KNOWLEDGE EXTRACTION TECHNIQUES APPLIED TO BLOTCH (*Cercospora coffeicola Berkeley & Cooke*) OCCURANCE MODELING IN COFFEE TREES IN SOUTHERN MINAS GERAIS

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ABSTRACT: Blotch progress lifting becomes potentially useful and understandable in understanding the disease and in the process of decision taking for control measures. In the last years, computer programs have been helping to elucidate which biotic or abiotic factors are more representative. The objective, in this study, was to investigate, using knowledge extraction technique, which environmental and phenological attributes influence the most in blotch occurrence in coffee trees in Southern Minas Gerais, under two crop systems: conventional and organic. To do so, blotch incidence data were organized on two crop systems, with climatic and phenological culture data, in five years of evaluation. Following that, a knowledge extraction algorithm based on decision tree was used to obtain the attributes which favor blotch occurrence the most. Generated models obtained 60% hit rate and showed that the average temperature was the most influential factor in total data and for conventional crop system. In organic management, monthly precipitation and phenology are the factors that interfere the most in disease occurrence.

Index terms: *Coffea arabica*, epidemiological data mining, plants disease epidemiology.

TÉCNICAS DE EXTRAÇÃO DE CONHECIMENTOS APLICADAS ÀA MODELAGEM DE OCORRÊNCIA DA CERCOSPORIOSE (*Cercospora coffeicola Berkeley & Cooke*) EM CAFEEIROS NA REGIÃO SUL DE MINAS GERAIS

RESUMO: *O levantamento do progresso da cercosporiose torna-se potencialmente útil e compreensível no entendimento da doença e no processo de tomada de decisão para medidas de controle. Nos últimos anos, programas computacionais têm ajudado a elucidar quais fatores bióticos ou abióticos são mais representativos. Objetivou-se, neste trabalho, investigar, utilizando técnicas de extração do conhecimento, quais atributos ambientais e fenológicos mais influenciam na ocorrência da cercosporiose em cafeeiros no Sul de Minas Gerais, sob dois sistemas de cultivo: convencional e orgânico. Para isso, foram organizados dados de incidência de cercosporiose nos dois sistemas de cultivo, com dados climáticos e fenológicos da cultura, em um período de cinco anos de avaliação. Em seguida, um algoritmo de extração do conhecimento baseado em árvore de decisão foi utilizado para obter os atributos que mais favorecem a ocorrência da cercosporiose. Os modelos gerados tiveram 60% de taxa de acerto e mostraram que a temperatura média foi o atributo de maior influência na totalidade dos dados e para o sistema convencional de cultivo. No manejo orgânico, a precipitação mensal e a fenologia são os fatores que mais interferem na ocorrência da doença.*

Termos para indexação: *Coffea arabica*, mineração de dados epidemiológicos, epidemiologia de doenças de plantas.

1 INTRODUCTION

Blotch is one of the oldest coffee tree diseases, caused by *Cercospora coffeicola* Berk & Cook. Characteristic symptoms are round light-brown to brown stains on leaves, with a white-grey dot on the middle, almost always surrounded by a yellow halo; and on the fruits there are elongated depressed lesions following the poles (CARVALHO; CHALFOUN; CUNHA, 2010).

The disease is widely spread throughout all of Brazil's coffee regions, causing setbacks in greenhouse stage as well as on the field, in young and adult plants, attacking leaves and fruits (CARVALHO; CHALFOUN, 2000). The period of most incidence of blotch in the field goes from January to May, when, in adult crops, causes severe defoliation, premature maturation and fall of fruits, increase in empty locule beans as well as the adherence of the pulp to the scroll, which makes depulping more difficult, causing negative reflexes over productivity and quality of final product (CARVALHO; CHALFOUN, 1998; CHALFOUN, 1997). According to Pozza et al. (2001), blotch can reduce from 15% to 30% field productivity, becoming a serious problem in coffee economy.

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Higher or lower intensity of disease is associated to environment, pathogen, host and crop management (CARVALHO; CHALFOUN; CUNHA, 2010). According to Salgado et al. (2007), success in culture management depends on knowledge of factors that influence disease development. As environment is concerned, rainfall, temperature and air humidity affect incidence as much as severity of disease.

Besides weather conditions, deficient and/ or unbalanced nutrition in clayey grounds, sandy or too compressed grounds, as well as deficient root systems or crooked root problem, are factors that predispose plants to disease. Ground and root conditions directly influence plants nutrition. Several works indicate that deficient or unbalanced nutrition have direct effect in blotch attack intensity (CARVALHO et al., 2008; POZZA et al., 2001; TALAMINI et al., 2001).

Despite the importance of blotch, little is known about its causing agent *Cercospora coffeicola* (MARTINS; MAFFIA; MIZUBUTI, 2008). Determination of environmental conditions which favor the disease are generic, as high relative humidity, temperatures between 10 and 25ºC, insolation excess and hydric deficit (ALMEIDA, 1986; ZAMBOLIM et al., 1997). Pozza and Alves (2008), determined, for controlled environments, high favorability of blotch occurrence in regions with monthly average temperatures between 18 and 24ºC and average rainfall of 3mm/day. However, Santos et al. (2008b), pointed that this knowledge was generated from studies of the disease in cofee trees conducted in a crop system called conventional, in which plants' nutrition is based on the use of mineral fertilizers promptly soluble and that, until this moment, little has been studied about the intensity of blotch in organic crop systems.

Effective disease control depends on wide knowledge of the environmental conditions that favors it and on techniques and tools that allow to widen the knowledge over its behavior.

Knowledge Discovery in Database - KDD is a process of identification, in a data set, of patterns that are valid, previously unknown, potentially useful and understandable, aiming to improve the understanding of a problem or decision taking process (FAYYAD et al., 1996).

Data mining (MD), is one of the steps of KDD, not a trivial process, which consists on the ability to identify, in data, valid patterns, new and significant, using statistic methods, visualization tools and artificial intelligence techniques. However, the knowledge that is posible to acquire through MD has been very useful in many different areas, such as in medicine, finances, marketing, weathercasting, agriculture, biocomputers, among others. MD extends the capacity to generate and validate hypotheses and therefore can incur in new (unexpected) knowledges, fortuitous and interesting (BUCENE; RODRIGUES; MEIRA, 2002; GALVÃO; MARIN, 2009).

Mucherino et al. (2009) present the use of data mining techniques in agriculture which is a relatively new research field. However, they also state that efficient techniques can be developed to solve complex problems in this area.

One of the data mining techniques is called classification, whose objective is to identify different features of predefined classes, based on a set of instances. Widely used in classification algorithms, decision trees represent, in a simple and effective way, knowledge. In decision trees, the knots represent the attributes; the edges receive the possible values for these attributes; and the leaves represent the different classes of a training set. Classification, in this case, is the construction of a tree (model) structure, which can be used to correctly classify all of the objects of the input data set. As an example of classification algorithms using decision trees, could be quoted: ID3, C4.5 and J4.8.

Galvão and Marin (2009) also explain that, with the use of the decision tree it is posible to produce an exact prediction model of find out the predictive structure of the problem. In the last case, the intention is to understand which of the variables and interactions conduct to the studied phenomenon.

Meira, Rodrigues and Moraes (2008) used decision trees to help understand of epidemic manifestations of coffee rust in Minas Gerais. According to these authors, the decision tree helped understanding which variables lead to the coffee rust epidemics and how these variables interact.

The objective, in this study, was to investigate, using data mining techniques, which environmental and phonological attributes influence the most on blotch occurrence, in coffee crops in Southern Minas Gerais, under two crop systems: conventional and organic.

2 MATERIALS AND METHODS

Data pre-processing

2.1 Blotch data

The experiment was conducted in the Experimental Farm (Fazenda Experimental de São Sebastião do Paraíso, MG), and installed in early 2000, with ground preparation and planting of two distinct areas, spacing 3,2 m x 0,8 m each area, occupying around 2.500 m^2, in a total of 1 ha. Two materials were evaluated being one of Rubi MG 1192 cultivar and the other Hibrid H-419 (Progeny in selection). Parcels were constituted by 8 Rubi MG 1192 cultivar coffee trees. Treatments had two harvest management systems, one managed in organic system and one managed in conventional system.

During 5 years of experiment evaluation, monthly assessments were performed for blotch incidence, in 100 leaves per parcel. These data were made available by six electronic spreadsheets, as shown in Table 1. 1300 samples were expected. However, there were 32 samples, in which infestation values could not be colected. Thus, 1268 samples were considered valid.

From the data showed in Table 1, the attributes Rising and Falling infestation were ignored. Due to the inexistence of standardized methods for quantification of blotch in field, total infestation was described in the following classes:

0 to 7 - Low infestation

8 to 15 – Medium infestation

>15 – High infestation

The attribute month was transformed and adjusted in a way to suggest the phenologic stage of the plant, according to Camargo and Camargo (2001), as seen in Figure 1.

TABLE 1 - Spreadsheet sample over blotch occurrence. The attributes rising and falling infestation indicate leaf collection sampling position, and the sum represents the percentage of total infestation.

Management	Cultivar	Month	Infestation (Rising)	Infestation (Falling)	Infestation (Total)
Conventional	Rubi	January	12	6	18
Conventional	Rubi	January	8	10	18
Conventional	Rubi	January	11	8	19
Conventional	Rubi	January	10	6	16
Conventional	Rubi	January	10	10	20
Conventional	Hibrid	January	5	7	12
Conventional	Hibrid	January	4	6	10
Conventional	Hibrid	January	3	3	6
Conventional	Hibrid	January	10	6	16
Conventional	Hibrid	January	8	4	12
Organic	Rubi	January	9	3	12
Organic	Rubi	January	3	2	5
Organic	Rubi	January	2	3	5
Organic	Rubi	January	7	2	9
Organic	Rubi	January	4	0	4
Organic	Hibrid	January	11	7	18
Organic	Hibrid	January	13	8	21
Organic	Hibrid	January	9	6	15
Organic	Hibrid	January	8	5	13
Organic	Hibrid	January	5	3	8

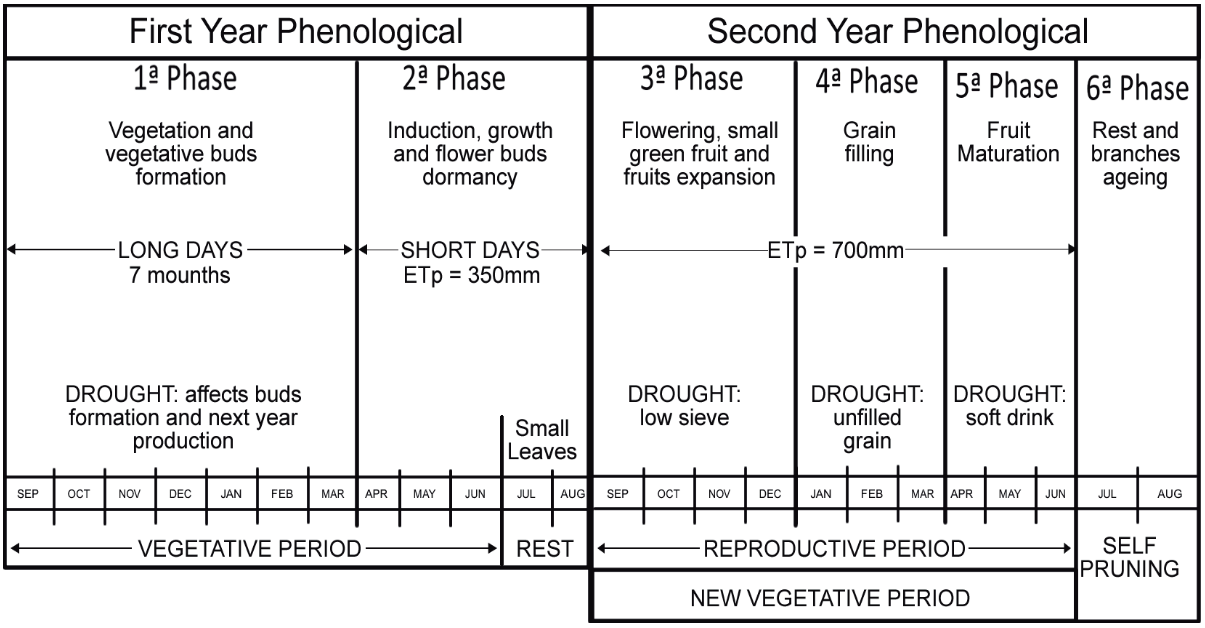

FIGURE 1 - illustration of phenology of coffee tree used to adjust occurrence date of blotch with the plant's phenological state. Source: Camargo and Camargo (2001).

2.2 Weather data

Weather data were collected in a conventional weather station present at EPAMIG's Experimental Farm, in partnership with INMET and were analysed the following data: Rainfall, Minimum Temperature, Maximum Temperature and Air Relative Humidity.

Since the weather data were daily and the disease were monthly, monthly averages data were used. From the minimum temperature and the maximum temperature data was generated the attribute average temperature. From the rainfall data, daily rainfall was generated, dividing the amount of rain of the month by 30.

The temperature and rainfall data discretization followed suggestion from Pozza and Alves (2008). Based in consultations, interviews were conducted with area experts who suggested the following classes: Monthly Rainfall: < 70 and >= 70. Humidity: < 60 and >= 60.

By the end of the pre-processing stage, disease and weather data were integrated (Table 2) and then went through the mining process.

Data were analyzed using Weka software (version 3.6.1, Waikato University, New Zealand), executed on Windows. Weka is a collection of algorithms of machine learning and associated tools, which also offers support to full data mining process. It is a free, open source software, used in data maining initiatives (MEIRA; RODRIGUES; MORAES, 2008).

The algorithm used was J4.8 (WITTEN; FRANK, 2005), which is a decision tree inducer. Configuration parameters had the Weka standard value. Only the parameter *'confidenceFactor'* was altered to 0,3, to generate more complete trees.

3 RESULTS AND DISCUSSION

The first experiment was performed with the full amount of data, which means all the 1268 samples. The results are shows in Figure 2. The hit rate was 60%.

The reading of the tree starts from the top (root knot) to the leaf knots, passing through the branches, according to attributes values tests. The leaf knots represent the study object, which means, the blotch infestation rate. Each branch of the tree is a conjunction of conditions, therefore, the tree route (from root to leaf) corresponds to one classification rule.

From this first experiment was verified that the average temperature was the highest separability attribute. Pozza e Alves (2008) rated as average the blotch favorability in conditions in which temperatures are between 12 and 18 and between 24 and 30 and rainfall keeps higher than 2 and lower or equal than or equal 3.

TABLE 2 - Sample of the pre-processing final result. Management, cultivar, phenology, weather and disease occurrence data were discretized and integrated in one single file.

Management	Cultivar	Phenology	Rainfall (Sum)	Rainfall (Average)	Average Temperature	Humidity	Total Infestation
Conventional	Rubi	Maturation of Fruits	>=70	<3	Between 18 and 24	>=60	Low
Conventional	Rubi	Maturation of Fruits	>=70	<3	Between 18 and 24	>=60	Low
Conventional	Rubi	Maturation of Fruits	>=70	<3	Between 18 and 24	>=60	Low
Conventional	Rubi	Maturation of Fruits	>=70	<3	Between 18 and 24	>=60	Low
Conventional	Hibrid	Maturation of Fruits	>=70	<3	Between 18 and 24	>=60	Low
Conventional	Hibrid	Maturation of Fruits	>=70	<3	Between 18 and 24	>=60	Low
Conventional	Hibrid	Maturation of Fruits	>=70	<3	Between 18 and 24	>=60	Low
Conventional	Hibrid	Maturation of Fruits	>=70	<3	Between 18 and 24	>=60	Low
Conventional	Hibrid	Maturation of Fruits	>=70	<3	Between 18 and 24	>=60	Low
Organic	Rubi	Graining of Fruits	>=70	>=3	Between 18 and 24	>=60	Low
Organic	Rubi	Graining of Fruits	>=70	>=3	Between 18 and 24	>=60	Low
Organic	Rubi	Graining of Fruits	>=70	>=3	Between 18 and 24	>=60	Low
Organic	Rubi	Graining of Fruits	>=70	>=3	Between 18 and 24	>=60	Low

The right branch of the tree confirms such authors. Although the attributes temperature and average rainfall have not been enough to determine disease favorability, where rainfall was lower than 3, disease infestation was high for the Rubi cultivar and average for the Hibrid. Through the entire tree, the Hibrid cultivar showed less blotch occurrence than the Rubi, result assigned to the genetic features of the material. Where rainfall was higher or equal to 3, infestation was low, regardless of the cultivar.

In the branch in which temperature is between 18 and 24 degrees, phenology was also a decisive attribute for disease occurrence. During the Rest, Senescence and Flowering stages, the infestation was always low, regardless of any other attribute. Fact explained by the time of the year (July to December), when the environmental conditions do not favor the disease.

In the maturation stage (April to June), temperature and phenology were not enough to decide infestation. The attributes average rainfall and monthly rainfall were necessary. When monthly rainfall was lower than 70 mm, infestation was low. For months when total rainfall was higher than 70 mm, average rainfall needed to be used. Therefore, monthly rainfall superior to 70 mm and daily above or equal to 3 resulted in average infestation. Monthly rainfall higher than 70 mm and daily lower than 3 resulted in low infestation. This last scenario indicates that it rained profusely on that month, however not in a regular basis. Occasional and more intense rains do not favor the disease, since they wash away the pathogens' propagules from the leaves' surface, making it harder to spread and infect (TALAMINI et al., 2003; WOLF; ISARD, 2007).

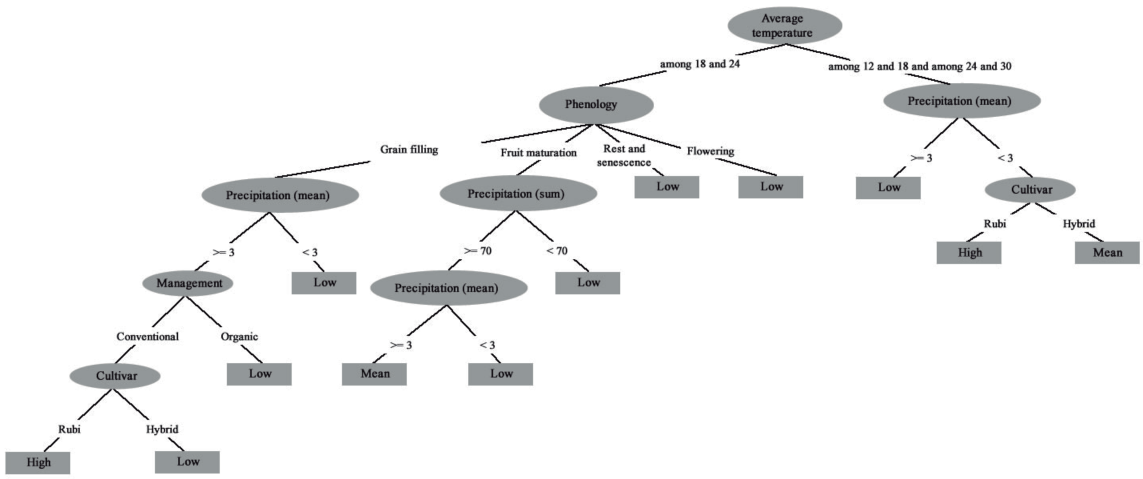

FIGURE 2 - Model for blotch occurrence, in conventional and organic production systems. The attribute of higher separability is temperature. The right branch indicates temperatures of less favorability of disease. In this case, the average rainfall atribute is the sencond most decisive for occurrence of disease. The right branch indicates higher favorability of disease, therefore, phenology is decisive for disease occurrence.

During the graining stage of fruits (January to March), the attributes temperature, phenology, monthly rainfall, management and cultivar were necessary to decide over the disease infestation. For monthly rainfall below 3, infestation was low, agreeing with Pozza and Alves (2008) and opposing to the one found in temperatures between 12 and 18 and between 24 and 30 degrees Celsius. For monthly rainfall above or equal to 3, consulting the management attribute was necessary. During the graining stage, the plant is subjected to a great drain for fruit formation, thus needs to be well nourished. This fact explains the use of management attribute. The imbalance in nutritional elements combinations can influence the plant's tolerance to a disease (BALARDIN et al., 2006). In coffee trees managed in organic system, mineralization of organic matter and slow nutrient release can promote the plant's temporary nutritional imbalance, making it less tolerant and favoring the disease (SANTOS et al., 2008a). on the other hand, in conventional management, the use of chemical fertilizers, due to their solubility, is promptly available, fulfilling their needs (MARSCHNER, 1995).

However, what is seen on Figure 2 is an opposite behavior. In organic management a low disease infestation prevailed, while in conventional management the infestation was high for the Rubi cultivar and average for the Hibrid cultivar. Such fact could be explained buy the use of copper sulfate, which, although used on coffee rust control, applied at the organic management plot, inhibited, in an effective way, the development of blotch. Meanwhile, in conventional management, the use of systemic fungicides was specific for coffee rust. In fact, according to Carvalho et al. (2008), the use of copper on coffee crops reduces the blotch infestation. Thus, the generated model was specific for the organic system with the use of a copper source.

Several tests were performed to determine classes of monthly rainfall that would better suit to the reality of the experiment. Figure 3 shows the results found, when the attribute classes monthly rainfall (<70 and >=70) were replaced for classes <150 and >=150. It was observed that the generated model shows the same tree structure as the model in Figure 2. However, the tree grew in complexity, keeping the same error rate as in the previous model. Therefore, the model was discarded. The best monthly rainfall classes found were <70 and >=70.

Two more experiments were performed, dividing the samples by management. Thus, an experiment was performed for conventional management (Figure 4) and other one for the organic management (Figure 5).

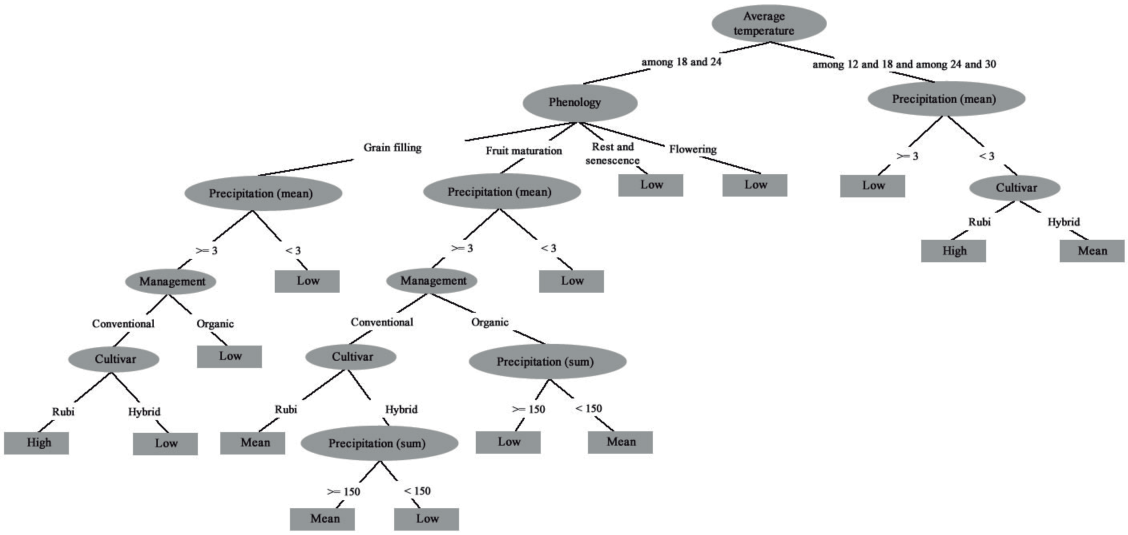

FIGURE 3 - Model for occurrence of blotch in conventional and organic management systems and rainfall attribute (sum) discretized between <150 and >=150. The tree kept the same structure as in figure 2, but grew in complexity, being refuted.

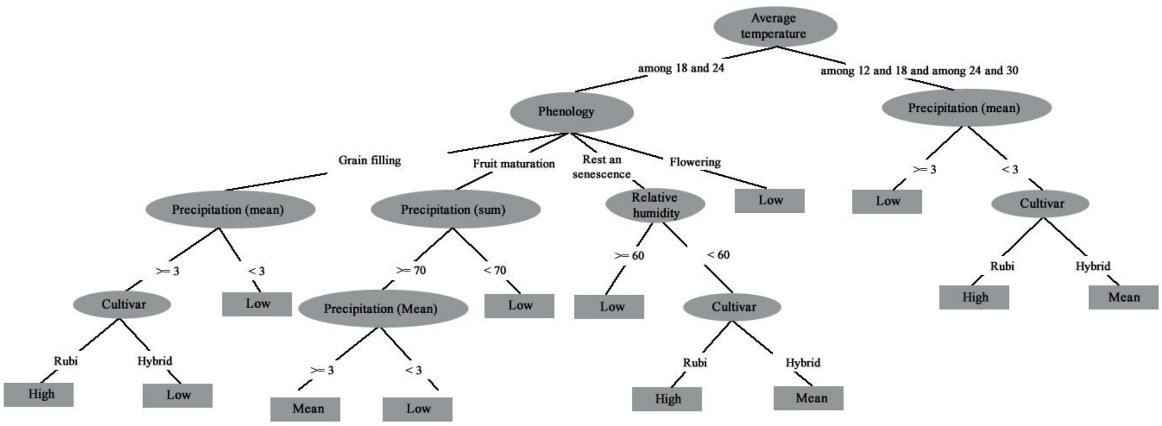

FIGURE 4 - Occurrence model for blotch in conventional production system. The model kept the structure of that in Figure 2. The main difference is in the rest and senescence phenology branch. In this case, the favorability of disease depends on Humidity and Cultivar.

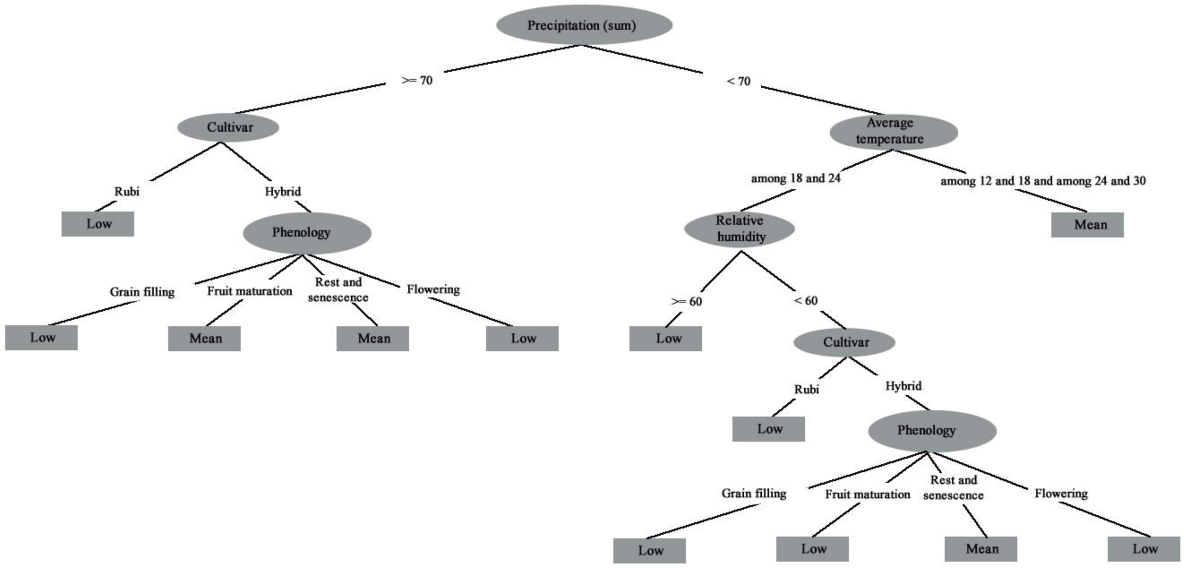

FIGURE 5 - Model of occurrence of blotch in organic production system, with the use of a copper source. The model is completely different from that of conventional system. In this case, the attribute of biggest separability is the total amount of rainfall. For rainfall values over 70 mm, temperature does not influence disease occurrence.

The model generated for conventional management has the same tree structure as in the previous models. The biggest difference occurred in the branch Phenology – Rest and Senescence. In this case, the attribute Humidity, which have not shown yet in previous models, emerged as decisive attribute. Such fact can be explained by the phonological stage of the culture which coincides with the unfavorable period for disease progress (CARVALHO; CHALFOUN; CUNHA, 2010).

The model generated for organic management (Figure 5) has a very distinct tree structure when compared to the previous models. In this management, monthly rainfall was the attribute that separated the most and phenology interferes in disease occurrence, when compared to conventional management. This demonstrates that the cultural practices interfere in the progress of the disease, being nutrition and blotch control measures adopted as the main components of the obtained result.

The limitation of these developed models is related to their coverage. Agreeing with Meira, Rodrigues and Moraes (2008), different regions in Southern Minas Gerais and other variables, which were not represented, can change, somehow, the structure of the models quoted above.

Take notice that the improvement in data collection for construction and validation of new models can bring to a better understanding of disease by researchers, technicians and producers.

4 CONCLUSIONS

It was noticed that disease occurrence in organic management is modelled in a different was than the one in conventional management and that temperature and phenology were the most highlighted attributes.

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