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Farming will never be a success unless the farmer
had more voice in the disposal of
his produce.—P. Morrel.

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# THE RELATION BETWEEN GROWTH AND INTAKE OF NUTRIENTS IN THE CHOLAM PLANT*

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This paper reports the results of a Study of the variation in chemical composition of the Cholam plant, at successive stages of growth, as shown by periodical analysis of representative samples taken from a field crop of Periamanjal Cholam. The analysis included the determination of Nitrogen, Phosphoric Acid, Potash, Calcium, Magnesium, Silica, Iron, Alumina, Total Mineral Ash, Carbohydrates and Diastatic Activity.

An examination of the changes occurring in the Chemical composition of the Cholam plant, is of use to us.—Firstly, to understand the mineral metabolism and the Biochemical changes taking place during growth; Secondly, to fix the nutritive value of the plant, which is used widely as fodder, with special reference to the mineral requirements of cattle, the importance of which has been much emphasized upon in recent nutrition researches; Thirdly, it would suggest the best stage at which to cut the crop, either for fodder or for grain; Fourthly, it gives the average composition of the Cholam grain, which is largely used as food by the people of this Presidency; and Lastly, it affords information to the agriculturist, as to how much of the mineral nutrients has been removed by the crop and has to be returned to the soil to keep up its fertility; in other words, it indicates the mineral requirements of the plant.

*(Paper read before the College Day Conference, Coimbatore, July 1929)

## MATERIALS AND METHODS

The Cholam Crop (Periamanjal) grown in Field No. 37 of the Agricultural College Estate (a Red Loam Soil) was selected for the experiment. It was sown on August 4, 1928. Representative samples of plants which had grown to the same extent, were chosen from different parts of the Field, once a fortnight, till the end of December, by which time the grain had completely matured and the plants also were getting dry. The samples were all collected at about 7 A.M. on the various days, taken immediately to the Laboratory, where the plants were carefully cleaned of adhering impurities and divided into the various parts, e.g., Leaves, stem, root, grain, etc. A weighed amount of each was taken for moisture determination and the rest was dried and bottled up for future determinations of the Chemical composition.

The analytical methods followed were, in main, those recommended by the A.O.A.C. In the estimation of *Iron*, *Ca* and *Mg*, the Phosphoric acid was removed as Ammonium Phospho-molybdate, a procedure which was found to give essentially the same results, though more convenient in manipulation than the more commonly adopted basic *ferric acetate* method. Diastatic activity was determined by reacting 1 gm. sample of the dry powder with 20 cc. of 2 per cent Soluble Starch Solution for 24 hours at the laboratory temperature (28° to 30° C), clarifying the solution with alumina cream, making up to 50 c.c and determining the reducing power of an aliquot by *Bertrand's Volumetric Permanganate* method. The results are expressed in milligrams of maltose produced. Phosphoric acid was determined by titrating Ammonium Phospho-molybdate with standard alkali. In the determination of Total Nitrogen, *Gunning's modification of Kjeldahl's* method was adopted.

The data obtained are contained in the annexed Tables Nos. I to V and, for the sake of clearness, have been expressed :—

(1) As percentages of the dry matter in each part—Leaves, Stem, Root etc.

(2) As absolute weights of the constituents per hundred plants, in each part separately, and also in the plant as a whole. The latter enables us to follow the total absorption of the nutrients from the soil by the plant at successive stages of growth.

The data are represented also graphically in Graphs Nos. I to VIII.

## NITROGEN

Nitrogen is an important constituent of Cholam Fodder, having regard to the Protein it constitutes, and as such, the variations in Nitrogen content during growth are of special interest.

The changes in the values for Total Nitrogen, expressed as percentages on the dry matter, are represented graphically in Fig. I. From the curves, it will be noted :—(1) that the leaves contain always a higher percentage of Nitrogen than the stem, and the latter, generally more in turn, than the root, and (2) that the proportion of Nitrogen in the dry matter, is highest in the early stages. For example, in the case of the leaves, it is

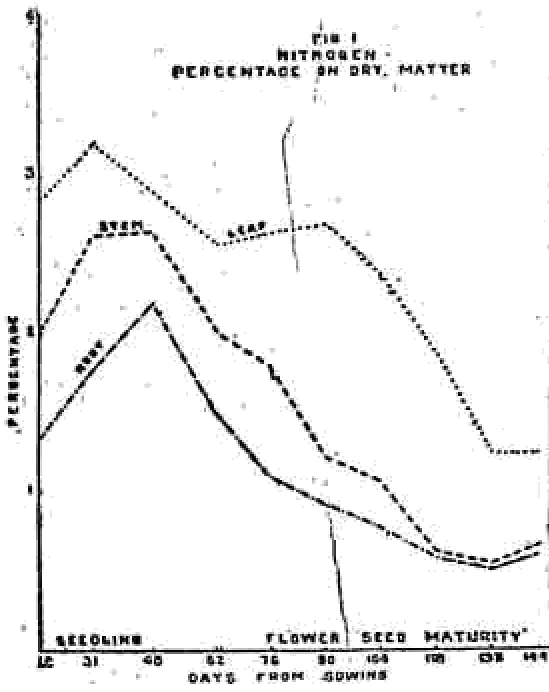
FIG I
NITROGEN
PERCENTAGE ON DRY. MATTER
PERCENTAGE
LEAF
STEM
ROOT
SEEDLING
FLOWER
SEED
MATURITY
DAYS FROM SOWING

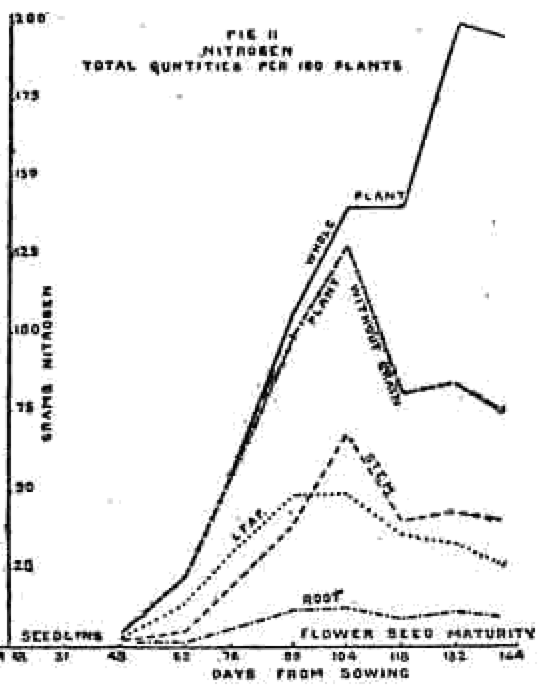
FIG II
NITROGEN
TOTAL QUNTITIES PER 100 PLANTS
GRAMS NITROGEN
WHOLE PLANT
PLANT WITHOUT GRAIN
STEM
LEAF
ROOT
SEEDLING
FLOWER SEED MATURITY
DAYS FROM SOWING

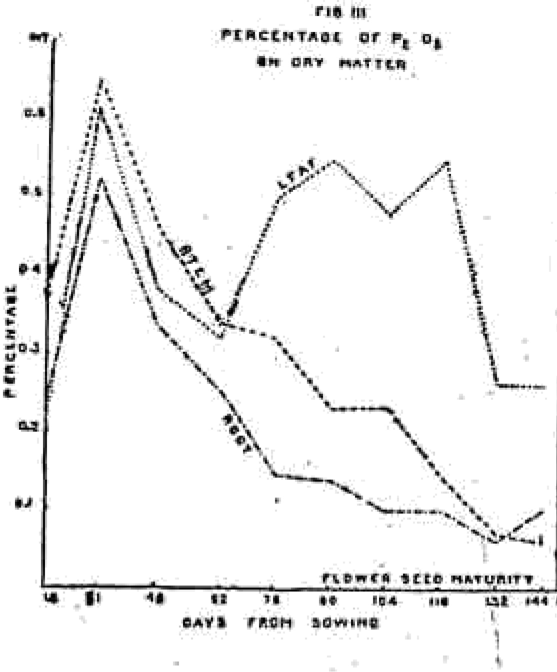
FIG III
PERCENTAGE OF P2 O5
ON DRY MATTER
PERCENTAGE
LEAF
STEM
ROOT
FLOWER SEED MATURITY
DAYS FROM SOWING

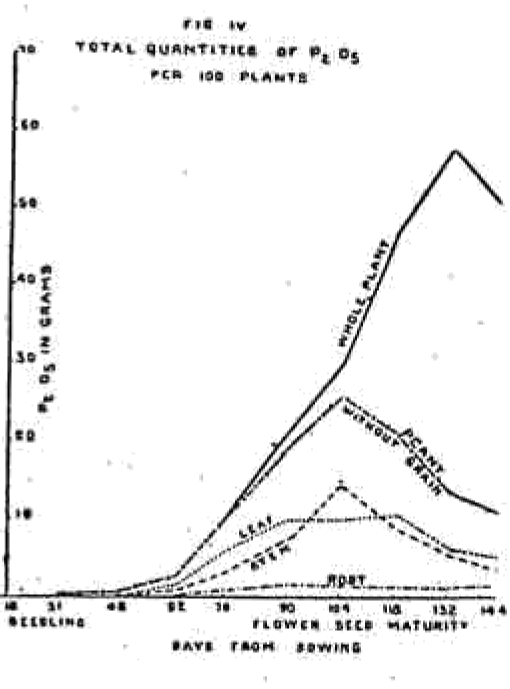
FIG IV
TOTAL QUANTITIES OF P2 O5
PER 100 PLANTS
P2 O5 IN GRAMS
WHOLE PLANT
PLANT WITHOUT GRAIN
LEAF
STEM
ROOT
SEEDLING
FLOWER SEED MATURITY
DAYS FROM SOWING

3·193 per cent, in the stem 2·658 per cent. and in the root 2·192 per cent. The proportion is kept at a fairly high level till the flowering stage. When flower buds appear, there is a sudden fall, due to the translocation of the accumulated nitrogen into the grain.

The values for the total quantity of Nitrogen absorbed and retained by the plant, show a steady rise in the various parts (Leaves, Stem and Root) till the stage of flowering, after which there is a rapid decline. Taking 100 plants as a convenient unit, there are, at the 'seed formation' stage, 49·56 gm. of Nitrogen in the leaves, 67·88 gm. in the stem and 11·30 gm. in the root, i.e., 128·8 gm. in the vegetative parts of 100 plants. After the seeds have become ripe, however, nearly about 60 per cent. of the Nitrogen is transferred into the grain, so that the grains contain more Nitrogen than the rest of the plant put together, even though the grains weigh only about half as much as the rest of the plant. As such, from the point of view of Fodder, the plant cut at the flowering stage, is much richer in Nitrogen than that allowed to ripen its seed.

The continued ability of the plant to absorb and store Nitrogen till the 'Seed' stage, would seem to indicate that the more Nitrogen that is applied as fertilizer to a plant prior to the stage of flowering (within limits, of course), the more will be the absorption and store of Nitrogen in the Tissues, which would be later available for the making of the grain. Hoagland (1) has found that the concentration of Nitrogen in the tissues and tissue-fluids varies directly, though not proportionally with the concentration in the external nutrient medium ; but the problem is complicated by other growth factors, depending on the individual peculiarities of each plant, as shown by Gericke in his interesting experiments on the effect of application of Nitrogen at different periods in the life of the wheat plant. He found (2) that very early applications, say, at or prior to sowing, merely tend to increase vegetative growth, whereas later applications (of course, before flowering), increase the protein content and hardness of wheat.

By a closer study of the Nitrogen Metabolism of the Cholam Plant, it might be possible for the Farmer so to regulate the quantity and time of application of Nitrogenous fertilizers to his crop, as to control the protein content of the grain, on which depend important factors like quality, fitness for Malting purposes etc.

## PHOSPHORIC ACID

The requirements of the plant for Phosphoric Acid are much smaller and steadier than for Nitrogen. It can be said in general, that the changes in Phosphorus follow those in Nitrogen.

Expressing the figures in terms of percentages of dry matter, we note that the curves show two maxima—one at the seedling stage, corresponding to a period of rapid root-development, and the other at the stage of grain-formation, showing the demand for Phosphorus at the two stage. As in the case of Nitrogen, the leaves usually contain more phosphorus than the stem, and the latter more so than the root. Taking the absolute quantities of Phosphorus present in the tissues, there is a progressive increase upto the seed formation stage, after which there is a decline, due to the transfer of a portion of the phosphorus to the grain. Thus the Phosphorus content of 100 plants (excluding grain), reaches a maximum value of 26·03 gm. at the seed formation stage, after which there is a fall to 10·86 gm. corresponding to the dead ripe stage, when the leaves and stem get dry.

From the point of view of use as Fodder, the crop cut at the flowering stage contains almost double the quantity of Phosphorus contained in the crop cut after the grains have become fully ripe.

In the case of Phosphorus, the plant does not appear to have the capacity to store it in the tissues, as it does Nitrogen. In the case of Nitrogen, out of about 200 gm. present per 100 plants, (including grain) at the stage of maturity, about 75 per cent. was already present in the plant at the stage of seed-formation, and only 25 per cent. was thereafter absorbed from the soil. This storage capacity in the case of Nitrogen is physiologically valuable, since, in the normal soil, there is only a small and steady supply of Nitrogen available in the form of Nitrate at any moment; and even this supply is apt to be leached away, if not immediately absorbed by the plant and stored for future requirements.

In the case of Phosphorus, out of about 58 gm. present per 100 plants at the stage of maturity, only about 21 gm. were present at the stage of flowering. After the grains are formed, however, there is a rapid absorption of phosphorus from the soil, to meet the physiological requirements of the plant, as shown by the rapid rise in the curve during the later stages of the plant's life; as much as 37 gm. are translocated to the grain within a period of about a month, of which only about 7 or 8 gm. have come from the previous store in the tissues and about 30 gm. have been freshly absorbed from the soil.

## POTASH

The demand for Potash, as in the case of Nitrogen and Phosphoric acid, seems to be particularly great in the early stages, for in the seedling stage, the percentage of Potash on the dry matter is highest (Leaf: 2·886 per cent, Stem 4·040 per cent and Root 5·178 per cent). The saying 'Potash goes to make carbohydrates' seems to hold good in a general way, for Potash accumulates chiefly in the stem and root, where there is also an accumulation of carbohydrates. There is however an essential difference between Potash Metabolism and that of Nitrogen or Phosphoric Acid, namely that, whereas in the latter two cases, all the extra Nitrogen or Phosphoric acid stored up in the vegetative tissues, is carried later on to the grain, the Potash is mostly left behind in the tissues and only small quantities are taken up by the grain. In the present experiment, out of about 180 gm. of Potash in 100 plants weighing about 12,000 gm. (dry matter without grain), only about 13 gm. are transferred into the grain, weighing about 6,000 gm. This seeming anomalous behaviour of Potash might serve to explain why increasing yields of grain are generally obtained by applications of Phosphoric acid and Nitrogen, while, Potash above a minimum value has no such effect. The absorption and accumulation of Potash in the stem continues so long as Carbohydrates are manufactured and stored. The fact that the Potash so accumulated, is left behind in the tissues,

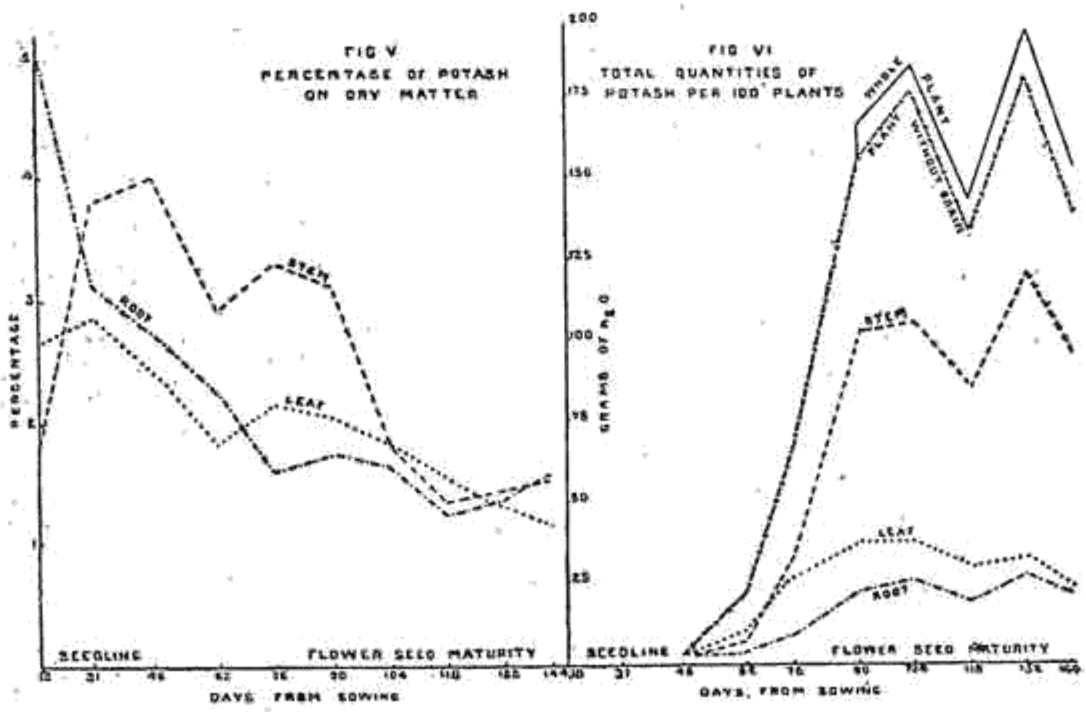
FIG V
PERCENTAGE OF POTASH
ON DRY MATTER
STEM
ROOT
LEAF
PERCENTAGE
SEEDLING
FLOWER SEED MATURITY
DAYS FROM SOWING
FIG VI
TOTAL QUANTITIES OF
POTASH PER 100 PLANTS
WHOLE PLANT
PLANT WITHOUT ROOTS
STEM
LEAF
ROOT
GRAMS OF K2O
SEEDLING
FLOWER SEED MATURITY
DAYS, FROM SOWING

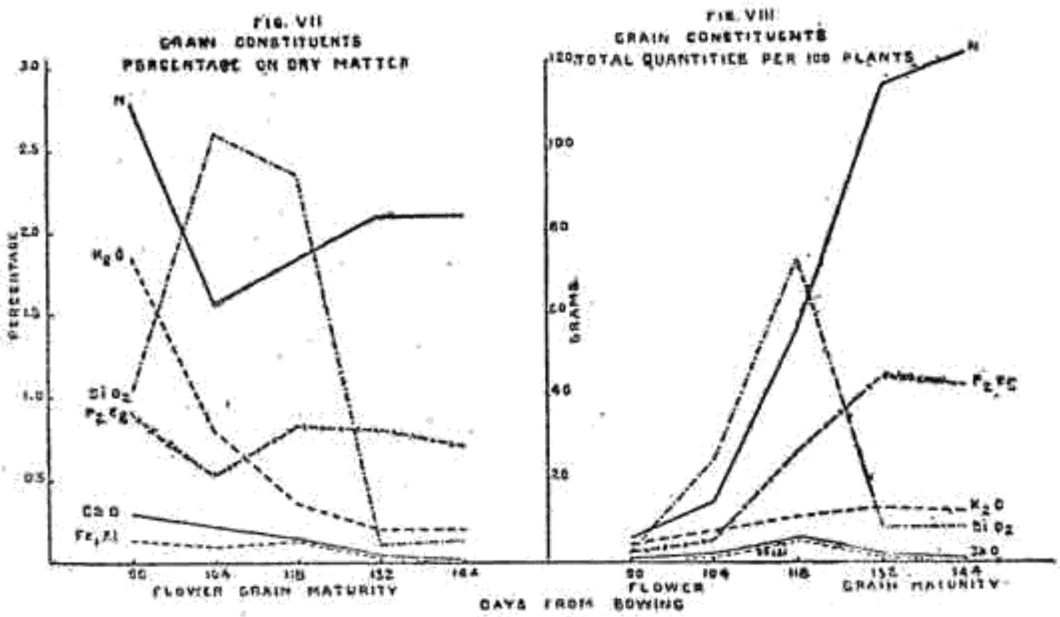
FIG. VII
GRAIN CONSTITUENTS
PERCENTAGE ON DRY MATTER
N
K2O
SiO2
P2O5
CaO
Fe2Al
PERCENTAGE
FLOWER GRAIN MATURITY
FIG. VIII
GRAIN CONSTITUENTS
TOTAL QUANTITIES PER 100 PLANTS
N
P2O5
K2O
SiO2
CaO
GRAMS
FLOWER
GRAIN MATURITY
DAYS FROM SOWING

while a large amount of the carbohydrates is transferred to the grain, would seem to indicate that Potash is more necessary in the manufacture of the Carbohydrates than in their translocation from one part of the plant to another.

## CALCIUM

Calcium shows a somewhat different variation, inasmuch as there is a continuous accumulation of this element in the leaf, from 0·644 per cent in the early stages to 1·190 per cent in the later stages. Such accumulation is not noted in the case of the stem or root.

The accumulation of Calcium in the Leaves, in the later stages might be closely connected with the translocation of Nitrogenous products to the grain. Parker and Truog (4) advanced the hypothesis that Calcium helps in the synthesis of Protein from the Carbohydrate and Nitrogen, by neutralizing the acids that are formed as by products of such synthesis. But the present experiments show that the main accumulation of Calcium takes place after most of the Nitrogen required has been absorbed and the results seem to indicate that Calcium plays an important part in the translocation of Protein and other Nitrogenous products from the tissues to the grain. In this connection may be cited the interesting results obtained by Gericke (3) who found that the Protein content of wheat grown for 10 weeks in a complete nutrient solution and later transferred to a solution devoid of Calcium, was only half the Protein content of the grain obtained from the normal plant.

## DEVELOPMENT OF THE CHOLAM GRAIN

Analysis of the Cholam flower, grain and Bhusa at various stages of development of the plant was also made, with special reference to the mineral constituents and Diastatic activity. The data are set out in Table No. IV and also graphically in Figs. Nos. VII and VIII.

The data show that the course of development of the Cholam grain, can be divided roughly into two periods of almost equal extent. The first period is one of building the cell-walls and tissue-fabric of the grain, for which a large amount of mineral matter, principally Silica and Calcium seem required. There is a simultaneous accumulation of nearly the whole of the Nitrogen and Phosphoric acid required by the grain. After the first stage of building the cell-fabric of the grain is over, certain of the auxiliary elements, which obviously find no further place in the economy of the grain, e.g., Silica, Calcium, Iron, Alumina, etc., are rapidly ejected from the grain, leaving only small quantities of them behind. These excrements find their way into the Bhusa, leaves and other tissues of the plant. In the second period, there is a rapid accumulation of carbohydrates. Potash and Magnesia show a steady increase throughout.

The chemical changes in the development of the grain follow in miniature that of the plant itself; the flower corresponds to the seedling stage, inasmuch as it is rich in the various nutrient elements (Nitrogen 2·768 per cent, Phosphoric acid 0·904 per cent, Potash 1·85 per cent, $CaO$ 0·306 per cent). The curves representing the percentage of the elements on the dry matter show generally a fall from the flowering stage to the earlier stages of grain formation, followed by a gradual recovery. The Bhusa is very poor in Nitrogen (0·657 per cent on dry matter) as compared with the flower (2·768 per cent) and grain (2·11 per cent)

The variations in the content of Silica during the development of the grain are very marked. Thus the flowers contained 1·032 per cent on dry matter, whereas in the initial stages of grain-development, the proportion rose up to 2·702 per cent. In the second half-period of development, however, there was a rapid fall to 0·140 per cent. This decrease is not due to the accumulation of other constituents but is absolute, as shown by the total quantities of Silica present in the seed at different stages. Expressed in grams per 100 plants, the flowers contained 2·23 gm., the seed in the earlier stages 25·43 gm. and 70·31 gm. and in the later stages 7·64 gm. and 8·32 gm. It is interesting to note that the Bhusa in the later stages contains nearly 70·15 gm. of Silica per 100 plants, showing that the excess of Silica has been returned from the grain to the Bhusa. Obviously, Silica plays an important part in the early stages of development of the grain, either in helping the transportation of organic Phosphorus compounds into the grain or in the building up of the cell fabric. Like $CaO$ and *Iron*, once its function is fulfilled, it is expelled from the grain into the Bhusa, which becomes rich in this element and contains as much as 7·872 per cent of it on the dry matter.

In the case of Iron and Alumina, and also Calcium, there is a similar rapid intake in the first-half period of the development of the grain, and a rapid fall in the Second period, not merely in the relative percentages on dry matter, but in the absolute quantities as well, in the grain of 100 plants. The causes underlying this characteristic fluctuation in Silica, $CaO$, Iron and Alumina require a more detailed examination of the matter, before definite conclusions can be arrived at.

## LOSS OF NUTRIENTS BY THE PLANT

It is interesting to note that after the grains become fully ripe, there appears to be set up a backward flow of nutrients from the plant to the soil. Thus it is found that at the stage of maturity, there are present per 100 plants, 1466·4 gm. of mineral matter but a fortnight later, at the 'dead' or 'over-ripe' stage when the leaves and stem get dry, the content of mineral matter falls to 1147·8 gm.—the fall being chiefly due to Potash from 193·7 gm. to 152·7 gm. Calcium from 86·3 gm. to 66·6 gm., Magnesium from 87·5 gm. to 69·5 gm. Iron and Alumina from 75·5 gm. to 45·2 gm. and acid insoluble matter taken as Silica from 906·7 gm. to 702·4 gm.

Though in the above interval, there is a slight increase in the content of Nitrogen, Phosphorus and other constituents in the grain, still, considering the above great loss of nutrients to the extent of about 20 per cent from the plant to the soil, it would seem economically better to cut the crop at the ripe stage and not to allow it to become 'dead' or 'Over-ripe': such practice would help to preserve the nutritive value of the fodder.

The above results, showing a loss of nutrients from the plant to the soil after the stage of maturity, is supported by the experiments of Burd (5) and Sekera (6) working on Barley and Jones and Huston (7) working on

Maize. All of them note a period of rapid absorption by the plant just prior to the beginning of head formation, followed by a long period of slow absorption, and finally a period of absolute loss from the plant.

Wilfarth, Romer and Wimmer (8) found that wheat and barley plants contained very considerably less Potash and Nitrogen at maturity than previously. They were of opinion that these elements after assisting in the performance of the physiological processes within the plant, return again to the soil through the roots.

It is interesting to note that the Soil Solution studies conducted by the Government Agricultural Chemist, Coimbatore, (unpublished record) with reference to cotton, also indicate a backward flow of nutrients from the plant to the soil after the stage of maturity.

## APPLICATION OF FERTILIZERS

The importance of choosing the time of application of fertilizers to coincide with the stage of maximum physiological capacity for asssimilation on the part of the plant, has been much stressed upon in recent researches in regard to other crops. Thus, Steece (9) in his Report on the Agricultural Experimental Stations of the U. S. A. for 1927, notes that at the Alabama Experimental Station, Nitrate of Soda, applied at the rate of 600 lbs. per acre for cotton, 14, 40 and 61 days after planting, was absorbed in 36, 14 and 11 days respectively. He finds a close correlation between the rates of growth and of Nitrate-absorption and observes :—'The results suggested that the loss of soluble Nitrogenous fertilizer, might be reduced by delaying the application until the crop is able to absorb it rapidly.'

In the case of Cholam, it will be premature to draw conclusions from one experiment and that not intended to examine the effect of application of manures at different periods of the plant's life, but the curves for the assimilation of Nitrogen and Phosphorus would tend to show that the demand for the nutrient elements is great at two stages—first, at the seedling stage, and secondly, prior to flowering. Though the intensity factor is great at the seedling stage, the total assimilation capacity is small, and hence in the case of fertilizers like Nitrates, which are apt to be leached away, it would seem advisable to apply only a small portion at the time of sowing, and reserve the bulk of the fertilizer for a somewhat later application, but not so late as to affect flowering and seeding.

## CONCLUSIONS

From the foregoing, it would therefore appear that :—

(1) The Cholam plant has got the capacity to absorb large qu
of Nitrogen in the early stages, and after meeting the requir
vegetative production, store the remainder for translocation to

(2) There is an accumulation of Nutrients in the plan
of flowering : the rate of absorption increases at first with
most rapid during the period just prior to flowering ; aft
rate slows down—the main business of the plant being the
the absorbed Nutrients to the Seed.

(3) The Tissues are richest in plant Nutrients at th
or immediately following it. The present practice of

I. Total
II. $P_2O_5$
III. $K_2O$
IV. CaO
V. MgO
VI. $SiO_2$
VII. $Fe_2O_3 + Al_2O_3$
VIII. Total Mineral Ash

crop at the above stage, is generally explained as due to the fear of the occurrence of cyanogen compounds in the earlier stages, but the present experiment shows that the practice is a sound one from the economic as well as the nutritional points of view.

(4) The varying capacity of the plant for assimilation of Nutrients, at different stages, would seem to indicate the advisability of regulating the application of manures in regard to time and quantity, to coincide with the periods of maximum capacity for absorption on the part of the plant; thus, nitrogenous manures in the form of nitrates, might, with a view to secure maximum growth and economy, be applied partly at the time of sowing as a basal dressing, and in much larger quantities at a later stage, prior to flowering.

(5) The data show that after the grains become ripe, there appears to be set up a backward flow of nutrients from the plant to the soil; and it is suggested that in order to preserve the nutritive value of the fodder, the crop be cut before becoming over-ripe.

(6) Taking an average crop of Cholam in these parts to yield about 1,000 lbs. of grain and 2,000 lbs. of (dry) straw per acre, the mineral nutrients removed by the crop, which have to be returned to the soil in the form of fertilizers, in order to keep up its fertility, are per acre, roughly as follows:— Nitrogen 35 lbs., Phosphoric acid 10 lbs., and Potash 32 lbs.

In conclusion, I wish to thank Mr. H. Shiva Rao and Rao Bahadur B. Viswa Nath for their kind interest in the experiment and for helpful criticism.

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TABLE I.—SHOWING THE VARIATION IN COMPOSITION OF THE DRY MATTER OF THE *LEAVES* OF PERIAMANJAL CHOLAM AT SUCCESSIVE STAGES OF GROWTH.—DATE OF SOWING AUGUST 4, 1928

| | No. of sample ... | I | II | III | IV | V | VI | VII | VIII | IX | X |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date of sampling ... | 22-8-28 | 4-9-28 | 19-9-28 | 5-10-28 | 19-10-28 | 2-11-28 | 16-11-28 | 30-11-28 | 14-12-28 | 26-12-28 |
| | No. of days from sowing... ... | 18 | 31 | 46 | 62 | 76 | 90 | 104 | 118 | 132 | 144 |
| | Stage of growth ... | Rapid Vegetative growth. | | | | | Flowers | Seed forms | ... | Grains ripe | Over-ripe |
| | Weight of dry matter in leaves of 100 plants, in grams ... | 3·33 | 16·86 | 66·0 | 558 | 1150 | 1800 | 2080 | 1920 | 2592 | 2080 |
| | *Constituents expressed as percentages on dry matter* | | | | | | | | | | |
| I. | Total Nitrogen ... | 2·836 | 3·193 | 2·904 | 2·575 | 2·658 | 2·685 | 2·383 | 1·891 | 1·260 | 1·260 |
| II. | $P_2O_5$ ... ... | 0·2192 | 0·6081 | 0·3827 | 0 3203 | 0·4989 | 0·5480 | 0·4820 | 0·5438 | 0·2593 | 0·2576 |
| III. | $K_2O$ ... ... | 2·708 | 2·886 | 2·368 | 1·829 | 2·151 | 2·045 | 1·822 | 1·547 | 1·286 | 1·158 |
| IV. | CaO ... ... | 0·6442 | 1·066 | 0·9630 | 0·8722 | 0·6774 | 0·8420 | 0·9738 | 1·019 | 1·190 | 1·116 |
| V. | MgO ... ... | 0·3239 | 0·6176 | 0·6320 | 0·5703 | 0·6063 | 0·6787 | 0·6210 | 0·6548 | 0·5954 | 0·5902 |
| VI. | $SiO_2$ ... ... | 2·461 | 6·127 | 5·533 | 5·381 | 5·538 | 7·403 | 9·625 | 12·55 | 14·58 | 14·03 |
| VII. | $Fe_2O_3 + Al_2O_3$ ... | 0·7032 | 0·4161 | 0·3386 | 0·3363 | 1·303 | 0·4068 | 0·5170 | 1·352 | 0 9074 | 0·3623 |
| VIII. | Total Mineral Ash ... | 12·81 | 13·38 | 11·54 | 10 51 | 10·85 | 13·38 | 14·64 | 18·40 | 19 38 | 18·21 |
| IX. | Diastatic Activity per gm. dry matter in Mg. Maltose ... | ... | ... | ... | 816·4 | 1450 | 850 | 823 0 | 606·7 | 204·2 | 79·20 |
| | *Total weight of constituents present in the dry matter of 100 plants, in grams* | | | | | | | | | | |
| I. | Total Nitrogen ... | 0 095 | 0 538 | 1·916 | 14·36 | 30·56 | 48·33 | 49 56 | 36·31 | 32·66 | 26·21 |
| II. | $P_2O_5$ ... ... | 0 007 | 0 102 | 0·253 | 1·786 | 5·737 | 9·865 | 10·02 | 10·44 | 6·720 | 5·358 |
| III | $K_2O$ ... ... | 0·090 | 0·487 | 1 563 | 10·21 | 24·74 | 36·81 | 37·90 | 29·70 | 33·34 | 24 08 |
| IV. | CaO ... ... | 0·022 | 0·180 | 0·635 | 4·866 | 3·895 | 15·16 | 20·26 | 39·10 | 30·84 | 23·21 |
| V. | MgO ... ... | 0·011 | 0·104 | 0·417 | 3·182 | 6·972 | 12·22 | 12·92 | 12 57 | 15·43 | 12·27 |
| VI. | $SiO_2$ ... ... | 0·082 | 1·033 | 3·651 | 30·02 | 63·68 | 133 2 | 200·2 | 240·9 | 377·9 | 291·8 |
| VII. | $Fe_2O_3 + Al_2O_3$ ... | 0·023 | 0·070 | 0·224 | 1·876 | 14·98 | 7·323 | 10·76 | 25·95 | 23·52 | 7·537 |
| VIII | Total Mineral Ash ... | 0·427 | 2·256 | 7·615 | 58·64 | 124·8 | 240·8 | 304·6 | 353·3 | 502·3 | 378·7 |

TABLE II.—SHOWING THE VARIATION IN COMPOSITION OF THE DRY MATTER OF THE *STEM* OF PERIAMANJAL CHOLAM AT SUCCESSIVE STAGES OF GROWTH—DATE OF SOWING 4-8-1928

| | No. of sample ... | I | II | III | IV | V | VI | VII | VIII | IX | X |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date of sampling ... | 22-8-28 | 4-9-28 | 19-9-28 | 5-10-28 | 19-10-28 | 2-11-28 | 16-11-28 | 30-11-28 | 14-12-28 | 26-12-28 |
| | No. of days from sowing. | 18 | 31 | 46 | 62 | 76 | 90 | 104 | 118 | 132 | 144 |
| | Stage of growth ... | ... | ... | Rapid vegetative growth. | | | Flowers | Seed forms | — | Grains ripe | Over-ripe |
| | Wt. of dry matter in Stem of 100 plants, in grams. | 1.26 | 4.20 | 19.92 | 248 | 1,040 | 3,290 | 6,350 | 6,263 | 8,060 | 6,300 |
| | *Constituents expressed as percentages on dry matter* | | | | | | | | | | |
| I. | Total Nitrogen ... | 2.028 | 2.644 | 2.653 | 2.028 | 1.808 | 1.233 | 1.069 | 0.6302 | 0.5480 | 0.6575 |
| II. | $P_2O_5$ ... | 0.3853 | 0.6524 | 0.4551 | 0.3395 | 0.3184 | 0.2293 | 0.2291 | 0.1462 | 0.0718 | 0.0605 |
| III. | $K_2O$ ... | 1.819 | 3.806 | 4.040 | 2.940 | 3.296 | 3.118 | 1.801 | 1.352 | 1.486 | 1.495 |
| IV. | CaO ... | 2.122 | 1.309 | 1.059 | 0.926 | 1.014 | 0.679 | 0.632 | 0.533 | 0.528 | 0.538 |
| V. | MgO ... | 0.849 | 0.847 | 0.946 | 1.164 | 1.468 | 0.864 | 0.665 | 0.606 | 0.539 | 0.481 |
| VI. | $SiO_2$ ... | 10.35 | 3.912 | 3.987 | 3.011 | 2.782 | 2.930 | 3.050 | 2.739 | 4.381 | 4.091 |
| VII. | $Fe_2O_3 + Al_2O_3$ ... | 1.797 | 0.248 | 0.224 | 0.263 | 0.358 | 0.261 | 0.287 | 0.228 | 0.320 | 0.287 |
| VIII. | Total Mineral Ash ... | 14.50 | 14.41 | 13.08 | 10.14 | 10.62 | 9.324 | 7.523 | 6.116 | 7.690 | 7.454 |
| IX. | Diastatic Activity per gm. dry matter in Mg. Maltose. | ... | ... | ... | 822.4 | 540.0 | 722.8 | 730.8 | 140.7 | 188.3 | 22.9 |
| | *Total weight of constituents present in the stems of 100 plants, in grams* | | | | | | | | | | |
| I. | Nitrogen (Total) ... | 0.026 | 0.111 | 0.529 | 5.03 | 18.80 | 40.56 | 67.88 | 39.47 | 44.17 | 41.42 |
| II. | $P_2O_5$ ... | 0.005 | 0.027 | 0.091 | 0.842 | 3.311 | 7.560 | 7.274 | 9.158 | 5.790 | 3.808 |
| III. | $K_2O$ ... | 0.023 | 0.160 | 0.805 | 7.291 | 34.28 | 102.6 | 114.4 | 84.67 | 119.8 | 94.19 |
| IV. | CaO ... | 0.027 | 0.055 | 0.211 | 2.295 | 10.54 | 22.32 | 40.10 | 33.36 | 42.52 | 33.86 |
| V. | MgO ... | 0.011 | 0.036 | 0.183 | 2.887 | 15.27 | 28.44 | 42.20 | 37.96 | 43.43 | 30.27 |
| VI. | $SiO_2$ ... | 0.130 | 0.164 | 0.794 | 7.467 | 28.93 | 96.40 | 193.7 | 171.6 | 353.1 | 257.7 |
| VII. | $Fe_2O_3 + Al_2O_3$ ... | 0.023 | 0.010 | 0.045 | 0.665 | 3.727 | 8.570 | 18.21 | 14.30 | 25.81 | 18.09 |
| VIII. | Total Mineral Ash ... | 0.183 | 0.605 | 2.605 | 25.15 | 110.4 | 306.8 | 477.8 | 383.0 | 619.7 | 469.6 |

TABLE III—SHOWING THE VARIATION IN COMPOSITION OF THE DRY MATTER OF THE *ROOT* OF PERIAMANJAL CHOLAM AT SUCCESSIVE STAGES OF GROWTH—DATE OF SOWING 4-8-1928

| | No. of sample ... | I | II | III | IV | V | VI | VII | VIII | IX | X |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date of sampling ... | 22-8-28 | 4-9-28 | 19-9-28 | 5-10-28 | 19-10-28 | 2-11-28 | 16-11-28 | 30-11-28 | 14-12-28 | 26-12-28 |
| | No. of days from sowing. | 18 | 31 | 46 | 62 | 76 | 90 | 104 | 118 | 132 | 144 |
| | Stage of growth ... | ... | ... | Rapid vegetative growth. | | | Flowers | Seed forms | ... | Grains ripe | Over-ripe |
| | Wt. of dry matter in Root of 100 plants, in grams. | 0·96 | 5·88 | 37·60 | 184·0 | 560 | 1250 | 1480 | 1458 | 2040 | 1500 |
| | *Constituents expressed as percentages on dry matter* | | | | | | | | | | |
| I. | Total Nitrogen ... | 1·343 | 1·767 | 2·192 | 1·507 | 1·096 | 0·9040 | 0·7672 | 0·6029 | 0·5480 | 0·6028 |
| II. | $P_2O_5$ ... ... | 0·2384 | 0·5216 | 0·3347 | 0·2515 | 0·1459 | 0·1381 | 0·0985 | 0·1048 | 0·0605 | 0·1131 |
| III. | $K_2O$ ... ... | 5·178 | 3·138 | 2·736 | 2·259 | 1·591 | 1·754 | 1·653 | 1·254 | 1·353 | 1·546 |
| IV. | CaO ... ... | 0·806 | 0·888 | 0·763 | 0·841 | 0·725 | 0·541 | 0·602 | 0·571 | 0·532 | 0·502 |
| V. | MgO ... ... | 0·609 | 0·618 | 0·434 | 0·596 | 0·692 | 0·538 | 0·467 | 0·450 | 0·420 | 0·390 |
| VI. | $SiO_2$ ... ... | 12·58 | 9·374 | 15·170 | 16·70 | 13·21 | 7·628 | 10·28 | 9·723 | 8·237 | 9·642 |
| VII. | $Fe_2O_3+Al_2O_3$ ... | 1·771 | 1·488 | 2·861 | 2·545 | 2·429 | 2·023 | 1·740 | 1·387 | 1·199 | 1·190 |
| VIII. | Total Mineral Ash ... | 20·66 | 18·60 | 23·55 | 24·58 | 18·47 | 12·75 | 15·19 | 14·37 | 12·02 | 12·61 |
| IX. | Diastatic Activity per gm. dry matter in Mg. Maltose ... | ... | ... | ... | 1888 | 1108 | 1191 | 482 | 74·1 | 159·4 | 41·4 |
| | *Total weight of constituents present in the roots of 100 plants, in grams* | | | | | | | | | | |
| I. | Total Nitrogen ... | 0·013 | 0·104 | 0·824 | 2·773 | 6·139 | 11·30 | 11·36 | 8·790 | 11·18 | 9·04 |
| II. | $P_2O_5$ ... ... | 0·002 | 0·031 | 0·126 | 0·463 | 0·817 | 1·726 | 1·457 | 1·528 | 1·233 | 1·696 |
| III. | $K_2O$ ... ... | 0·050 | 0·185 | 1·029 | 4·157 | 8·910 | 21·93 | 24·46 | 18·28 | 27·60 | 23·19 |
| IV. | CaO ... ... | 0·008 | 0·052 | 0·287 | 1·547 | 4·061 | 6·756 | 8·910 | 8·322 | 10·85 | 7·532 |
| V. | MgO ... ... | 0·006 | 0·036 | 0·163 | 1·097 | 3·875 | 6·719 | 6·920 | 6·563 | 8·563 | 5·842 |
| VI. | $SiO_2$ ... ... | 0·121 | 0·551 | 0·571 | 30·73 | 73·98 | 95·37 | 152·1 | 141·8 | 168·1 | 144·6 |
| VII. | $Fe_2O_3+Al_2O_3$ ... | 0·017 | 0·088 | 0·108 | 1·682 | 13·60 | 25·28 | 25·74 | 20·23 | 24·46 | 17·84 |
| VIII. | Total Mineral Ash ... | 0·198 | 1·093 | 8·855 | 45·23 | 103·4 | 159·3 | 224·8 | 209·5 | 245·2 | 189·1 |

TABLE IV SHOWING THE VARIATION IN COMPOSITION OF THE GRAIN OF *Andropogon Sorghum* AT DIFFERENT STAGES OF GROWTH

DATE OF SOWING 4-8-28

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ... | No. of sample ... | I | II | III | IV | V | VI |
| | Date of sampling ... | 2-11-28 | 16-11-28 | 30-11-28 | 14-12-28 | 26-12-28 | 26-12-28 |
| | Part analysed ... | Flowers | Grain | Grain | Grain | Grain | Bhusa |
| | Weight of dry matter of the part in 100 plants in grams. | 216 | 941·2 | 3,100 | 5,460 | 5,770 | 890 |

*Constituents expressed as percentages on dry matter*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| I. | Total Nitrogen ... | 2·768 | 1·562 | 1·835 | 2·110 | 2·110 | 0·6575 |
| II. | $P_2O_5$ ... ... | 0·9038 | 0·5195 | 0·8090 | 0·7920 | 0·8167 | 0·1038 |
| III. | $K_2O$ ... ... | 1·850 | 0·7941 | 0·3513 | 0·2369 | 0·1954 | 0·6135 |
| IV. | CaO ... ... | 0·3064 | 0·2481 | 0·1501 | 0·0380 | 0·0341 | 0·3574 |
| V. | MgO ... ... | 0·5460 | 0·3410 | 0·3553 | 0·3678 | 0·3655 | 0·2393 |
| VI. | $SiO_2$ ... ... | 1·032 | 2·702 | 2·268 | 0·1368 | 0·1441 | 7·872 |
| VII. | $Fe_2O_3 + Al_2O_3$ ... | 0·1332 | 0·0955 | 0·1618 | 0·0319 | 0·0301 | 0·0715 |
| VIII. | Total Mineral Ash ... | 5·909 | 5·151 | 4·562 | 1·816 | 1·911 | 9·766 |
| IX. | Diastatic Activity per gm. dry matter in Mg. Maltose. | ... | 522·8 | 482·8 | 138·5 | 35·90 | ... |

*Total wt. of constituents present in the grain of 100 plants in grams*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| I. | Total Nitrogen ... | 5·980 | 14·70 | 56·90 | 115·2 | 121·8 | 5·86 |
| II. | $P_2O_5$ ... ... | 1·953 | 4·889 | 25·08 | 43·24 | 47·15 | 0·925 |
| III. | $K_2O$ ... ... | 3·997 | 7·473 | 10·89 | 12·93 | 11·28 | 5·468 |
| VI. | CaO ... ... | 0·6619 | 2·335 | 4·654 | 2·075 | 1·969 | 3·185 |
| V. | MgO ... ... | 1·180 | 3·209 | 11·02 | 20·08 | 21·10 | 2·132 |
| VI. | $SiO_2$ ... ... | 2·229 | 25·43 | 70·31 | 7·635 | 8·320 | 70·15 |
| VII. | $Fe_2O_3 + Al_2O_3$ ... | 0·2877 | 0·8986 | 5·016 | 1·742 | 1·738 | 0·637 |
| VIII. | Total Mineral Ash ... | 12·77 | 48·48 | 141·5 | 99·15 | 110·4 | 87·12 |

TABLE V SHOWING THE TOTAL WEIGHTS OF CONSTITUENTS PRESENT PER 100 PLANTS, *Andropogon sorghum*, AT SUCCESSIVE STAGES OF GROWTH: DATE OF SOWING AUGUST 4, 1928. ALL WEIGHTS IN GRAMS

| | No. of sample ... | I | II | III | IV | V | VI | VII | VIII | IX | X |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date of sampling ... | 22-8-28 | 4-9-28 | 19-9-28 | 5-10-28 | 19-10-28 | 2-11-28 | 16-11-28 | 30-11-28 | 14-12-28 | 26-12-28 |
| | No. of days from sowing ... | 18 | 31 | 46 | 62 | 76 | 90 | 104 | 118 | 132 | 144 |
| | Stage of growth ... | Rapid vegetative growth. | | | | | Flowers | Seed forms | ... | Mature | Over-ripe |
| | *Total weight of constituents in vegetative parts of 100 plants (Plants without grain)* | | | | | | | | | | |
| | Weight of dry matter in vegetative parts of 100 plants, in grams ... | 5·6 | 26·94 | 123·5 | 990 | 2750 | 6340 | 9910 | 9641 | 12,692 | 9,880 |
| I. | Total Nitrogen ... | 0·133 | 0·753 | 3·269 | 22·16 | 55·50 | 100·19 | 128·79 | 84 57 | 88·01 | 76·67 |
| II. | $P_2O_5$ ... | 0·014 | 0·161 | 0·469 | 3·091 | 9·865 | 19 15 | 26·03 | 21·13 | 13·74 | 10·86 |
| III. | $K_2O$ ... | 0·163 | 0·831 | 2·469 | 21·66 | 67·93 | 161·34 | 176·74 | 132·65 | 180·74 | 141·46 |
| IV. | CaO ... | 0·056 | 0·287 | 1·133 | 8·708 | 18·49 | 44·24 | 69·27 | 61·23 | 84·21 | 64·60 |
| V. | MgO ... | 0·027 | 0·176 | 0·769 | 7·166 | 26·12 | 47·38 | 62·03 | 57·09 | 67·42 | 48·38 |
| VI. | $SiO_2$ ... | 0·333 | 1·748 | 5·016 | 68·22 | 100·0 | 238·96 | 546 0 | 554·3 | 899·1 | 694·1 |
| VII. | $Fe_2O_3 + Al_2O_3$ ... | 0·043 | 0·168 | 0·376 | 7·223 | 32·31 | 41·17 | 54·71 | 60·48 | 73·79 | 43 47 |
| VIII. | Total Mineral Ash ... | 0·808 | 3·954 | 19·08 | 129·0 | 338·6 | 706·9 | 1007 | 945·8 | 1367 | 1037 |
| | *Total weight of constituents in 100 complete plants (Plants with grain)* | | | | | | | | | | |
| | Weight of dry matter in 100 complete plants, in grams ... | 5·6 | 26·94 | 123·5 | 990 | 2750 | 6556 | 10851 | 12741 | 18152 | 15652 |
| I. | Total Nitrogen ... | 0·133 | 0·753 | 3·269 | 22·16 | 55·50 | 106·17 | 143·49 | 141·47 | 203·21 | 198·47 |
| II. | $P_2O_5$ ... | 0·014 | 0·161 | 0·469 | 3·091 | 9·865 | 21·10 | 30·92 | 46·21 | 56·98 | 58·01 |
| III. | $K_2O$ ... | 0·163 | 0·831 | 2·469 | 21·66 | 67·93 | 165·34 | 184·21 | 143·54 | 193·67 | 152·74 |
| IV. | CaO ... | 0·056 | 0·287 | 1·133 | 8·708 | 18·49 | 44·89 | 71·61 | 65·89 | 86·29 | 66·57 |
| V. | MgO ... | 0·027 | 0·176 | 0·769 | 7·166 | 26·12 | 48·56 | 65·24 | 68·11 | 87·50 | 69·48 |
| VI. | $SiO_2$ ... | 0·333 | 1·748 | 5·016 | 68·22 | 100·0 | 241·2 | 571·1 | 624·6 | 906·7 | 702·4 |
| VII. | $Fe_2O_3 + Al_2O_3$ ... | 0·043 | 0·168 | 0 376 | 7·223 | 32·31 | 41·46 | 55·61 | 65·49 | 75·53 | 45·21 |
| VIII | Total Mineral Ash ... | 0·808 | 3·954 | 19·08 | 129·0 | 338·6 | 719·67 | 1055·7 | 1087 | 1466·4 | 1147·8 |