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Yield, Yield Components, Soil Minerals and Aroma of KDML 105 Rice in Tungkularonghai, Roi-Et, Thailand

Kanlaya Kong-ngern, Tossapol Buaphan, Duangsamorn Tulaphitak, Naug Phuvongpha, Sirirut Wongpakonkul, Piyada Threerakulpisut

***Abstract*—**Pearson's correlation coefficient and sequential path analysis has been used for determining the interrelationship among yield, yield components, soil minerals and aroma of Khao Dawk Mali (KDML) 105 rice grown in the area of Tungkularonghai in Roi-Et province**,** located in the northeast of Thailand. Pearson's correlation coefficient in this study showed that the number of panicles was the only factor that had positive significant (0.790**) effect on grain yield. Sequential path analysis revealed that the number of panicles followed by the number of fertile spikelets and 100-grain weight were the first-order factors which had positive direct effects on grain yield. Whereas, other factors analyzed had indirect effects influencing grain yield. This study also indicated that no significant relationship was found between the aroma level and any of the factors analyzed.

***Keywords*—**2-Acetyl-1-Pyrroline, rice aroma

I. Introduction

IT is well known that Thai aromatic rice, especially the cultivar KDML 105 is the world most popular rice due to its high cooking quality and high aroma level. Its price in the rice world market is almost double that of other cultivars of rice. The biggest KDML 105 rice production area is in Tungkularonghai**.** This area is located in the Northeastern part of Thailand and two-third of this area is located in Roi-Et province.

The volatile aromatic compounds of KDML 105 rice have been studied extensively by a number of researchers. 2-acetyl-1-pyrroline (2-AP) is considered to be the most important aroma compounds in KDML 105 rice [1]. This aroma is similar to that found in popcorn [2]- [4], wheat and rye bread crusts [5]-[6], roasted beef [7], and pandan [2], [8]-[9].

Aroma level of KDML 105 rice was highly influenced by environmental factors in the production area (soil quality, soil salinity, soil minerals, weather etc.), cultivation methods and especially the drought conditions during the ripening stage [1]. It has been reported that 2-AP is accumulated in aleurone layer, which is removed during milling, more than in endosperm. Biosynthesis of 2–AP occurred before starch structure formation in rice kernels [10]. It is released when the grain is cooked [11]. It has been reported that L-proline is related to the formation of 2-AP in aromatic rice and L-proline accumulation is a common metabolic response to water deficits, salinity stresses, light and carbohydrate [12]-[13]. However, the information of the difference in 2-AP content in KDML 105 grown in different areas is still lacking.

To gain a better understanding of the interrelationship among yield, yield components, soil minerals and aroma of KDML 105 rice, Pearson's correlation coefficient and sequential path analysis was performed in order to determine this interrelationship. This interrelationship is hope to be useful information for increasing the yield and the level of the 2-AP in KDML 105 grown in other places.

Kanlaya Kong-ngern and Piyada Threerakulpisut Are with the Genomics and Proteomics Research Group for Improvement of Salt-tolerant Rice, Department of Biology, Khon Kaen University, Thailand (corresponding author to provide phone: + 66-43-342908; fax: +66-43-364169;
e-mail[1]: kkanla@kku.ac.th)
Tossapol Buaphan is with the Roi-Et Irrigation Project,Thailand
Duangsamorn Tulaphitak is with the Department of Plant Science and Agricultural Resources, Faculty of Agriculture, Khon Kaen University, Thailand
Naug Phuvongpha is with the Department of Chemistry, Khon Kaen University, Thailand
Sirirut Wongpakonkul is with the Associate Professor, Department of Statistics, Faculty of Science, Khon Kaen University, Thailand

II. Material And Methods

A. Plant materials

Rice cv. KDML 105 plants were grown by direct seeding in 22 rice growing fields in Tungkularonghai area in Roi-Et Province which covers 4 districts; Patumrut, Kaseatwisai, Ponsine and Suwannapum (Table 1) during April-October, 2007. Three replications per site were carried out.

B. Rice data (seeds, yield components and grain yield)

Rice data (seeds, yield components and yield) and soil samples were collected from 22 rice growing fields. The following yield components were determined: number of productive tillers per plant, number of panicle per m^2, panicle length, number of filled and unfilled spikelets per panicle, 100 grain weight, and straw yield per plant. Width, length and thickness of kernels were measured. Grain yield per plant was calculated as follows:

Grain yield = the number of filled spikelets per panicle x the number of panicles x weight per grain

C. Quantitative analysis of the volatile compounds (2-AP)

After one month of the harvest, the moisture content of rice grain samples was measured using oven drying at 60 °C for 3 days until the moisture content reached 14%, and then the rice grain samples were dehusked by hand to yield uncooked brown rice seeds before sending to Chemistry Lab, Chiang

Mai University, Thailand for determination of 2-AP contents by the method of [14]. In brief, the brown rice seeds were ground and then screened through a 35-mesh sieve where crude particles were filtered out. Five grams of the ground rice powder was weighed and the 2-AP was extracted from the brown rice. Then headspace gas lower temperature and gas chromatography (HS-GC) was employed for quantitative analysis of 2-AP in KDML 105 rice samples using 2, 4-dimethylpyrridine as internal standard.

D. Soil minerals quantitative analysis

During the rice sampling at harvest, the soils were randomly sampled at 3 positions and the electrical conductivity and pH value were measured. Quantitative analysis of eleven essential elements for plants [percentage of total nitrogen and content (ppm) of available phosphorus, potassium, sodium, calcium, magnesium, copper, ferrous, manganese, zinc and chloride], and organic matter (%) in the soil samples was performed in the soil samples according to the method of [15].

E. Statistical analysis

Both of Pearson's correlation coefficient and sequential path analysis were used to interpret information on the nature of interrelationships among yield, yield components, soil minerals and aroma of KDML 105 rice.

III. Results And Discussion

In order to identify the interrelationship among yield, yield components, soil minerals and aroma of KDML 105 rice, Pearson's correlation coefficient and sequential path analysis

From Figure 3, it was found that yield and yield components of KDML 105 rice in the 22 studied rice field varied widely as follows: number of productive tillers per plant (3.2-9.4), number of panicle per m^2 (60-150),panicle length (20-28 cm), the number of filled spikelets per panicle (47-148), 100 grain weight (2.3-2.7 g), straw yield per plant (2.6-12.8 g), and grain yield (227.78-801.09 kg./Rai; 1 Rai equal 1600 Km^2).

The average 2-AP contents in this study varied from 0-0.61 ppm as shown in Figure 4. These values appeared to be close to those previously reported such as 0.07 ppm [8], 0.34 ppm [16] and 0.3-0.6 ppm [13]. However, 2-AP content in this study appeared to be much lower than those reported by [14] who reported the 2-AP content of 1-5 ppm. The 2-AP contents in this study were determined by the same method used by [14]. The reason for the difference in contents of 2-AP could be due to the loss during the step of removing the husks to yield brown rice before sending for 2-AP analysis. Beside, in this year, rice plants experienced relatively low level of drought stress, because we observed that the rice fields still had high soil moisture at the harvesting stage which could result in the low level of observed 2-AP contents.

The 2-AP content at site nos. 1-3 at Patumrat District were higher than most sites at the other three districts. Rice field at site no. 2 had the highest grain yield as well as the highest 2-AP content in grains. The second highest 2-AP content was

were used to analyze rice (seeds, yield components and yield) and soil data collected from 22 rice growing fields in 4 districts of Roi-Et Province located in Tungkularonghai area. Map of locations of study sites as well as soil texture and soil quality map of Roi-Et province are shown in Figure 2. Mean values of grain yield and yield components of the 22 studied sites are shown in Figure 3 and 2-AP contents in rice grains in Figure 4. Figures 5 and 6 showed the data on soil analysis at the 22 rice fields at the time of grain harvest.

TABLE I
TWENTY-TWO RICE GROWING FIELDS IN EACH DISTRICT IN ROI-ET PROVINCE LOCATED IN TUNGKULARONGHAI, THAILAND

District	Paddy area (Rai)	Rice field number
Patumrut	193,350	1, 2, 3
Kaseatwisai	389,611	4, 5, 6, 7, 8, 9, 10
Suwannapum	390,084	11, 12, 13, 14, 15, 16, 17, 18
Ponsine	96,123	19, 20, 21, 22

Fig.1 A study sites in Roi-Et Province located in Tungkularonghai, Thailand

found in rice from site no. 3. It was noted that site no. 1, 2 and 3 had similar values of soil properties including pH value, conductivity-EC, organic matter and the content of potassium, sodium, calcium, magnesium, manganese, zinc and copper. However, sites no. 2 and 3 had higher content of nitrogen and chloride than site 1. The difference in soil properties between sites no. 2 and 3 compared with site no. 1 may contribute to the difference in 2-AP levels. However, this concept cannot be used to explain the differing of the 2-AP content in the other sites.

We also found that site no. 1 had the lowest yield whereas site no. 2 has the highest yield. It can be seen that soils at site no. 1 are clay soil with pH 5.27 and 0.54% organic matter. Whereas, site no. 2 has high sandy soil with pH 5.27 and 0.48% of organic matter. The large difference in 2-AP content between site no. 1 and site no. 2 could be due to the difference in soil texture. The sandy soil at site no. 2 has less water retention capacity and hence the plants there experienced more water stress than at site no. 1.

Based on a data of grain yield, yield components, soil minerals data and quality of kernel of KDML 105 rice, both Pearson's correlation coefficient and sequential path analysis were used to determine the interrelationship among these parameter. We found that the Pearson's correlation coefficient displayed that the number of panicles was the only factor that showed highly significant positive correlations (0.790**) with grain yield. This may indicate that increasing the number of panicles would likely be an effective target for improvement of grain yield.

Interrelationships among twenty-four yield-related characters on grain yield for direct-seeded rice cultural systems using path-coefficient analysis that describes a priori order factors which had positive or negative effects on grain yield are presented in Figure 7. The sequential path analysis revealed that the first-order factors which had positive direct effects on grain yield were the number of panicles followed by the number of fertile spikelets and 100-grain weight ($p = 0.938$, $p = 0.554$ and $p = 0.209$, respectively). Although, the first-order, hundred grain weights had low direct effects on grain yield. Whereas, other factors analyzed such as the number of productive tillers per m^2, straw yield per plant (g), and % organic matter acted as the second-order factors which had positive indirect effects influencing grain yield and the number of unfilled spikelets per panicle and the content (ppm) of soil manganese acted as the second-order factors exhibiting negative correlation with grain yield. The positive direct effects of these characters observed in the present study are in accordance with the findings of other researchers [17], [18]. Interestingly, both Pearson's correlation coefficient and sequential path analysis also indicated that there are no significant relationship was found between the aroma level and any of the factors analyzed. This finding indicates that the grain yield could be increased by increasing the yield components which had the direct effect on yield such as the number of panicles followed by number of fertile spikelets and hundred grain weights. The yield components which had indirect effects such as number of productive tillers per m^2, straw yield per plant (g), and % organic matter acted as factors to promote the direct effects.

IV. Conclusion

This study revealed that Pearson's correlation coefficient and sequential path analysis can only indicate the interrelationship between yield and the factors analyzed, but can not indicate the interrelationship between aroma and any of the factors analyzed in KDML 105. There is a true relationship with grain yield and the number of panicles, the first-order and the only significant factor affected the increase in grain yield. However, there is a lack of correlation between the factors analyzed and aroma. It is possible that there may be other factors such as local conditions, cultivation methods and water deficit which could play important roles in determining the aroma content in KDML 105.

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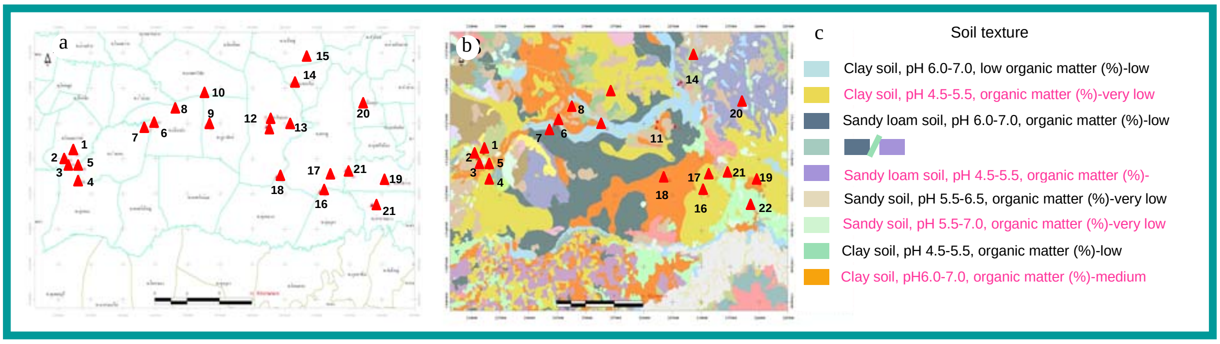
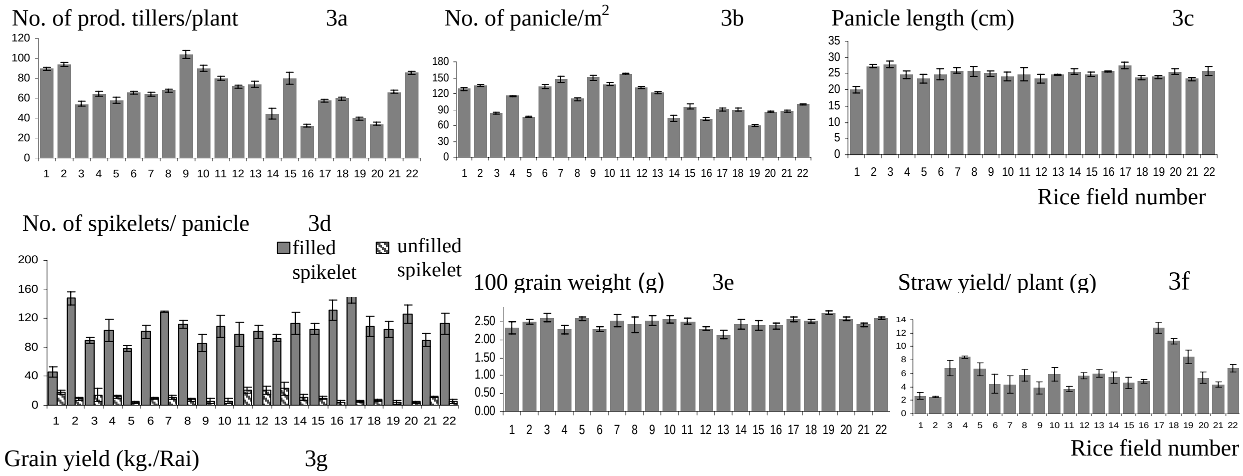


Fig. 2 Map showing the location of 22 study sites in 4 districts of Roi-Et province (a), soil quality map of Roi-Et province (b) and detail of soil texture on soil quality map (c)
Source: Regional Center for Geo-informatic and Space Technology, Northeastern of Thailand (1:50,000)



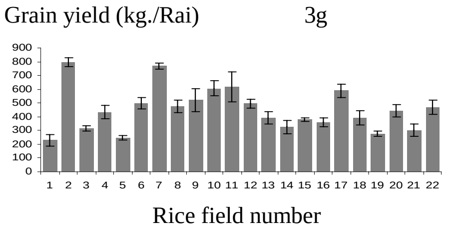


Fig. 3 Yield components (a-f) and grain yield (kg./Rai) (g) of KDML 105 rice grown in Tungkularonghai area in 22 rice field study sites in 4 Districts of Roi-Et Province; Patumrut (rice field no. 1-3), Kaseatwisai (rice field no. 4-10), Ponsine (rice field no. 11-18) and Suwannapum (rice field no. 19-22) during April-October, 2007.

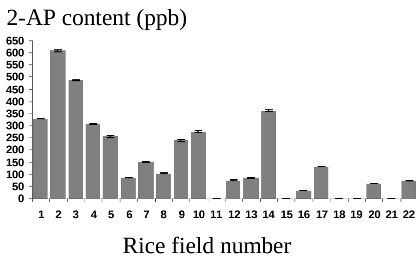


Fig. 4 2-AP contents were identified by SPME-GC technique in brown rice samples of KDML 105 collected from the 22 rice growing sites in Tungkularonghai area in Roi-Et Province covering 4 districts; Patumrut (rice field no. 1-3), Kaseatwisai (rice field no. 4-10), Ponsine (rice field no. 11-18) and Suwannapum (rice field no. 19-22) during April-October 2007. (ppb = parts per billion; 10^{-9}).

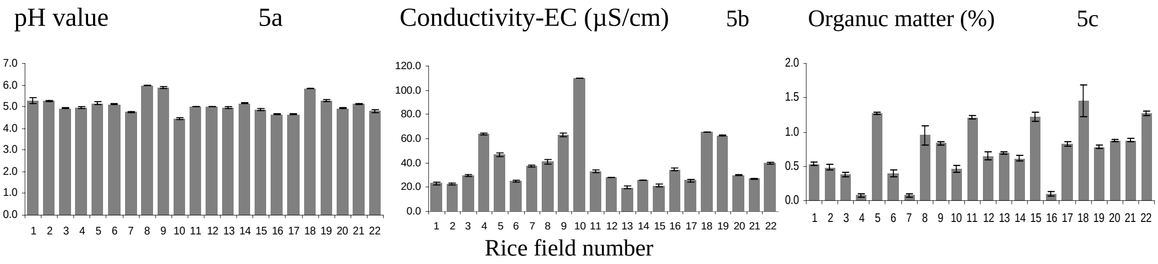


Fig. 5 pH value (a), conductivity-EC (µS/cm) (b) and organic matter (%) (c) in soil collected from 22 rice growing fields in Tungkularonghai area in Roi-Et Province covering 4 districts; Patumrut (rice field no. 1-3), Kaseatwisai (rice field no. 4-10), Ponsine (rice field no. 11-18) and Suwannapum (rice field no. 19-22)

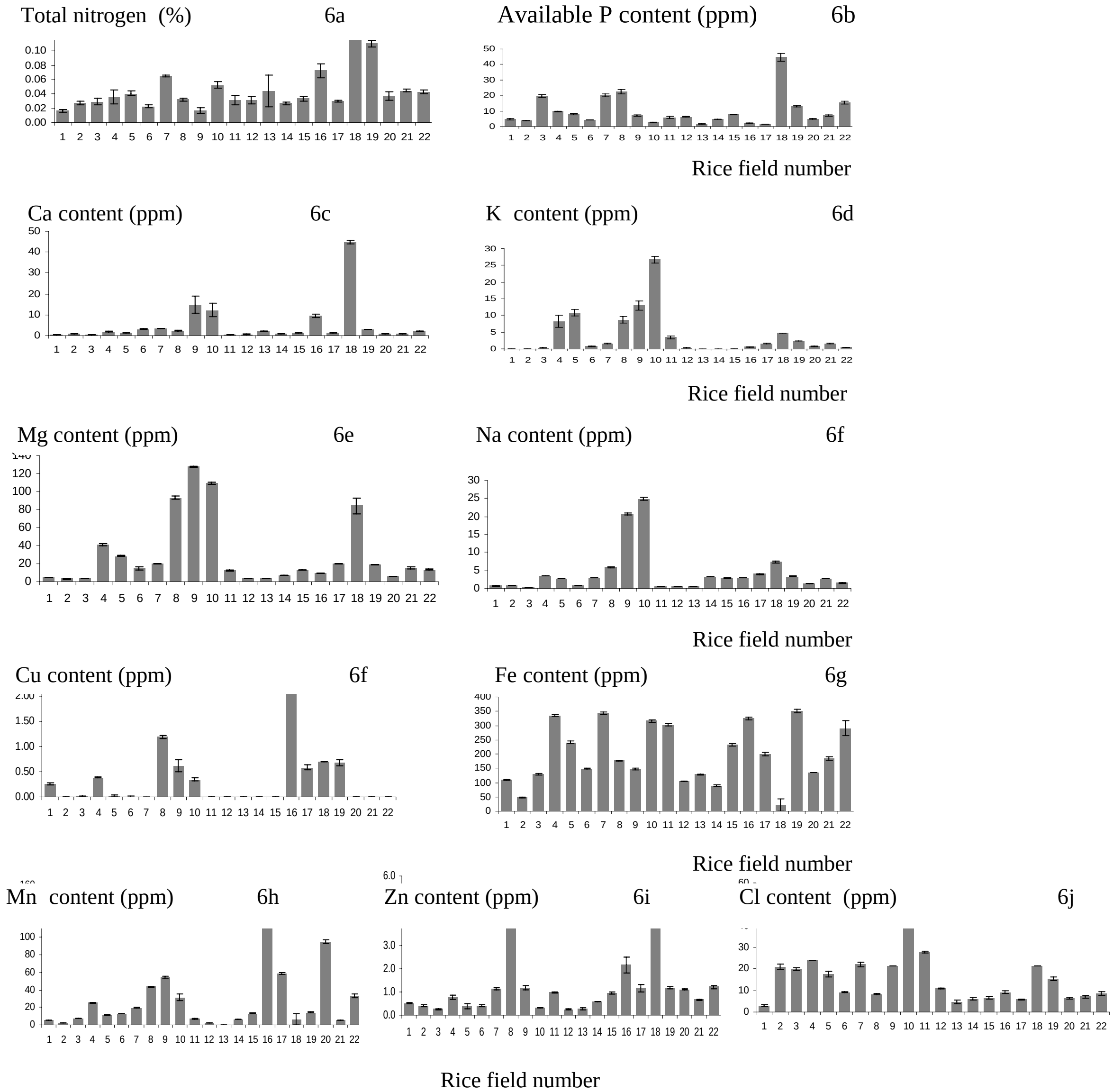


Fig. 6 The content of eleven soil minerals (a-k) in soils collected from 22 rice growing fields in Tungkularonghai area in Roi-Et Province covering 4 districts; Patumrut (rice field no. 1-3), Kaseatwisai (rice field no. 4-10), Ponsine (rice field no. 11-18) and Suwannapum (rice field no. 19-22).

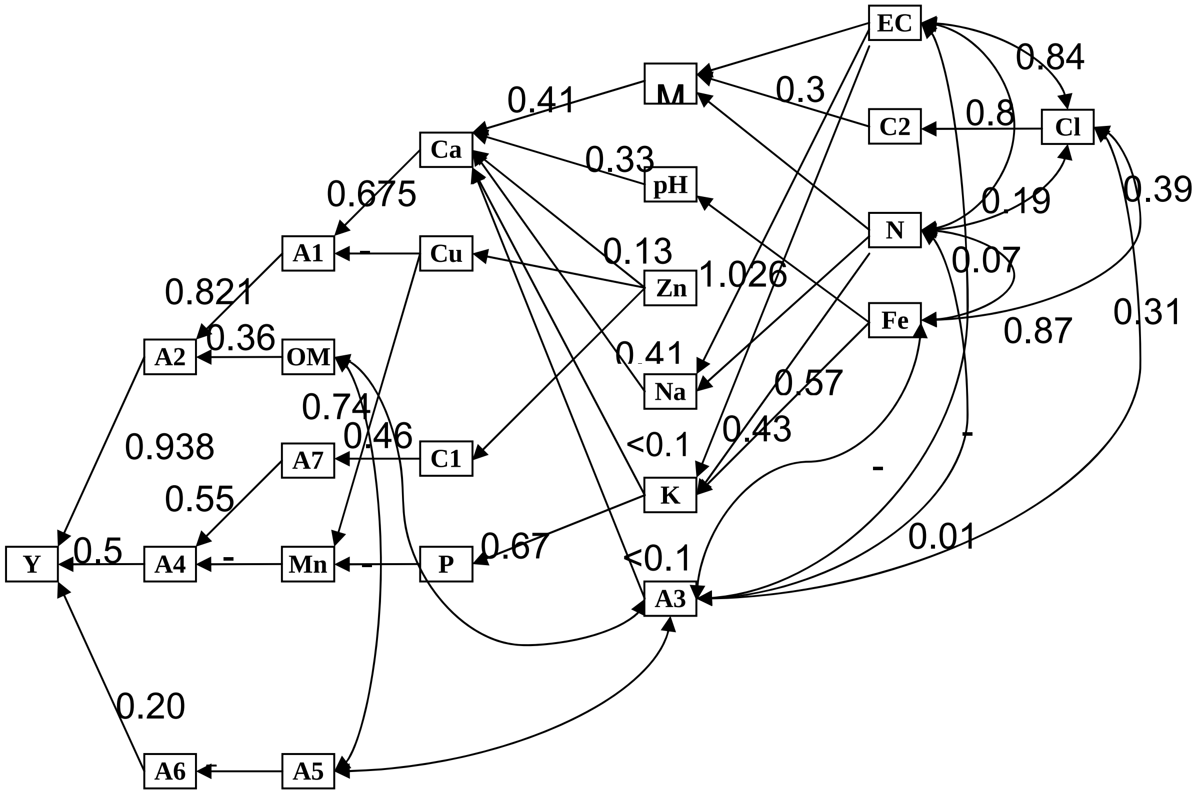


Fig. 7 Sequential path model indicating interrelationship among yield (Y), yield components and soil minerals of KDML 105 grown in Tungkularonghai in Roi-Et province. [A1 = number of productive tillers per m^2, A2 = number of panicles per plant, A3 = panicle length, A4 = number of filled spikelets per panicle, A5 = number of unfilled spikelets per panicle, A6 = 100-grain weight (g), A7 = straw yield per plant (g), OM= % organic matter]