CASSAVA CULTURAL PRACTICES

Proceedings of a workshop held in Salvador, Bahia, Brazil, 18-21 March 1980

Editors:
Edward J. Weber, Julio Cesar Toro M., and Michael Graham

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Long-Term Fertility Considerations in Cassava Production

S.K. Chan

This paper presents the results of studies on (1) effects of repeated cropping with cassava under different fertility conditions on yields, soil pH, and nutrient status of the soil and of the plant, including nutrient removal by cassava; and (2) effects of manural history on root yield. It is concluded that soil fertility would decrease under successive cropping with cassava if the rate of fertilizer application was just enough to maintain yield.

It is often said that cassava is very exhausting to the soil. The statement is readily acceptable if there is no attempt to replenish the soil with what has been removed by the crop; for all crop species grown in the same way, harvest would impoverish the soil sooner or later. But cassava being a hardy plant is made notorious for this, because in the past it was often used by growers to exploit the soil without fertilizer input for short-term gain.

Nevertheless, published figures on nutrient uptake do indicate that cassava removes considerably large quantities of nutrients at harvest, particularly potassium. Greenstreet and Lambourne (1933) reported that cassava with root yields of 28–30 t/ha consumed, in metric equivalents per ha, 114–209 kg of N, 25–37 kg of P₂O₅, and 240–335 kg of K₂O. Hendershot et al. (1972) gave the average nutrient removal per hectare by 14-month cassava producing 59 t of roots as 106 kg of N, 47 kg of P (108 kg as P₂O₅), 467 kg of K (563 kg as K₂O), 145 kg of Ca (203 kg as CaO), and 45 kg of Mg (75 kg as MgO).

With cassava grown as a monocrop, Greenstreet and Lambourne (1933) presented results from three cropping seasons showing increased yield with fertilization and no signs of decline in yield. With cassava grown in rotation with other crops, Ofori (1973) reported important responses to K throughout the cropping period and to P in the earlier years of cropping when it was grown in rotation with maize and groundnuts for 19 years without indications of decrease in yield.

The important question remains: Do the present cultivars and cultural practices of cassava tend to create poorer soil conditions and the need for increasing fertilizer application? This paper reports the effects of repeated cropping of cassava under different fertility conditions on yields, soil pH, nutrient composition of both soil and plant, and nutrient removal by cassava. It is hoped that the results of these studies will increase awareness of the importance of maintaining soil fertility in cassava production and promote greater research efforts in the development of new varieties and cultural practices that require less fertilizer to produce the same yield of roots.

Materials and Methods

Experiment (a)

The design of this experiment was a factorial NPK 3³ with two replicates. Each replicate had 27 treatments allocated to three incomplete blocks each containing 9 treatments, thus partially confounding the second order interactions. The three major nutrients, N, P, and K, were factorially combined with three rates of nutrient application as follows: level 0 no fertilizer; level 1 56 kg/ha N, 34 kg/ha P (as P₂O₅), 76 kg/ha K (as K₂O); level 2 112 kg/ha N, 68 kg/ha P (as P₂O₅), 156 kg/ha K (as K₂O). For the eighth and ninth crops, the rates of K application were

---

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raised at level 1 from 78 kg to 156 kg of K₂O and at level 2 from 156 kg to 312 kg of K₂O.

The forms of N, P, and K fertilizers were sulfate of ammonia, triple superphosphate, and muriate of potash, respectively. Plots, including border rows, were 3.7 × 14.6 m and contained 4 rows of plants with 16 plants per row at a planting distance of 0.9 × 0.9 m. Experimental data were obtained from the inner two rows, which consisted of 20 plants in each plot.

In the ninth cropping season, Mg was incorporated as an additional treatment such that half of each plot with the original treatment received Mg and the other half did not. The rate of application was 50 kg MgO/ha. The Mg fertilizer was kieserite.

The trial was laid down on a colluvial soil at Serdang, previously planted with groundnuts, soybeans, and sweet potatoes. After the last crop of sweet potato, the land was used for the long-term fertility trial with cassava, cv. Black Twig. The land was plowed, harrowed, and rotovated before planting. Stakes (23 cm long) were planted horizontally approximately 5 cm beneath the soil.

For the first planting, stakes were obtained from cv. Black Twig grown in another plot of land. Because of a shortage of Black Twig planting materials, two other cultivars were used as border plants, cv. Green Twig for Replicate I and cv. Ubi Putih for Replicate II. In all subsequent plantings only Black Twig was used. Beginning with the third crop, well-grown border plants were selected as planting material and randomly distributed to the plots.

Fertilizers were applied about 3 weeks after planting. Before fertilization, soil samples in each plot were taken to a depth of 23 cm near the planted stakes. However, results of analyses were available only from samples taken at the sixth, seventh, eighth, and ninth seasons of planting.

Manual weeding with a cangkol was usually carried out twice within the first 6 months after planting. Sometimes, about a month before harvesting, weeds were sprayed with paraquat to facilitate harvesting.

During the growing period, beginning with the third crop onwards, leaf samples for chemical analyses were taken from the experimental plants at the sixth leaf position 3 months after planting.

At harvest, the fresh weight of roots was recorded from every plot. For the first crop at harvest, samples of leaves, leaf stalks, whole stems, and roots were analyzed for N, P, K, Ca, and Mg. Results of these analyses were used to estimate quantities of nutrients taken up by Black Twig on 1 ha of land. The quantity of a nutrient consumed by a plant component was estimated as a product of the dry weight of the plant component and its content of the nutrient on a dry-weight basis. For the seventh, eighth, and ninth crops, 5-cm sections of stems were taken at 50 cm above ground level and analyzed for N, P, K, Ca, and Mg on a dry-weight basis.

In the soil, available P was determined by Bray and Kurtz No. 1 method; exchangeable K, Ca, and Mg were extracted with 0.5 N ammonium acetate solution, and water-soluble K was determined with distilled water. For measuring soil pH, distilled water was also used. Organic carbon content of the soil at planting of the third and fifth crops was determined by the Walkley-Black Method.

For foliar analyses, standard procedures were used in determining total N, P, K, Ca, and Mg, expressed as a percentage of dry weight of the leaf.

Experiment (b)

Eight types of stakes were obtained from the eighth crop in Rep. I of Expt. (a), which had the following different fertilizer treatments: N₈P₆K₀ (control) no nutrients applied; N₆P₆K₀ only N applied at 112 kg N/ha as sulfate of ammonia; N₆P₆K₀ only P applied at 68 kg P₂O₅/ha as triple superphosphate; N₆P₆K₀ only K applied at 312 kg K₂O/ha as muriate of potash; N₆P₆K₀ both N and P applied; N₆P₆K₀ both N and K applied; N₆P₆K₀ both P and K applied; and N₆P₆K₀ all N, P, and K applied.

The eight types of stakes were tested in two separate experiments at the same location, i.e. Expt. (i) without basal dressing of NPK mixture and Expt. (ii) with basal dressing of NPK mixture consisting of 60 kg N, 30 kg P₂O₅, and 120 kg K₂O/ha. In both experiments, the stakes were planted in three complete randomized blocks. The 23-cm stakes were placed horizontally to a depth of 3 cm under the soil and at a planting distance of 1 × 1 m. Plot size including border plants was 4 × 12 m. Harvested plot size was 2 × 10 m, giving 20 harvested plants per plot.

The trial was conducted on a colluvial soil at Serdang, Selangor. Before planting, the land was plowed, harrowed, and rotovated. Just after planting, a preemergence herbicide, Fluometuron, was sprayed uniformly on the plots.

The plants were harvested after 6 months in the field. In each plot the fresh weight of roots was recorded. Residual effects in the stakes on the yield of roots were analyzed by applying Yate’s method.
Results and Discussion

Experiment (a)

Rainfall Distribution During Cropping Periods

Table 1 shows the rainfall distribution at quarterly periods for a total period of 360 days from the time of planting of each crop. In the fifth cropping season, there was a dry spell when the crop was 3-6 months old. In the eighth cropping season, there was another dry spell when the crop was 9-12 months old. These dry spells could account for low-yield performance.

Ages of Crops at Harvest and Fallow Periods

Ages of crops estimated from the time of planting to harvesting and fallow periods between two consecutive crops are shown in Table 2.

As seen from Table 2, the third crop had a longer growing period and a much longer fallow period before planting compared to other crops. The second crop also had a relatively long fallow period of nearly 6 months before it was planted. These differences in age and fallow period should be considered in comparing the yields of the various crops.

Yields of Roots as Affected by Potassium

The yields of the nine crops at three levels of potassium application are shown in Fig. 1. At the K₀ level, the root yields from the highest to the lowest did not correspond to the same order of successive crops from the first to the ninth. Instead of being the highest in yield, the first crop at K₀ had the same yield as the sixth crop. This was due to the adverse competition caused to Black Twig by the more vigorous varieties used as border rows during the first season of planting. The yield of the second crop was exceeded by that of the third. The very long fallow period of 1 year and a growing period of 14 months could be the reasons for the excellent yield performance of the third crop. The yield of the fifth crop was exceeded by the yields of the sixth and seventh crops, apparently because there was a very dry period (Table 1) during the fifth cropping season. For the same reason, the yield of the eighth crop was exceeded by that of the ninth crop.

Except for the first crop, the yields of all the other crops were markedly increased by the application of potassium. From the first to the seventh crops, the highest level of K applied to each crop was 156 kg K₂O/ha. Even at this rate of application, the yield of the seventh crop appeared to decline in comparison with earlier crops not affected by dry period. Hence, the higher rates of K application at 78 kg and 156 kg K₂O/ha were doubled for testing in the eighth and ninth cropping seasons keeping the K₀ rate unaltered. At 312 kg K₂O/ha, the yield of the ninth crop exceeded that of the seventh crop, which was fertilized at 156 kg K₂O/ha. A similar performance was not shown by the eighth crop for the reason already given.

Yields of Roots as Affected by Nitrogen and Phosphorus

The responses in fresh root yield to nitrogen and phosphorus were different in the two replicates. In Rep. I, Fig. 2, the seventh, eighth, and ninth crops consistently showed that root yield was increased by application of P in the absence of N. However, applying P at the highest level of N application resulted in yield decrease. Good yields were obtained by applying N at the highest level without P, by applying P at the highest level without N, or by application of both N and P at intermediate levels, i.e. 56 kg N and 34 kg P₂O₅/ha.

In Rep. II, NP interaction occurred in the opposite way, as shown in Fig. 3. Without N application, fertilizing with P decreased fresh-root yield. Similarly, without P application, fertilizing with N reduced yield. The adverse effect of one fertilizer applied at the highest rate
Fig. 1. Root yields of successive crops as affected by levels of potassium application. (Rates of K application were doubled at K1 and K2 for the eighth and ninth crops.)
Fig. 2. Root yields of the seventh, eighth, and ninth crops in Rep. I as affected by N and P fertilization.

Fig. 3. Root yields of seventh, eighth, and ninth crops in Rep. II as affected by N and P fertilization.
was greatly reduced by adding the other at the highest rate.

The causes of these NP interactions have not been identified, but their repeated occurrences deserve a more thorough investigation. Unless these interactions are properly understood, the haphazard application of N and P could lead to any of the three results: more yield, no change in yield, or even less yield.

**Yields of Roots as Affected by Magnesium**

Symptoms of magnesium deficiency were observed on the leaves of the eighth crop in Rep. II, but not in Rep. I. When these symptoms first occurred is not known. In planting the ninth crop, Mg was included as an additional treatment. Results of statistical analysis show that the mean fresh-root yield was increased by Mg treatment in Rep. II (from 30 to 35 t/ha), but there was no significant difference due to this treatment in Rep. I. It is also noted that the soil in Rep. II (9 ppm) contained less Mg than that in Rep. I (11 ppm).

**Treatments Giving More Than 40 t/ha**

As a result of different NP interactions in Rep. I and Rep. II, the treatment that gave the highest average yield (46 t/ha) per cropping season in Rep. I was N2P0K2, and the treatment that gave the highest average yield (45 t/ha) per cropping season in Rep. II was N2P2K2. The average yield of control (N0P0K0) was 36 t/ha in Rep. I and 29 t/ha in Rep. II (Fig. 4). Other treatments that gave more than 40 t of fresh roots per ha per crop are shown in Table 3.

**Soil pH as Affected by Successive Cropping and Sulfate of Ammonia**

The colluvial soil under this long-term experiment is classified as silty clay loam. The average organic carbon content at the time of planting the third and fifth crops was 2.1% and 1.8%, respectively. The soil in Rep. I had better drainage than that in Rep. II. Consequently the soil in Rep. II had a darker appearance than that in Rep. I. From the seventh to the ninth crop, soil pH was monitored.

It was observed that pH of the soil was decreased from 4.7 to 4.5 by fertilizing with sulfate of ammonia at the highest rate of application. Nevertheless, pH was generally increased by successive cropping with cassava including that of the soil under the highest rate of application of the fertilizer. The soil pH in the two replicates did not appear different.

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### Table 3. Fresh-root yield (t/ha) of treatments giving more than 40 t/ha per cropping season.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>N1P0K2</td>
<td>N1P1K2</td>
<td>N1P2K0</td>
</tr>
<tr>
<td>1st</td>
<td>34</td>
<td>36</td>
</tr>
<tr>
<td>2nd</td>
<td>55</td>
<td>41</td>
</tr>
<tr>
<td>3rd</td>
<td>47</td>
<td>54</td>
</tr>
<tr>
<td>4th</td>
<td>40</td>
<td>49</td>
</tr>
<tr>
<td>5th</td>
<td>34</td>
<td>46</td>
</tr>
<tr>
<td>6th</td>
<td>39</td>
<td>46</td>
</tr>
<tr>
<td>7th</td>
<td>47</td>
<td>30</td>
</tr>
<tr>
<td>8th</td>
<td>51</td>
<td>40</td>
</tr>
<tr>
<td>9th</td>
<td>49</td>
<td>38</td>
</tr>
<tr>
<td>Mean</td>
<td>44</td>
<td>42</td>
</tr>
</tbody>
</table>

**NOTE:** The yields in the 9th cropping season are average over two treatments, i.e. with and without Mg.

### Table 4. Soil N, P, and K as affected by cropping and fertilization.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Total N (%)</th>
<th>Available P (ppm)</th>
<th>Exchangeable K (ppm)</th>
<th>Water-soluble K (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N0</td>
<td>N1</td>
<td>N2</td>
<td>P0</td>
</tr>
<tr>
<td>Rep. I</td>
<td>6th</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td></td>
<td>7th</td>
<td>0.14</td>
<td>0.14</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td>8th</td>
<td>0.11</td>
<td>0.12</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>9th</td>
<td>0.10</td>
<td>0.10</td>
<td>0.09</td>
</tr>
<tr>
<td>Mean</td>
<td>0.12</td>
<td>0.12</td>
<td>0.12</td>
<td>12</td>
</tr>
</tbody>
</table>

| Rep. II | 6th | n.a. | n.a. | n.a. | 24 | 23 | 29 | 75 | 87 | 94 | 16 | 19 | 17 |
|         | 7th | 0.14 | 0.14 | 0.13 | 19 | 22 | 25 | 48 | 48 | 47 | 10 | 9 | 10 |
|         | 8th | 0.12 | 0.14 | 0.13 | 20 | 24 | 30 | 29 | 39 | 42 | 7 | 7 | 8 |
|         | 9th | 0.11 | 0.12 | 0.11 | 14 | 12 | 19 | 26 | 24 | 40 | 4 | 5 | 6 |
| Mean   | 0.12 | 0.13 | 0.12 | 19 | 20 | 26 | 45 | 50 | 56 | 9 | 10 | 10 |

**NOTE:** n.a. = not analyzed.
Fig. 4. Root yields of successive crops comparing unfertilized treatments in Reps. I and II with the highest yielding treatments in the respective replicates (— Rep. I; --- Rep. II).
Table 5. Leaf and stem content of N, P, and K (%) as affected by cropping and fertilization. (Figures for leaves are means for the third to ninth crops, for the stems the figures are means for the seventh to ninth crops.)

<table>
<thead>
<tr>
<th></th>
<th>N₀</th>
<th>N₁</th>
<th>N₂</th>
<th>P₀</th>
<th>P₁</th>
<th>P₂</th>
<th>K₀</th>
<th>K₁</th>
<th>K₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaves</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rep. I</td>
<td>5.2</td>
<td>5.2</td>
<td>5.6</td>
<td>0.40</td>
<td>0.40</td>
<td>1.8</td>
<td>2.1</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>Rep. II</td>
<td>5.3</td>
<td>5.2</td>
<td>5.3</td>
<td>0.39</td>
<td>0.38</td>
<td>1.8</td>
<td>2.3</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>Stems</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rep. I</td>
<td>0.51</td>
<td>0.50</td>
<td>0.56</td>
<td>0.21</td>
<td>0.25</td>
<td>0.27</td>
<td>0.9</td>
<td>1.2</td>
<td>1.8</td>
</tr>
<tr>
<td>Rep. II</td>
<td>0.51</td>
<td>0.55</td>
<td>0.57</td>
<td>0.21</td>
<td>0.24</td>
<td>0.24</td>
<td>1.0</td>
<td>1.2</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Soil N, P, and K as Affected by Cropping and Fertilization

From the sixth to the ninth crop, the soil was monitored for levels of total N, available P, exchangeable and water-soluble K. These are shown in Table 4, where total N, available P, and available K are given for three levels of applied N, P, and K, respectively. The data are an average for nine readings.

Total soil N was reduced by cropping with cassava under all levels of N application, and was apparently not affected by N application. The mean values of soil N in Rep. I and Rep. II were nearly all the same.

Generally there was more available P in Rep. II than in Rep. I. Soil P was increased by P fertilizer applied to crops, but it declined substantially under all levels of P fertilization at the time of planting the ninth crop.

Losses in exchangeable and water-soluble K in the soil under each level of K fertilization were so great that the soil was in danger of being depleted of available K, especially water-soluble K. Although available K in the soil was apparently increased with higher rates of K fertilization as observed at the times of planting the eighth and ninth crops, even the highest rate of K application (312 kg K₂O/ha) could not raise soil K to former levels. It is noted that the soil in Rep. I contained more exchangeable K than the soil in Rep. II.

Leaf N, P, and K as Affected by Cropping and Fertilization

The content of N, P, and K from the third to ninth crop was monitored in the leaves. It was observed that K content in the leaves was increased by the addition of K fertilizer (Table 5).

Similarly, the content of leaf N was increased by N fertilization as seen in most of the crops of Rep. I, but this increase was not apparent in Rep. II except in the third and eighth crops. The effect of P fertilizer on the content of leaf P was not detectable. However, the fluctuations of leaf nutrient levels with cropping seasons did not reflect the declining fertility of the soil as expected under conditions of no fertilizer applications.

Contents of N, P, and K in the Stem as Affected by Cropping and Fertilization

Analyses were performed to determine the N, P, and K content in the stems of the seventh, eighth, and ninth crops. It was observed that the content of K in the stem became less and less with cropping, reflecting the decline in soil fertility with respect to content of K in the soil. A similar trend of decrease in stem uptake of N was observed in the seventh and eighth crops that were analyzed, but a difference between the two crops in the uptake of P was not apparent.

Nutrient Removal by Cassava

The first crop of Black Twig, which yielded 28 t of roots per hectare, is estimated to have removed in total about 88 kg N, 32 kg P, 181 kg K, 39 kg Ca, and 16 kg Mg (Table 6). These are equivalent to 88 kg N, 73 kg P₂O₅, 218 kg K₂O, 55 kg CaO, and 27 kg MgO.

Based on the above figures, a crop with a yield of 40 t of roots per hectare is estimated to remove 126 kg N, 46 kg P, 259 kg K, 56 kg Ca, and 23 kg Mg. These are equivalent to 126 kg N, 105 kg P₂O₅, 312 kg K₂O, 78 kg CaO, and 38 kg MgO.

Therefore, the quantities of N, P, and K removed by successive crops with an average
Notes on Fertilization Practices in Plantations and Smallholder Farms

Table 7. Effect of residual manure on fresh-root yields

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Root yield (t/ha)</th>
<th>LSD (p = 0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>12</td>
<td>5.73</td>
</tr>
<tr>
<td>NPK</td>
<td>15</td>
<td>5.73</td>
</tr>
<tr>
<td>PK</td>
<td>17</td>
<td>5.73</td>
</tr>
<tr>
<td>N</td>
<td>17</td>
<td>5.73</td>
</tr>
<tr>
<td>No manure</td>
<td>19</td>
<td>5.73</td>
</tr>
</tbody>
</table>

Establishment of the plants was 100% in both experiments. Owing to basal fertilizer application in Exp. (ii) the plants in Exp. (i) were generally taller than those in Exp. (ii). The nitrogen to potassium ratio of the fertilizers used was 4 to 1. The nitrogen concentration of the fresh-root yield of cassava 8 months after planting was increased significantly by using stakes with a previous history of K fertilization and those of K-fertilized plots. It became insignificant when NPK mixture was applied. More important residual effect of potassium was the residual effect of potassium in the stakes. These findings are comparable with those of Keating et al. 1979, who showed that the residual effect of potassium in the stakes was important. But in the current crop, potassium was applied to the current crop. Potassium was important when no NPK mixture was applied. The stakes with a previous history of potassium were more important than those without it, regardless of whether the NPK mixture was applied to the current crop or not. Nitrogen was applied to the current crop, and those stakes that had received potassium fertilizer before planting had increased potassium levels in the fresh-root yield of cassava 8 months after planting.

K-deficiency must be balanced positively by an excess of K applied to another crop in the rotation or the residue of K applied to another crop in the rotation of the fresh-root yield of 40 t/ha would have exceeded the highest annual application rates of N (112 kg/ha), P (68 kg/ha), and K (56 kg/ha) just matched the estimated quantity of K to 312 kg/ha/ha. Because nearly one-third of the total quantity of nutrients are found in the stems, possibilities of reducing nutrient consumption exist. It is possible to select for suitable characteristic varieties in the selection of plant varieties at harvest to reduce the number of unbranched stems. Increases in yield as a result of using 60-cm stakes for vertical planting were reported by Loria 1962; Chan 1975. To redeem soil fertility, a fallow under leguminous cover should be included for cassava production.
The residual effects of phosphorus and potassium in the stakes have important implications with regard to maintenance of high root yields. In Expt. (a) on successive cropping with cassava, the decline in root yields in all those plots that did not receive fertilizer, particularly potassium, would have been more pronounced if plants from the same plots were used as planting materials. In cassava farms, replanting with stakes taken from plants having the same manurial treatment is a general practice. Where the standard fertilizer practice does not provide sufficient nutrients, particularly potassium, planting materials within the farm will become poorer. This will further aggravate any subsequent decline in yield due to an inadequate external supply of nutrients.

### Conclusions

Yield and the number of consecutive crops having similar yields are expected to vary with soils, climate, varieties, and cultural practices. Therefore, the experimental data should not be used for determining the economics of cassava production. From these studies the following conclusions were made.

1) If seasonal differences in other factors, such as rainfall, organic matter content of the soil, and fallow period, were not large enough to affect root yield, then a constant yield for successive crops could be maintained by continually increasing the application rates of those nutrients in short supply, which eventually would be high enough to equal or exceed those removed by the crop at harvest.

2) When a decline in the yield of cassava can be eliminated by applying more of a particular nutrient, this means its availability in the soil has decreased and a greater supply from an external source is required. Thus, if the rate of fertilizer application were increased just enough to maintain the same yield as before, soil fertility would continue to decrease until an equilibrium was reached.

3) Successive cropping with cassava will result in an increasing demand for applied K. But the effects of N and P on root yield may be complicated by the occurrence of different NP interactions. An increase or decrease in yield may result from either applying both N and P or applying one nutrient in the absence of the other. It is necessary to investigate the causes of these interactions and to determine whether NP interactions are important in different cassava growing areas.

4) Regular applications of only N, P, and K to successive cassava crops will eventually bring about foliar symptoms of Mg deficiency. When this occurs, application of Mg to the following crop will correct the deficiency and increase yield.

5) If stakes are equally fertilized with K, those originally deficient in K may produce lower root yields than those that were not deficient.

6) The pH of the soil may be decreased by increasing the rate of application of ammonium sulfate as nitrogen fertilizer, but it will be increased by successive cropping with cassava even when ammonium sulfate is regularly applied to the soil.

7) The nutrient status of the leaves 3 months after planting fluctuates with season of planting; as such it is unable to give indications of decreases in the nutrient uptake of the plant or the nutrient availability in the soil. The nutrient status of the stake at harvest appears useful in providing such diagnostic indications.

8) As judged by present cultural practices for cassava, whether grown as monocrop or in rotation with other crops, soils that have been under cultivation with cassava for many years are expected to have become poorer, regardless of whether cassava crops have not been fertilized or have been fertilized just enough to maintain similar yields.

9) Like the soil in which they grow, cassava planting materials are also a reservoir of nutrients that may become deficient for plant growth. In the case of little or no fertilization, low yield will be followed by lower yield because the farmer uses the same land and the same source of planting materials, both of which become poorer in nutrient content with each successive season of cropping.

10) To check increasing fertilizer requirements caused by a decrease in natural fertility of the soil, high priority should be given to the breeding for more efficient, less nutrient-demanding varieties and the development of cultural practices that are both applicable and effective in maintaining yield and soil fertility at desirable levels.

11) Cassava production seems more viable under smallholder than plantation conditions, not because the smallholder always grows a better crop, but because he does not depend on growing cassava alone for a living. Moreover, for the smallholder who manages to maintain consistent yields, he does not have to depend entirely on the use of chemical fertilizers.
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