Chapter 8

TEADISEASE: A Rule Based Object-Oriented Expert System For Disease Management In Tea+

8.1. Introduction

Disease of tea plant is one of the productivity barriers which demands a considerable attention throughout the year. Several types of disease attack on both young and matured tea plants often cause considerable damage in the localized area. Primary root diseases cause extensive damage to tea, resulting not only an immediate crop loss but functional physiology of the bushes is also affected [1]. They may kill one to nine bushes at a time in any one patch. If they spread from a diseased shade tree or there are more than one closely situated centres of infection, even more deaths may occur. Young nursery plants may even be killed if the attack is severe. Loss of crop from sections damaged by the diseases varies according to the severity of attack. Moreover, tea manufactured out of infected leaves becomes flaky [2].

Some disease persists in the same areas for years if not controlled, causing gradual deterioration in the health of the tea bush and loss in crop. It is neither possible to remove the sources of infection outside the tea areas nor can tea be treated in such a way as to eradicate the disease permanently. Control operations must start as soon as the disease appears [2].

To reduce the crop loss due to the diseases, proper diagnosis of the disease and the corresponding application of chemical fungicides in a proper dose are very essential. In tea industry the diseases are being controlled mostly by the cultural practices along with chemical fungicides. Any practice regarding the diagnosis of the disease and the corresponding control measures are taken by the human experts. A proper diagnosis of the active disease, effective choice of chemical fungicides and cultural practices demand adequate expertise.

For proper disease management, sufficient human expertise is needed but the experts are scarce in order to cover up the large area. So in a large number of cases, inadequate practices are the ultimate result leading to crop losses. There are evidences that on many estates managers are paying bitterly for the neglect of root disease by past management [3]. Thus to mitigate the lack of human expertise, computer-aided expert system for disease management would be useful. ES-technologies are already

+ This is based on the paper ["*TEADISEASE*: A Decision Support System for Disease Management in tea crop" (Communicated)] of the author.

in application for disease management for some crops [4-11]. But to the best of our knowledge, no such work for disease management has been reported in tea, at least in Indian environment.

Two aspects of disease management can be identified; first the proper identification of the disease and the weakness of the field status, secondly, the application of proper fungicides along with the proper cultural practices to be adopted.

This work describes an object-oriented expert system for disease management in tea crop. This kind of automated system can be easily available and consistent in decision making as well as it can be used in a number of sites.

In section 8.2, the major diseases are mentioned with their taxonomic nomenclature. Problems of current practices are discussed in section 8.3. Section 8.4 describes the knowledge engineering. Section 8.5 presents the system architecture. System implementation is described in section 8.6. In section 8.7, a real field case illustration is produced for better understanding of the system. Performance evaluation is discussed in section 8.8. Lastly discussion and conclusion are produced in section 8.9.

8.2. Major diseases of tea

Fungal diseases of tea plants have been reported from the very beginning of plantation for over 150 years [12]. The diseases of tea are rather numerous. They attack different parts of the plants such as leaves, stems and roots. It is fairly known today that world over about 385 species of fungi occur on tea, of which just about half occur on tea in North-East India [13].

The nursery plants are not being spared. Collar rot and Dumping off diseases cause death to the young vegitatively propagated tea plants in nurseries. Considering the site of damages the diseases are classified in four groups as depicted in chapter 2 : (i) nursery disease (ii) root disease (iii) stem disease and (iv) leaf disease [14]. The following diseases causing major damage to the tea plants have been considered in the design of the present expert system and are presented in the Table 8.1 as a ready reference.

Table 8.1. Major diseases of tea.

Taxonomic Nomenclature	Common Name
Nursery diseases:	
Phomopsis sp.	Collar Rot
Pythium sp.	Dumping off
Root diseases:	
Fomes lamaoensis (Murr.) Sacc. and Trott.	Brown root rot
Ustulina zonata (Lev.) Sacc.	Charcoal Stump Rot
Poria hypolateritia (Berk.) Cooke.	Red Root Rot
Rosellinia arcuata Petch	Black Root Rot
Hypoxylon asarcodes (Theiss.) Mill	Tarry Root Rot
Helicobasidium compactum Boedijn	Purple Root Rot
Sphaerostilbe repens B. & Br.	Violet Root Rot
Botryodiplodia theobromae Pat.	Diplodia
Poria hypobrunnea Petch	Poria / Branch Canker
Stem Diseases:	
N. cinnebarina (Tode ex Fr.) Fr. and *Nectria* sp.	Nectria
Marasmius pulcher, (B. & Br.) Petch	Thread Blight
Pellicularia salmonicolor B.& Br. Rogers and *Corticium salmonicolor* B. & Br.	Pink Disease
Aglaospora sp.	Thorny Blight
Physalospora neglecta Petch	Macrophoma
Aschersonia sp.	Aschersonia
Leaf Diseases:	
Corticium invisum Petch and *C. theae* Bernard	Black Rot
Exobasidium vexams Massee	Blister Blight
Pestalozzia theae Sawada.	Grey Blight
Collectotrichum camelliae Mass.	Brown Blight
Limacinula theae Syd. & Bult., *Capnodium* sp., *Meliola* sp. etc.	Sooty Moulds
Cephaleuros parasiticus Karst	Red Rust

8.3. Current practices and their lacunae

In tea industry the diseases are being controlled mostly by the cultural practices along with chemical fungicides. Any practices regarding the identification of the disease and the corresponding control measures are taken by the human experts. A proper diagnosis of the active disease, effective choice of chemical fungicides and cultural practices demand adequate expertise.

In many cases, it is not possible to provide such experts to each and every corner of this wide spread industry. So in a large number of cases, inadequate practices are the ultimate result leading to crop losses. There are evidences that many tea estates are loosing crops for the neglect of root disease by the past management [3]. In one particular instance a garden which adopted incorrect method in the past, lost 20 to 30 thousand bushes , representing between 7 and 10 acres of tea, per annum [14]. Moreover, sufficient expertise is essential to recognise the differences between the symptoms due to the attack of diseases and that of by other causes such as lightning, water lagging etc. because in many cases the symptoms are being confused with that of the diseases.

After proper identification of the disease, systematic control measures are also very important to increase the productivity; as an example, control of the disease with two rounds of fungicides application over two years resulted in a net increase of 11% yield per year for the next 5 years and ensured better bush health [15]. It is particularly important to apply proper control measures in young tea and in good well-filled sections, because the losses from root disease, if neglected, are cumulative and the number of deaths increasing each year.

In recent years, the diseases are being controlled by cultural practices along with the chemicals with little importance laid on the hazards of the chemicals. Indiscriminate and excessive use of chemicals create bio-amplification of the residue in human system and consequently invites bio-disorderliness in human health.

It might be the case that an alternative choice of cultural practices may reduce the use of chemicals to control the disease. As an example, bushes suffering from lack of aeration of the soil may carry violet root rot in their roots in a mild form for years without being killed. On the other hand bushes may be killed off by this disease within a matter of weeks if they are subjected to flooding or to accumulation of water around the collar, in saucer-like depression, caused by faulty cultivation methods [3].

8.4. Knowledge engineering

The system's knowledge had been acquired from sources. As the first source of knowledge, multiple human experts, as in the case of *TEAPEST* had been consulted through structured interviews. Forms were prepared to record the knowledge extracted from those experts. The experts were requested to give their judgment for different set of possible observations.

Secondly, knowledge was elicited from various literatures, books on the subject, and workshop reports published by Tea Research Association, India [1-3,12-18].

For real field study, regular visits were conducted to the disease affected sections of various tea estates of North Bengal districts of West Bengal, India in different seasons.

All physical observations were recorded and incorporated in the knowledge base of the system.

The unstructured knowledge as acquired from the above three sources were structured and formalized by the authors. The knowledge is then represented in object-oriented form for later implementation as shown in Appendix B. Object-oriented approach of Knowledge Representation (KR) scheme is more structured than other well known schemes and this is more suitable to improve consistency, understandability, maintainability and modifiability of knowledge base [19]. The knowledge in the system is stored as group of objects. Each group of object is represented by a class with its attributes. A class defines the general properties and structure of a group of objects; attributes describe the object's important characteristics. The knowledge library class serve as a database. The linguistic attribute values like "Curl or bended over", "White powdery patches", "Concave oily" etc. are very common terms used in tea domain. Both the experts as well as workers are well accustomed with these terms and observations. So these are incorporated in the system as attribute values.

8.5. System architecture

The system is designed to aid the decision making process for identification of disease(s) of tea and the control measures (selection of chemical fungicides and cultural practices). The block diagram of the system is shown in fig. 8.1.

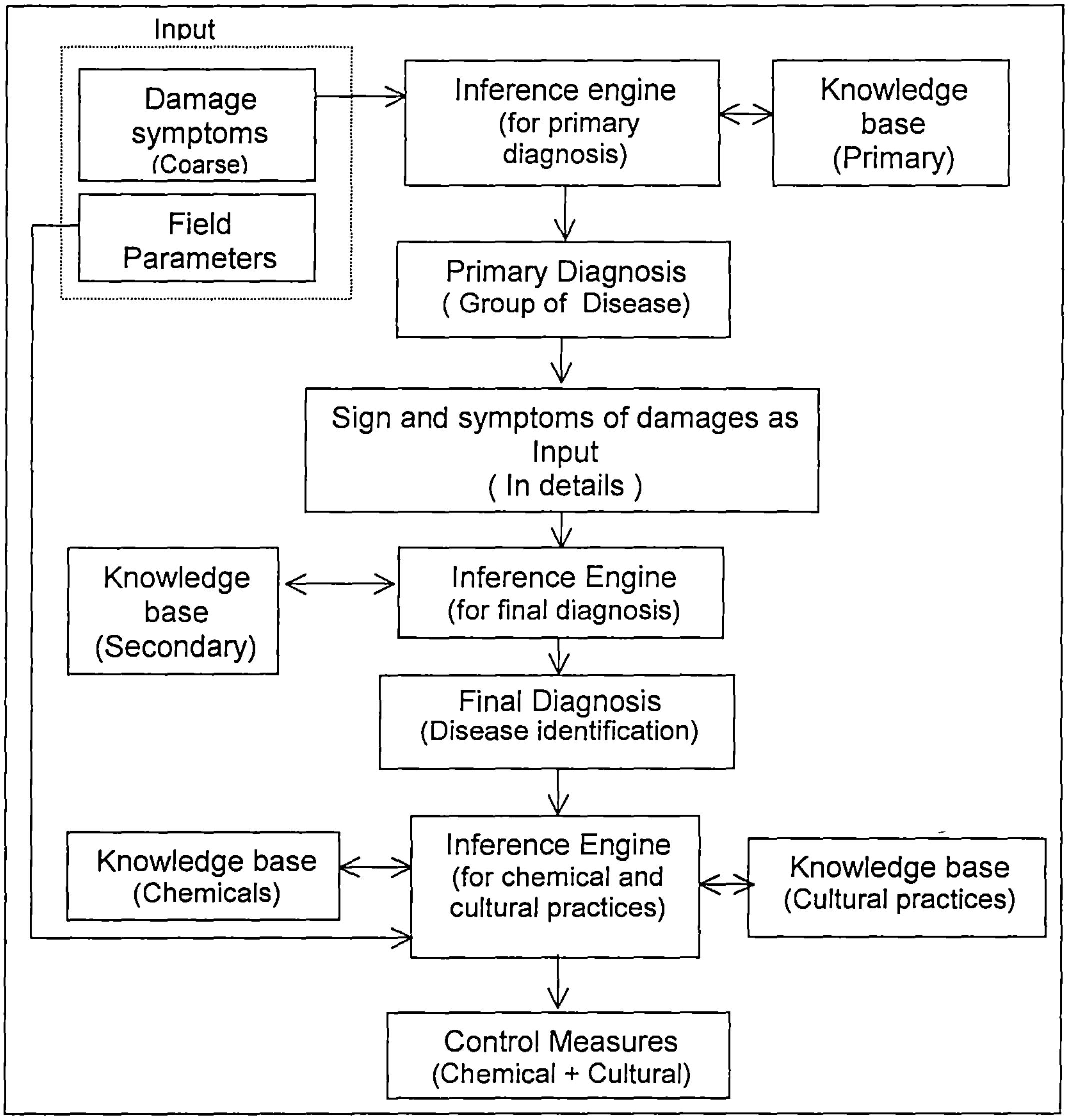

Fig. 8.1. Block diagram of *TEADISEASE.*

The system starts with the inputs of various field parameters such as soil condition, rain fall, humidity, plantation status etc. along with the apparent appearance of the bushes affected by the disease. With these findings, it proceeds for primary selection of the disease indicating the specific region such as root, stem or leaves of the bush where the disease is most probable to be present. Depending upon the primary selection, the system interacts with the user to take specific sign and symptoms in more details to diagnose one or more diseases active in the plant. As inference propagates from damage symptoms (starting with inputs) to the identification of disease (goals), forward chaining of rules had been found suitable in this case [20].

The system has been designed in three phases. In Phase I, the system detects the most probable group of the disease(s) which is likely to be present. In Phase II, depending upon the primary group selection, the system asks for more specific observations and diagnoses the specific disease(s). With the identified disease(s) and field parameters, the system suggests control measures in Phase III. The flow diagram of the system is shown in fig. 8.2.

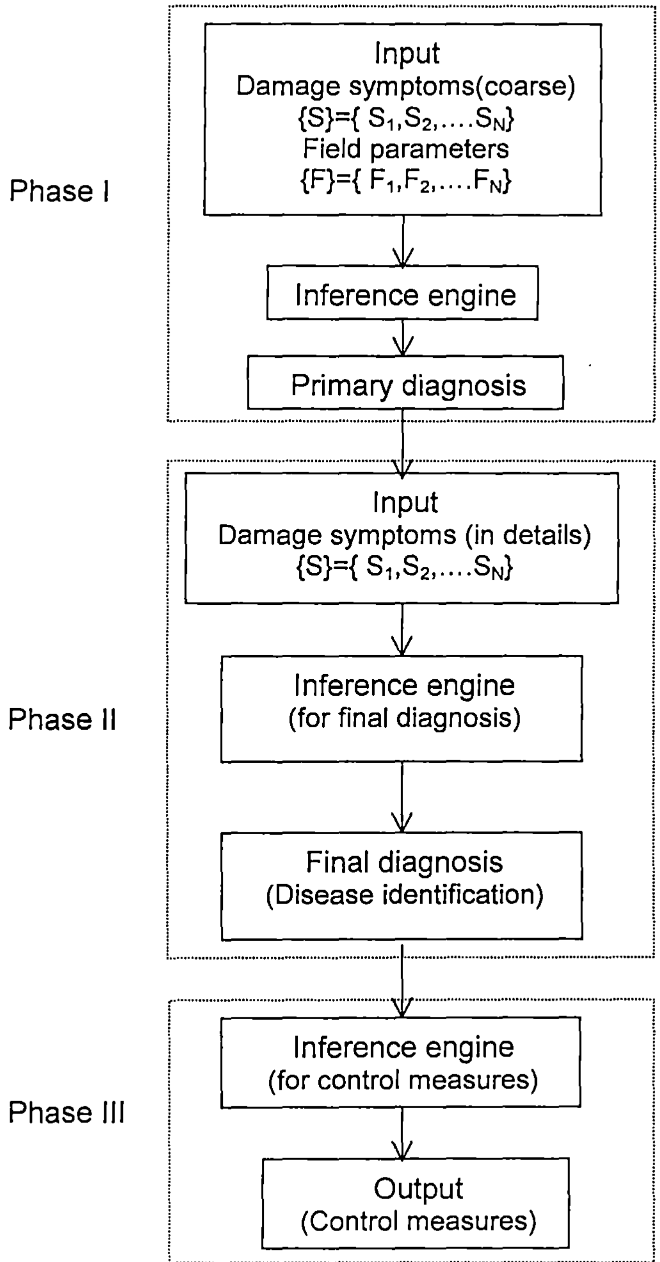

Fig. 8.2. Flow diagram of *TEADISEASE*.

The inference engine contains rules. ' IF {S} THEN {D} CF' rules have been used for inferences, where {S} is the plant damage symptoms, {D} is the disease and CF is the certainty (confidence) factor associated with the rule. The certainty factor CF attached to every rule represents the truth membership (confidence) of that rule. The value assigned to CF ranges from 0 to 100. The higher the value of CF, higher is the confidence associated with that consequent. For each rule, the value of CF has been obtained from multiple experts during knowledge acquisition and finally modified after test run with real field data.

The system displays the result of the diagnosis in two parts, the name of the disease and the possibility of appearance of the disease. The possibility of appearance has been estimated by certainty factor of a particular set of features and the cases with certainty factor > 20 has been considered. Using the certainty factor model, the probability of appearance of a particular disease has been classified in three fuzzy variables (i) "may be present" (ii) "positive" and (iii) "diagnosed". The certainty factor between 20 to 50 leads to the fuzzy variable "may be present", that of having values between 51 to 80 leads to "positive" and certainty factor more than 80 leads to "diagnosed".

The format chosen for definition of rules allows flexibility in structuring the knowledge. An antecedent of any rule may be a composite of a number of clauses or atomic propositions connected via the logical operations .AND. and .OR. This diagnosis phase contains 176 rules. Examples of decision making rules used here are:

- **RULE Pry root 8**

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IF (Primary findings on collar region IS Mycelium growth OR
Primary findings on collar region IS Encrustation OR Primary
findings on collar region IS Bracket like growth OR Primary
findings on collar region IS Shot or thorn like growth)
THEN Primary root disease OF Primary goal action data CF 52
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- **RULE Blister blight 6**

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IF (Leaf appearance IS Curl or bended over AND Primary findings
on stem IS White powdery patches AND Spot on upper leaf IS
Concave oily AND (Lower leaf spot IS Convex white and powdery OR
Lower leaf spot IS Convex pink and powdery))
THEN Blister blight OF Secondary goal rule group CF 91
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- **RULE Black root 10**

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IF (Bush appearance IS Whole bush dies suddenly AND Collar
observations IS Black grains of shot AND (Root surface IS Black
cobwebby cords of mycelium OR Root surface IS Greyish black
cobwebby cords of mycelium) AND Root bark peeled away IS Black
star like threads of mycelium)
THEN Black root rot OF Secondary goal rule group CF 95.
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After completion of the diagnosis, the system proceeds for suggesting control measures which is again a decision activity. It is evident that to control the disease, not only the chemicals but some cultural practices take vital role [18]. A judicious blending of chemical fungicides along with the adequate cultural practices is more appropriate for better control of the diseases. In case of chemical selection, the possible parameters like age of the bush, nature of the disease, type of the chemicals, their toxicity etc. have been considered.

Cultural practices depend on field parameters like soil status, rain fall, temperature, humidity, shade status etc. So the system takes required field parameters as inputs along with the sign and symptoms of the diseases and suggests the cultural measures to be taken in association with the appropriate chemical fungicides.

Suggesting suitable control measures for disease is again a decision activity. 'IF ({D} AND {F}) THEN ({C} AND {P}) CF' rules have been used for inferences, where {D} is the disease, {F} is the field observations, {C} is the chemical fungicide and {P} is the cultural practice. All rules have been grouped under various rule-groups depending upon the task. If multiple rules have been fired in a group, then the rule with highest certainty factor value is trapped for next course of action. Currently control phase consists of 64 rules. Examples of these rules are:

- **RULE fumigation 1**

```
IF (Secondary_cf[ 13] > 20 OR Secondary_cf[ 14] > 20 OR
Secondary_cf[ 15] > 20 AND Soil status IS Heavy AND Weekly Av
Temperature IS High AND Average Humidity IS High AND Weekly Av
rainfall IS Low OR Weekly Av rainfall Is Low)
THEN Soil fumigation OF Chemical rule group CF 81
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- RULE trench 1

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IF ((Plantation status IS Old OR Plantation status IS To be
uprooted) AND (Secondary_cf[ 13] > 20 OR Secondary_cf[ 14] > 20
OR Secondary_cf[ 15] > 20 OR Secondary_cf[ 16] > 20) AND Soil
Status IS Heavy AND Weekly Av Temperature IS High AND Weekly Av
rainfall IS High)
THEN Trench OF Cultural rule group CF 76
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8.6. Implementation

The system was implemented in an object oriented environment by using LEVEL 5 Object for Microsoft Windows (release 3.0 or higher) by Information Builders Inc, USA. It is an application development tool to combine client/server technology, object-oriented programming, graphical user interfaces and knowledge-based systems. LEVEL 5 Object has an integrated array of powerful tools (GUI development, forms and display builders) and has the capability to chain more than one knowledge base together. The GUI offers a great flexibility in designing the user interfaces. GUIs are widely used for interaction with computers because of their transparencies, ease of use, user friendliness, and robustness as they provide the user to interact with the system by manipulating the graphical objects [21,22].

8.7. A case illustration

For better clarification of the system, a real field case study is being produced here.

Primary observations :

1. Plantation status	:	Matured
2. Soil status	:	Not known
3. Weekly Av. temperature	:	Moderate (25-30^0 C)
4. Shade status	:	Adequate
5. Average humidity	:	Moderate (75 – 85%)
6. Weekly Av. rainfall	:	High
7. Bush appearance	:	Normal
8. Leaf appearance	:	Curl or bended over & Spots / patch on surface
9. Leaf colour	:	Normal
10. Primary findings on stem	:	White powdery patches
11. Primary finding on Collar	:	Normal

Primary diagnosis:

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1.   Leaf  Disease   . . . . positive
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Specific observations:

1. Spot on upper leaf surface	:	Concave oily
2. Colour of the upper patch	:	No patches
3. Upper patch symptom	:	None
4. Upper leaf film	:	No film
5. Lower leaf spot	:	Convex white and powdery
6. Film or lumps on lower surface	:	No film
7. Lower leaf patch	:	No patch

Final Diagnosis by the system:

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1.  Blister Blight   . . . . diagnosed
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Control measures suggested by the system :

A. Chemical fungicides :

1. Spray 0.25% (i) Copper Oxychloride 50 % WP, (ii) Carboxin 75 % WP or (iii) Carbendazim 50 % WP at an interval of 7 to 10 days.

B. Cultural practices :

1. Remove all dead and dying branches with sharp knives.
2. Skiff or prune the section.
3. Apply COC and bitumen paint on cut surface.
4. Trichoderma bioformulation (10 % aqua) is very effective.
5. Try to protect medium pruned tea from sunscorch.
6. Protect labour movement from affected area to the unaffected area.

A case illustration with the actual system is shown in **Appendix D.**

8.8. Performance evaluation

After fine tuning with real field case observations, it has been installed to work with real field cases of Radharani Tea Estate in West Bengal, India since last one and half year. For each case, both the suggestions of the human expert(s) and that of the our system were recorded independently. The results obtained from the system are as good as in the case of human experts. The precision and quality of the result is very appreciable and coincides with human experts for more than 90% cases. For better validation of the system, some randomized examples of system's suggestion vs. expert's recommendation for real field cases are produced in Appendix F.

8.9. Discussion and conclusion

In case of test run, *TEADISEASE* suggested the goal(s) which almost coincides with the advice(s) of various field experts. Finally, it has been introduced in Radharani Tea Estate, India for actual field case studies. For each case, the system's output has been compared with both the expert's opinion and as well as real field observations. It produces results of equally good quality and precision as in the case of available expert of the above said tea estate.

It is an object-oriented rule based expert system developed to meet up the needs of tea industry, at least partially. The prime objectives of our approach are (i) mitigating the lack of proper human experts in the domain, (ii) as a part of practicing integrated disease management and (iii) ultimately optimize the tea production. The results obtained by this system are equally good as that of the human experts. But tea is a wide spread industry under different varying conditions. The system should have some region specific adaptability for updation of knowledge base which essentially means that the system leaves scope for further refinement with region specific cases. Hopefully this system will contribute to the production of tea.

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