PRECISION NUTRIENT MANAGEMENT OF CASSAVA AT FIELD SCALE BY A MODELING APPROACH

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ABSTRACT

In India, cassava is cultivated in an area of 0.232 million ha with a total production of 8.06 million tons of tuberous roots and we have the dubious distinction of having the highest productivity of cassava in the world with average yield of 34.76 t/ha. The cassava tuberous root is consumed as a secondary staple along with the staple, rice and many rural poor consume it as the staple in different forms of preparations. Besides being used as a secondary staple, it is also used for industrial production of sago and starch in the states of Tamil Nadu, Andhra Pradesh, Maharashtra, Gujarat, etc. Approximately 300 000 tons of sago and starch are manufactured from cassava roots by nearly 1200 factories in these states. In order to increase the yield of cassava, field scale nutrient management technology has been developed using IT tools and by conducting on station and on farm field experiments during the past 9 years. We have parametrized and calibrated the QUEFTS model for making field level NPK fertilizer recommendations for cassava in India. The derived parameters of minimum and maximum accumulation of nitrogen (35 and 80), phosphorus (250 and 750) and potassium (32 and 102) are proposed as standard borderline values in the QUEFTS model for cassava. A linear increase in tuberous root yield was suggested by the model with N, P and K uptakes of 17.6, 2.2 and 15.6 kg N, P and K per 1000 kg tuberous root yield. The average N : P : K ratio in total plant dry matter was 7.6 : 1 : 6.9. Validation of the model using experimental data resulted in good agreement between predicted and measured yields. The calibrated model can be used in other regions also, provided that we develop the relations between soil supply and soil chemical properties. The study shows that fertilizer recommendations can be improved by the calibrated QUEFTS model based on the derived parameters and equations. A nutrient decision support system has also been developed for precision nutrient management of cassava in India.

Keywords: Cassava, Precision Nutrient Management, QUEFTS.

1. INTRODUCTION

In India, cassava is consumed as a secondary staple along with the staple rice and many rural poor consume it as the staple in different forms of preparations. Approximately 300 000 tons of sago and starch are also manufactured from cassava roots by nearly 1200 factories. The present average productivity of cassava in India is 31.44 t ha–1 of fresh tuberous roots, but is still far below the potential yield of 80 t ha–1 produced under experimental conditions (Howeler, 1981). For the past four decades, it has been recommended to follow a blanket application of NPK fertilizers over varying agroclimatic and pedogenic conditions (Mohankumar, 2000). But when we extrapolate the results from experimental stations to farmers’ fields, the yield cannot be increased beyond a certain level (Witt et al., 1999). The further increase in yield and nutrient use efficiency can be possible only by managing the large spatial and temporal variability existing in soil nutrient supply, nutrient use efficiency and crop response to nutrients among different farms (Doberman and White, 1999). Real time nitrogen management of cassava using chlorophyll meter and leaf color chart significantly increase the nitrogen use efficiency and tuberous root yield (Byju and Haripriya Anand, 2009a; Byju and Haripriya Anand, 2009b; Haripriya Anand and Byju, 2008).

Better fertilizer recommendations can be made by using simulation models. The QUEFTS (Quantitative Evaluation of Fertility of Tropical Soils) model originally developed by Janssen et al. (1990), takes into account the interactions of N, P and K. With this concept in mind, a study was conducted to quantify the variation in soil nutrient supply in cassava fields in major cassava production regions of India, where cassava is cultivated on a large scale and to develop a new approach for Site Specific Nutrient Management (SSNM) using a modified QUEFTS model. The main objectives of the present paper are to (1) derive parameter values that enable NPK fertilizer recommendations, (2) establish maximum and minimum nutrient uptake efficiencies, (3) estimate soil indigenous nutrient supply and (4) determine apparent recovery efficiency of fertilizer nutrients as affected by fertilizer levels.

2. MATERIALS AND METHODS

Data from several field experiments on cassava with N, P and K applications conducted in India during the years 1975 to 2002 were collected for the purpose. We have distinguished four major production regions of cassava,
Kerala, Tamil Nadu, Andhra Pradesh and Maharashtra. At each of these regions, the field experiments included a control plot (unfertilized) and plots with different rates of NPK (fertilized) which varied between the regions and years. Initial soil samples before the start of the experiments were collected from the 0–15 cm soil layer and a representative composite sample from ten sampling locations per plot was prepared for different soil chemical analysis. The crop was harvested manually and total weights of tuberous roots, leaves and stems were measured separately. Tuberous root yields were obtained at harvestable maturity and yields were reported. The stem and leaf weights were also recorded besides the number of fallen and standing leaves. From all the experimental plots, both unfertilized and fertilized samples of leaf, stem and tuberous roots were collected at the time of harvest for estimation of N, P and K uptake. The indigenous nutrient supply for a particular nutrient is defined as the amount of that nutrient taken up by the crop under optimal conditions when all other nutrients are supplied amply (Liu et al., 2006). In all these experiments, the indigenous N supply was calculated as the N uptake in unfertilized plots. But, indigenous P and K supplies were calculated as the P and K uptakes from plots that received no P and K fertilizer respectively. The difference between N uptake of fertilized and unfertilized plots will give an idea about the recovery efficiency of fertilizer N whereas the P and K uptakes of plots that received no P and K fertilizer respectively, will give an idea about the recovery efficiency of fertilizer P and K.

3. RESULTS AND DISCUSSION

The results of the validation of the model are given by Byju et al. (2012). The constants of ‘a’ and ‘d’ showing the internal efficiencies at maximum accumulation and dilution of the nutrients are given in Table 1. The mean values of internal efficiency of N (IEn), P (IEp) and K (IEk) are 61.2, 510.0 and 67.1 kg tuberous root yield (dry weight) kg⁻¹. The mean reciprocal internal efficiency (RIE) i.e., the amount in kg of N, P or K removed to produce 1000 kg tuberous root yield, values are 13.4, 2.3 and 14.5 for cassava. The relationship between tuberous root yield and NPK uptake in total plant dry matter of cassava is shown in Figure 1. When the internal efficiency values of N, P and K were analysed from unfertilized and fertilized plots separately, it could be observed that the values were higher in unfertilized plots for N and K and for P, the values were higher in fertilized plots. The potential yield of cassava ranged from 17.5 to 24.5 t ha⁻¹ tuberous root dry matter (Byju et al., 2006). Irrespective of the yield potential, the calculated NPK uptake ratios in the total plant dry matter of cassava were 7.6 : 1 : 6.9 in the linear part of the relationship. The NPK uptake requirements in total plant dry matter for 1000 kg tuberous root in the linear part of the relation was 17.6, 2.2 and 15.6 kg N, P and K irrespective of the yield potential. The corresponding IE values for N, P and K were 56.2, 451.7 and 64.6 kg kg⁻¹.

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Set 1</th>
<th>Set 2</th>
<th>Set 3</th>
<th>Set 4*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a (2.5th)</td>
<td>d (97.5th)</td>
<td>a (2.5th)</td>
<td>d (97.5th)</td>
</tr>
<tr>
<td>N</td>
<td>34.5</td>
<td>79.7</td>
<td>36.7</td>
<td>74.3</td>
</tr>
<tr>
<td>P</td>
<td>250.4</td>
<td>749.8</td>
<td>261.8</td>
<td>722.6</td>
</tr>
<tr>
<td>K</td>
<td>31.7</td>
<td>101.9</td>
<td>34.2</td>
<td>97.5</td>
</tr>
</tbody>
</table>

Note: Constants ‘a’ and ‘d’ of set 1, 2 and 3 were determined after eliminating the lowest and highest 2.5, 5 or 7.5 percentiles respectively of all Internal Efficiency (IE) data presented in table 1. *Recommended standard parameters of the ‘a’ and ‘d’ values for cassava. The r-values, the minimum uptake of N, P and K needed to produce any measurable tuberous root yield of QUEFTS model were fixed as zero due to lack of required data.

The soil indigenous nutrient supply and different soil test values (pH, organic carbon, available N, P and K) were plotted in all possible combinations to develop the relationships between them. The regression equations and their correlation coefficients developed for the four major cassava production regions in India are given in Table 2. There were wide variations in the fertilizer nutrient recovery efficiencies of N, P and K by cassava. Another major observation from the data set was the considerable variation in REn, Rep and REk with the amount of fertilizer applied. We developed the relationships between recovery efficiency and amount of NPK fertilizers applied and are given in Table 3. The calibrated QUEFTS model for cassava was validated using data from four major cassava production regions (Table 2). The four locations were selected in such a way so that they represented the different soil types and major cassava production regions of India. Figure 1 shows the relation between cassava tuberous root yields predicted by the model and measured yields at different cassava production regions and it showed good agreement which indicates that the calibrated model can be used to improve NPK fertilizer recommendations for cassava in India.
Table 2: Indigenous Supply of N, P and K (kg ha\(^{-1}\)) from Four Cassava Production Regions Expressed in Soil Chemical Properties

<table>
<thead>
<tr>
<th>Location</th>
<th>Regression Equations</th>
<th>n</th>
<th>(R^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kerala</td>
<td>INS = 188.84 OC – 6.2265</td>
<td>35</td>
<td>0.78</td>
</tr>
<tr>
<td></td>
<td>IPS = 0.3302 Bray 1 P + 8.3511</td>
<td>21</td>
<td>0.73</td>
</tr>
<tr>
<td></td>
<td>IKS = 0.7398 Exch K – 9.9405</td>
<td>22</td>
<td>0.83</td>
</tr>
<tr>
<td>Tamil Nadu</td>
<td>INS = 221.94 OC + 4.8519</td>
<td>23</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>IPS = 0.6067 Olsen P + 1.084</td>
<td>15</td>
<td>0.82</td>
</tr>
<tr>
<td></td>
<td>IKS = 0.2499 Exch K + 29.051</td>
<td>15</td>
<td>0.81</td>
</tr>
<tr>
<td>Andhra Pradesh</td>
<td>INS = 129.11 OC + 54.055</td>
<td>24</td>
<td>0.41</td>
</tr>
<tr>
<td></td>
<td>IPS = 0.3586 Bray 1 P + 3.3456</td>
<td>11</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>IKS = 1.0296 Exch K – 41.702</td>
<td>11</td>
<td>0.81</td>
</tr>
<tr>
<td>Maharashtra</td>
<td>INS = 221.94 OC + 4.8519</td>
<td>10</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td>IPS = 0.6067 Olsen P + 1.084</td>
<td>10</td>
<td>0.83</td>
</tr>
<tr>
<td></td>
<td>IKS = 0.2499 Exch K + 29.051</td>
<td>10</td>
<td>0.95</td>
</tr>
</tbody>
</table>

Table 3: Regression Equations Describing the Relation between Recovery Efficiency (%) and NPK Application (kg ha\(^{-1}\)) for Cassava

<table>
<thead>
<tr>
<th>Regression Equation</th>
<th>n</th>
<th>(R^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(RE_n = -0.0032N^2 + 0.7589N + 3.1553)</td>
<td>48</td>
<td>0.75</td>
</tr>
<tr>
<td>(RE_p = 39.498e^{-0.0061P})</td>
<td>36</td>
<td>0.66</td>
</tr>
<tr>
<td>(RE_k = -0.0021K^2 + 0.6608K + 0.8699)</td>
<td>60</td>
<td>0.78</td>
</tr>
</tbody>
</table>

Table 4: Predicted Yield of Cassava by the QUEFTS Model at Salem in Tamil Nadu State, India

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Indigenous Supply (kg ha(^{-1}))</th>
<th>NPK Fertilizer Requirement (kg ha(^{-1}))</th>
<th>Predicted Nutrient Uptake (kg ha(^{-1}))</th>
<th>Predicted Yield (t ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>134.2</td>
<td>120</td>
<td>185</td>
<td>10.50</td>
</tr>
<tr>
<td>P</td>
<td>15.7</td>
<td>30</td>
<td>24</td>
<td>10.50</td>
</tr>
<tr>
<td>K</td>
<td>123.4</td>
<td>93</td>
<td>164</td>
<td>10.50</td>
</tr>
</tbody>
</table>

Note: The measured yield is 11.41 t ha\(^{-1}\). The yield potential was set to 24.50 t ha\(^{-1}\).

Fig. 1: Cassava Tuberous Root Yields Predicted by QUEFTS Model and Measured in Major Cassava Production Regions of India
4. CONCLUSIONS

The QUEFTS model has been parameterized and calibrated for making NPK fertilizer recommendations for cassava in India. The fertilizer NPK requirements for a target yield can be calculated using the model. Data collected from different field experiments conducted in major cassava production regions of India during 1975 to 2002 were used to calibrate the model. The derived parameters of minimum and maximum accumulation of nitrogen (35 and 80), phosphorus (250 and 750) and potassium (32 and 102) are proposed as standard borderline values in the QUEFTS model for cassava. A linear increase in tuberous root yield was suggested by the model with N, P and K uptakes of 17.6, 2.2 and 15.6 kg N, P and K per 1000 kg tuberous root yield. The average N : P : K ratio in total plant dry matter was 7.6 : 1 : 6.9. The paper also developed the relationship between soil NPK supply and soil chemical properties for major cassava production regions of India. Relationships between fertilizer nutrient recovery efficiencies and fertilizer rates were also developed. Validation of the model using experimental data resulted in good agreement between predicted and measured yields. The calibrated model can be used in other regions also, provided that we develop the relations between soil supply and soil chemical properties. Also, if we can develop the basic equations for nutrients other than N, P and K, the model can include other nutrients also. The study shows that fertilizer recommendations can be improved by the calibrated QUEFTS model based on the derived parameters and equations.

REFERENCES


