—	52·8	10·0	—	—	53·4	18·0	53·8	21·9	52·3	25·4	
S.H. III	85	53·0	3·8	52·0	12·8	53·4	25·1	52·8	36·2	54·0	44·1	52·4	47·7	
CaP.	86	—	—	51·9	13·2	53·0	22·9	53·5	32·9	54·5	38·8	52·6	42·0	

Table V.

Showing water consumption on Verona East *soil. Normal wt. f. L.*=48·0; *for H.*=53·0 *Kg.*

Series.	Pot No.	To 25.9.23.		To 16.10.23.		To 6.11.23.		To 27.11.23.		To 18.12.23.		To 8.1.24.		General.
		Wt.	Water.	Wt.	Water.	Wt.	Water.	Wt.	Water.	Wt.	Water.	Wt.	Water.	
		Kg.	Litre.	Kg.	Litre.	Kg.	Litre.	Kg.	Litre.	Kg.	Litre.	Kg.	Litre.	
Soil: V; *Wat. Cont:* L; *Fert:* Ca — II	18	47·6	3·6	47·8	7·6	—	—	48·1	13·2					Slight wilting, esp. 18; often sprayed; Tube leaking on 23.
	19	48·1	3·7	48·1	7·8	48·4	11·8	47·6	14·8					
	23	—	—	48·2	6·8	48·1	10·4	47·8	13·1					
III	20	—	—	47·6	7·8	48·0	13·5	48·2	17·6	48·5	20·1	48·3	21·3	Tubes leaking. Slight wilting. Often sprayed.
	21	47·8	3·9	47·6	9·0	48·1	16·1	47·8	20·8	48·5	23·9	48·0	25·2	
	25	—	—	47·7	8·0	47·9	14·1	48·1	18·7	48·8	21·5	48·1	22·7	
V L CaKNP — II	—	47·8	3·2	48·3	5·9	48·5	9·4	47·6	13·0					Often wilted. Often sprayed.
	30	47·6	3·4	48·3	6·1	48·3	9·8	47·4	13·4					
III	33	47·8	3·2	48·0	6·3	47·7	11·5	48·2	16·1	48·6	20·1	47·3	21·9	Often wilted, most on 32 and least on 33. Often sprayed.
	31	47·7	3·3	47·9	6·4	—	—	48·1	15·3	48·5	19·0	47·7	20·7	
	32	47·8	3·2	48·1	6·1	48·6	10·3	48·0	13·9	48·7	17·2	47·6	18·8	
V.H. Ca — II	15	—	—	53·0	12·2	—	—	51·2	35·7					Tube leaking.
	13	52·6	4·0	53·6	12·0	52·9	23·3	50·9	36·3					
	24	52·3	3·8	52·9	12·5	—	—	50·6	37·7					
III	22	52·4	3·8	52·7	12·8	—	—	51·9	37·9	52·3	47·5	51·3	51·0	
	16	—	—	52·6	13·0	52·6	26·1	52·3	37·7	52·0	47·0	51·0	51·0	
	17	52·6	3·8	52·8	12·6	52·6	25·9	52·0	36·7	51·8	46·6	51·0	50·5	
V.H. CaKNP — II	36	52·5	3·5	52·9	12·6	52·8	22·8	50·5	37·5					
	37	—	—	53·0	12·3	53·6	20·6	50·9	31·9					Mildew. Excess moisture?
III	34	52·4	3·2	51·6	13·9	52·3	27·0	52·3	41·9	53·1	53·4	51·7	57·3	
	35	52·6	3·5	52·1	13·6	52·9	24·1	52·4	38·1	52·7	50·9	50·6	58·5	
	38	—	—	52·3	13·1	52·7	24·6	52·5	38·1	53·1	49·1	51·5	53·2	
V.H. III O	11	—	—	51·5	12·3	52·4	23·3	52·4	32·8	53·6	38·9	52·4	42·1	Distilled water.
	12	52·6	3·6	52·6	21·9	52·6	21·9	52·1	31·8	52·5	38·7	52·4	41·3	Distilled water.
V.H. III CaKN	27	—	—	52·9	12·7	52·7	25·2	52·1	38·8	51·9	50·3	50·7	55·0	
	28	52·8	3·1	53·2	11·1	53·2	22·2	53·1	33·1	53·2	42·6	51·8	45·5	Excess moisture?
V.H. III CaP	14	52·2	3·6	52·0	14·0	52·3	26·5	52·5	38·7	52·1	48·5	51·5	52·1	
	26	49·9	4·0	53·3	11·6	52·0	18·5	51·6	24·1	50·8	29·2	49·7	32·3	Swamped. Corr. wt. 51 kg.

Fairly full details about the *water requirements* are given in tables III to V. As regards the first growth period (to 25.IX), up to this date, when in no case the amount of plant growth was an important factor yet, there is already a slight difference in water consumption for the three soils, Armoedsvlakte pots using about 5 litres, whereas Shepstone and Verona East series consumed 3.5 to 4 litres. An appreciable difference for varying moisture content of the soil could not be expected yet, as the first differentiation in that respect only dated some 10 days previously. Though the tables show only a very slight difference for fertiliser treatments, a distinct difference was nevertheless noticeable practically from the beginning. From the daily observations it was very evident that the pots receiving full fertiliser or full fertiliser without phosphorus consumed, during the first part of this period, less water[32b], seemed to retain a moist surface longer, or, in the case of the 40 per cent. S. and V. series, showed a greater tendency to wilting. On all the soils the lowest water requirement seemed to be on the CaKN pots. Towards the end of this period, the Armoedsvlakte high water-content series, receiving phosphorus or full fertiliser, were definitely requiring more water than those receiving other manurial treatment (on account of the more vigorous growth).

The first well defined differences in *plant growth* became apparent on the 14.IX.25, on which date it was already perceptible that the Armoedsvlakte soil favoured growth most and the Shepstone soil least. By 25 IX. it was evident on both A.H. and S.H. pots that CaKNP and CaP plants were broader leaved than those on the O, Ca, or CaKN pots and were beginning to require more water. Also on A.L. CaKNP an improvement in the growth was becoming noticeable. On the S.L. series, however, fertilising was affecting most plants adversely, although a few individual plants seemed to be doing very well. On Verona soil no beneficial effect of any fertiliser was visible up to this date; but on the contrary, full fertiliser seemed to retard the growth on the low moisture series. By this date a beneficial influence of the higher water content was becoming faintly perceptible on Shepstone and Verona soils, but not on Armoedsvlakte soil.

A few weeks after starting the experiment, it was noticed that some plants were becoming infected with mildew. An attempt at combating the trouble by dusting with sulphur and removal of badly infected leaves, met with only a certain measure of success. The mildew was not confined to any particular soil or treatment, though in general it affected the luxuriously growing plants most (i.e., high water content and full fertiliser). Only a few pots suffered rather severely. These are specially marked in the tables. Undoubtedly the attack of mildew was largely due to the unfortunate circumstance that the air circulation in the pothouse was very unsatisfactory.

The differences in water requirements and growth for the period 25.IX to 16.X ran more or less parallel and were easily noticeable for differences in manurial treatment, moisture level and soil nature. Details of water requirements for this period appear in the tables already given, whereas some idea of the state of growth can be obtained from plates I to V.

The pots shown on these plates were photographed on 17.X.23. From every series, the pot that was considered the most representative was selected. The first three photographs give a comparison of the influence of soil moisture and fertiliser for each of the three soils. Plates IV and V illustrate the effect of fertilising on the three soils for low and high soil moisture respectively. Furthermore, under the heading "Period of Growth I," Tables X to XII (see later) give average figures, illustrating the stage of growth on 16.X. The data about the weight, size and P_2O_5 content of the plants were obtained on one or two supposedly representative plants cut down from each pot of a series.

It is evident that during the three-weekly period 25.IX to 16.X the *water requirements* have increased more or less considerably on all the high water content series. On the "low moisture" series only the fertilised Armoedsvlakte pots show a definite increased rate of water consumption, whereas both Shepstone series have actually used less water during this period. Comparing "low moisture" with "high moisture" series, we find an increase in the water consumption for the latter in the case of all soils, for both fertilised and unfertilised pots, although on the Armoedsvlakte and Shepstone unfertilised soils this difference is only small. In most series an important bearing of manurial treatment on water consumption is also brought out by the figures. A notable exception is the Verona East soil, which shows practically the same water requirements for all five manurial treatments, where the water content of the soil was not a limiting factor. If the soil was fairly dry, however, full fertiliser had the effect of lowering the water consumption for the two "stiffer" soils (notably V.L. series; less on S.L.). If the soil was sufficiently moist and naturally poor in plant food, fertilising increased the water consumption considerably.

The notes made during this period show that on 23.IX all the CaKN and full fertiliser pots were given 5 gms. NH_4NO_3 dissolved in 300 c.c. water. It was originally the intention to supply this as a "topdressing," but as the S.L. and V.L. pots were already visibly suffering from water shortage, the fertiliser was supplied instead through the ventilating tube. A spell of hot weather set in just about this time and on 25.IX it was noticeable that the V.L. pots particularly 29, 30 and 32 were beginning to suffer. On the 27th a hot, windy day, these three pots were badly wilted and even most of the unfertilised V.L. pots as well as the S.L. pots were showing signs of distress. From 2.X the weather became cooler and now the plants on the Verona East soil seemed practically normal again although the S.L. fertilised pots, particularly No. 90, showed considerable wilting still (except some plants on 93). In spite of the raised soil moisture level and the surface watering, the *plant growth* on S.L. Ca series remained minimal, and many of the plants were dying off. Also on the S.L. full fertiliser series many plants were dying or were quite dead by the end of this period, although, as already noted, individual plants seemed to be able to adjust themselves to their environment and were now beginning to make marked progress. On the Armoedsvlakte soil, the low water content at no time seemed to cause any trouble to the fertilised plants, which were making very good growth and approximating to the A.H. CaKNP series, although the water consumption was still relatively low.

The unfertilised A.L. pots also did fairly well at first. Notes made under date 29.IX, however, indicate that from now on plants on these pots were beginning to suffer from lack of plant food. They were now becoming yellowish in colour, were increasing only slowly in height, and the bottom leaves were shrivelling up and dying off. Towards the end of this period, the plants on the V.L. Ca series had caught up with and were even beginning to overhaul them (i.e. A.L. Ca). Growth on the full fertiliser V.L. series was at this time still much poorer than on the corresponding unfertilised pots.

In the case of the " high moisture " O and Ca series, Verona pots were now considerably ahead of the Armoedsvlakte pots, which in their turn were far superior to the Shepstone pots. On both Armoedsvlakte and Shepstone soils, the plants were now visibly suffering from lack of food or other unfavourable growth conditions. The interesting observation could be made early in this period that growth was better on S.H. Ca than on S.H. O. On 14.X the entry was also made that A.H. Ca seemed to be better than A.H. O. No difference between these two treatments was apparent on Verona soil. It should here be added that the six unlimed pots received distilled water throughout the experiment as the Onderstepoort tap-water contains a fair quantity of lime salts.

So far (up to 16.X) KN treatment was not clearly responded to; for no difference was apparent on any of the soil types between pots receiving Ca only or CaKN, neither between CaP and CaKNP. In fact, on the Armoedsvlakte soil, it seemed at this stage as if the CaP pots were better than CaKNP. Phosphorus, on the other hand, either with Ca alone or in conjunction with CaKN, produced an enormous improvement in growth, on both Armoedsvlakte and Shepstone soils, provided soil moisture was not a limiting factor. On the Verona soil, however, the effect of P was apparently negligible. A comparison of the " low moisture " series with the corresponding " high moisture " series showed clearly a marked beneficial effect of a high moisture content for Verona soil (both fertilised and unfertilised), hardly any effect for Armoedsvlakte soil (whether fertilised or not) and a marked effect for Shepstone soil, if in conjunction with phosphatic fertiliser, but little effect otherwise.

The average figures in tables X to XII referring to this period, bear out on the whole, the observations recorded. Naturally they can make no claim to absolute accuracy. It was in some cases, where the plants showed great individual differences (especially on the S.L. series) a very difficult matter to decide whether plants were " representative." Though the values given for total crop weight and total phosphorus removed, as well as all the figures dependent thereon are not strictly accurate, the estimate is probably near enough to allow of a comparison with similar figures for the later periods. The figures for " average lengths " and " average counts " were obtained by measurements of, or counts on, the so-called " typical plants " or their parts, and averaging these. The counts in the tables included very small stems and dead leaves. These were also separately counted and in some cases helped to show up differences between the different soils and treatments more clearly. For example, comparing the three soils with each other we find that whereas on the A.H. Ca series 24 per cent. of the leaves were dead (36 out of 149 leaves for 20 plants), on S.H. Ca the number of dead leaves amounted to 37 per cent. (43 out of 117) and on V.H. Ca only 8 per cent. (12 out of 160). Where a heavy dressing of full fertiliser had been applied, there was very little difference for the three soils between the percentages or numbers of leaves dying at an early stage, viz., on A.H. CaKNP 14 per cent. (44 out of a total of 320), on the corresponding S.H. series 18 per cent. (44 out of 243), and on V.H. 18 per cent. (35 out of 200).

Measurements of the breadth of the leaves and thickness of the stems were also made, but as these ran fairly parallel with the length measurements and weights, they are not included in the tables. As an illustration the stem of the fresh plant measured 0.9 mm. in diameter on A.H. Ca, 0.8 mm. on S.H. Ca, and 1.4 mm. on V.H. Ca, as against 2.2, 1.5 and 1.7 mm. on the corresponding full fertiliser series.

Proceeding to what is denoted in the tables by " Period of Growth II " (i.e. the six weeks from 16.X to 27.XI) we find that, on the whole, the further growth and water consumption are in accordance with the earlier observations. The same influence of soil nature, moisture-level and fertiliser was manifest. Amongst the outstanding observations noted down during this period, the following may be mentioned :—

Verona soil continues to show clearly that if the soil moisture level is high, fertiliser treatment has little effect on the water consumption or on the growth. However, the plants on V.H. Ca were now also noticed to be somewhat taller than those on V.H. O, and on most of the V.H. CaKNP pots the foliage seemed to be slightly more abundant. In the case of the Verona fertilised low moisture series, the plants had by 23.X learned to adapt themselves to the conditions as shown by the total disappearance of wilting, an increasing water requirement and a gradual approach in height to the parallel Ca series, which latter, however, remained far inferior to any of the H.W.C. series. On the Shepstone soil, the S.L. Ca as well as the S.H. O seemed to be so detrimentally affected by the unfavourable conditions, that extremely little further growth was being made. On the S.L. CaKNP series, however, certain plants had by now adjusted themselves so well to their environment that they were able to make very fair growth, so that from 30.X these pots, as a whole, were definitely superior to S.L. Ca and were using more water. On the S.H. Ca and S.H. CaKN series the growth remained stunted, though a marked improvement over S.H. O was evident. Both S.H. series receiving phosphatic fertiliser were showing about as good growth as the corresponding Verona series. The two parallel Armoedsvlakte series were, however, using far more water during this period than either Shepstone or Verona series and were much superior in growth. By 23.X the full fertiliser A.H. series had caught up with the A.H. CaP series and was from now on visibly gaining on it, both as regards growth and water requirement. On all three soils it was also now evident that in the case of full fertiliser and high water content the plants seemed darker green, had developed more leafy material, were broader leaved and were less firm. This was more noticeable on the Armoedsvlakte soil, where also the fertilised low moisture series showed the same characteristics. This latter series, in spite of its much lower water consumption, was in crop production fully the equal of CaP though it could not quite catch up with A.H. CaKNP pots. A comparison of the A.H. O with the A.H. Ca pots no longer left any doubt about the beneficial effect of lime.

During this period several cases became noticeable where particular pots showed themselves, in respect of water consumption or growth, or both, as more or less clear exceptions to the controls undergoing the same treatment. It has already been noted that mildew attacked the plants and that especially the more luxuriantly growing series suffered. The mildew was worst on the A.H. CaKNP series and of these six pots 66 suffered only slightly and 67 rather severely. Also on A.H. CaP and A.L. CaKNP most pots were attacked during the early part of this period, although 55 and 64 remained exceptionally free from it. On the other soils or series only Nos. 99 (S.H. CaKNP) and 37 (V.H. CaKNP) need be mentioned as appearing somewhat affected by the attack of mildew. From about 6.XI this latter pot was definitely making less progress than its mates and apart from the presumable slight influence of mildew, it seemed as if some other hindering factor was present. This was seemingly also the case on No. 28 (V.H. CaKN). Possibly a too moist soil might have been the disturbing factor on these pots; in fact from the writer's experience there is some ground for assuming that a heavy clay soil will not give maximum[33] results if the soil moisture level is permanently kept as high as 80 to 85 per cent. of the total water-holding capacity. It was further found that pot No. 26 (V.H. CaP) was, from about the beginning of October, continually wet on the surface, even when "underweight." On examination the pot was found to be practically waterlogged. The only explanation that could be advanced for this exceptional condition was to assume that the layer of 2 Kg. of unfertilised soil had been inadvertently omitted in this case. Therefore, after weighing this pot on 16.X, it was decided not to water it in future if the weight exceeded 51 Kgs. The effect on the plants of growing for several weeks on a more or less waterlogged soil became distinctly evident only after this date.

In the case of pot 65, which was also perceptibly falling behind its parallels (series A.H. CaKNP) in growth and particularly in water requirement, the cause was considered to be insufficient aeration of the soil, as the ventilator tube was partially to completely clogged up for the whole duration of the experiment. Some of the S.L. and V.L. pots which had frequently shown wilting in the previous stage, seemed to have received a slight permanent setback. Nos. 90; 29, 30; and 18 were notable examples of this; whereas those pots in the same series, which had normally been much less affected by wilting, were now also showing improved growth (e.g., 93 and 33). Also Nos. 54 (A.H. Ca) and 83 (S.H. Ca) were making better progress than their respective mates, although no reason for this was apparent.

From the notes we further find that already on 24.X the first ear had appeared. This was on pot 56, i.e., one of the high water content Armoedsvlakte pots, receiving phosphorus. Ears now rapidly appeared on other pots as well and by 30.X one or more were showing on both A.H. CaP pots (55 and 56), on one of the S.H. CaP pots (86), on four V.H. Ca pots (15, 13, 24 and 17), on one V.H. O pot (12), on two V.L. Ca pots (21 and 25) and in addition some stunted, sickly-looking ears were showing on various pots of the series A.H. O, A.H. Ca, A.L. Ca (41; 50, 49; 43, 48, 45, and 47). By 6.XI ears had appeared, or at any rate spikes were showing, on all the pots with the exception of two of the A.L. CaKNP series (61, 62), two A.H. CaKNP (65, 69), all S.L. Ca (73-78), all S.L. CaKNP (89-94), all S.H. Ca (79-84), both S.H. CaKN (87-88), all V.L. CaKNP (29-33), both V.H. CaKN (27, 28) and three V.H. CaKNP (36, 37, 38). The largest and healthiest ears were on A.H. CaP, V.H. Ca, V.H. CaP and V.H. O series. Ears appearing on Armoedsvlakte soil without P were small and unhealthy-looking. By 20.XI only about half-a-dozen pots (belonging mainly to the two S.L. series) showed no traces of ears yet. Shepstone soil without P produced extremely stunted ears, definitely inferior to the corresponding Armoedsvlakte series. The ears on the unfertilised (O and Ca) Verona pots looked quite normal.

It was decided that half the pots on the major series should be harvested on 27.XI, so as to obtain data for an " intermediate " stage of growth. In selecting the pots to be harvested, the general rule was to leave over for the final harvest those pots showing little or no irregularity, i.e., seemingly typical of the particular treatment. To ensure more rapid drying of the harvested material, the selected pots were not watered during the final three days, which fact accounts for the low weight of the harvested pots.

It may be added that on account of the large amount of water supplied to even the low water content pots (at least 3.5 litres) and the relatively very low weight of the crop (maximum under 200 gm. fresh material), no correction was considered necessary in estimating the daily water requirements.

The harvested plants were weighed fresh and approximate measurements of the average lengths of whole plant, stem and longest leaf taken. These results appear in Tables X to XII under the heading " Period of Growth II." When the plants were thoroughly dry, the crops of two parallel pots (highest and lowest where three had been harvested) were combined, tied up in a bundle and photographed. Plates VI and VII refer.

The remaining pots were kept in the experiment until the bulk of the plant material on practically all of them had ripened. This was the case after a further six weeks, i.e. 8.I.24. A few further exceptions became noticeable during the final period. On pot 93 (S.L. CaKNP) several of the plants had made such exceptional growth that the total crop on this pot seemed considerably more than on the parallels. A continued action of mildew was probably a part cause of the earlier cessation of growth on pots 63 (A.L. CaKNP) and 69 and 70 (A.H. CaKNP). On pot 95 (S.H. CaKNP) a number of plants remained stunted. Pot 26 (V.H. CaP) had apparently suffered permanent injury from the one-time excess of moisture and during this period it fell still further behind the other V.H. pots. Also on 81 (S.H. Ca) a slight falling off in plant production became perceptible. The best crops obtained on each series were selected and arranged for photographing so as to enable comparisons for the various treatments and soils. They are reproduced in Plates VIII to XII.

An interesting fact was that whereas on most series a very marked drop in water consumption was recorded for the final period (" Period of Growth III " of tables X to XII), on series A.H. Ca, A.H. CaKN, S.H. Ca, S.H. CaKN, S.H. O and S.L. CaKNP, this decrease was comparatively slight. Actual observation showed that on all these series there was still a fair amount of green material, in some cases close up to the date of final harvesting. On those series where growth had stopped comparatively soon, e.g. A.H. CaKNP, S.L. Ca, V.L. Ca, the water requirement, relative to the requirements of the *same* pots in the previous six weeks, was low. A scrutiny of the weekly figures for the pots harvested 8.I.24, given in table VI, show up marked differences for soil type, moisture level and fertiliser treatment. As every pot was not weighed on each occasion, these averages are not absolutely exact, for in computing them "estimated weights" for the unweighed pots had to be included.

The last two columns give the maximum three-weekly water consumption for each series and the period during which this was recorded. For the purpose of ready comparison the total water consumption during the 18 weeks for the four major series on each soil are also presented in the form of graphs.

Tables III-VI already given earlier contain full particulars about the water requirements. The following tables VII to IX now bring full information about crop production, phosphorus content and total phosphorus removed on the individual pots.

TABLE VI.

Showing the average weekly water consumption per pot.

Series.	First 3 weeks.			Second 3 weeks.			Third 3 weeks.			Fourth 3 weeks.			Fifth 3 weeks.			Sixth 3 weeks.	Maxm. f. 3 weeks.	
	–11/9	–18/9	–25/9	–2/10	–9/10	–16/10	–23/10	–30/10	–6/11	–13/11	–20/11	–27/11	–4/12	–11/12	–18/12	–8/1	Amt.	Date.
	Litre.	Litre.	Litre.	Litre.	Litre.	Litre.	Litre.	Litre	Litre.	Litre.	Litre.	Litre.	Litre.	Litre.	Litre.	Litre.	%	
A.L. Ca............	1·5	1·4	2·0	1·8	1·3	2·1	2·0	1·8	1·7	1·6	1·3	1·7	1·5	1·4	1·1	2·0	23	10/10—30/10
S.L. Ca............	1·8	1·3	1·5	0·7	0·6	1·1	1·2	0·7	0·7	0·3	0·2	0·4	0·4	0·4	0·3	0·7	37	3/ 9—25/ 9
V.L. Ca............	1·0	1·3	1·4	1·5	1·2	1·9	2·6	2·0	1·7	1·7	1·3	1·5	1·3	0·9	0·6	1·2	28	10/10—30/10
A.H. Ca............	1·6	1·3	2·0	2·0	1·9	2·4	2·7	2·4	2·0	2·9	1·8	2·5	2·8	2·6	2·1	5·0	21	21/11—11/12
S.H. Ca............	1·5	1·1	1·6	1·6	1·6	2·3	1·9	1·4	1·3	1·3	1·0	1·3	1·5	1·4	1·3	3·5	23	3/10—23/10
V.H. Ca............	0·5	1·1	2·2	2·6	2·5	3·9	4·8	4·2	4·2	4·3	3·1	4·0	4·0	3·2	2·5	3·8	26	17/10— 6/11
A.L. CaKNP.........	1·4	1·6	1·6	1·7	1·6	3·0	4·0	5·3	5·8	6·5	5·0	5·2	4·6	4·1	3·1	3·6	30	24/10—13/11
S.L. CaKNP.........	1·7	1·1	1·4	0·7	1·0	1·0	1·4	1·1	1·0	1·2	1·0	1·4	1·7	1·5	1·3	2·4	22	21/11—11/12
V.L. CaKNP.........	0·9	0·9	1·4	1·0	0·9	1·1	1·8	1·6	1·2	1·6	1·2	1·4	1·3	1·2	1·2	1·7	23	17/10— 6/11
A.H. CaKNP.........	1·4	1·5	2·0	3·1	3·7	7·4	8·0	8·3	9·1	9·8	5·6	5·2	3·2	1·7	1·4	3·1	37	24/10—13/10
S.H. CaKNP.........	1·5	0·9	1·5	3·1	3·0	4·6	4·8	3·2	3·6	4·2	3·1	3·5	3·2	2·5	1·8	3·5	26	10/10—30/11
V.H. CaKNP.........	0·6	1·0	1·8	3·2	3·1	3·9	3·6	3·8	4·3	5·3	4·0	4·8	4·4	4·3	3·1	5·2	25	7/11—27/11
A.H.O..............	1·5	1·5	1·9	2·6	2·1	2·9	3·1	2·0	2·2	2·2	1·5	1·8	1·5	1·5	1·3	3·7	24	3/10—23/10
S.H.O..............	1·4	1·1	1·5	1·8	1·2	2·1	2·0	1·1	1·1	1·3	0·8	1·2	1·2	1·2	1·1	3·2	23	3/10—23/10
V.H.O..............	0·6	1·2	1·9	2·5	2·0	3·5	3·8	3·5	3·6	3·6	2·8	3·3	3·0	2·1	1·4	2·9	26	17/10— 6/11
A.H. CaKN..........	1·3	1·3	1·8	2·2	1·8	2·6	2·0	2·5	2·2	2·5	2·0	2·5	3·0	2·6	2·3	4·8	22	21/11—11/12
S.H. CaKN..........	1·1	0·9	1·7	2·2	1·5	2·4	1·8	1·2	1·2	1·4	0·9	1·1	1·5	1·2	1·1	3·2	25	26/ 9—16/10
V.H. CaKN..........	0·6	1·0	1·7	2·7	2·2	3·8	4·1	3·3	4·3	5·0	3·5	4·0	4·3	3·8	2·2	3·8	25	31/10—20/11
A.H. CaP...........	1·6	1·5	2·6	5·0	4·1	7·4	7·0	5·6	4·8	5·5	3·5	4·7	3·7	3·2	2·8	5·0	29	10/10—30/10
S.H. CaP...........	1·2	1·2	1·4	2·6	2·1	4·5	3·9	3·5	3·8	4·2	3·0	3·4	2·7	2·3	1·9	3·4	27	10/10—30/11
V.H. CaP...........	0·5	1·2	1·9	3·3	2·6	4·5	4·1	3·8	4·6	4·5	3·4	4·3	4·1	3·3	2·4	3·6	25	24/10—13/10

REMARKS.—The large differences for the first week are due to the fact that the pots were not started simultaneously. The average water consumption for a three-weekly period would be 17 per cent. if the rate were uniform. No allowance has been made for water lost by surface evaporation.

TABLE VII.

Showing crop production, water requirement, and phosphorus removal on ARMOEDSVLAKTE *soil.*

Series.	Pot No.	Plants per Pot.	Wt. of Crop. Per Pot.	Wt. of Crop. Per 20 Plants.	Wt. of Crop. Per 100 Litre Water.	Water used. Per Pot.	Water used. Per 20 Plants.	Water used. Per 100 gm. Crop.	P_2O_5 removed. Per 100 gm. Crop.	P_2O_5 removed. Per 20 Plants.	P_2O_5 removed. Per Pot.	General.
			gm.	gm.	gm.	Litr.	Litr.	Litr.	gm.	mg.	mg.	
II	43	20	8·4	8·2	43	19·5	19·1	232	·32	26	27	
Soil : A	44	20	8·5	8·3	44	19·4	19·0	228 }	·26	22	22	
Wat. Cont. : L	48	20	7·9	7·7	41	19·1	18·7	242 }		20	21	
Fert. : Ca	45	21	10·2	9·5	39	26·0	24·4	255	·33	31	33	0·55 gm. grain with 1·31% P_2O_5.
III	46	21	9·4	8·8	37	25·8	24·2	274 }	·28	25	26	
	47	21	9·5	8·9	35	26·9	25·2	283 }		25	27	
II	61	20	35·0	35·0	91	38·4	38·4	110	·80	280	280	
A.L	62	20	35·7	35·0	88	40·8	40·3	114 }	·84	294	301	
CaKNP	64	21	42·7	40·0	103	41·5	39·5	97 }		336	360	
	59	21	44·2	41·4	74	59·9	56·6	136	·83	344	368	1·25 gm. grain with 1·52% P_2O_5.
	60	20	44·0	43·3	73	60·1	59·6	137 }	·82	355	362	
III	63	20	43·7	43·0	80	54·3	53·8	124 }		352	359	
II	50	20	9·7	9·5	38	25·3	24·8	261	·28	26	27	
A.H	53	20	9·3	9·1	37	25·0	24·5	269 }	·29	26	27	
Ca	54	24	11·3	9·3	38	29·8	24·4	264 }		27	32	
	49	23	14·0	12·0	34	40·7	35·0	291	·33	40	46	1·05 gm. grain with 1·28% P_2O_5. ·98% CaO (grain removed); 2·18% N.
III	51	20	11·7	11·5	32	36·3	35·8	310 }	·29	33	34	1·01% CaO (whole plant); 2·34% N.
	52	23	12·5	10·7	34	36·8	31·6	294 }		31	36	
II	67	20	43·4	42·5	70	62·0	61·1	143	·97	414	426	
A.H	65	20	41·8	40·0	90	46·5	44·7	111 }	·97	388	411	
CaKNP	68	20	46·0	46·0	73	63·1	63·1	137 }		446	446	
	66	23	62·2	52·5	78	79·6	67·7	128	·93	488	584	1·55 gm. grain with 1·43% P_2O_5; 2·48% N. in straw.
	69	20	48·0	48·0	68	70·6	70·6	147 }	·94	451	451	2·90% N. in whole plant.
III	70	21	51·4	48·1	70	73·4	69·0	143 }		452	486	
A.H III	41	22	9·6	8·7	27	35·9	32·6	374	·20	17	19	0·80 gm. grain with 1·26% P_2O_5; 2·02% N. in straw.
O	42	24	8·1	6·8	26	30·6	25·5	378		Lost.		85% CaO (whole plant); 2·21% N.
A.H III	58	25	15·0	12·0	39	38·0	30·4	253	·25	30	38	0.30 gm. grain P_2O_5 not determ.; 2·97% N. in straw.
CaKN	57	25	13·7	11·0	37	36·7	29·4	268	·28	31	38	3·05% N. in whole plant.
A.H III	55	21	42·6	38·9	58	73·1	67·9	172	·86	334	365	10·25 gm. grain with 1·25% P_2O_5; 1·32% N. in straw.
CaP	56	22	37·7	32·6	60	62·9	55·5	167	·85	277	320	1·60% N. in whole plant.

TABLE VIII.

Showing crop production, water requirement, and phosphorus removal on SHEPSTONE *soil.*

Series.	Pot No.	Plants per Pot.	Wt. of Crop.			Water used.			P_2O_5 removed.			General.
			Per Pot.	Per 20 Plants.	Per 100 Litre Water.	Per Pot.	Per 20 Plants.	Per 100 gm. Crop.	Per 100 gm. Crop.	Per 20 Plants.	Per Pot.	
									gm.	mg.	mg.	
II	77	23	2·0	1·7	20	10·1	8·6	505	·23	4	5	
Soil: S.	75	25	1·7	1·3	17	9·8	7·7	576 }	·22	3	4	
Wat. Cont.: L.	78	25	2·7	2·1	25	10·6	8·3	393 }		5	6	
Fert.: Ca.	74	25	2·9	2·2	22	13·2	10·4	455	·26	6	8	Grain = O.
III	73	23	2·3	1·9	20	11·7	10·0	509 }		Lost.		
	76	25	2·5	1·9	21	11·9	9·4	476 }				
II	89	23	6·7	5·7	55	12·1	10·3	181	·63	36	42	
S.L.	90	25	6·4	5·0	57	11·2	8·7	175 }	·60	30	38	
	94	25	7·9	6·2	60	13·2	10·3	167 }		37	47	
CaKNP.	93	22	17·4	15·7	71	24·4	21·9	140	·69	108	120	1·15 gm. grain with 1·41% P_2O_5.
III	91	20	12·1	12·0	64	19·0	18·7	157 }	·66	80	80	
	92	22	12·9	11·6	66	19·4	17·4	150 }		77	85	
II	80	25	5·5	4·3	29	18·7	14·6	340	·22	9	12	
S.H.	82	25	4·2	3·3	22	18·8	14·7	448 }	·28	9	12	
	83	25	6·1	4·8	30	20·6	16·2	338 }		13	17	
Ca.	84	25	6·8	5·4	26	25·8	20·3	379	·25	14	17	Grain = 0·05 gm.
III	79	25	6·5	5·1	25	26·4	20·8	406 }	·26	13	17	} ·94% CaO. (whole plant).
	81	22	5·0	4·5	20	24·6	22·0	492 }		12	13	
II	99	22	27·0	24·1	82	33·0	29·5	122	·55	132	150	
S.H.	97	23	27·5	23·5	82	33·4	28·5	121 }	·53	125	147	
	100	25	26·5	20·8	80	33·2	26·1	125 }		110	142	
CaKNP.	98	22	35·0	31·4	72	48·3	43·4	138	·53	166	186	0·75 gm. grain with 1·48% P_2O_5.
	95	20	29·3	28·8	61	48·4	47·8	165 }	·53	153	157	
III	96	25	31·5	24·8	67	47·0	37·1	149 }		131	167	
S.H. III	71	25	3·3	2·6	14	23·9	19·1	724	·13	3	4	Grain = O.
O.	72	25	2·8	2·2	12	22·7	18·2	811	No	material	left.	·47% CaO. (whole plant).
S.H. III	87	25	6·3	5·0	27	23·4	18·7	371	·21	10	13	Grain = O.
CaKN.	88	25	6·2	5·0	24	25·4	20·3	410	·23	11	14	
S.H. III	85	25	29·4	23·0	62	47·7	37·4	162	·52	120	154	0·25 gm. grain } with 1·35% P_2O_5.
CaP.	86	25	26·7	20·8	64	42·0	32·8	157	·48	100	128	0·20 gm. grain }

TABLE IX.

Showing crop production, water requirements and phosphorus removal on VERONA EAST *soil.*

Series.	Pot No.	Plants per Pot.	Wt. of Crop.			Water used.			P_2O_5 removed.			General.
			Per Pot.	Per 20 Plants.	Per 100 Litre Water.	Per Pot.	Per 20 Plants.	Per 100 gm. Crop.	Per 100 gm. Crop.	Per 20 Plants.	Per Pot.	
			gm.	gm.	gm.	Litre.	Litre.	Litre.	gm.	mg.	mg.	
II	18	20	9·2	9·0	70	13·2	12·9	143	·47	42	43	
Soil: V	19	23	11·7	10·0	79	14·8	12·6	126		47	55	
Wat. Cont.: L	23	20	9·2	9·0	70	13·1	12·8	142	·53	48	49	
Fert.: Ca	20	25	15·5	12·2	73	21·3	16·8	137	·51	62	80	1·70 gm. grain with 1·26% P_2O_5.
III	21	24	15·2	12·6	60	25·2	20·8	166	·46	58	70	
	25	22	13·3	11·9	59	22·7	20·4	171		55	62	
III	29	25	9·1	7·2	70	13·0	10·2	143	·91	66	83	·81% CaO (whole plant).
	30	22	9·0	8·1	67	13·4	12·0	149		74	83	
V.L.												
CaKNP	33	25	17·1	13·6	78	21·9	17·4	128	·87	118	149	0·90 gm. grain with 1·35% P_2O_5.
II	31	20	16·6	16·5	80	20·7	20·5	125	·81	134	135	
	32	22	12·4	11·2	66	18·8	16·9	152		91	101	
II	15	23	25·3	21·7	71	35·7	30·6	141	·59	128	150	
	13	24	24·8	20·4	68	36·3	29·9	146	·54	110	134	
V.H	24	25	25·8	20·4	68	37·7	29·8	146		110	138	
Ca	22	25	31·3	24·8	61	51·0	40·4	163	·57	142	180	8·50 gm. grain with 1·22% P_2O_5 and ·07% CaO. Straw = ·69% CaO.
III	16	25	28·4	22·5	56	51·0	40·4	180	·54	122	154	·51% CaO (whole plant).
	17	25	28·7	22·7	57	50·5	40·0	176		123	155	
	36	25	27·0	21·2	72	37·5	29·6	139	·88	187	240	·74% CaO (whole plant).
II	37	22	25·5	22·7	80	31·9	28·5	125		200	226	
V.H												
CaKNP	34	25	39·5	31·2	69	57·3	45·4	145	·96	300	378	1·55 gm. grain with 1·42% P_2O_5.
III	35	25	37·5	29·6	64	58·5	46·4	156	·91	269	344	1·90 gm. grain with 1·42% P_2O_5.
	38	25	37·5	29·6	70	53·2	42·2	142		269	344	
V.H. III	11	25	23·8	19·0	57	42·1	33·7	177	·57	108	135	4·75 gm. grain with 1·30% P_2O_5; ·56% CaO (grain removed).
O	12	22	23·7	21·5	57	41·3	37·5	174	·53	114	126	·46% CaO (whole plant).
V.H. III	27	25	33·6	26·9	61	55·0	44·0	164	·48	129	160	3·60 gm. grain with 1·32% P_2O_5.
CaKN	28	25	26·2	21·0	58	45·5	36·4	174	·44	92	116	
V.H. III	14	25	32·0	25·6	61	52·1	41·7	163	1·03	264	330	3·20 gm. grain with 1·37% P_2O_5.
CaP	26	25	17·4	13·9	54	32·3	25·8	186	·83	115	144	(Exception, and not comparable).

In addition to the actual experimental figures, the water required for the production of 100 gms. of dry plant material and, conversely, the amount of dry material produced per 100 litres of water consumed have also been calculated and included in the previous tables. Furthermore, as the pots unfortunately did not all have precisely the same number of plants*, the probable crop production, water consumption and phosphorus removal per " ideal pot " of 20 plants have also been deduced. These figures do not materially alter any of the results or affect the deductions drawn from them. Neither is any particular significance claimed for them, as it is a well-known fact that, within certain limits, there is a strong tendency for complete compensation of any shortage in production due to a smaller number of plants by a correspondingly increased production per plant. The " 20-plant figures " are nevertheless included as some readers may prefer comparisons on the basis of an exactly equal number of plants, but more particularly, to allow of a better comparison with the values for growth period I, which were necessarily based on an equal number of plants. The writer has, however, chosen the " pot figures " for drawing his comparisons and conclusions.

* The intention was at first to reduce the number of plants on each pot to 20-22, i.e. 20 for the final stand and the rest for examination at 6 weeks. After a preliminary weeding out of unthrifty plants had been effected, and some of the A. pots brought to the desired number of plants, it was noticed in several cases (notably S. soil) that plants were still turning yellow. It was therefore deemed advisable to stop further adjustment and to count instead all plants still showing any growth after 4 weeks.