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LEAF AGE INDEX : A PARAMETER FOR THE STAGE OF DEVELOPMENT. A BASIS FOR THE QUANTITATIVE MODELS FOR THE EVALUATION AND CONTROL OF NUTRITIONAL STATUS OF RICE

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Summary

This paper presents an attempt to transfer a new fertilization system developed in Denmark to rice crop in Thailand. Fertilizer experiment with varying amounts of N, P, K and N topdressing was conducted in a growth chamber by simulating the climatic conditions prevailing in Central Plain of Thailand. Rice variety RD-1 was used for the study. The concentrations of N, P, K, Ca, Mg and Na were determined in the aboveground portion of the plants at different intervals during the growing period and at maturity.

The concept of Leaf Age Index (LAgI) was introduced to examine the possibilities of using this parameter for defining the stage of development. It was found that although LAgI is supposed to represent a uniform stage of inner development and it is rather clear to identify, its application as an expression of the stage of development was unsuitable, primarily due to ambiguous and nonreproducible relationships between grain yield and concentration of a nutrient at different LAgI and also due to difficulties in identifying a stage of development (in terms of LAgI) corresponding to which the interaction between various nutrients is minimum.

Introduction

The estimation of the requirements of a given soil for specific manures and the study of behaviour of soil towards manuring have been the main problems confronting agricultural scientists. Special consideration used to be directed to the interpretation of results of soil analysis obtained from the laboratory to the field condition. However, it is difficult to obtain definite and clear relations between the availability of a nutrient in the soil and intake of that nutrient by the plants. Even the more modern methods for the determination of available nutrients failed to give

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the required information. Hence, from time to time attempts have been made to attack the problem from another side and to use living plant as an analytical agent. During the last few decades, a great deal of work has been directed exclusively towards the application of plant analysis as a means of diagnosing the nutrients requirements of plants and soils.

Several investigations[1-4] have duly emphasised the importance of stage of crop, if the plant composition is to be used as a criterion for the diagnosis of soil conditions. During the course of progress in this branch of science, various approaches were developed, without giving due emphasis on selection of a suitable parameter for the stage of development. This limitation however, severely curtailed the success of many of the approaches.

A new hope was thus brought into light by the remarkable success of methods developed by Nielsen[5] in applying plant analysis for the diagnostic purposes. His emphatic findings, of using a fixed dry matter weight level (DMw-level) as a parameter for stage of development and selection of reference values of nutritional status of plants based on highest obtainable final yields and corresponding chemical compositions of the plants at fixed DMw-level, have been the bases for developing quantitative methods for the evaluation and control of grain yield of cereals[6-8]. Based on the above principles a new fertilization system was developed in Denmark and later on transferred and applied to few more crops in other countries in Europe[9]. Various attempts are also in progress in transferring these methods to different crops in Southeast Asia particularly Thailand[10]. The main emphasis is however on developing a new fertilization system for rice, since rice is the important food crop in Southeast Asia. A parallel investigation was carried out to explore the possibilities of developing the quantitative methods based on a growth chamber experiment by simulating the climatic conditions prevailing in Central Plain of Thailand, which accounts for 80 percent of rice growing area in the country. The paper presents various techniques in developing the quantitative models for the evaluation and control of rice yield based on the results of climate chamber experiments. A new parameter for the stage of development, namely Leaf Age Index (LAgI) was introduced, with the idea of simplifying and choosing a parameter morphologically easier to identify, unlike fixed DMw-level. The evaluation of suitability of this parameter for the stage of development as a basis for developing the quantitative models for the evaluation and control of nutritional status of rice plants is presented in this paper. A report on detailed approach on developing diagnosis, yield prognosis and therapy models is under preparation.

Materials and Methods

The experiment was conducted in a growth chamber at The Royal Veterinary and Agricultural University (RVAU), Copenhagen, Denmark, with two soils representing a brackish water alluvial soil (Rice Experiment Station, Klong Luang, Thailand) and a sandy loam soil (Experiment Station of RVAU, Taastrup, Denmark). Some physico-chemical properties of the soils are shown in Table I.

TABLE I: SOME PROPERTIES OF THE SOILS IN THIS WORK

Locations	Classification	Texture analysis (per cent)				Per cent humus	pH (1:2.5 soil : water suspension)	Resin extractable phosphate mg P/100 g soil
		Coarse sand	Fine sand	Silt	Clay			
Klong Luang Thailand (S_1)[a]	Brackish water alluvial soil	1.3	3.2	43.7	51.8	2.6	4.2	0.198
Taastrup Denmark(S_2)[b]	Sandy loam soil	24.2	39.4	16.9	17.9	1.9	7.3	2.031

Sources: [a] Ref. 11.
[b] Landbohojskole, Karforsogsstationen, Taastrup, Denmark.

Pot experiment

Soil was air dried, ground and weighed into portions of 8 kg each and transferred to plastic pots of 30 cm diameter and 30 cm height. Varying levels of N, P and K were applied. The amounts and sources of N, P and K nutrients are shown in Table II. Fertilizers were applied in solution form and soil was puddled in the

TABLE II: TREATMENT DETAILS: GRAM PER POT N, P AND K IN THE FORM OF UREA (45% N), SUPER PHOSPHATE (8% P) AND MURIATE OF POTASH (50% K) APPLIED TO TWO SOILS

Sandy loam soil			
Increasing N g N P K/pot	Increasing P g N P K/pot	Increasing K g N P K/pot	N Top dressing[a] g N P K/pot
0.00 : 0.56 : 1.04	1.25 : 0.00 : 1.04	1.25 : 0.56 : 0.00	1.25 : 0.56 : 1.04 + 0.31 N
0.31 – –	– 0.14 –	– – 0.26	– – – + 0.62 N
0.62 – –	– 0.28 –	– – 0.52	1.25 : 0.28 : 1.04 + 0.31 N
0.94 – –	– 0.42 –	– – 0.78	– – – + 0.62 N
1.25 – –	– 0.56 –	– – 1.04	1.25 : 0.56 : 0.52 + 0.31 N
1.57 – –	– 0.70 –	– – 1.30	– – – + 0.62 N
1.88 – –			1.25 : 0.28 : 0.52 + 0.31 N
			+ 0.62 N

Brackish water alluvial soil[b]		
Increasing N g N P K/pot	Increasing P g N P K/pot	Increasing K g N p K/pot
0.00 : 0.56 : 1.04	1.25 : 0.00 : 1.04	1.25 : 0.56 : 0.00
0.62 – –	– 0.28 –	– – 0.52
1.25 – –	– 0.56 –	– – 1.04
1.88 – –		

[a] Top dressing was done 60 days after transplanting.
[b] $CaCO_3$ was applied at rhe rate of 3.0 g per kg soil.

TABLE III: CLIMATIC FACTORS IN GROWTH CHAMBER DURING DIFFERENT GROWTH STAGES

Climatic factors	Basic vegetative phase	Photoperiod sensitive phase to penicle emergence	Penicle emergence to maturity
Temperature (°C day/night)	28/22	32/26	28/22
Photoperiod (hours day/night)	12/12	10/14	12/12
Light intensity	14	19	17
Dew point temp. (°C)	20	20	20

pots. Rice seedlings of variety RD-1 (25 days after emergence) were transplanted into the pots. Six hills were planted per pot with two seedlings per hill. Soon after the seedling establishment, standing water 5 cm deep was maintained throughout the growing period. The experiment was conducted in a growth chamber and the climatic conditions were regulated at different stages of growing period as shown in Table III. The positions of pots were changed at a regular interval in order to eliminate the differences in light intensity.

Plant sampling and analytical methods

Plant samplings were done at LAgI 58, 69, 76 and 100 and also at maturity. LAgI was calculated based on the relationship,

$$\text{LAgI} = \frac{\text{Plant age by leaves at a particular time}}{\text{Total number of leaves on the main culm}} \times 100$$

In all the samplings only the aboveground portion of the plants were harvested. Samples were then cleaned with deionised water, dried at 80°C for 48 hours, and ground for analyses. The concentrations of N, P, K, Ca, Mg and Na in the samples were determined. At maturity the straw and grain were analysed seperately. The concentration of N was determined by micro-Kjeldahl method according to Black[12]. The plant material was dry-ashed and dissolved in 0.2 N HNO_3 for the analysis of the rest of the nutrients. Concentration of P was determined by using Technicon Auto-Analyser. Na and K was determined by using a flame photometer, while an atomic absorption spectrophotometer was used for determining concentrations of Ca and Mg.

Results and Discussion

A proper understanding of the relationships between supply of nutrients, chemical composition of plants and the final yield, and the factors seriously influencing such relationships are of utmost importance in developing useful methods for the evaluation and control of nutritional status of plant species. According to Smith[2], next to the supply of element, the physiological age of tissue is the most important factor affecting the chemical composition of plants.

Fig. 1. The area of relationships showing grain yield as a function of concentrations of N, P and K at different Leaf Age Indices (LAgI). The grain yield was plotted against the concentrations at each LAgI and enclosed to represent the area of relationships. Note that only the point corresponding the maximum grain yield is shown, with different notations to demarkate these areas according to LAgI. The area of relationships at LAgI 58, 69, 76, 100 and at maturity (LAgI = 100) are marked by the notations ○, X, ▲, ● and △ respectively.

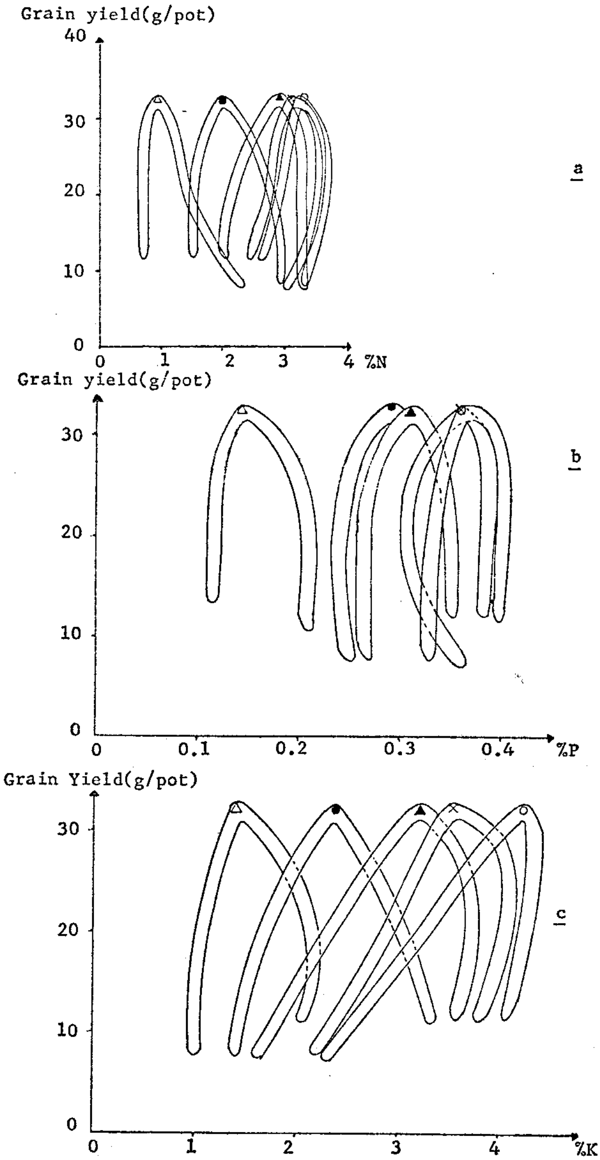
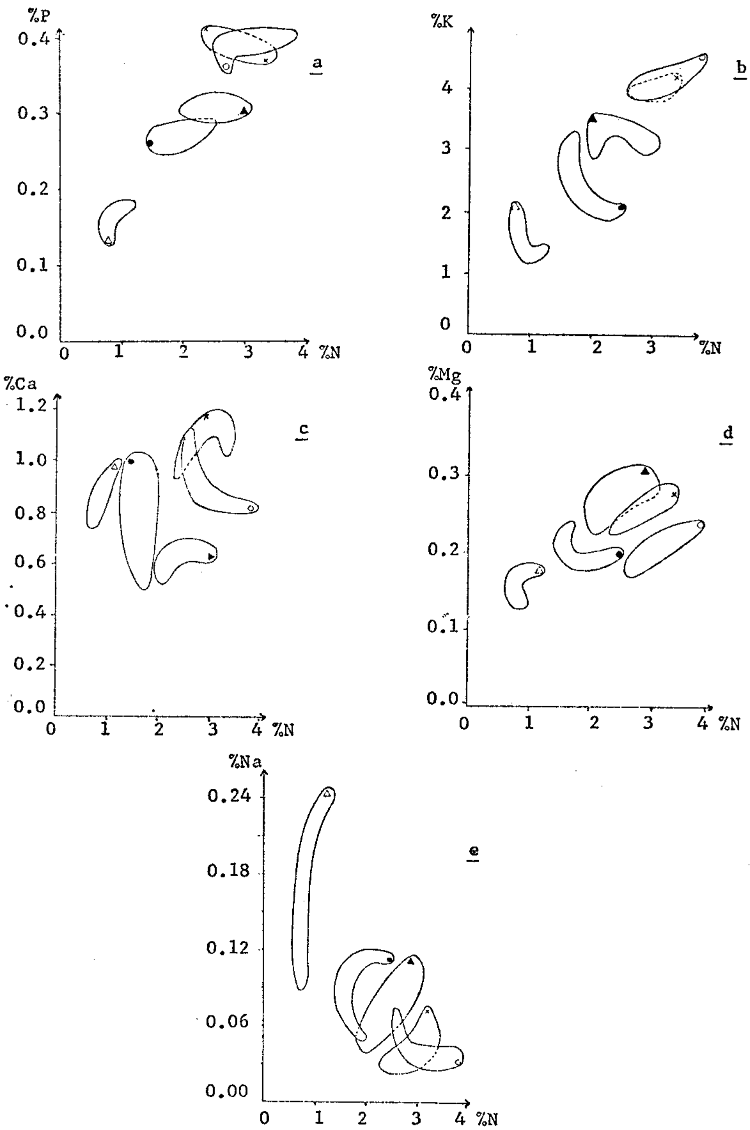
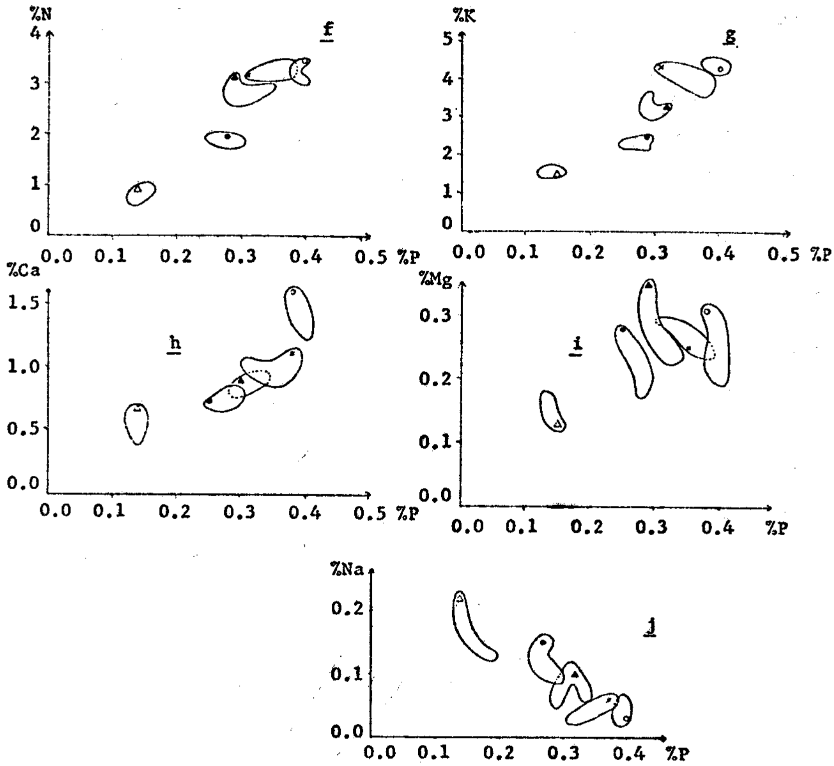


Fig. 2. The area of relationships showing the concentrations of other nutrients as a function of concentrations of N(2a–2e), P(2f–2j) and K(2k–2o) with the increasing applications of N, P and K raspectively. These areas in each system of coordinates are demarkated by the notations O, X, ▲, ● and △ corresponding to LAgI 58, 69, 76, 100 and at maturity (LAgI = 100). The point shown in each area of relationship represent the point corresponding to maximum grain yield, while the remaining points are not shown.

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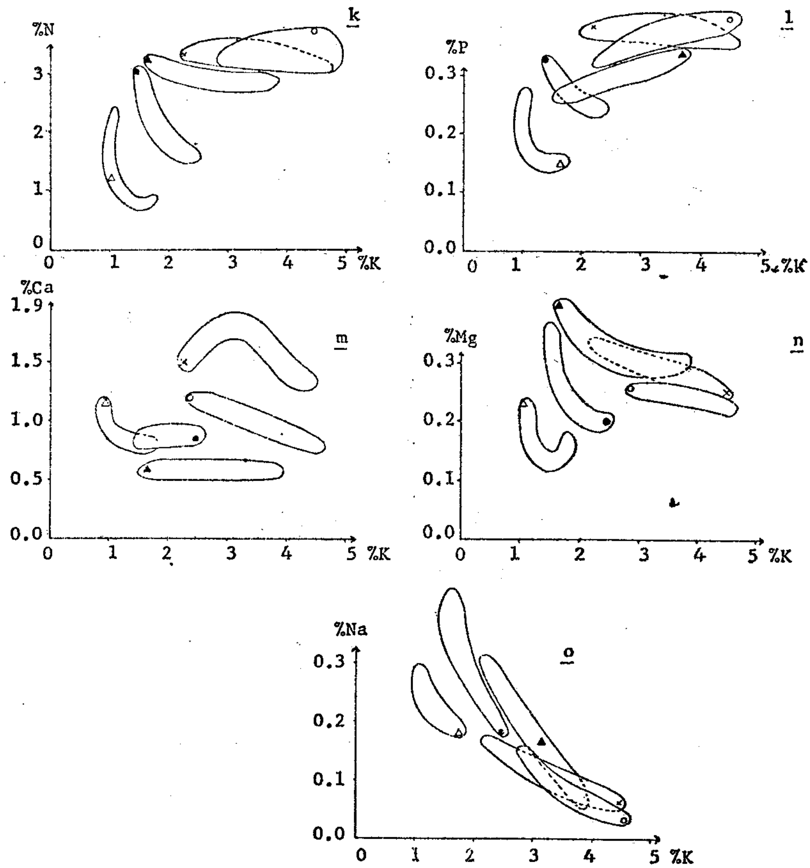
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Since the supply of nutrient is a factor properly accounted for, a greater emphasis need to be given to age of the tissue or physiological stage of plant growth. The pattern of nutrient content in the tissue varies with species, nutrient status of the soil and the age of plant. Therefore, it is imperative that due consideration need to be given to changes in the nutrient content with age. It is highly necessary that the physiological age of plants to be uniform, if the nutrient concentrations have to be compared between a deficient and non-deficient growing conditions. The low rate of uptake of a nutrient in deficient condition is compensated by relatively longer time required to attain the particular stage of growth as compared to the plant in non-deficient condition. Therefore, any interpretation of results of plant analysis would be ambiguous and non-reproducible unless the growth stage at sampling is well defined. Regardless of crop species or growing conditions, the basic requirement for the successful practical application of the methods for the evaluation and control of nutritional status of plants, the development of such methods should necessarily be based on the chemical composition of plants during the early growing period. Normally, nutrient interactions are more pronounced towards later growing period as compared to the early period. This makes the interpretation of the results difficult if it should be based on plant analysis at later growing period. Besides, the methods developed for the evaluation and control of nutritional status of plants would find increased applicability if the diagnosis and yield prognosis could be possible at a early stage of the crop, so that the required nutrient supplement could be done for the same crop.

In accordance with the above requirements, Nielsen[5] introduced a fixed Dry Matter weight level (DMw-level) as a well defined expression of the stage of development. The DMw-level was selected as early as possible during the growing period, corresponding to which the response to nutrient is clear and direct to the relevant nutrient, with minimum interactions. Thus, the selected parameter formed a well defined basis for the further interpretation of results of plant analysis for diagnostic purposes[6]. Eventhough fixed DMw-level as a parameter for the stage of development is well defined and suitable basis for developing quantitative methods for the diagnosis and yield prognosis, it is our intention to study if this could be substituted by a parameter which is morphologically clear and easily identifiable. Thus, the concept of Leaf Age Index (LAgI) was introduced to define the stage of development and its applicability was tested.

While selecting a parameter for the stage of development, the main emphasis is on the inner development. So, a morphologically identifiable parameter should in turn represent a uniform inner development. According to Matsubayashi[13], for rice varieties bearing same total number of leaves on the main culm, irrespective of growing conditions, the inner development will be the same at a particular leaf age. Since the total number of leaves on the main culm is a variable characteristics, LAgI as an expression of the stage of development represents a uniform inner development in different varieties.

The dry matter weight and concentrations of N, P, K, Ca, Mg and Na in the aboveground portion the plants at different samplings (corresponding to respective Leaf Age Indices) are presented elsewhere[10]. The relationships between grain yield and concentrations of N, P and K in plant tissue are shown in Figs. la, 1b and 1c respectively. The relationships are shown seperately for different samplings at LAgI 58, 69, 76 and 100 during vegetative growth period and also at maturity (LAgI = 100. At each LAgI the points corresponding to grain yield vs concentration of a nutrient (N, P or K as the case may be) are enclosed to show the area of relationship. However, for the clarity of presentation only the points corresponding to highest grain yield are marked in the respective area of relationships.

The area of relationships for the nutrient interactions between N, P, K, Ca, Mg and Na at different LAgI are shown with increasing N (Figs. 2a-2e), P (Figs. 2f-2j) and K (Figs. 2k-2o) applications.

The evaluation bases for judging the suitability of any parameter for the expression of stage of development are,

1. The stage of development should be the earliest possible during the growing period.
2. The area of relationships between grain yield and concentrations of major nutrients should be clear, reproducible and follow a definite pattern.
3. The interactions between various nutrients should be minimised to the extent possible.

Fig. 1 shows that the nutrient response curves (area of relationships) follow the same trend for all nutrients. With increasing LAgI these curves are shufted towards Y-axis, thus indicating the dilution of nutrients. During the early growing period these curves are closer and overlaping in some instances. This could be partly due to shorter sampling intervals for the 3 samplings at LAgI, 58, 69 and 76 respectively and partly due to mechanism of nutrients uptake. Generally lowland rice continues to absorb nutrients at a faster rate until penicle initiation stage (roughly corresponding to the stage, LAgI = 76). As a result the dilution is kept minimum during the early period.

The greater overlapping of the curves during the early period makes it difficult to select a LAgI as a well defined expression of the stage of development. Besides, the nutrient responses at different LAgI are ambiguous. In all the cases the grain yield increases with increasing concentration of relevant nutrient, attains maximum, but there is also a proportionate decrease in grain yield with further increase in concentration. Nutrient response of this nature makes the interpretation difficult and ambiguous.

The area of relationships representing the nutrients interactions are shown in Fig. 2. We do not intend to discuss the pattern of nutrients interactions with the increasing levels of nutrients application nor with increasing LAgI. The emphasis here is on the extent of interactions between the various nutrients in order to identify a particular LAgI corresponding to which the interaction is minimum. However, the results in Fig. 2 show that the area of relationships for the nutrients interactions are widely distributed, and are not clearly reproducible. That is to say that the physiological stage expressed as LAgI suffers from the limitation that it is difficult to identify a LAgI at which the interaction between the nutrients is minimum. This is a serious limitation for using the plant analysis for diagnostic purposes.

In conclusion it appears that, eventhough LAgI as a parameter for the stage of development, which can represent a uniform stage of inner development, has its advantage of being morphologically clear to identify, there are serious limitations for the use of this parameter as a basis for developing quantitative methods for the evaluation and control of nutritional status of plants. The main limitations are,

1. The area of relationships between grain yield and concentrations of nutrients are ambiguous and not reproducible.

2. A clear relationship between grain yield and concentrations of nutrients is difficult to identify in the early stage of growth, a stage which calls for special emphasis for the interpretation of chemical composition of plants for diagnostic purposes.

3. It is difficult to identify a stage corresponding to which the nutrients interactions are minimum.

Attempts are in progress for selecting alternative parameter for the stage of development and to develop reliable and reproducible methods for the evaluation and control of nutritional status of rice plants[10].

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บทคัดย่อ

บทความนี้รายงานความพยายามที่จะนำระบบปุ๋ยแบบใหม่ที่ได้พัฒนาขึ้นในเดนมาร์กมาใช้ในประเทศไทย ในการทดลองได้ให้ปุ๋ย N,P,K และ N topdressing กับข้าวชนิด RD-1 ซึ่งปลูกในห้องที่จัดสภาพให้คล้ายสภาพในที่ราบของภาคกลาง ได้หาความเข้มข้นของ N,P,K, Ca, Mg และ Na ในส่วนของพืชที่อยู่เหนือดิน ตามระยะเวลาต่าง ๆ จนกระทั่งเติบโตเต็มที่

ได้ทดลองเสนอการใช้ดัชนีอายุของใบ (LAgI) เป็นตัววัดระยะของการเติบโต พบว่า ถึงแม้ดัชนีนี้คงจะบ่งถึงระยะของการเติบโตภายในพืช และวัดได้ง่ายก็ตาม แต่ไม่เหมาะสมที่จะใช้ในที่นี้ เนื่องจากมีความกำกวมและไม่แน่นอนในความสัมพันธ์ระหว่างผลผลิตเป็นเมล็ดข้าว และความเข้มข้นของโภชนะ ที่ค่า LAgI ต่าง ๆ และเนื่องจากมีความยากลำบากในการหาค่าของ LAgI ที่โภชนะต่าง ๆ มีกริยาระหว่างกันน้อยที่สุดด้วย