nique Text Book

RICE CULTIVATION TECHNIQUES IN INDONESIA

ICULTURAL DEVELOPMENT COOPERATION DEPARTMENT
PAN INTERNATIONAL COOPERATION AGENCY

FOREWORD

Japan's technical cooperation in West Java Food Production Increase Project, extended in two stages each lasting three years from May 1968 and May 1971 under an agreement between the Government of Japan and Indonesia with the view to assisting the Indonesian Government in promoting its accelerated food production programme was completed in May 1974, and it is at present in the stage of follow-up cooperation under the Colombo Plan.

The ultimate objective of overseas technical cooperation in any industrial field including agriculture consists in the widespread extension and practical application of advanced techniques and know-how which the experts introduce into the recipient country.

From this viewpoint, a series of textbooks were complied in Japanese, English and Indonesian upon completion of the said project on the strength of the experience, and surveys which were gained or conducted by Japanese experts for improvement of rice cultivation techniques in Indonesia.

It is earnestly hoped that this booklet, which is one of the said series of textbooks, will prove instrumental in providing the guiding principle to the experts, members of survey teams and other individuals who will be dispatched to Indonesia, the country which is sure to carry greater weight in Japan's future overseas technical cooperation activities.

Progress of technology is unlimited and socio-economic condition is changing from day to day. In order for this textbook to be compatible with such progress and changes, it is planned that revisions will be made from time to time with the assistance of agricultural experts who will be sent to Indonesia in the coming years.

Thanks are due to Mr. Kazuma Sugo who not only devoted himself to the promotion of the project over the last six years but also gave an enormous impetus to the compilation of this textbook.

The active endeavours made by the many other experts in their respective specialized fields are also gratefully acknowledged.

June, 1974

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INTRODUCTION

It has been known for years that the yield (ton/ha) of paddy grown in Indonesia, particularly that of the recommended short-culmed varieties, is quite poor relative to their active prophase (incipient to intermediate) growth. On my arrival in Indonesia, the author suspected by intuition that this might perhaps be assignable to depression in later growth stage (ie: AKIOCHI) in the broad sense of the term.

In the 1971–1972 wet season, therefore, I carried out a basic experiment on the recommended short culmed varieties in order to check my intuitive perception from their growth and morphological features.

The results was exactly what the author expected. To be more precise, the experiments disclosed that these recommended varieties have minus factors in respect of growth and morphology despite of their high profuse tillering and high lodging resistance, and that the technical defect in the conventional cultural practice gives rise to unfavourable plant type and consequently to poorer yield.

On the strength of these findings, a series of tests were conducted through four seasons, i.e., 1972 dry season to 1973–1974 wet season, chiefly in an attempt to improve the plant type of the recommended short-culmed varieties to increase their yield and also to introduce advanced cultural method in Indonesia. These tests produced the results which nearly met the author's expectation.

This textbook contains the data of experimental cultivation carried out in Cihea (Cianjur), Muara (Bogor) and a number of Kabupatens in West Java, clarifies defects involved in the traditional cultural practices, and suggests the course of future technical improvements in paddy cultivation. Needless to say, however, there still remain many problems which await closer technical study in future.

It will give the author great pleasure if this textbook is used at colleges and by senior agricultural engineers and specialists in Indonesia as well as by the technicians engaged in field activities in Propinsis and Kabupatens.

Thanks are due to Mr. Sugo, Leader of the Japanese Expert Team for West Java Food Production Increase Project, for the valuable assistance and advice rendered in compiling this textbook.

The kind arrangements made by Mr. Dedi, Kepara, Tani Makmur Cihea, for various tests and experiments are also gratefully acknowledged.

January, 1974

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CONTENTS

I. Theory and Practice of Paddy Cultivation

1. Fundamental Approach to Paddy Cultivation

In the past years, success of paddy cultivation tended to be judged directly by the yield, and yet it often occurred that the yield failed to reach the anticipated yield level.

It is known that even the experienced farmers suffered an unexpected yield drop in many cases when their attention was directed too much to yield increase only.

Except when the occurrence of disease or insect pest damage is apparent, yield drop assignable to the above cause tends to be attributed to the small number of panicles or tillers.

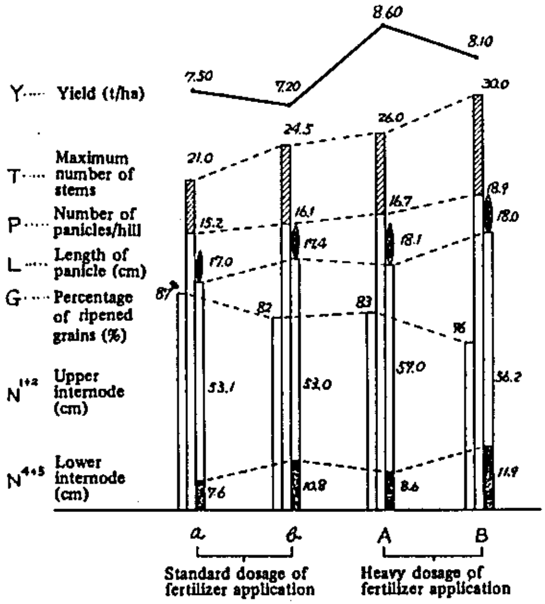


Fig. 0 Relationship between Yield and Number of Panicles per Hill (Short-culmed Variety)

Greater number of tillers or panicles does not always promise yield increase. Yield increase cannot naturally be expected if panicles are too small in number. However, if the number of tillers is too large, growth is stimulated to excess, and the percentage of ripened grains is dimished, so that yield increase cannot be hoped for.

Anyone who keeps on nursing the mistaken notion that yield depends on the numbers of tillers and panicles can neither enjoy stabilized increase of yield nor introduce improved cultivation method, although he may be favoured with a good crop once in a while.

Theoretically, fulfillment of the following two requirements should promise steady increase of yield regardless of place and season.

Growing good panicles (qualitative requirement) in the largest possible number of panicle per unit area (quantitative requirement). This means that the conventional cultivation method which attaches importance only to the quantitative requirement (i.e., number of tillers) should give place to the new method in which qualitative requirement (i.e., growing good panicles) is given priority. Future improvement in paddy cultivation must be based on this fundamental attitude.

However, there are two serious technical obstacles attending the attempt to fill the above two requirements.

Obstacle 1: Good panicles must satisfy all the following three conditions.

a) Number of grains per panicle is large;

b) Percentage of ripened grains is high;

and c) Weight of 1,000 hulled grains is heavy.

Conditions b) and c) are complementary to each other. But condition a) is generally considered to be inconsistent with conditions b) and c), and if so, producing good panicles which fill all the three conflicting conditions becomes a matter of impossibility.

Obstacle 2: Granting that the presence of good panicles fully or nearly satisfying the above conditions can be theoretically accepted, nothing definite is yet known as to what plant type of paddy can produce such good panicles. In other words, opinions are divided on the question of "high yielding plant type".

In addition, experimental cultivation is conducted only for the evaluation of the yield and hardly any analysis is made on the plant type which is responsible for the yield. As regards "high yielding plant type", in particular, things are still in the state of "groping in the dark".

Photo 1—Growth of Seedlings (30 days and 20 days)

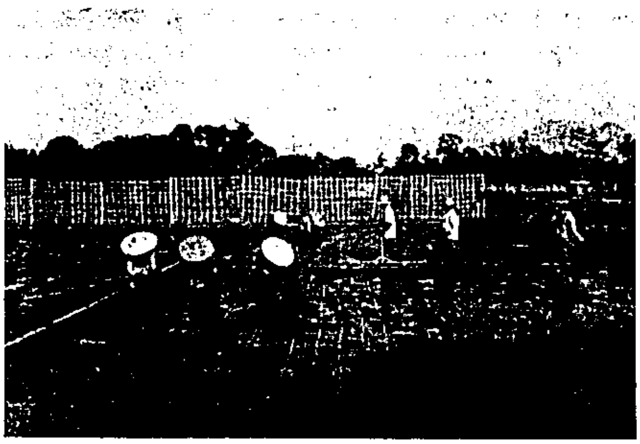


Photo 2–Transplanting (Stepping forward planting with markers)

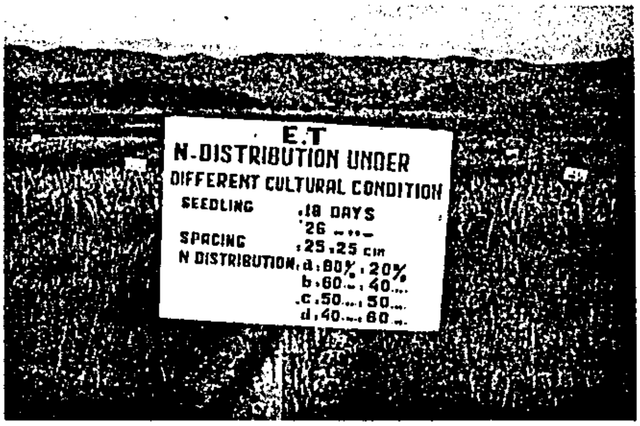


Photo 3–Growth Condition of Experimental Field (N–distribution test)

Photo 4 – Quasi-ideal type of paddy (Yield of fresh grains – 10.3 t/ha)

2. "High Yielding Paddy" and "Poor Yielding Paddy"

It has been said since old that a master hand in paddy cultivation can tell the yield and quality simply by touching the rice stubble immediately before reaping or the rice bundles immediately after reaping.

If comparison is made between paddies grown in bumper season and lean season or between paddies grown in two adjoining fields which registered different yields in the same season, one would note by careful observation of their terrestrial parts that their stems and leaves show a wide divergence of growth condition with the corresponding difference in the yield. This would make it possible for anyone to imagine that there is some close relationship between the plant type (i.e., growth condition) and the yield. Therefore, if some simple and scientific method is devised to express the relationship between the plant type and the yield without resorting to the tactual sensation, it would certainly prove very expedient.

The proverb "A sound mind in a sound body" applies to the apparent fact that good panciles (a sound mind) can be formed only on the paddy of good shape (a sound body).

Needless to say, "paddy of good shape" indicates the paddy which has the "plant type promising high production efficiency" or the "plant type with a trait conductive to high production efficiency". In rice cultivation, constant effort should be exercised to find out the paddy of such type. Let us assume a paddy type which exhibits the highest production efficiency and call it the "ideal type". It is the intrinsic and ideal type of paddy that should be sought at all cost.

Actually, however, all paddies (even if of the same variety), currently grown present a great diversity of random shape which will be referred to as the "phenomenal type" in the following pages. Most of such paddies present the types which are considerably distorted when compared to the "ideal or intrinsic type". The greater the distortion, the poorer the yield. Conversely, the smaller the distortion, the higher the yield.

It follows, therefore, that the attempt at yield increase is to be made by resorting to every possible means to the "phenomenal type" to "ideal or quasi-ideal type". In other words, improvement of rice culture hinges on the successful improvement of the plant type of paddy.

"Improvement of rice culture" has often been confused with "improvement of rice cultivation techniques". Improvement of such individual techniques as applied to the rearing of healthy seedlings, fertilizer application or planting system are the means but not the purpose of "rice culture improvement". Application of a new and highly excellent technique does not always lead to the "improvement of rice culture" because it sometimes might give an adverse effect on the plant type.

Thinly sown seedlings are excellent in nature. However, if they are gown in infertile land or by light dosage of fertilizer application, their incipient growth is accelerated to invite growth depression and random shapes of paddy in the latter stages, which often results in a poor yield. This is a good example to show that technical improvement often works adversely on the plant type.

3. Method and Propriety of External Diagnosis

When making a diagnosis of the major external characters of paddy, each character should be checked against the following two conditions in order to judge the propriety of its diagnosis.

(1) Reliability – Diagnosis of the character in question should be closely related to the yield as well as respective yield components.

(2) Easiness of diagnosis – The character in question should allow the diagnosis to be made with relative easy by anyone regardless of place.

Propriety of major characters of paddy for diagnostic materials is described below from the viewpoint of the above two conditions.

A. Plant Height (Culm Height) and Number of Tillers (Number of Panicles)

The growth condition of paddy is generally judged by the plant height and the number of tillers (culm height and number of panicles). The plant height (culm height) and the number of tillers (panciles) per hill can be readily checked by anyone. These two characters provide a general idea about the growth condition at a certain time, but they cannot be used for judging the yield or crop condition. Hence, they are not very reliable nor appropriate as diagnostic materials . . . . . Class Bb.

However, the quality of tillering (which is determined by the time of emergence of tillers) is closely related to the yield components and serves as reliable data for judging the crop condition, although its diagnosis involves some intricate work . . . . Class Ab.

B. Leaf Colour and Its Changes

Since old, leaf colour and its changes have been an important yardstick for judging the growth condition, and they need to be observed carefully in each growth stage of paddy. However, this diagnostic advantage is reduced by the fact that the leaf colour varies to an extent by varieties and there are no adequate means to express its intensity. For the present, therefore, this character serves as the diagnostic materials only around the young-ear formation stage, although it is closely related to the crop condition . . . . . Class Ba.

C. Arrangement and Density of Leaves

Arrangement and density of leaves generally accepted as being favourable for yield increase are such that foliage grows with optimum density during the middle stage of growth period and that the upper three leaves shoot upright from the heading time to the ripening period. Paddy presenting such a type has an excellent form for light receiving which leads to a high percentage of ripened grains. These characters are therefore closely related to the yield.

However, measurement of these characters, i.e., leaf area index and foliar angle, not only involves substantial difficulty but is also subject to large individual variation and regional difference relative to other characters. Propriety of such measurement for judging the growth condition or yield is therefore very poor, so that the two characters do not serve as good diagnostic materials . . . . . Class Bc.

D. Root Condition

It leaves not doubt that the sound growth of the root throughout the growth period is an indispensable prerequisite to yield increase. If the stubble is pulled out several times during the growth period to check the rooting acitivity and root colour, it is possible to judge, though to an extent, the growth condition of paddy each time. Defect of this method, however, lies in the fact that nothing is known yet about what is the "healthy root" of high-yielding paddy is like or how it grows and undergoes changes.

Granting that the rooting activity is closely releated to the growth of paddy, the extreme difficulty entailed in its diagnosis makes it impractical for the present to base the judgement of crop condition on it. Hence, the rooting condition is not a suitable diagnostic materials . . . . . Class Ca.

4. Shape and Features of Healthy Paddy and High-yielding Paddy

By "healthy paddy" is meant a "paddy possessing the trait and morphological features from which stabilized yield can be expected reglardless of season or environmental condition". "High-yielding paddy", on the other hand, may be construed as a "paddy improved from the healthy type paddy for morphogenesis that promises increased yield regardless of place". To put in plain words, they are the high-yielding varieties which have a high production efficiency of unhulled grains relative to straw production, exhibit a high resistance against diseases and external damages, and further put on a large number of good panicles.

Of the many characters representing the shape of paddy, the length of internode of culm and the length of leaf blade (leaf sheath) are known to allow for the diagnosis to be made with ease and high reliability.

The number of nodes of main culm is usually fixed for each variety. In the case of the paddy varieties grown in Indonesia, it ranges from 17 to 16 for short-culmed varieties and from 18 to 17 for long-culmed varieties, and six each of nodes and internodes are found on the terrestrial culm. The length and thickness of each internode are very sensitive and to a subtle change in the surrounding environmental condition or cultural method. The change in the internode length and thickness causes the corresponding change in the length of leaf blade and leaf sheath as well as in the elongation of panicle neck-node. While a diversity of plant types are created by the combination of these four characters, the change in the plant type is most sharply reproduced by the length of internode of culm.

Accordingly, if constant attention is paid to the internode elongation throughout the growth period, one would see that it reflects various types of paddy with the change in the environmental condition and would also be enabled to judge accruately the growth and crop condition of paddy.

Morphological features of healthy and high-yielding varieties are introduced below together with their advantages (Ref. Fig. 1).

A) Internode

(1) Lower internodes are short, thick and stout

1) Starch content in the lower aerial part is high and accumulated.
2) Nutrients and water are smoothly transferred to the upper aerial part.
3) Vegetative growth is smoothly switched over to reproductive growth.
4) Number of spikelets (grains) per panicle does not increase to excess.
5) Ratios of withered grains and empty grains decline to increase the percentage of ripened grains.
6) High lodging resistance is exhibited.
7) Resistance against drought injury, flooding damage, insect and disease damage increases.
8) Adaptability to the surrounding environment is enhanced by self-control of growth.

9) Stubbles and panicles become uniform

(2) Upper internodes are well elongated and developed.

1) Nutrients and water are transferred in ample quantities to panicles.
2) Emergent ability of panicle neck-node is strengthened.
3) Length of panicles and each rachis (primary and secondary) increases to stimulate the photosynthetic ability of panicles.
4) Degeneration of grains is suppressed to increase the percentage of complete grains.
5) Grain texture (Tsubu-hari) improves and the weight of 1,000 unhulled grains becomes heavier.

B) Leaf Blade, Leaf Sheath and Other Characters

Paddies having the internodes described in Items (1) and (2) generally present the following secondary features.

1) The lower fourth leaf does not overgrow and is usually shorter than the third leaf.
2) Of the upper three leaves, the third leaf is the longest and the elongation of the first (flag) leaf is conspicuous.
3) Distance between the auricles of the third and fourth leaf is short, but that between the second and third leaf is long.
4) Culm does not overgrow, but it is not too short.
5) Upper three leaves grow upright with an exellent form for light-receiving that maintains them green until the late stage of growth.
6) Lower leaves are free from early withering.
7) Root is healthy and well developed, and exhibits an active manure absorptive power until the late stage of growth.

C) Names and symbols of respective characters are listed below.

N_0–Elongation of panicle neck-node .... Length from the apex of flag leaf sheath (S_1) to the panicle neck-node.

N_1, N_2–Upper internode length.... Length of the upper first and second internodes close to the panicle neck-node.

N_4, N_5, N_6–Lower internode length .... Length of the fourth, fifth and sixth internodes counted from the apex of culm.

B_1, B_2, B_3–Upper leaf blade length .... Blade length of the first (flag), second and third leaves from the apex of culm.

B_4, B_5–Lower leaf blade length.... Blade length of the fourth and fifth leaves.

S_1, S_2, S_3–Upper sheath length.... Sheath length of the upper B_1, B_2 and B_3.

S_4, S_5–Lower sheath length .... Sheath length of B_4 and B_5.

Ac^{1-2}, Ac^{2-3}, Ac^{3-4} .... Distance between the auricles of B_1 and B_2, B_2 and B_3, and B_3 and B_4.

Notes: N_3 (length of the third internode) is omitted because it is hardly related to the panicle or shape of paddy.

As will be clear from Table 1 and Fig. 1, lower internodes (N_4, N_5 and N_5) of "healthy type" are short and stout, whereas those of "unhealthy type" are overgrown and weak. Table 1 also indicates that the longer the upper internodes (N_1 and N_2), the greater the weight and length of panicle, which is clear evidence of "healthy and high-yielding type" capable of putting on panicles of good quality.

Table 1—Types and Characters of Paddy

	Ⓐ Healthy Type	Ⓑ Unhealthy Type
Panicle Length	23.7 cm	22.0 cm
Panicle Weight	3.48 g	2.41 g
Emergent length of Panicle neck node	+0.7 cm	-1.8 cm
Culm Length	82.0 cm	83.1 cm
Leaf Blade Length B_1	25.5 cm	20.3 cm
Leaf Blade Length B_3	40.1	37.5
Leaf Blade Length B_4	39.7	44.6
Internode Length Upper $N_1 + N_2$	55.1 cm	47.8 cm
Internode Length Lower $N_4 + N_5 + N_6$	13.9	21.5
Weight of 1,000 Unhulled Grains	30.1 g	27.9 g

(PB–5)

Central Agricultural Experiment Station, Bogor, 1972, WS.

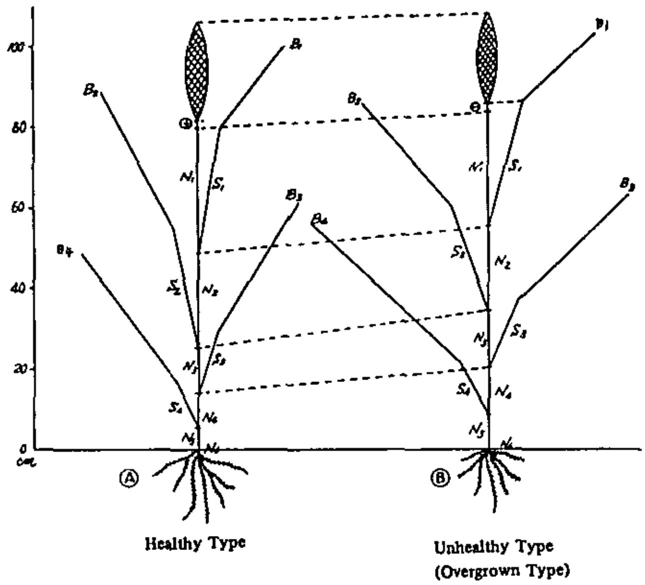


Fig. 1–Difference in Paddy Shape between
Healthy and Unhealthy Types

On the contrary, increase in the length of lower internodes usually causes accelerated lodging and diminishes the elongation of upper internodes and emergent ability of panicle neck-node, whereby the panicle becomes light relative to its weight. When these symptoms are presented, blade length of the lower fourth and fifth leaves (B_4 and B_5) become over-luxuriant even if lodging is avoided and in addition, the form for light-receiving is degraded due to the spreading of the upper three leaves, whereby the percentage of ripened grains drops. These are the features of "unhealthy type".

A high degree of negative correlation is generally observed between the lower internode length and the upper internode length as well as between the lower leaf blade length and the upper leaf blade length. Hence, careful attention should be paid to the mutual relations between these four characters (Refer to Fig. 2 and Table 2).

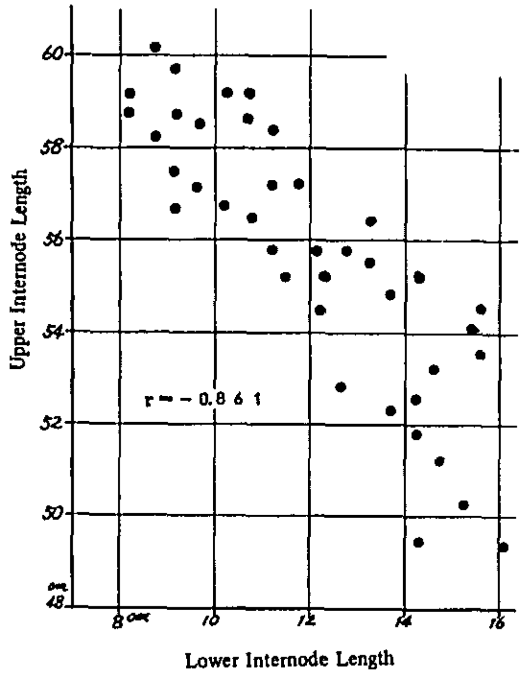


Fig. 2-I – Correlations between Upper Internode Length and Lower Internode Length (Pelita 1-1, 1972)

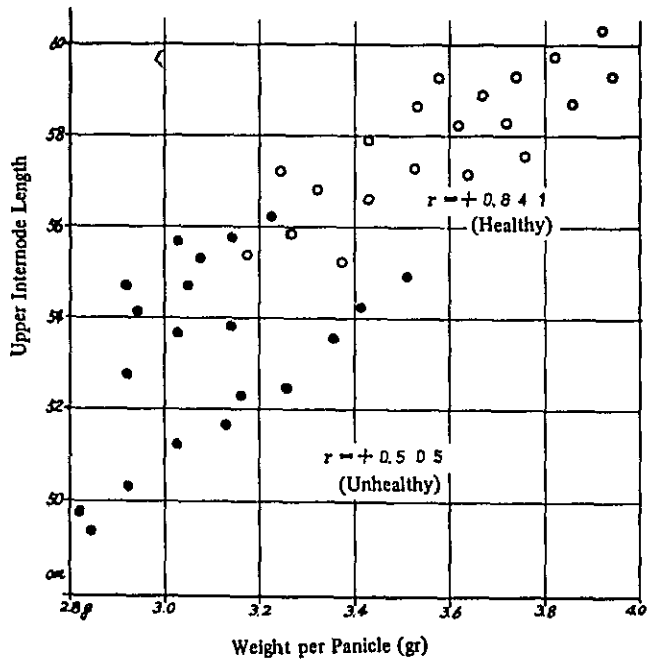


Fig. 2-II – Correlations between Upper Internode Length and Weight per Panicle (Pelita 1-1, 1972)

Table 2–Correlations between Major Characters of Paddy

I) (Pelita 1-1, 1973)

	Lower Internode Length ($N_4+N_5+N_6$)	Panicle Weight	Panicle Length	*Emergent* Length of Panicle Neck-node	Weight of 1,000 Grains	(Paddy Type)
Upper Internode Length (N_1+N_2)	−0.861	+0.841 +0.505	+0.613 +0.444	+0.588 +0.425	+0.563 +0.488	Healthy Type Unhealthy Type
Lower Internode Length	–	−0.770	−0.677	−0.875		Healthy Type

II)

	Distance between Auricles				Leaf Blade Length		
	Ac^{4-5}	Ac^{3-4}	Ac^{2-3}	Ac^{1-2}	B_3	B_2	B_1
N_5	+0.830				−0.769		
N_4		+0.888				−0.810	
N_3			+0.831				+0.850
N_2				+0.934			
N_1				+0.923			
B_1			+0.840		(Weight of 1,000 Grains)		
Emergent Length of Panicle Neck-node					−0.822		
Young Panicle Length		+0.881	+0.500				

5. Elongation of Internode, Leaf Blade and Leaf Sheath, and Their Interrelations

Changes in the length of internode, leaf blade and leaf sheath are an excellent means of accurately grasping the paddy shape. In order to make clear such changes and their interrelations, it is necessary to have the full prior knowledge, preferably for each major variety, as to when and how the elongation takes place.

In the case of short-culmed varieties grown in Indonesia, elongation generally follows the process described below.

Main culm node number is generally fixed for each variety and subject to little variation. Short-culmed varieties usually have a total of 16 to 17 nodes comprised of 6 leaf emerging nodes of the terrestrial culm and 10 to 11 underground tillering nodes. These nodes maintain constant in number unless the climatic or cultural condition undergoes a drastic change, so that they are most stabilized of all the other characters of paddy. Compared with the node number, the internode length and thickness are more vulnerable to a slight change in the surrounding environmental condition. In particular, the lower internodes (N_4 and N_5) are very susceptible to the change in the surrounding condition.

Thus, the length of culm internodes of vulnerable character in environmental conditions, although culm-node number is stabilized, can be made use of as an excellent materials for diagnosing the paddy type, but the diagnosis resorting to the internode length presupposes careful study of the time and pattern of elongation (See Fig. 3).

Elongation of the lowest sixth internode (N_6) begins about 40 days before the heading time (or at time of turning point of leaf emergence rate which is about 40 to 42 days after transplanting), reaches its peak in 5 to 6 days, and stops usually in the subsequent 4 to 5 days or 25 to 26 days before the heading time. The fifth internode (N_5) and the fourth internode (N_4) start elongation 5 to 6 days and 10 to 12 days later respectively, the former reaching the peak 25 to 26 days before the heading time and the latter 20 to 21 days before the heading time. Elongation of these two internodes stops in 5 to 6 days after reaching the peak. It can therefore be said that the peak elongation period of the lower internodes (N_6, N_5 and N_4), which demands careful observation for successful rice cultivation, lasts about two weeks extending from the 34th ~ 35th day

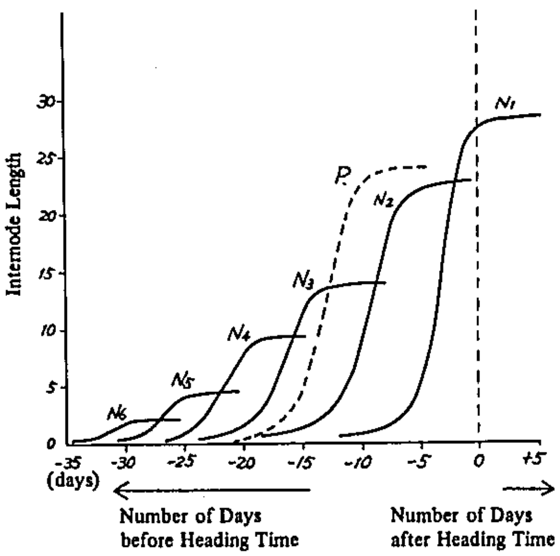


Fig. 3–Elongation Process of Internode and Young Panicle

to the 20th day counting back from the heading time.

The young panicle becomes 1.5 mm ~ 2.0 mm long just before the N_4 elongation reaches its peak (or about 23 to 24 days before the heading time). The period when the young panicle attains the said length is called the "young panicle formation stage". In time with this, elongation of the third leaf (B_3) comes to an end and the second leaf (B_2) enters the elongation period. In this stage, the foliar age index registers 90.

About a week later or from the 12th ~ 16th day before the heading time, N_4 elongation dwindles followed by conspicuous elongation the third internode (N_3). In parallel with N_3 elongation, young panicle (P) grows rapidly day after day, attaining its full length 5 to 6 days before the heading time.

Elongation of the upper second internode (N_2) and first internode (N_1) starts successively about 15 to 10 days before the heading time, accelerating its pace from several days before the heading time through the heading time. The two internodes keep on growing after that though at a dwindled pace, with N_2 stopping elongation soon after heading and N_1 5 to 6 days after heading. Emergence of panicle neck-node (N_0) from the first leaf sheath (S_1) takes place in parallel with the elongation of N_1, so that it stops completely 5 to 6 days after the heading time.

Table 3–Internode Elongation and Simultaneous Growth of Main Characters

Internode	Number of Days before Heading Time		Simultaneous Growth					
	Peak Elongation Period	Completion of Elongation	Internode Length N	Leaf Sheath Length S	Leaf Blade Length B	Distance between Auricles Ac	Emergent Length of Panicle Neck-node N_0	Panicle P
N_6	30±3 days	26	N_6	S_5	B_4	–		
N_5	26±3	20	N_5	S_4	B_3	Ac^{4-5}		
N_4	21±3	14	N_4	S_3	B_2	Ac^{3-4}		
N_3	14±3	7	N_3	S_2	B_1	Ac^{2-3}		P
N_2	7±3	+2	N_2	S_1	–	Ac^{1-2}	N_0	P
N_1	1±3	+5	N_1	–	–	–	N_0	

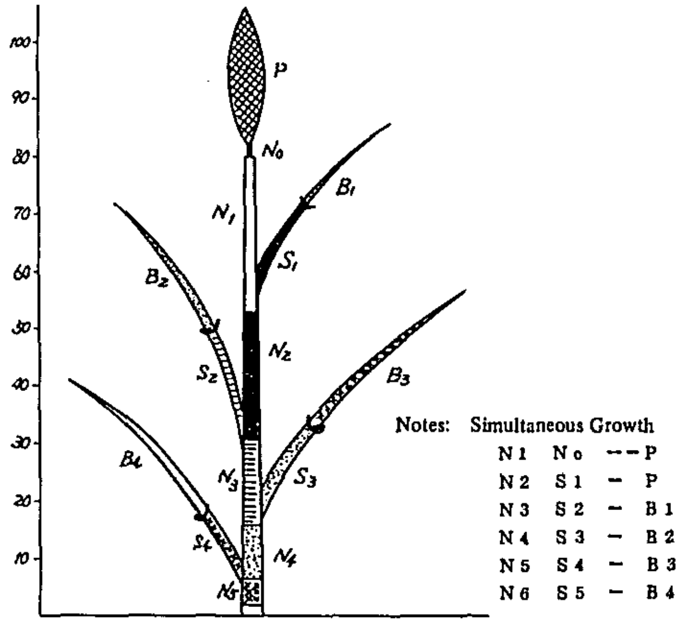


Fig. 4–Simultaneous Growth of Respective Characters (Pelita 1-1)

Table 3 and Fig. 4 indicate that the three characters, i.e., internode, leaf sheath and leaf blade, grow simultaneously.

To be more precise, simultaneous growth can be observed with each of the three groups, i.e., [B_1, S_2, N_3], [B_2, S_3, N_4] and [B_4, S_5, N_6] and young panicle (P) grows synchronously with B_1 group. A detailed explanation on this subject will be given later in this textbook.

The characters described above and their pattern of elongation are the standard applicable only to Pelita 1-1 which has registered a normal growth record and are not to be understood as being always stabilized. The reason is that internode, leaf sheath and leaf blade differ from each other in the degree of susceptibility to the change of environmental condition or variety, with internode being most vulnerable and leaf sheath less so. Another important reason is that even in case of a same variety, these characters present different degrees of vulnerability between the primary and secondary tillers of culm and between the lower tillers and upper tillers.

These facts must be taken in mind when sampling specimens for the morphological survey which will be explained later.

6. Life of Paddy and Characteristics of Its Growth

a) Growth in Nursery Bed

Rice seed germinates any time if given suitable moisture at a suitable temperature. The temperature best suited to germination and rooting ranges from 30 to 35°C. Rice seeds start germinating when they have absorbed water equivalent in weight to 23 ~ 25 % of dried seeds. Therefore, if soaked and sprouted seeds are to be used, they should be larger by about 20 % in volume or about 30 % in weight than dry seeds. Deep soaking of seeds for 48 to 60 hours in a room maintained at a temperature of 26 ~ 28°C results in slight sprouting.

Rice seeds which have germinated in the nursery bed absorb nutrients from the endosperm, whereby both the radicle and the plumule grow larger. However, by the time when the third true leaf starts shooting, the nutrients of the endosperm are used up and those of the newly formed crown root are absorbed for further and independent growth. This period is called the "weaning stage".

Emergence of leaves takes place in the following sequence. At first tubular coleptile (C) appears, which is followed by successive elongation and spreading of the imperfect leaf (Prophyll = P) and the first true leaf (1.0). The growth speed of seedlings is closely affected by temperature, and it is considered that an accumulated temperature of 100 ~ 120°C is required for each additional leaf to emerge. Hence, in those areas of West Java where the daily atomospheric temperature averages 27 ~ 29°C, an additional leaf shoots every 4.0 ~ 4.5 days. This means that in order to raise seedlings with 5.5 L ~ 6.0 L which are suited to planting, the number of nursery days should range from 22 to 27 days. Since seedlings grow fast and call for a short nursery period in Indonesia, it hardly occurs that the leaves of seedlings turn extremely yellowish towards the end of the nursery period. Thus, seedlings raised in Indonesia are virtually free from any such symptom as "decline of seedling growth".

b) Growth in Paddy Field

Since seedlings are raised at close spacing, tillering in the nursery bed is generally limited except when thinly sowing is adopted. Soon after they are planted in the paddy field, the seedlings develop the new root and their plant height increases. This process is called the "rooting". The rooting period is extremely short in Indonesia, and the growth of both the terrestrial and subterranean parts begins from about the third day after planting (See Fig. 5).

(1) Tillering Process

Seedlings which have taken root in the paddy field grow larger in plant height, and tillers developing from the lower part increase with the number of leaves of main culm. Generally, tillers per hill register the largest number 42 to 45 days after transplanting, and this stage is called the "Maximum tiller number stage". Culms tilled in the earlier stage

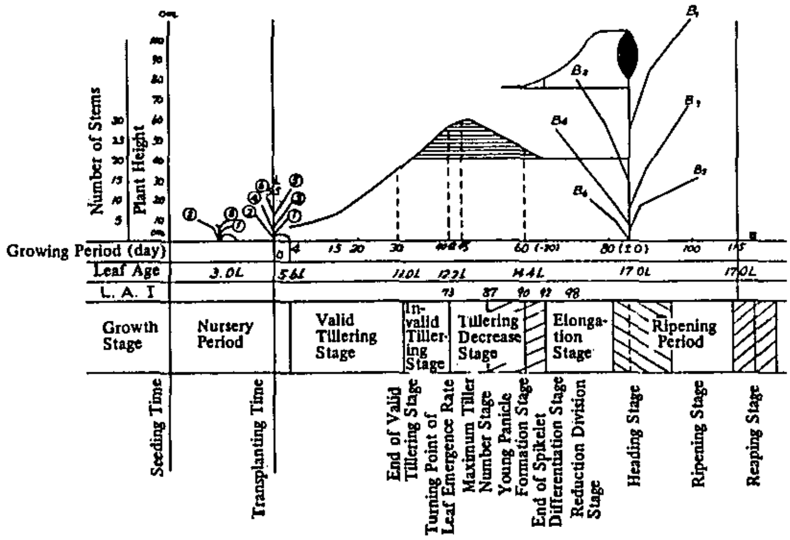


Fig. 5—Life of Paddy and Process of Its Growth
(Pelita 1-1, W.S. Cropping)

from the lower part grow into "effective culms" and put on large panicles, and most of small culms tilled in the later stage are non-effective and eventually wither away. The number of culms per hill after maximum tiller number stage does not increase but slowly decreases. The main culm starts growing upright 14 to 20 days after the said stage, whereby the number of effective culms per hill or unit area is generally determined before the "young panicle formation stage". This period is called the "tillering decrease stage".

If any culm does not put on four or more true leaves before it starts growing upright, it is usually non-effective.

In Indonesia, however, the high atmospheric and water temperatures induce quick decomposition and absorption of manure, so that supply of a limited quantity of fertilizer or water gives rise to new tillering even after the upright growth of culm has started. This often disturbs the transfer from the vegetative to reproductive growth and causes delayed differntiation or emergence of young panicles, which leads to uneven heading.

After Transplanting, the number of tillers increases gradually until the productive culms and panicles of each hill become equal in number, and this period is called the "valid tillering stage". The time when the development of productive culms ends is called the "End of valid tillering stage". The period between this time and the maximum tiller number stage is called the "invalid tillering stage", and the ratio of panicle number to the maximum number of culms is called the "ratio of effective tillers".

The middle spikelet differentation stage bears closely upon satisfactory paddy cultivation both physiologically and morphologically. In Japan, a certain period of time including this stage is called the "critical period" to which farmers are advised to pay particular attention. During this period, transfer from the vegetative growth to the reproductive growth takes place and the growth of paddy undergoes a notable change.

(2) Growth of Plant Height and Panicle

For some time after seedlings have taken root, the growth of plant height is slow relative to the development of the root. After the lapse of a week or so, however, it becomes quicker with the active absorption of manure, and this rapid growth continues until the maximum tillering stage. This is followed by the tillering decrease stage during which the differentiation of flag leaf and panicle takes place inside the plant with reduced root development, and this results in the decline of water and manure absorptive power. At this time, the growth of plant height dwindles sharply and appears as if it is temporarily suppressed. In time with this, the culm and leaves become harder as their starch content increases relative to the nitrogen content, and the leaves become yellowish.

The time when the growth of plant height is temporarily retarded (or to be exact, the time when the emergent rate of main culm leaves is decelerated) is called the "turning point of leaf emergence rate" which is generally observed 2 to 3 days before the maximum tillering stage.

When the culm starts growing upright followed eventually by the emergence of young panicle, the development and functions of the root become active again, manure absorptive ability increases, and assimilation of culm and leaves becomes active. Particularly during the "booting stage" which lasts from the reduction division stage (16 to 12 days before the heading time) to the heading time, elongation of stems and leaves is accompanied by the rapid growth of upper internodes of culm and the panicle becomes larger day after day until its emergence. Throughout its life, paddy grows most actively in this stage both externally and internally, and presents the most pleasing external appearance from this stage to immediately after full heading.

As described above, the plant height (culm height) grows at difference paces from transplanting to heading time. As can be seen from the following illustration, its normal elongation repetitively depicts an S-curve which naturally varies to an extent by variety, area and cultural method, etc.

Very slow —	Slow —	Rapid —	Very slow —	Rapid
(Rooting stage)	(Tillering stage)		(Tillering decrease stage)	

— Very rapid —	Slow —	Stops elongation
(Booting stage)	(Full heading time)	

7. Emergence Order and Growth of Tillers

Seedlings take root in 3 to 4 days after planted in the paddy field. Development of the new root gives rise to the growth of plant height which is eventually followed by tillering and increase in the number of tillers. Even in case of single planting per hill, it is usually the case that the paddy plant comes to put on as many as 15 to 16 panicles. Some panicles are large and some are small, and some are well ripened while there are some with a lot of empty grains.

To be more precise, the quality of panicles of a hill varies by whether they are put on the main culm or tilled culm, and panicles put on tilled culms vary in quality by the order of tillering.

If observed superficially, tillering of paddy appears to be irregular and lacks anything like order. It is known, however, that the emergence of main culm and growth of tilled culms take place according to the established order.

In the case of the short-culmed varieties grown in Indonesia, the number of nodes usually ranges from 17 to 16 for the main culm and from 16 to 15 for the tilled culm, and one culm should in principle emerge from each node. However, the lower several nodes of tranplanted seedlings grow into rooting nodes and the upper several nodes become the terrestrial elongation nodes, so that the tillering nodes are limited to the middle 5 to 6 nodes. In the base of seedlings or the so-called subterrenean part, nearly 2/3 of main culm nodes (about 9 to 10 nodes) are found close together like the sections of bamboo shoot. In the case of transplanted seedlings, the lower 3 to 4 of these substerrenean nodes become the rooting nodes and the first group of tillers emerge from 4 to 5 nodes immediately above these rooting nodes. This is followed by tillering from each of the 6th to 10th nodes at a rate of one tiller per 5 to 6 days. These tillers which emerge from the main culm are called "primary tillers", and "secondary tillers" emerge from the lower tillering nodes of early primary tillers as in the case of main culm. With the lapse of time, "tertiary tillers" develop from the secondary tillers. Thus, a large number of tillers develop from a single seedling.

Since it is quite troublesome and difficult to identify each of these tillers, numerical symbols are adopted to express the main culm and the position and order of emergence all tillers (See Fig. 6-I and 6-II).

Symbols of Tiller Order and Position

Main culm	0
6th leaf of main culm	6/0
2nd leaf of primary tiller from 4th node of main culm	2/4
2nd leaf of 1st node of secondary tiller from 4th node of main culm	2/4.1

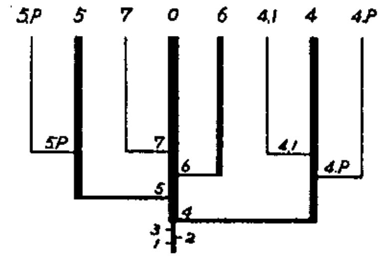
Notes: 1. Denominator indicates the tiller order and numerator the leaf order.

2. Denominator in one digit) indicates (primary tiller
   " two digits) indicates (secondary tiller

The leaf emergence stage and tillering of main culm are closely related to each other. If paddy is in normal growth condition, emergence of any leaf of main culm is simultaneously accompanied by the emergence of the first leaf of primary tiller from the third tillering node counting from the main culm leaf.

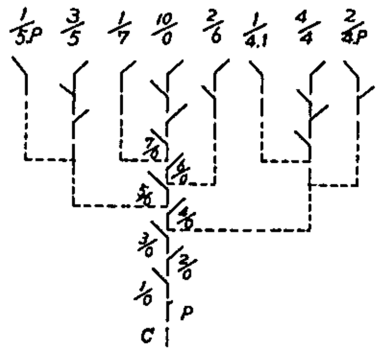
For example, when a seedling is planted in the state of 6.0 L (6/0), 7.0 L (7/0) begines to emerge in 5 to 6 days. Almost in time with the emergence of 1/7, the 1st leaf of the 4th tillering node (1/4) which is 3 nodes lower than 7/0 begins to put forth.

These two (i.e., 1/7 and 1/4) keep growing thereafter at about the same pace. Tillers like the one explained above which develop and grow in time with the main culm leaf are called the "synchronously emerging tillers" and their leaves are called the "synchronous emerging leaves. And such simultaneous growth is called the "synchronous growth".



Synchronously Emerging Tiller

Fig. 6-I—Tillering Pattern
(Synchronously emerging tiller and leaf, 10/0)



Synchronously Emerging Leaf

Fig. 6-II

Since this principle of synchronous growth exists between main culm and tillers and between tillers, the advent of each tillering stage and elongation speed can be readily known simply by checking the leaf emergence date at regular intervals after transplanting. This method is instrumental in judging the growth condition of paddy as well as in assuring rational manuring practice.

The days required for any main culm to shoot a new upper leaf after emergence of the immediately lower leaf, or the "leaf emergence interval, varies by variety, area and quality of seedling. In the case of short-culmed varieties grown in Indonesia, leaves emerge at a rate of one in 5.0 to 6.0 days during the early stage of growth period which lasts 42 to 43 days from transplanting to the turning point of leaf emergence, and at a rate of one in 10 to 12 days during the late stage of growth period (See Table 9). Strictly speaking, quick or slow growth as generally referred to means short or long "leaf emergence interval" or high or slow "leaf emergence rate".

Of a number of tilled culms, the main culm, 4th and 5th primary tiller from the main culm, and lower secondary tillers put on good panicles than others. The lower tilled culms have short and stout lower internodes (N_4, N_5 and N_6) and long and well developed upper internodes (N_1 and N_2), which indicates that they are the "healthy type". On the contrary, most of main culm upper tillers and secondary tillers have overgrown lower internodes (N_4 and N_5), while their upper internodes (N_1 and N_2) are short and poorly developed, and this is a clear indication of "unhealthy type" (See Table 5).

Thus, the quality of panicles is determined by the emergence order of tillers. In paddy cultivation, therefore, effort should be exerted to secure the vigorous tillering from lower nodes in the early stage and suppress the delayed emergence of weak upper tillers, with endeavours also made to accelerate the later vegetative growth of the secured effective tillers.

Table 4—Synchronously Emerging Tillers and Leaves
(Planted with 6L/0 and Grown to 12L/0)

Main Culm	6/0	7/0	8/0	9/0	10/0	11/0	12/0
Primary Tillers	0	1/4	2/4	3/4	4/4	5/4	6/4
			1/5	2/5	3/5	4/5	5/5
				1/6	2/6	3/6	4/6
					1/7	2/7	3/7
						1/8	2/8
							1/9
Secondary Tillers				1/4.P	2/4.P	3/4.P	4/4.P
					1/4.1	2/4.1	3/4.1
					–	1/4.2	2/4.2
					–	–	1/4.3
					1/5.P	2/5.P	3/5.P
						1/5.1	2/5.1
						–	1/5.2
						1/6.P	2/6.P
							1/6.1
							1/7.P
Number of Synchronously Emerging Leaves	0	2	3	5	8	12	17

If three seedlings are planted for each of 20 hills per m^2, it is not at all difficult to produce 8.0 tons of fresh grains per ha if 320 effective panicles are secured per m^2. This means that the number of effective panicles need not be any larger than 16 per hill or slightly less than 5.4 per seedling.

Table 5–Emergence Order of Tillers and Difference in Paddy Type

Tillering Number	Panicle length	Panicle neck-node emergent length	Leaf blade length		Internode length		Internode weight (1N+2N)	
			B_1	B_2	Upper (1N+2N)	Lower (4N+5N+6N)	N_1	N_2
(Main culm)	cm	cm	cm	cm	cm	cm	g	g
0	24.3	7.9	40.3	46.3	65.9	6.6	4.96	15.6
4	24.4	7.4	42.3	53.1	67.0	5.9	5.57	15.2
5	23.0	7.1	34.6	45.8	64.3	6.7	4.90	16.0
6	23.6	6.0	34.5	45.3	63.3	7.2	5.07	13.8
* 7	22.8	5.5	34.0	43.4	62.3	7.6	50.9	13.6
* 4_1	20.8	7.1	27.3	37.7	63.1	10.3	3.91	13.6
* 8	21.6	5.8	28.9	38.8	61.7	8.1	3.72	12.4
* 5_1	21.6	6.0	31.7	44.3	62.1	9.2	3.87	12.3
* 4_2	20.9	5.4	28.8	37.8	61.2	12.9	3.77	12.3

* Note: Synchronous growth (1956)

In order to secure the above-mentioned number of panicles, a total of six culms consisting of the main culm, four primary *tilled culms (4/0, 5/0, 6/0 and 7/0) and one secondary tilled* culm (1/4) will suffice. If seedlings are to be planted at the age of 6.0 L (6/0), calculation based on the leaf emergence rate will disclose that a period of 25 to 28 days after transplanting suffices to obtain the six effective culms.

8. Differentiation and Growth Stage of Young Panicle

As will be clear from Table 6, differentiation of panicle neck-*node begins 36 to 34 days before the heading date (40%), which* is accompanied by the growth of the lower fourth leave (B_4) and lower sixth internode (N_6). This is followed by the differentiation of primary and secondary branches and spikelet which takes place during a period of about 12 to 14 days before the young panicle formation stage. By this time, the numbers of branches and spikelets per panicle are determined.

Growth of B_4 reaches its peak 28 to 25 days before the heading time. If nitrogen fertilizer is applied to excess around this time, the numbers of secondary branches and spikelets per panicle increase. This leads to conspicuous increase of empty grains and decline of seed setting rate.

The number of primary rachis branches does not vary much by variety or cultural condition, nor does it show any notable difference between short-culmed varieties bearing short-panicles and long-culmed varieties putting on long panicles. Therefore, it can be taken granted that the number of grains is determined by that of secondary rachis branches.

Young panicle formation of almost all varieties takes place 24 to 23 days before the heading time, and it coincides with the peak growth stage of B_3 and N_5. The fourth internode (N_4), which is most susceptible of all lower internodes to the changes in surrounding condition starts growing from about this time, and deceleration of its growth is observed during the 18th ~ 20th day before the heading time. Emergence of the flag leaf (B_1) is observed just before this period. During this period, young panicles are usually 0.5 to 1.0 cm long and distance between auricles 3.0 L ~ 4.0 L (Ac^{3-4}) generally ranges from 4.0 to 6.0 cm. Nitrogen top dressing at young panicle proves safe and most effective if conducted for 4 to 5 days starting from this stage.

"Reduction division" reaches its peak 14 to 13 days before heading, with young panicles grown as long as 10 cm to 18 cm. The peak of reduction growth can be readily estimated because N_4 stops growing and distance between auricles 1.0 L ~ 2.0 L (Ac^{1-2} = ±0) becomes ±0 during this period. From about 10 days before heading, growth of N_3 dwindles and flag leaf (B_1) stops growing, with the leaf age index registering 100.

From the 5th to 6th days before heading, panicles attain full length (24.0 ~ 26.0 cm) and exhibit active emergent ability of panicle neck-node, which is eventually followed by heading.

Table 6–Relationship between Growth Stage of Young Panicle and Elongation of the other characters.

Leaf Age Index	Growth Stage of Young Panicle	Number of Days before Heading Date	Length of Young Panicle	Elongation of Internode	Elongation of Leaf Blade	Elongation Period of Distance between both Auricles
				Early, Peak	Early, Peak	
75		42–40 days			(Turning Point of Leaf Emergence) (76)	
77	Panicle Neck-node Differentiation Stage	36–34		N_6	B_4	
81	Primary rachis Branch Differentiation Stage	32–30				
85	Secondary rachis Branch Differentiation Stage	29–28	Visible by naked eye.	N_5 N_6	B_3 B_4 B_4	
87	Early Spikelet Differentiation Stage	27–25	1.0 mm			
90	Middle Spikelet Differentiation Stage (Young Panicle Formation Stage)	24–23	1.5–2.0 mm	N_4 N_5	B_2 B_3 B_3	Ac^{4-5}
92	Late Spikelet Differentiation Stage (Ear Manuring Stage)	20–19	5.0 mm – 1.2 cm	N_3 N_4 N_4	B_1	Ac^{3-4} 4.0–5.0 cm Ac^{2-3} ±0–1.0
95		18–17			Emergence of B B_2 B_2	
97	Early Reduction Division Stage	16–15	6.0–8.0 cm	N_4 stops growing		
98	Peak Reduction Division Stage	14–13	10.0–18.0	N_2 N_3	B_1 B_1	Ac^{1-2} ±0 cm
100		11–10	22.0–24.0		B_1 stops growing	
100	Late Reduction Division Stage	6– 5	Panicle growth stops. 24.0–25.0	N_1 N_2		Ac^{1-2} ±15.0 cm
100	Early Heading Time	2– 0	10% heading	N_1		Ac^{1-2} ±25.0 cm
100	Heading Time	0–+2	40% heading	N_2 stops growing		
100	Full Heading Time	+3–+5	80% heading	N_1 stops growing		

Notes: Elongation of respective internodes starts 4 to 5 days before the time shown in the table.

9. Emergence of Panicle Neck-node, Heading and Flowering

In parallel with the growth of the first internode, emergence of panicle becomes active. In the case of short-culmed varieties grown in Indonesia, it usually takes 5 to 6 days for each head to come out completely after its tip started emerging from the sheath of the flag leaf. In the first 3 to 4 days, the head grows at a rate of 6 to 7 cm per day, which slows down to 3 to 4 cm per day in the remaining 2 to 3 days.

The emergence rate varies by varieties. Pelita I-1 exhibits a high emergence rate, while PB-5 and C_4 show a slower rate. The emergence rate also varies by the surrounding condition. In the case of healthy type paddy, heads grow vigorously and evenly at a high emergence rate. However, if the paddy is "unhealthy type" or its growth is impeded in and around the heading time by continuous cloudy weather, rains, low temperature and deficient sunshine, emergence of heads is retarded and takes a longer period, and this results in uneven heading.

Concentrated nitrogen application in the early stage of growth period causes extremely poor emergence as compared with that conducted in the later stage of growth period (See Table 7).

Among the varieties grown in Indonesia, long-culmed local varieties generally have a high emergence rate and a long emergence length, whereas short-culmed varieties are featured by their extremely low emergence rate and surprising short emergence length.

The emergence length and rate of the panicle neck-node serves as a data for judgeing the crop condition. It is therefore necessary to make constant observation of the emergence length and ability.

Generally, one panicle has nine to ten primary rachis branches and each primary rachis branch has two to four secondary branches. A panicle is formed as each of the

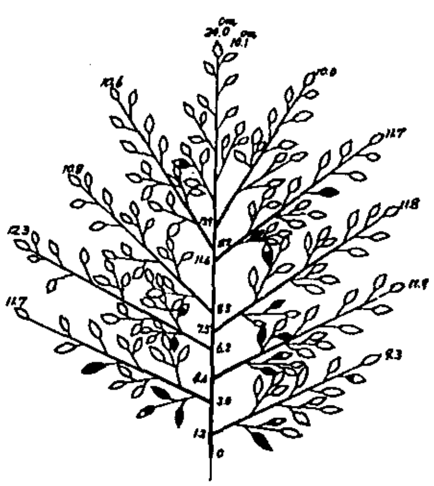
Table 7–Daily Emergence Condition of Panicle Neck-node

(Pelita 1–1)

Method of Fertilization \ Number of Days from Start of Emergence			2nd Day	3rd Day	4th Day	5th Day	6th Day	Total Emergence Length (a)	Panicle Length (b)	Panicle Neck-node Emergence Length (c)=(a)–(b)
			cm	cm	cm	cm	cm	cm	cm	cm
Concentrated Nitrogen Application of Early Stage of Growth Period % (35 : 30 : 35)	a	1	7.2	7.4	6.7	1.6	0.2	24.1	24.6	–0.5
		2	7.0	8.1	6.4	1.1	0.4	24.3	23.2	+1.1
	b	1	7.4	7.7	6.4	1.4	0.2	25.3	24.8	+0.5
		2	6.4	7.7	6.8	2.0	0.3	25.7	24.5	+1.4
Concentrated Nitrogen Application of Later Stage of Growth Period % (20 : 30 : 50)	a	1	7.4	8.5	6.6	0.8	0.1	26.8	24.4	+2.4
		2	6.7	8.0	6.9	1.1	0.1	26.3	24.4	+2.4
	b	1	6.5	8.8	8.1	2.2	0.4	28.3	25.8	+2.5
		2	7.2	8.3	7.4	0.7	0.1	27.7	24.5	+3.2

Fig. 7–Grain Bearing Condition of One Panicle

(Pelita 1–1, 1972, WS)



Rachis branch	Complete Grain	Withered Grain	Empty Grain	Total
Upper 4 Branches	56	2	1	59
Middle 3 Branches	51	2	2	55
Lower 3 Branches	36	4	7	47
Total 10	143	8	10	161
Primary Branches 33	54	1	2	57
Secondary Branches 33	89	7	8	104
Total	143	8	10	161

secondary rachis branches puts on three to four grains.

Compared with the grains of secondary rachis branches (which grow on the inner side), those of primary rachis branches (which grow on the outer side) ripen quicker with higher seed setting rate. Among the grains of primary rachis branches, upper ones ripen quicker with higher seed setting rate. Grains of secondary rachis branches which are found in the inner and lower parts of panicle are delayed in growth with poor seed setting rate, and this results in a high rate of withered grains or empty grains.

Changes in the environmental condition do not cause any notable change in the number of primary rachis branches, but secondary rachis branches are very vulnerable to such changes. In the case of smoothly grown paddy, number of secondary rachis branches averages 3.1 to 3.3 per primary rachis branch and any larger number of secondary rachis branches is liable to decrease the percentage of ripened grains.

It is generally said that high atmospheric temperature and short day-length are the necessary conditions for prompt differentiation of young panicles, smooth transfer from vegetative growth to reproductive growth, and early heading and flowering. However, in tropical countries like Indonesia where the temperature is high throughout a year and diurnal or seasonal viariation of atmospheric temperature is extremely small, it is not conceivable that heading or flowering will be prompted or delayed by the change of atmospheric temperature. In these countries, therefore, heading and flowering time is affected primarily by the change of day-length and degree of photosensitivity of the variety in question.

In case of seedlings of Pelita 1-1 with a nursery duration of 25 days, vegetative growth period (from transplanting to young panicle formation) lasts 57 to 58 days for wet season cropping, and this period becomes shorter by 4 to 5 days for dry season cropping. Growth period required for dry season cropping is usually about a week shorter than for wet season cropping in case of other short-culmed varieties and long-culmed varieties. (See Table 8).

Table 8–Growth Stages of Major Varieties

Variety / Growth Stage	Pelita 1–1		PB–5		Syntha	
Nursery Duration	25 days (20–30)		25 (20–30)		25 (25–35)	
Leaf Age at Time of Transplanting (L)	5.6L (5.5–5.8)		5.7 (5.6–5.9)		5.8 (5.6–6.0)	
Plant Height at Time of Transplanting	25 (23–27)		26 (25–28)		32 (30–35)	
(Number of Days Elapsed after Transplanting)	(Dry Season)	(Wet Season)	(Dry Season)	(Wet Season)	(Dry Season)	(Wet Season)
End Valid Tillering Stage	28	28	30	30	35	35
* Turning Point of Leaf Emergence Rate	41	43	42	44	43	45
Maximum Tillering Stage	43	45	44	46	46	48
Young Panicle Formation Stage	54	58	56	62	57	64
End Spikelet Differentiation Stage	57	62	60	65	62	67
Reduction Division Stage	63	68	66	71	67	73
Heading Stage	77	82	80	85	82	87
Reaping Stage (Growth Period in Paddy Field)	107	112	110	116	112	118
Total Growth Period	132	137	134	141	137	143

(1973)

Notes: Growth period after the turning point of leaf emergence rate (asterisked) becomes 0.7–0.8 days shorter for each one-day extension of nursery duration and 0.7–0.8 days longer for each one-day reduction of nursery duration.

Difference in day-length between dry and wet seasons is relatively small in Indonesia when compared with other parts of the tropics. However, the average day-length during the vegetative growth period (Nov. ~Dec.) is 1.0 ~ 1.5 hours shorter in the dry season than in the wet season. The varieties grown in Indonesia exhibit a relatively high photosensitivity, and this is considered to account for the accelerated young panicle differentiation which is more noticeable in the dry season than in the wet season.

Heading is immediately followed by flowering. The temperature suited to flowering is about 30°C, so that flowering of almost all spikelets takes place between 10:00 a.m. and 12:00 p.m. Time required to complete flowering is about 30 minutes for each spikelet, 1.5 to 3.0 hours (2 days) for each rachis branch, 6 to 7 days for each panicle, and about 12 days for all panicles of a hill. The flowering takes place in the fixed order. Spikelets on a panicle flower from the upper to lower part and from the outer to inner side. In the case of spikelets on a rachis branch, the one on the apex blooms at first and then successive flowering from the lowermost spikelet to upper ones occurs. Spikelets on rachis branches in the inner and lower parts of a panicle often wither away without blooming. The seed setting rate per panicle or hill is determined by the flowering pattern described above.

After flowering and fertilization are both completed, the ovary grows larger day after day and enters the ripening stage. The ripening period is determined chiefly by temperature, so that it can be considered to last 30 days after flowering in both wet and dry seasons.

The ripening period is divided into milk-ripe stage, dough-ripe stage, yellow-ripe stage, full-ripe stage, and dead-ripe stage. In the tropics where the temperature difference between days and nights is small, the time interval between the yellow-ripe stage and the dead-ripe stage is extremely small. It is therefore abnormal early ripening.

II. Application of Improved Cultural Method

10. Features of Recommended Short-Culmed Varieties as Considered from Cultural Point of View

Promotion of technical guidance and improvement of cultural practice always presuppose the study made from the cultural viewpoint on the features, merits and demerits of the variety or varieties currently grown or planned to be extended in the area in question.

In this section, therefore, a general study is made on the features of recommended short-culmed varieties (chiefly Pelita 1-1) grown in West Java from the point of view of both growth and morphology.

a) Study from the Viewpoint of Growth

1) Raising of Seedling: Cycle of leaf emergence of seedlings is shortened due to the high temperature during the nursery period. In the later stage of the nursery period, in particular, the plant height increases with delayed rooting, and this is liable to cause seedlings overgrow and small in R/T ratio as will be described later.

2) Paddy Field Period: In the case of Pelita 1-1, the paddy field period (from the transplanting to the ripening stage) lasts about 117 days for seedlings planted at an age of 20 days for wet season cropping and about 112 days for the same seedlings planted for dry season cropping. Thus, the growth period is shorter in the dry cropping season. The growth period in the paddy field becomes 4 to 5 days shorter if the nursery duration is made 5 days longer. (See Table 8)

The fact that the growth period of the same variety varies by the cropping season or the nursery duration is assignable to the difference in the photo-sensitivity during the vegetative growth period. The growth period from transplanting to the young panicle formation stage is the longest for young seedlings planted for wet season cropping and tends to be the shortest for matured seedlings for dry season cropping.

It is often the case that the growth period is determined by the lapse of time from several days before the turning point of leaf emergence rate to the young panicle formation stage (See Table 8).

3) Early stage growth is not balanced with later stage growth.

Except in few hilly districts, the paddy grows vigorously and quickly from transplanting until the whole middle stage of growth period. As a matter of fact, the middle stage growth tends to be stimulated to excess. After the young panicle formation stage, however, the growth dwindles gradually and is markedly decelerated in the ripening stage. Thus, *the growth pattern involves the depression in the later* stage, and this can be clearly evidenced by the cycle of main culm leaf emergence.

Major early maturing varieties grown in Japan require approximately the same paddy field growth period as Pelita and PB-5. While Japanese varieties need 7 to 8 days and 8 to 9 days respectively for their first and second cycles of leaf emergence, Indonesian short-culmed varieties require only 5 to 6 days for their first cycle of leaf emergence and need as long as 10 to 12 days for the second cycle. This outstanding trend maintains itself, although the cycle could change to a minor degree depending upon the variety, nursery duration, planting depth, method of nitrogen application, cropping season, etc.

What described above is good evidence to show that *paddy cultivation in Indonesia is generally prone to suffer* "depression in the later stage of growth period" which deserves serious attention for improvement of cultural method.

Table 9–Cycle of Leaf Emergence and Turning Point of Leaf Emergence Rate

Cropping Season	Variety	Planting Depth Nursery Duration	Cycle of Leaf Emergence		Turning Point of Leaf Emergence Rate		
			Cycle I	Cycle II	Lapse of Days after Transplanting	Leaf Age	Leaf Age Index
Wet Season 1971	Pelital–1	22 days–3.0 cm	6.06 days	12.04 days	42 days	12.4	77
	PB–5	22 –3.0	6.53	10.89	44	12.3	77
Dry Season 1973	Pelital–1	20 –3.0 cm	5.46	9.93	38	12.1	76
		30 –3.0	6.00	10.34	40	12.5	78

4) Number of spikelets per panicle is too large.

Considering the fact that they are short-culmed, many tillering type, the currently recommended varieties put on rather large panicles. Although the number of primary rachis branches per panicle averages 8.5 to 9.0 and is not therefore very large, secondary panicles are conspicuously large in number. It is considered that balanced growth of panicle can be assured if an average of about 3.0 secondary rachis branches are found on each primary rachis branch. But, in the case of Indonesian short-culmed varieties, the number of secondary rachis branches per primary rachis branch averages 3.2 to 3.5 and sometimes surpasses 4 or 5 (See Table 10).

If there are many secondary rachis branches, the number of spikelets in the inner and lower parts of panicle increases correspondingly, and this constitute the primary reason for the low percentage of ripened grains of the recommended varieties.

5) Duration of reaping stage is short.

During the ripening period in Indonesia, the atmospheric temperature rises to excess and the temperature difference between days and nights is very small, so that grains ripen quickly and their yellow-ripe stage lasts only 4 to 5 days. This often results in the failure to reap at the optimum time. In case the temperature keeps on standing at 30°C or higher or the temperature difference between days and nights is smaller than 6 ~ 7°C, respiration is more intensified than assimilation and the resultant consumption impedes tha thickening growth and ripening of grains. This is one of the causes of quicker aging to which Indonesian varieties are liable in the mautration period. The quick aging trend is observed more often in flat areas than in hilly districts.

b) Morphological Study

1) The paddy shape is formed bascially by the culm internodes. One of the characteristics of short-culmed varieties is that while the lower internodes (N_4, N_5 and N_6) are all relatively short, elongation and development of the upper ones (N_1 and N_2) is very poor. Whether this is due to the varietal characteristics or to some secondary factors such as natural environment and cultural condition is unknown yet. It must be pointed out, however, that this is a serious morphological defect tot he desired yield increase.

2) In the case of short-culmed varieties grown in Indonesia, the blade of the fourth leaf (B_4) is generally longer than that of the third leaf (B_3). The leaf length becomes shorter consecutively from the fourth to the first leaf, and the difference in length between each two adjoinging leaves is very large. In particular, the flag leaf is extremely short.

It is generally considered that varieties which sustain depression in the later stage of growth period are typified by such a paddy shape (See Table 10).

3) Emergent ability of panicle neck-node is poor and heading is not even.

As described already, one of the conspicuous characteristics of Indonesian short-culmed varieties is that the ability of panicle neck-node to emerge from the sheath tip of the flag leaf (B_1) is very poor and the emergence length is extremely short. Table 7 showing the transition of emergent ability indicates that the panicle neck-node grows at an average rate of 7.0 ~ 8.0 cm per day from the start of emergence until the third day, but its growth declines from the fourth day on and stops completely on the sixth day when the panicle comes out fully. This short emergence period causes poor shooting of the panicle neck-node from

Table 10—Relationship between Plant Type and Yield Components (Pelita 1-1)

Average Weight of a Grain	Plant type	Plant type Factors						Average Number of Secondary rachis Branches	Panicle Length	Yield Components				Number of Secondary rachis Branches per 10 cm of Panicle Length
		Internode Length		Leaf blade Length			Emergent Length of Panicle Neck-node			Panicle Weight	Complete Grains per Head			
		Upper	Lower	1L	3L	4L					Number of Grains	Percentage	Weight of 1,000 Grains	
		cm		cm			cm		cm	g				
Over than 4.0 g	A	59.2	11.5	26.7	40.5	34.8	+3.8	3.19	25.1	4.56	142	90.1	29.7	12.7
	B	57.5	11.9	25.3	39.1	35.8	+2.6	3.30	25.1	4.39	132	84.8	29.5	13.2
	C	55.1	14.8	22.4	38.5	37.8	+1.7	3.42	24.8	4.35	131	84.4	29.2	13.8
	D	52.9	16.0	20.8	37.8	38.9	+0.7	3.43	24.6	4.30	134	83.6	28.4	14.0
Lighter than 4.0 g	A	59.0	9.9	27.2	38.1	33.0	+3.8	3.28	24.7	3.48	105	85.0	29.2	13.2
	B	57.1	10.4	26.6	36.5	33.8	+2.3	3.40	24.9	3.42	104	83.2	28.9	13.7
	C	54.9	13.9	24.0	35.9	35.9	+1.8	3.47	24.0	3.20	97	81.7	28.3	14.5
	D	51.5	15.3	21.5	35.6	36.2	+0.8	3.53	23.8	3.14	96	81.1	27.8	14.8

Notes: A – Upper internode length is longer than 58.5 cm.
B – " 56.5 cm.
C – " 54.5 cm.
D – " shorter than 54.5 cm.

the flag leaf, and there can be observed many panicles which pass the emergence period without having their neck-node come out at all. This is one of the causes of uneven heading.

Fig. 8 shows the difference in the panicle emergent ability and eveness of heading between Japanese and Indonesian short-culmed varieties. The coordinate axis represents the number of panicles per hill and the abscissa represents the emergence period and emergence rate.

Eveness of heading improves as the rectangle formed by (a, a', e, e') in Fig. 8 nears a regular square, and the emergent ability increases as the areas (b, b', c, c') and (c, c', d, d') becomes wider. Also, this figure can be used for comparison between "healthy type paddy" and "unhealthy type paddy".

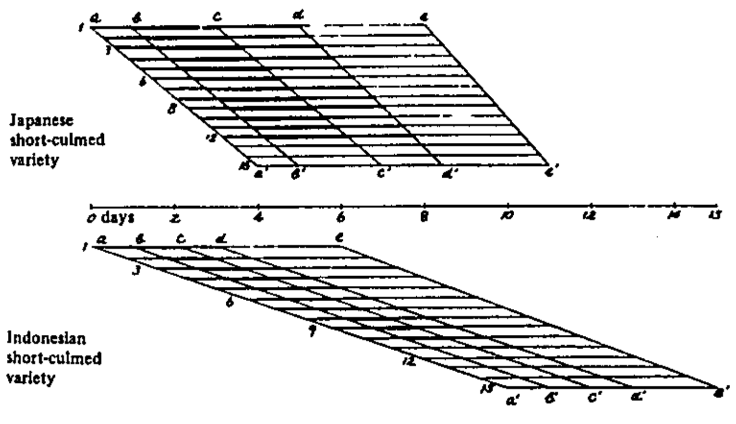


Fig. 8–Panicle Emergent Ability and Eveness of Heading (1973)

11. Significance and Need of "Healthy Seedlings"

Indonesian farmers still adhere to the practice of planting aged, yellowish and overgrown seedlings raised from extremely thickly sown seeds. They also make it a practice to plant deeply as many as six to ten seedlings per hill.

However, it cannot be justified to reject the conventional seedling raising techniques altogether as being completely irrational because the farmers are placed under unfavourable cultural conditions which are enumerated below.

1) Most of widely grown local varieties which are generally long in plant height exhibit low fertilizer response and put on low-tillering panicles.
2) Land is infertile and liable to cause depression in the late stage of growth period.
3) Irrigation and drainage faiclities are not consolidated.
4) Yield target is low (less than 3.0 ~ 4.0 t/ha on the average).

In fact, the traditional cultural practices include, as described later, some passive measures devised against yield drop from the accumulation of past experience.

Considering, however, that the cultural environment changes season to season in Indonesia, it leaves no doubt that seedling raising techniques compatible with such changes should be introduced, applied and extended.

Such new techniques should positively meet the purpose of yield increase for reasons given below.

1) Strong and short-culmed varieties of high profuse tillering type which require heavy fertilizer application are increasingly introduced and cultivated.
2) Dosage of fertilizer application in paddy fields is increasing.
3) Use of agro-chemicals is also increasing, and as a result.
4) Yield target is rising (higher than 5.0 ~ 7.0 t/ha on the average).

Seedlings as Called by Different Names and Their Features:

1. Good seedling: "Good seedling" is a rather vague expression based on the abstract idea which the person using the term entertains about the quality of seedlings in question. Such an abstract idea naturally varies according to each person's subjective point of view. Hence, this term does not suit the purpose of expressing concretely the external characters or inherent nature of any seedling.

2. Matured seedlings: This term is used as antonym of young seedling. Maturity is determined by the seedling age and its internal components. A matured seedling is required to have about one third of the main culm leaf numbers inherent to the variety, and to have a higher carbonhydrate content than nitrogen content (i.e. to have C/N ratio of about 14). Thus, the term is quite a scientific expression.

   Availability of matured seedlings is the basis of paddy cultivation, but "overmatured seedlings" is not suited for satisfactory paddy production.

   Save for few exceptional ones, "matured seedlings" usually satisfy the requirements of "healthy seedlings" under normal cultural condition.

3. Healthy seedlings: This terms has been generally employed to indicate "sound seedling" which is stout, short and resistant against insect and disease damage.

   "Healthy seedlings" as used in this textbook indicates such a seedling which is "equipped with traits, characters and conditions conductive to the growth of healthy type paddy after transplanting".

   Healthy seedlings of short-culmed varieties is required to satisfy the following conditions.

   1) Seedling age ranges from 5.3 L to 5.7 L and C/N ratio from 14 to 15.

2) Plant height ranges from 24 to 26 cm after a nursery period of 24 to 25 days.
3) Length of the third leaf sheath is short (5 to 6 cm).
4) T/H ratio is high.
5) R/T ratio is high.
6) Leaves present light yellow colour towards the end of the nursery period, with the upper fourth and fifth ones growing upright (See Table 11).

Seedlings filling these conditions are little subject to transplanting injury, exhibit excellent rooting activity, and grow smoothly after transplanting.

Table 11–Dosage of Nitrogen Application and Seedling Characters in Nursery Bed (Variety Pelita 1-1, 1973)

Dosage of Urea Application g/m² / Item		0 g	5	10	15	20
Germination Percentage		% 80.7	% 96.4	% 94.3	% 83.6	% 77.2
Seedling rate		52.2	76.4	80.0	68.0	61.5
Seedling Aged 20 Days at Transplanting time	Plant Height	22.2	22.0	21.8	22.4	23.1
	Leaf Age	4.89	4.97	5.21	5.15	5.20
	Length of Third Leaf Sheath (cm)	6.04	6.10	6.17	6.35	6.60
R/T Ratio						
Seedling Aged 20 Days	6 Days before Transplanting	17.7	24.3	25.0	23.2	20.4
	6 Days after Transplanting	60.9	69.2	74.5	63.3	59.1
	11 Days after Transplanting	61.7	65.5	62.1	58.6	56.4
Seedling Evaluation		△	◎	⊚	△	×

4. Optimum seedling: This terms is used to indicate seedlings which exhibit their capacity and characters according to the paddy field condition and cultural condition. It is the most concrete way of expressing seedlings which fit the given cultural condition. Whether a seedling is optimum or not is not determined by its external appearance or inherent characters because a seedling which is evaluated as being optimum under a certain condition could fail to enjoy the same evaluation under other conditions. For instance, thinly sown seedlings are generally equipped with the conditions of "healthy seedlings" and promise good crop in fertile land under heavy dosage of fertilization. Under such cultural condition, they can be considered optimum. However, they cannot be considered optimum for cultivation in degraded paddy field or infertile land where they are liable to grow to excess in the intial stage and sustain heavy depression in the later stage of growth period.

12. Characters of Seedlings and Problems in Seedling Raising

Details of the seedling raising method practised in Indonesia are given separately in

1) Establishment of seedling raising techniques meeting the conditions of respective areas

The purpose of seedling raising is to secure the required number of "healthy seedlings of uniform quality". To attain this purpose, it is essential to find out if the seedlings raised by the method practised in each area in question are equipped with the conditions of "healthy seedlings". If such conditions are not filled by the seedlings examined, then their characteristic difference from healthy seedlings and causes of such difference must be detected. This is an indispensable prerequisite to the establishment of seedling raising techniques because the nursery bed environment varies according to the climatic and soil conditions but changes in such conditions do not justify the application of a same raising method (See Table 12).

Table 12—Difference in Seedlings Qualities by Area (1973)

Area	Plant Height (H)	Seedling Age (L)	Dry Matter Weight: Subterrenean Part (R)	Dry Matter Weight: Terrestrial Part (T)	R/T Rating	T/H Rating	Ranking
A Pelita 1–1 Seedling Age–20 Days							
	cm	L	g	g			
Cihea	24.3	5.2	2.45	9.38	26.1	38.6	1
Cianjur	17.4	5.0	1.75	5.00	35.0	28.7	4
Karawang	22.3	4.9	1.50	6.58	22.8	29.5	3
Sebang	26.0	5.3	1.83	7.83	23.0	30.1	2
Bogor	–	–	1.72	6.50	26.5	–	
B Pelita 1–1 Seedling Age–30 Days							
	cm	L	g	g			
Cihea	33.0	6.0	3.28	11.95	27.5	36.2	1
Cianjur	24.5	5.7	2.80	8.00	35.0	32.6	2
Karawang	36.8	6.1	3.32	16.40	20.2	44.5	3
Sebang	38.2	6.2	2.65	12.60	21.0	33.0	4
Bogor	–	–	2.71	11.60	23.4	–	
C Syntha Seedling Age–20 Days							
	cm	L	g	g			
Cihea	33.5	5.3	2.85	10.58	28.2	31.3	1
Cianjur	16.3	4.7	1.40	3.63	38.5	22.3	4
Karawang	34.5	4.9	1.41	8.63	16.5	25.0	3
Sebang	37.3	5.3	2.10	10.00	21.0	26.8	2
Bogor	–	–	2.20	8.00	27.5	–	–
D Syntha Seedling Age–35 Days							
	cm	L	g	g			
Cihea	44.5	6.5	7.55	25.12	30.1	56.4	1
Cianjur	34.3	5.9	2.90	10.85	26.9	31.6	2
Karawang	56.5	6.4	3.28	24.18	13.5	42.8	3
Sebang	60.5	6.7	3.58	20.75	17.3	34.3	4
Bogor	–	–	3.65	19.45	13.7	–	

Notes:
1. All specimens were smapled on the day of transplanting.
2. Dry matter weight represents that of 100 seedlings.
3. Seeding rate (70 g/m^2) and dosage of nursery fertilization (10 g/m^2 of urea) are the same in all areas.

Table 12 shows the difference in growth condition of seedlings raised in several major Kabupatens of West Java. The table indicates the notable fact that both Pelita 1-1 and Syntha were raised from same seeds sown at the same rate and at the same dosage of fertilizer application, but their characters vary larger by each area.

Compared with the seedlings raised in others areas, those raised in Cihea excel in characters regardless of variety and nursery duration. They fulfill the conditions of "healthy seedlings" with a high R/T ratio and T/H ratio which are the yardstick for judging the quality of seedlings.

In Cinajur, R/T ratio is the highest but T/H ratio is the lowest in all plots. (ie: Ⓐ, Ⓑ, Ⓒ, Ⓓ). It is because of the delayed and extremely poor growth of the terrestrial part that seedlings of such type were produced despite of the fact that the development of root presented no appreciable difference from other areas excluding Cihea. Probable causes are; i) atmosperhic temperature is low, ii) productivity of nursery bed is poor, iii) designated dosage of urea application (10 g/m^2) is deficient, and iv) manure absorptive power is poor. The table also indicates that insofar as the seedlings raised in Cianjur are concerned, 30-day old seedlings of both varieties (Pelita 1-1, Syntha) were observed to be better equipped with the requirements of "mature seedling" than 20-day old seedlings.

In Karawang and Sebang which are both found in flat area, R/T ratio is extremely low regardless of variety or nursery duration, and this is assignable to the fact that the growth of the terrestrial part and foliage was stimulated to excess relative to that of the root. It is noted for both varieties that R/T ratio declines and T/H ratio rises with the increase of nursery duration. This unfavourable trend is conspicuous in Karawang and suggests that the growth unbalance between the terrestrial and subterrenean parts will be accelerated after transplanting. In flatland areas, the atmospheric temperature is high and nursery beds are rich in productivity. If irrigation water used in such areas contains lots of nutrients, seedlings are prone to become weak and overgrown.

In these two areas, therefore, thinly sowing (65 ~ 70 g/m^2) and light dosage of nitrogen application (5 ~ 7 g/m^2 of urea) should be adopted, and the nursery period should be determined according to the variety. It is also advisable to rationalize water management of nursery beds and maintain optimum moist condition for them.

2) Seeding Rate and Seedling Rate

Semi-irrigated nursery bed is best suited in West Java where the water temperature is high throughout the day. It is advisable to create elevated nursery beds each measuring 10 to 12 cm in height, 1.2 m in widght and having a suitable length. After sowing on the somewhat compacted nursery bed, the bed surface should be kept moistened throughout the nursery period or water should be filled to a shallow depth only in the later nursery period. In both cases, it is necessary to replace water every day.

In order to secure the required number of "healthy seedlings" which are suited to transplanting, it is necessary to estimate the seeding rate per m^2 of nursery bed and the seedling rate per unit area. If the seeding rate is too high, the seedling rate is liable to drop. In this case, it is possible to secure the required number of seedlings and reduce the area of seed bed, but "healthy seedings" cannot be obtained. If thinly sowing is adopted, on the other hand, healthy seedlings can be easily secured but it often becomes necessary to expand the area of seed bed since the number of mature seedlings per unit area decreases. (See Table 13)

It often occurs in West Java that seeds sown for wet season cropping are partly washed away by the shower immediately after sowing or drifted to one side by rain, and this

Table 13– Relationship of Seeding Rate with Germination and Seedling Rates (Wet Season Cropping) (With: Obstacle to establishment due to afternoon shower) (PB-5, 23 day old)

Seeding Rate / Water Management after Sowing	60 g/m²		80 g/m²		100 g/m²		120 g/m²	
	Non-Irrigated Section	Irrigated Section	Non-Irrigated Section	Irrigated Section	Non-Irrigated Section	Irrigated Section	Non-Irrigated Section	Irrigated Section
Germination Rate	% 86.5	91.0	71.3	93.0	77.5	92.4	71.8	78.1
Seedling Rate	70.0	80.0	62.8	80.0	62.3	76.7	58.6	61.4
Number of Mature Seedlings/m²	1,460	1,680	1,760	2,240	2,180	2,680	2,460	2,580
Seedling Age/Plant Height Ratio	2.70	2.53	2.71	2.28	2.60	2.24	2.31	2.03
Evaluation	-	+	+	+++	++	+	-	-

Notes: In non-irrigated sections, the nursery bed was kept moistened after sowing. In irrigated sections, water was supplied only for several hours in the afternoon for 5 to 6 days to fill it to a depth of 2.0 to 3.0 cm and then drain it.

makes the germination rate and the seedling rate extremely low. Therefore, the thick sowing practice is considered to have settled among the farmers as a means to secure the necessary number of seedlings.

In order to protect seeds against showers and improve germination and establishment of seedlings, the following measures should be taken.

a) Seeds should be sown on levelled and somewhat compact beds. It is prohibitive to allow the bed soil to become too soft.

b) Sown seeds should be covered and pressed lightly with banana leaves or the like so that they will not be exposed.

c) If necessary, the bed surface should be thinly covered with cut straws or chaffs.

d) The bed should be kept moistened but not irrigated. For several days after sowing, however, water should be drained. This irrigation and drainage practice should be repeated for several days (See Table 13).

As will be clear from Table 13, it is possible to alleviate the adverse effect of showers on germination and establishment by repetitive irrigation conducted for several days after sowing. It is to be noted that irrigated rice nursery in which water is constantly filled to the bed from the time of sowing is not advisable because seeds are liable to be putrefied before germination due to high water temperature and lack of oxygen.

Seedling age/plant height ratio is a criterion for judging whether a seedling is equipped with the requirements of "healthy seedling". Taking this ratio at 2.3 ~ 2.5 and seedling rate at 80 % from Table 13, one can see that 70 g/m^2 of dry seeds will suffice to secure 2,000 mature seedlings of short-culmed varieties per m^2. The optimum seeding rate, therefore, is 65 ~ 75 g/m^2 or 70 g/m^2 on the average in terms of dry seeds. This rate is to be increased by 20 to 30 % in case of presprouted seeds.

The nursery bed area and seed quantity per ha of paddy field can be calculated with ease from Table 17.

3) Dosage of Nitrogen Application in Nursery and Seedling Characters

Dosage of fertilization in nursery, particularly that of nitrogen application, affects not only the seedling characters but also the germination and seedling rate. Therefore, care must be exercised so as to determine the dosage according to the conditions of respective areas (See Table 14). In the tropics where the atomospheric and water temperatures are high, fertilizers are decomposed and absorbed quickly so that the growth of seedlings is accelerated and the nursery period is generally short. Nitrogen fertilizer used as basic fertilizer of nursery should therefore be applied at a low dosage. Additional fertilizer application is not required for nursery except in special cases.

Table 14—Seedling Quality and Its Influence on Initial Growth Stage after Transplanting (Pelita 1-1, 1973)

	Raising Condition		Seedling Quality	Difference of Paddy Growth in One Week after Transplanting					
	Urea m^2	Seeding Rate m^2		Plant Height (H)	Leaf Age (L)	Dry Matter Weight: Sub-terrenean Part (R)	Dry Matter Weight: Terrestrial Part (T)	R/T Ratio	T/H Ratio
	g	g		cm	L	g	g	%	%
①	5	70	+++	25.0	5.8	5.00	11.00	45.5	44.0
②	5	100	++	26.9	5.8	4.85	11.40	42.6	42.4
③	10	70	+++	27.5	5.9	4.50	11.75	38.3	42.8
④	10	100	+	28.2	5.9	4.20	12.00	35.0	42.5
⑤	20	70	-	28.9	6.0	4.00	12.25	32.7	42.4
⑥	20	100	- -	30.5	5.9	3.75	11.75	32.0	38.5

Notes:
1. 20-day old seedlings of Pelita 1-1 with the following conditions were used.
   Seedling age—5.1 L ~ 5.3 L, plant height—25.0 ~ 28.0 m
2. All seedlings were made uniform in size by cutting the plant to 25.0 cm and root to 2.0 cm at transplanting time.

As will be clear from Tables 11 and 14, the following are the optimum dosages of nitrogen fertilizer applicable in different areas as basic fertilizer of nursery.

Fertile land in flat and not hilly areas	5 ~ 7 g/m^2 of urea
Fairly fertile land in flat and not hilly areas	8 ~ 10 g/m^2 of urea
Piedmont and mountainous areas rising to a high elevation	12 ~ 15 g/m^2 of urea

Application either in excess or short of the above dosages will result in the decline of the germination and seedling rates and will degenerate the seedling characters as well.

It is often observed in Indonesia that seedlings are overgrown except in hilly areas, and this is due to the heavy dosage of nitrogen application (prevailing dosage is 15 ~ 20 g/m^2 of urea). In the future, an appropriate dosage should be determined according to the soil conditions because the quality of seedlings bears closely upon the growth in the paddy field. As seen in Table 14, weak and overgrown seedlings planted under the same condition as healthy ones expose their defect soon. In a matter of week after transplanting, it becomes clear that their plant height is 3 to 4 cm longer than that of healthy seedlings, the root is poorly developed, and R/T ratio is low. Seedlings having such defects are very prone to grow into "unhealthy type" paddy.

4) Water Management of Nursery Bed

Water management in nursery bed not only affects the germination and seedling rates but is also closely related to the characters of seedlings. Hence, it is very important for securing healthy seedlings.

The length of the third leaf sheath is used as one of the criteria for judging if the seedling is "healthy". If seedlings are raised from thickly sown seeds in an irrigated nursery constantly supplied with deep water under a heavy dosage of nitrogen application, their third leaf sheath tends to grow too long and their characters are prone to be degraded. Conversely, if the nursery is infertile and not supplied with basic fertilizer or fertilizer is applied at a low dosage, or if the seed bed becomes too dry during the first half of the nursery period, then the third leaf sheath becomes too short, T/H ratio drops, and seedling characters are degraded.

In the case of short-culmed varieties currently grown in West Java, an average of 5.0 ~ 6.0 cm is the optimum length of the third leaf sheath of seedlings. It should be neither longer nor shorter than this average. In order to raise seedlings satisfying this requirement, the nursery bed should be maintained moistened throughout the first half of the nursery period, i.e., for 12 to 13 days after sowing. After the lapse of this period, the bed should be continuously kept moistened. Otherwise, water should be supplied to a depth of 1.0 cm to 2.0 cm only for a few days towards the end of the nursery period.

Not much attention has so far been paid to water management in nursery despite of the important role it plays in securing "healthy seedlings". It is therefore hoped that carefully planned water management will be implemented in future.

13. Relationship of Nursery Duration with Yield and Growth Period

When the seedling raising techniques are improved to a certain level, it is likely that the yield will not be so seriously affected by the difference in the type of seedlings since Indonesia is favoured with high atmospheric temperature, provided that the variety to be grown is not too thermosensitive and the seedling characters are not too poor.

What described above can be substantiated by the following factors.

1) The high atmospheric temperature assures satisfactory compensation and quick recovery of growth in the paddy field, so that the difference of seedlings growth in nursery period can be reduced with ease.
2) Cultural techniques applied in the paddy field (particulary the dosage of fertilizer application, method of fertilization, planting density, water management, etc.) exert a far greater effect than the seedling quality upon the plant type which is closely related to the yield.
3) Consequently, the advantage of high quality seedlings is often prone to be offset or diminished by these factors.

Nevertheless, it cannot be justified to make little of the need for raising "healthy seedlings" because they have the "traits and characters conductive to the growth of "healthy type paddy", and moreover raising such healthy seedlings is intended to make the paddy shape "healthy" rather than to increase the yield immediately. Unless the seedlings are aged and overmatured or weak, the nursery duration exerts a smaller influence on the seedling characters and plant type than such other elements as the seeding rate and dosage of nitrogen fertilizer application. It is therefore considered that the nursery duration affects the yield only to a limited extent and need not be fixed as in the past specially because of the tropical climate which Indonesia enjoys.

As will be clear from Table 15, the yield difference is negligible if the nursery duration ranges from 20 to 30 days. However, if the cultural condition in the paddy field is liable to disturb the plant type by concentrated nitrogen application in the first half of growth period or due to the level of seedling raising techniques being low, for example, disparity of yields cuting to the difference in the nursery duration becomes definite. It is in such a case that the use of "healthy seedlings" exhibits an outstanding yield increase effect as the "best and indispenable means".

Table 15–Relationship of Nursery Duration with Yield and Growth Period

(Pelita I-1, 1972)

A) In case of the same transplanting time

Distribution of Nitrogen Application		16-Day Old Seedling		22-Day Old Seedling		28-Day Old Seedling		34-Day Old Seedling	
		a	b	a	b	a	b	a	b
Ⓐ Concentrated Nitrogen Application in Early Stage of Growth Period (35 % : 30 : 35)	Growth Period	days 83	days 129	days 79	days 131	days 76	days 134	days 72	days 136
	Yield	6.17	88	6.98	<u>100</u>	6.92	99	6.60	95
Ⓑ Concentrated Nitrogen Application in Later Stage of Growth Period (20 % : 30 : 50)	Growth Period	82	128	78	130	75	133	71	135
	Yield	7,52	109	7.85	113	8.05	115	7.40	107

Notes: a .... Transplanting to heading time.
b .... Sowing to reaping stage.
Number of hills .... $16.7/m^2$

B) In case of the same sowing time

Planting Density		19-Day Old Seedling		24-Day Old Seedling		29-Day Old Seedling		34-Day Old Seedling	
		a	b	a	b	a	b	a	b
Ⓒ Thin planting plot $16.7/m^2$	Growth Period	days 80	days 129	days 78	days 132	days 76	days 135	days 74	days 138
	Yield	6.23	87	7.13	<u>100</u>	7.03	99	6.92	97
Ⓓ Thick planting plot $22.2/m^2$	Growth Period	79	128	77	131	75	134	73	137
	Yield	6.42	90	7.23	102	7.31	103	7.20	101

Notes: Nitrogen fertilizer is applied concentrically in the first half of growth period.

It follows, therefore, that a suitable allowance should be provided to determine the "Range of nursery duration" according to the variety and conditions of respective areas. The actual nursery duration can then be fixed with account taken of the cultural condition and other factors to be considered within the "Range of nursery duration".

Table 16 shows an example of "Range of nursery duration". Since this table was prepared just by way of example, it is desirable that a similar table be prepared by area and variety.

Maximum allowance for nursery duration is larger in local long-culmed varieties than short-culmed varieties :

The "maximum allowable nursery duration" is applicable only to "healthy seedlings" and not to all seedlings. "Unhealthy seedlings" such as thickly sown seedlings, overgrown seedlings, excessively large seedlings, or seedlings with a high nitrogen content are not "best and necessary" for stabilizing the yield, and they are certain to disturb the plant type in the field and incurs a large yield gap.

Before the nursery period, therefore, it is preferable to determine the optimum nursery duration within the "maximum allowable nursery duration" or "Range of nursery duration" in order to obtain the best and healthiest seedlings that could be raised in eaoh area. It must be noted that an attempt to raise "healthy seedlings" with the nursery duration fixed for all areas as now involves the trouble of applying different raising techniques by area.

Table 16 - Nursery Duration by Varieties

Area	Short-culmed Varieties		Long-culmed Varieties	
	Nursery Duration	Average	Nursery Duration	Average
	day day	day	day day	day
Flat Area	20~30	24	25~35	30
Intermediate Area	23~33	27	27~37	32
Hilly Area	25~35	30	30~40	35

The reason is that in raising seedlings, their characters must be given prime consideration and individual techniques are considered to be the mere means to attain such characteristic seedlings.

Further, even in case of the seedlings of the same variety transplanted under the same nursery duration, their size at the transplanting time varies considerably by districts and level of raising techniques (See Table 12). Hence, effort should be exerted to raise seedlings equipped with the qualifications of "healthy seedling". For 25-day old seedlings of short-culmed varieties, plant height of 25 to 27 cm and leaf age of 5.5 L to 5.7 L may be taken as general criteria of "healthy seedling". Ordinarily, not much difference in the leaf age can be observed if the seedlings are of the same variety, but the plant height varies largely by the raising condition and district, and this gives rise to the difference in the seedling characters. Except in some hilly and cool districts or infertile areas, seedlings raised in West Java tend to be overgrown, with their plant height grown to excess relative to the leaf age during the nursery period. Seedlings are therefore liable to become unhealthy, with their terrestrial part lacking balance with the growth of the root. Accordingly, one of the keys to raising healthy seedlings in the actual nursery stage is to control the plant height within "Range of nursery duration" allowed for each individual variety.

Calculation of the nursery bed area can be worked by the method explained in Table 17.

Table 17 - Method of Calculating Seed Bed Area and Seed Weight

$$\text{Seed bed area } (m^2/ha) = \frac{\text{Number of hills per } m^2 \times \text{Number of seedlings per hill} \times 10{,}000}{\text{Number of grains per kg of dried and winnowed rough rice} \times \text{Seedling rate} \times \text{Seedling rate per } m^2 \text{ (g)}}$$

(Example of Calculation)

$$\frac{20 \text{ hills}/m^2 \times 3 \text{ seedlings} \times 10{,}000}{36{,}000/1 \text{ kg} \times 0.8 \times 70 \text{ (g)}} = \frac{600}{2.016} = 300 \ m^2/ha$$

Seed requirement for the above case :

70 g x 300 = 21.0 kg

Notes: Number of grains per kg of dried and winnowed rough rice can be obtained by calculation worked out reversely from the weight of 1,000 grains.

14. Planting Depth (Shallow and Deep Planting)

Since long-culmed local varieties whose seedlings are large in size and require a long nursery period have been cultivated for long years in Indonesia, deep planting (5.0~9.0 cm) was established as part of the traditional cultural practices. This practice is still followed in many parts of this country for currently recommended short-culmed varieties although improvements are effected gradually.

Insofar as the yield is concerned, it is the common knowledge that shallow planting is more remunerative than deep planting for all varieties except in few special cases.

The recommended short-culmed varieties exhibit a high tillering capacity which makes it possible to secure a sufficient number of effective panicles per hill. But they have their own demerits. Since tillering activity is continued until a late stage, non-effective tillers are liable to develop and the ratio of weak and small panicles is prone to increase, and in addition, the ratio of vigorous effective panicles which emerge in the early stage is apt to decline. Shallow planting is aimed at accelerating the growth in the initial stage immediately after transplanting and promoting the development of vigorous tillers from lower nodes so that the rate of vigorous panicles per hill will be increased. To enhance such effect of shallow planting, effort should be made to suppress the development of late-emerging or non-effective tillers and minimize weak tillers as need arises. At the same time, it is necessary to establish the cultural system under which suitable practices can be taken to prevent abnormal aging of early-emerging vigorous panicles and ensure their satisfactory later growth.

Establishment of such cultural system is a must in tropical countries like Indonesia where the incipient growth is expedited by the high atmospheric temperature. Application of techniques intended for accelerated incipient growth (e.g., thinly sowing, raising of large seedlings, raising of young seedling, thin planting, shallow planting, heavy application of nitrogen basic fertilizer, etc.) is sure to stimulate the growth to excess, accelerate the ageing of paddy in the later stage of growth period, and result in a poorer yield than expected.

Table 18 indicates that both Pelita 1-1 and PB-5 produce a greater yield by shallow planting (3.0 cm) than by deep planting (7.0 cm). The advantage of shallow planting over deep planting is also clear from the weight of 1,000 grains and percentage of ripened grains. While it is natural that the plant

Table 18 - Effect of Planting Depth on Plant type and Yield

(Pelita 1-1, 1971–72)

		Yield			Plant type							
Variety	Planting Depth	Yield t/ha	Weight of 1,000 Grains of rough rice	Percentage of Ripened Grains	Panicle Length	Number of Secondary rachis Branches	Emergence Length of Panicle Neck-node	Internode Length		Leaf Blade Length		
								Upper	Lower	1 L	3 L	4 L
	cm	t	g	%	cm		cm	cm				
Pelita	3.0	8.35	29.1	87.3	23.7	3.25	+2.2	54.7	11.6	20.5	37.8	33.2
1–1	7.0	7.85	28.7	84.3	24.6	3.38	+1.4	53.8	15.0	19.6	37.6	37.7
PB–5	3.0	8.05	28.0	86.1	22.6	–	+1.8	54.8	14.6	21.4	38.6	35.4
	7.0	7.75	27.4	84.6	23.8	–	+0.9	53.6	16.5	21.0	36.0	36.4

type varies according to the planting depth, the table indicates that shallow planting make all the characters point closer to "healthy type" than deep planting.

Conversely speaking, deep planting causes yield drop because it is more liable than shallow planting to make paddy "unhealthy". What discriminates deep planting from shallow planting is the notable fact that the former results in the longer length of lower internodes and fourth leaf blade and shorter emergence length of panicle neck-node.

Such degradation of the characters which constitute the plant type explains why the yield drops by deep planting although the panicle length becomes longer by deep planting than by shallow planting.

As described already, yield by deep planting of young seedlings and matured seedlings is apparently smaller than by shallow planting. However, with the extension of the nursery duration, the yield difference becomes smaller and smaller until it becomes negligible though this naturally results in the drop of aboslute yield. On the other hand, the yield gap due to the nitrogen distribution method is known to be larger for shallow planting than for deep planting. Thus, the yield variation due to the change of cultural condition is generally larger in case of shallow planting (See Table 19~I, II). It follows, therefore, that under unfavourable cultural conditions (e.g., degraded paddy field, infertile land, paddy field habitually subjected to drought injury, drought season, cultivation by light fertilization, extension of nursery period due to shortage of water, low yield level, etc.), deep planting could serve as a passive means to prevent yield decline.

Table 19~I Nursery Duration and Planting Depth

(Pelita 1-1, 1972)

Nursery Duration / Nitrogen Distribution Method / Planting Depth		18 days		24 days		32 days		40 days	
		Yield	Ratio	Yield	Ratio	Yield	Ratio	Yield	Ratio
	% %								
3.0 cm	F-65 : L 35	8.00	94	8.50	100	7.47	88	7.27	86
	F-40 : L 60	8.40	99	9.07	107	8.13	95	7.53	89
7.0 cm	F-65 : L 35	7.33	87	8.13	95	7.73	91	7.60	90
	F-40 : 60	7.90	93	8.25	97	8.00	94	7.75	91

Notes: F .... First half of growth period
(basic fertilizer + first top dressing)
L .... Latter half of growth period
(second top dressing)

15. Number of Plant stand (Thin Planting and Thick Planting)

Although many experiments on planting density have been conducted in different places in the past, it was often the case that the yield difference due to the number of hills per m^2 was not made clear.

In the experiments on planting density, it is the common practice to arrive at the conclusion on the basis of the yields attained by applying the same cultural method in both thick-planting and thin-planting. This practice is often prone to produce a wrong conclusion for the reason described below.

Assuming that all the cultural conditions excluding the number of hills per m^2 are made identical in all the experimental plots, the difference in the growth condition or the plant type should become wider with the variation in the number of hills. This makes it highly probable that some of the

Table 19~II Nursery Duration and Plant Type

Planting depth	N-distribution method \ Nursery duration	18 days N 1 + 2	18 days N 4+5+6	18 days Neck & Panicle	24 days N 1 + 2	24 days N 4+5+6	24 days Neck & Panicle	32 days N 1 + 2	32 days N 4+5+6	32 days Neck & Panicle	40 days N 1 + 2	40 days N 4+5+6	40 days Neck & Panicle
	% %	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm
3.0 cm	F-65 : L-35	57.8	17.0	+2.9 23.5	55.8	15.9	+1.2 24.1	56.5	14.3	+1.5 24.2	54.2	14.6	+0.4 22.3
	F-40 : L-60	56.5	15.2	+3.4 23.3	55.6	13.8	+2.0 24.1	55.9	13.3	+2.1 24.2	55.4	13.8	+2.7 23.3
7.0 cm	% % F-65 : L-35	54.6	17.4	+1.0 22.8	55.8	16.1	+1.4 23.0	54.5	14.5	+1.5 23.2	57.4	12.7	+1.6 23.9
	F-40 : L-60	57.6	15.2	+1.4 24.0	55.3	15.0	+1.4 23.9	58.9	15.0	+1.5 24.4	57.7	12.2	+1.6 25.0

(Pelita 1-1, 1973)

techniques employed under the said identical cultural conditions for the purpose of increasing the accuracy of experiment will work as minus factors in some plots and as plus factors in some others in improving the plant type. Under cultural conditions which, as a whole, are liable to disturb the plant type, in particular, it is generally difficult to see the yield difference due to the variation in the number of hills.

In order to attain increased yield by thick planting, it is of great importance to grow the paddy into healthy type and apply cultural techniques which are effective for satisfactory later growth. This fact will be clearly understood by careful study of Fig. 9 and Table 20.

Fig. 9 - Relationship between Number of Plant Stands and Nitrogen Distribution (Pelita 1-1)

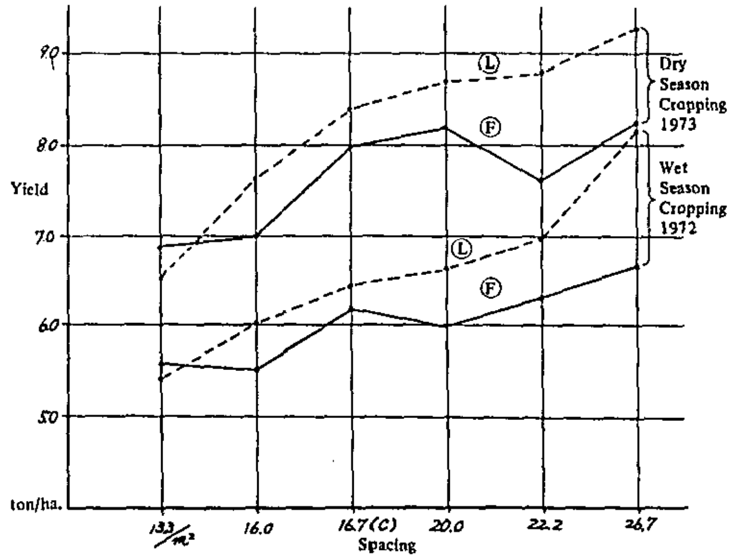


Table 20 - Relationship between Number of Planting Density and Nitrogen Distribution (Yield Increase Effect of Thick Planting)

(Pelita I–1)

Cropping Season / Number of hills/m² / N–distribution	Wet Season Cropping 1972						Dry Season Cropping 1973					
	13.3	16.0	16.7	20.0	22.2	26.7	13.3	16.0	16.7	20.0	22.2	26.7
Ⓕ Concentrated Nitrogen Application in First Half of Growth Period (35% : 30 : 35)	t 6.85 % 97	7.04 100	8.00 114	8.17 116	7.61 108	8.25 117	t 5.60 % 101	5.52 100	6.20 112	6.00 109	6.31 114	6.67 121
Ⓛ Concentrated Nitrogen Application in Latter Half of Growth Period (20% : 20 : 60)	t 6.52 % 93	7.66 109	8.42 120	8.72 124	8.78 124	9.28 132	t 5.43 % 98	6.06 109	6.47 117	6.63 120	6.95 126	8.17 148

If nitrogen fertilizer is applied concentrically in the first half of the growth period as widely practised at present, the absolute yield is low fôr both wet and dry season cropping and the yield difference due to the variation in the number of hills is extremely small and in addition, the yield is subject to fluctuation. While thin planting naturally results in poor yield, increasing the hill number to more than 16.7 hills/m^2 produces a very small yield increase which cannot be taken as anything like a significant difference. In other words, the yield increase effect of thick planting in this case is not clear.

However, if nitrogen fertilizer is concentrically applied in the latter half of growth period, the yield increases as the number of hills is augmented beyond the level of 16.0 hills/m^2 and notable yield increase effect of thick planting can be observed, although the yield does not change even in this case if extreme thin planting (13.3 hills/m^2) is adopted.

In case nitrogen is applied at half the ordinary dosage (200 kg/ha of urea), the yield is large and thick planting exhibits a clear yield increase effect provided that concentric application is conducted in the latter half of the growth period. However, yield difference between thick planting and thin planting can be hardly observed if nitrogen is applied in other ways. This is because the yield increase effect of thick planting is offset by the light dosage of nitrogen application which works negatively as a kind of growth inhibiting factor. (See Table 30).

In heavy manuring culture, the number of planted hills is closely related with the seedling characters and method of nitrogen application.

Table 21 - Composite Effect of Cultural Techniques

(Pelita 1–1)

Classification / Nitrogen Distribution	Dosage of Nitrogen Application (Number of Hills / Nursery Duration)		Thin planting plot 16 hills/m^2				Thick planting plot 22.2 hills/m^2			
			20-day old seedling		30-day old seedling		20-day old seedling		30-day old seedling	
			Yield	Ratio	Yield	Ratio	Yield	Ratio	Yield	Ratio
		Kg	t	%	t	%	t	%	t	%
Ⓕ Concentric Nitrogen Application in First Half of Growth Period % (35 : 30 : 35)	Heavy	13.5	7.70	96	7.65	95	8.15	95	8.15	101
	Medium	11.5	7.40	92	7.60	95	7.50	93	7.80	96
	Standard	9.2	8.05	100	8.45	105	8.10	100	8.05	100
	Light	7.2	7.85	97	7.75	96	7.50	93	7.50	93
Ⓛ Concentric Nitrogen Application in Latter Half of Growth Period % (20 : 20 : 60)	Heavy	13.5	8.60	107	8.45	105	9.30	115	9.60	119
	Medium	11.5	8.25	103	8.10	100	8.85	110	9.20	114
	Standard	9.2	8.10	100	8.35	103	8.65	107	8.40	104
	Light	7.2	8.05	100	7.55	94	7.20	90	7.60	94

Note: Concentric application of nitrogen in the first half of growth period on 16 hills/m^2 of 20-day old seedlings at the standard dosage was taken as the standard cultural method.

As can be seen in Table 21, the combination of heavy dosage, concentric nitrogen application in the first half of growth period, and thin planting generally results in reduced yield irrespective of the seedling characters. However, if nitrogen is applied concentrically in the latter half of the growth period at a heavy dosage, the yield is larger than can be obtained from the above combination regardless of the nursery duration and number of hills. In this case, thick planting exhibits an outstanding yield increase effect. If, again, matured seedlings are used, the yield increases 20% or by slightly less recorded in the standard plot (the highest yield recorded was 10.4 t/ha in this case).

The above test results serve as a fine example of the composite effect of the four yield increasing elements, i.e., heavy dosage, rational nitrogen distribution, thick planting, and use of healthy seedlings. It deserves attention that these four conditions proved to be essential for yield increasing means in Indonesia as in Japan.

16. Fertilizer Application in Paddy Field (Specially Nitrogen Fertilizer)

Of the three major elements of fertilizer, nitrogen exerts by far the greatest influence upon the growth, plant type and yield of paddy. Dosage of fertilizer application for paddy cultivation used to be small in Indonesia, but the recent extension of short-culmed many tillering type varieties have given rise to heavier dosage of fertilizers of various kinds which are contributing to yield increase.

New or additional input of fertilizers in the paddy fields which have long been cultivated with no or light fertilization should naturally result in the corresponding yield increase. However, mere increase of fertilizer amount does not promise stabilized yield or further yield increase. Need therefore arises for applying fertilizers in a most rational way.

Nitrogen fertilizer for paddy cultivation is generally applied in the following three ways.

1) 2 split applications consisting of basic fertilizer and top dressing at panicle formation stage.
2) 3 split applications consisting of basic fertilizer, first top dressing, and second top dressing (at panicle formation stage).
3) 4 split applications consisting of basic fertilizer, first top dressing, second and third top dressings (at panicle formation stage and at heading stage).

Choice between the above three methods and percentage determination for each split application should be made according to the variety, area, soil condition, dosage, yield target, kind of fertilizer, and so forth.

Method of fertilization is described below with special account taken of urea which is the most widely applied nitrogen fertilizer in Indonesia.

Distribution of Nitrogen Fertilizer:

For the recommended short-culmed varieties grown in West Java, it was recommended to adopt the 3 split applications consisting of 35 to 40% of basic fertilizer, 30% of first top dressing after transplanting, and 30 to 35% of second top dressing at panicle formation stage. At present, this method is widely applied chiefly for fertilization in the first half of growth period (transplanting to young panicle formation stage). Needless to say, nitrogen application in this period is intended, whether basic fertilization or top dressing, to prompt tillering and secure the lower vigorous tillers at the earliest possible date.

In other words, its objective is to enhance the vegetative growth in the former period and not to ensure satisfactory later growth. It is to be pointed out here that if the dosage of basic fertilizer application or first top dressing is given to excess to attain the above objective or first top dressing is delayed, the growth of root is retarded although growth of the terrestrial part from the early to middle growth stage becomes active and presents an "excellent apprarent growth condition". There are many cases where the middle stage growth is stimulated to disturb the plant type and invite degeneration of the later growth. Transplanted seedlings take root very rapidly as described earlier by virtue of the high atmospheric temperature, but this involves both plus and minus elements, i.e., the earlier growth (incipient to middle stage growth) is simply excellent, but the later growth is vulnerable to degeneration and depression.

Table 22~1 Dosage of Basic Fertilizer and R/T Ratio

Area	Variety / Nursery Duration / R/T Ratio / Dosage of Basic Fertilizer and % (urea) Kg		Pelita 1-1				Syntha			
			20-day old seedling		30-day old seedling		20-day old seedling		35-day old seedling	
			R	R/T Ratio	R	R/T Ratio	R	R/T Ratio	R	R/T Ratio
		%	g	%	g	%	%	%	g	%
Cihea (Intermediate Area)	Heavy	35	0.21	51.8	0.52	53.0	0.24	43.0	0.32	36.4
	Light	20	0.35	56.0	0.48	59.2	0.28	51.6	0.35	43.1
Cianjur (Hilly Area)	Heavy	35	0.17	56.2	0.34	55.9	0.18	66.4	0.22	36.3
	Light	20	0.16	60.9	0.42	64.5	0.17	74.0	0.32	47.3

Notes: 1. Dosage of urea application per ha.
Pelita 1-1 ..... 200 kg, Syntha ..... 120 kg.
2. R .... Dry matter weight of subterrenean part.
T .... Dry matter weight of terrestrial part.
3. R/T ratio ... Measured in one week after transplanting.

Excessive nitrogen application as basic fertilization and first top dressing strengthens the above tendency to make the paddy "unhealthy" and cause the growth of terrestiral part unbalanced with that of the root. It is not therefore advisable to apply a large amount of nitrogen for basic fertilization.

Table 22 indicates that heavy application of nitrogen as basic fertilization tends to make the rooting poor and growth of terrestrial foliage excessive as compared with light application for about a week after transplanting. The table also shows that such heavy application invites drop of R/T ratio and unbalanced growth irrespective of area, variety or nursery duration.

This is considered due to the progress of reduction around the root of seedlings, which temporarily impedes the growth and development of the root. From the 10th day after transplanting,

Table 22~II Relation between Plant Type and Yield

Nursery duration	N-distribution \ Plant type	N N 1 + 2	N 4+5+6	Emergent length of Neck	Panicle	Yield	Ratio
	% %	cm	cm	cm	cm	ton	%
20 days	F-65 : L-35	52.5	13.1	+1.6	24.2	6.16	100
	F-40 : L-60	57.8	12.1	+2.9	24.9	7.37	119
30 days	F-65 : L-35	54.2	11.8	+0.7	23.9	6.29	102
	F-40 : L-60	56.7	10.1	+2.3	25.4	7.65	124

(Pelita 1-1, 1973 Chihea)

however, the rooting ability becomes strengthened and the growth condition is also gradually recovered.

In paddy cultivation, the method of nitrogen distribution and the skill in applying that method bear closely upon the growth and yield, although such method varies slightly by the total dosage per ha and soil condition. It must be noted that the nitrogen distribution carries the heaviest weight for improving the plant type among all cultural techniques.

Plant type is readily improved or degraded by whether the nitrogen distribution is rational or not. Furthermore, many other cultural techniques such as the nursery duration, planting density, etc. are also closely affected by the nitrogen distribution. In many cases, each of these individual techniques cannot be successfully applied in actual cultivation without the skillfull nitrogen distribution (See Fig. 9).

From the test data introduced above, it is clear that the concentrated application in the later half of growth period is far more contributory to yield increase than any other nitrogen distribution methods insofar as the Indonesian short-culmed varieties are concerned.

As already described, the first top dressing is intended to cover the shortage of nitrogen applied as basic fertilizer and ensure smooth and uniform growth of paddy. It should therefore be completed, at the latest, by the 14th day after transplanting. Dosage of nitrogen as top dressing should be equivalent to or slightly more than that for basic fertilization. What counts more than dosage is to make sure that the top dressing is completed in time. Delayed top dressing works adversely on the growth as it induces the development of non-effective and weak tillers and disturbance of plant type.

17. Effect and Method of Top Dressing at Panicle Formation Stage

Nitrogen top dressing at panicle formation stage is conducted to ensure the setting of spikelets as well as to prevent their degeneration so that withered grains will be minimized and the ratio of complete grains increased. It is also aimed at satisfactory seed setting, large percentage of ripened grains, and production of large and heavy grains.

Effect of top dressing at this stage is conspicuous in the tropics where the later growth is subject to early deterioration (See Table 29 and Fig. 10).

In the case of "healthy" or nearly healthy type paddy grown smoothly through the first half of growth period (trans-

Table 23 - Distribution of Nitrogen Fertilizer

Area	Total Amount	Basic Fertilizer	First Top Dressing (to be completed by the 15th day after transplanting)	Second Top Dressing (at young planicle formation stage)	Third Top Dressing (to be completed 4~5 days before heading
	Kg	%	%	% %	%
Flat and Fertile Area	200	20	20	60 (50)	(10)
Flat and Fairly Fairly Area	200	20	30	50	-
Intermediate Area	200	20	30	50	-
Mountainous Area	200	30	20	50	-
Infertile Area	200	30	20	40	10
High-yielding Culture	250	20	30	40	10
Long-culmed Varieties	120	30	20	50	-

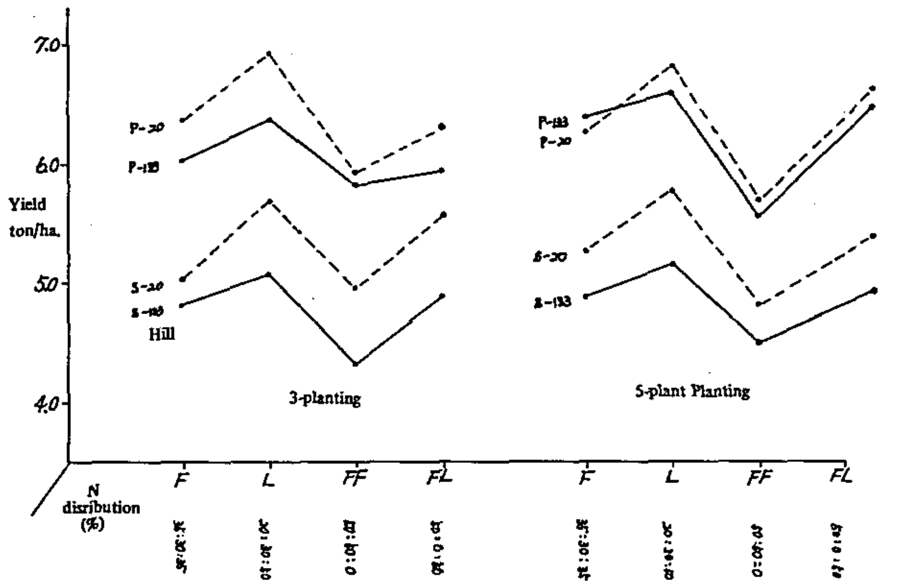
planting to the young panicle formation stage), this ear manuring exhibits a yield increase effect. But no such effect can be expected if the paddy is of "unhealthy type" which has overgrown in the middle stage of growth period. Ear manuring occasionally produces an adverse effect on such paddy as well as local long-culmed varieties whose lower internodes are prone to overgrow.

In order for ear manuring to exhibit its effect fully, it is very important to carry it out at the right time which is the young panicle formation stage (middle spikelet differentation stage when the young panicle length ranges from 0.2 to 1.0 cm) or 24 to 25 days before the heading time. However, if quick-acting fertilizer such as urea and ammonium sulphate is to be used, it is both safe and effective to apply it 4 or 5 days later, i.e., at the late spikelet differentiation stage which takes place 20 to 18 days before heading (young panicle length at this stage ranges from 0.5 to 1.0 cm). The length of young panicle at this stage can be obtained from the nomograph devised by the author (Fig. 13) and Table 32.

In Indonesia, farmers tend to conduct ear manuring too early. If it is conducted at the spike neck differentiation stage which takes place 28 to 33 days before the heading time, the plant type is disturbed by accelerated growth of the lower fourth leaf (B_4) and lower internodes (N_6, N_5 and N_4) and too many secondary rachis branches develop from primary rachis branches, so that sterile grains increase and the percentage of ripened grains drops.

It has been often noted in Indonesia that the nitrogen percentage for basic fertilization and first top dressing is too large or late (25 to 35 days after transplanting). This causes paddy overgrow from the spike neck differentiation stage to the young panicle formation stage. Leaves of such paddy present deep colour. In the case of such "unhealthy paddy", it is advisable to omit ear manuring or conduct it at a later stage at a low dosage.

Fig. 10 - N-distribution and Planting Density under Light Nitrogen Application



Note : P .... Pelita I~1
S .... Syntha

New tillers do not usually develop during the period from the spike neck differentiation stage to the young panicle formation stage because this period coincides with the tillering decrease stage. However, since fertilizers are absorbed quickly in Indonesia, a very low dosage of additional nitrogen application in this period causes the paddy to resume vegetative growth, whereby the development of small and non-effective tillers continues until a late stage. As this is the secondary cause of further disturbance of plant type, it is very important to refrain from premature ear manuring.

The closer the paddy to "healthy type" irrespective of variety, the greater the yield increase effect and contribution to satisfactory later growth that can be expected of nitrogen top dressing at the panicle formation stage (See Fig. 10).

Execution of a cultivation plan which is carefully worked out in advance to take full advantage of top dressing at the panicle formation stage always leads to stabilized yield.

Additional application of nitrogen fertilizer at a low dosage before or after the heading time is called "top dressing for ripened grains". The purpose of this top dressing is to raise the percentage of ripened grains by increasing the rate of complete grains per panicle, enhance thickening growth of grains, and make grains uniform in size and weight and high in quality. It is better that the nitrogen content of grains and leaves is substantially high even after the heading time. Top dressing at this stage is therefore an effective means to increase the percentage of ripened grains.

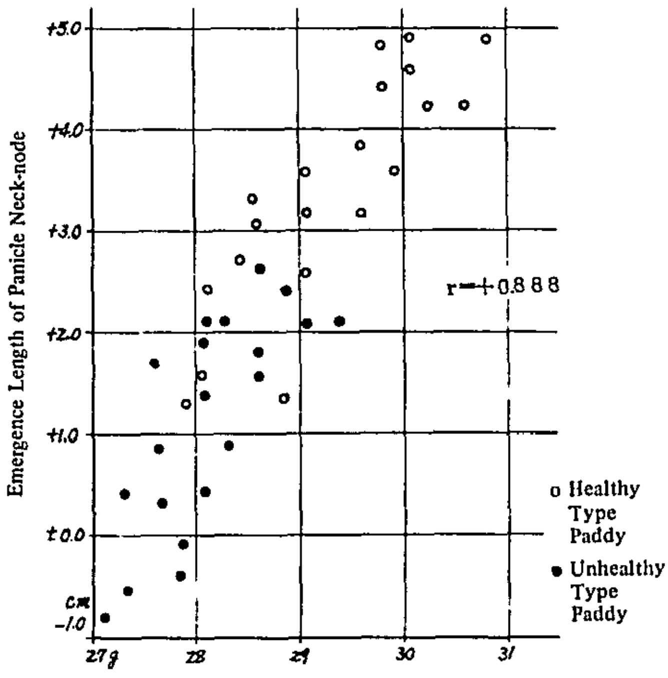
Top dressing at the heading stage is not always effective just as that conducted at the panicle formation stage. Its effect is manifested if the paddy is "healthy type" but weakened if the paddy is "unhealthy". Unhealthy paddy usually have overgrown internodes and its percentage of ripened grains is low. Since the emergence of its panicle neck-node from the flag leaf is poor and its grains are consequently poorly ripened, top dressing at the heading stage does not exhibit any effect.

If quick-acting fertilizer such as urea and ammonium sulphate is to be used, it produces a higher effect by applying 4 to 5 days before heading. In case the split application method is adopted, it is to be applied before and after heading.

Application after heading only produces the supplementary effect of improving the percentage of ripened grains. If applied 4 to 5 days before heading, however, the top dressing enhances the emergence of panicle neck-node and promotes even heading, so that grains thicken and ripen uniformly and their quality improves (See Fig. 11).

Fig. 11 · Emergence Length of Panicle Neck-node and Weight of 1,000 Grains

(Pelita 1-1 1972)



Since top dressing at the heading stage is essentially an auxiliary means of paddy fertilization, it is advisable that its dosage of nitrogen be limited to 20 kg ~ 30 kg/ha.

18. Irrigation and Drainage

Water requirement of paddy varies from stage to stage and is large in the rooting period, booting period and heading and flowering period. In the invalid tillering period and tillering decrease period, paddy does not need much water.

After transplanting, it is prohibitive to keep the water level in the paddy field high or leave the paddy field flooded because this not only causes impeded growth and quicker deterioration of the root but also accelerates the deterioration in the later stage of growth period. Irrigation and drainage therefore calls for prudent care.

In order to prevent planting injury, the water depth in the paddy field should be held at 5 to 6 cm for several days after transplanting until the seedlings take root. During the subsequent valid tillering period, the water depth should be maintained at 2 to 3 cm. In the tropics where the water temperature rises in the daytime and impedes the growth of the root, it is necessary to replace water every 3 or 4 days by intermittent irrigation or to carry out continuous plot-to-plot irrigation.

During the invalid tillering period which lasts from several days before the maximum tillering stage to the young panicle formation stage, water should be drained. This intermediate drainage is not always effective. It proves effective if the paddy field is fertile or ill-drained but no effect can be generally expected if the paddy field is infertile or well-drained.

In order to augment the effect of the mid. drainage, it is very important to select the right time and degree. As regards its degree, intermediate drainage should preferably be conducted rather lightly to the extent that the soil presents blackish colour with small cracks. As for the period, 14 to 20 days is advisable. If the soil surface becomes whitish during this period, running water should be supplied two or three times.

Mid. drainage should be started rather late and continued to a late time. Starting it too early often calls for re-irrigation which could lead to decreased yield.

The purpose of intermediate drainage is to improve the aeration of soil, prevent root rot, enhance the regeneration and health of the root, and adjust the growth so that the paddy will grow into "healthy and high-yielding type". Farmers tend to start this drainage too early to suppress the development of non-productive tillers and are often required to start re-irrigation at an early date. The higher the degree of mid. drainage, the greater becomes the soil fertility and effectiveness of nitrogen and potassium, whereby the paddy resumes active vegetative growth after irrigation is restarted and smooth transfer to reproductive growth is hindered. Early mid drainage conducted to a high degree produces the same result as the early top dressing of nitrogen at the panicle formation stage, i.e., disturbance of paddy shape, decline of seeding rate, and decrease of yield (See Table 24). This is why lodging is observed after mid drainage.

Table 24 - Test on Mid. Drainage Period (Pelita 1–2)

Drainage Period (lapse of days after seeding)	Number of Later Emerging Tillers	Number of Panicles per Hill	Per Panicle		Complete Grains 1,000 g	t/ha	
			Complete Grains	Sterile and Withered Grains		Complete Grains	Withered and Sterile Grains
a 56 days~ 66 days	2.9	16.9	77.3	35.1	29.9	5.38	0.64
b 61 ~ 71	2.8	18.1	77.2	37.1	30.2	5.36	0.62
c 66 ~ 76	2.3	17.4	75.3	34.8	29.8	5.44	0.63
d 71 ~ 81	2.2	17.6	75.1	32.5	29.8	5.68	0.57
e Constantly Flooded - 5.0 cm Depth	3.7	17.6	73.6	37.9	30.0	5.55	0.64

Notes: By LP–3, 1972 dry season.

It is not necessary to restart irrigation to keep the paddy field flooded from several days before the young panicle formation stage. Re-irrigation after mid. drainage can be made both effective and safe if water is supplied gradually to a shallow depth just before applying top dressing at panicle formation stage.

19. Harvesting (Reaping)

Duration of the period from the heading time (the day when the heading of about 40% of all panicles in a field is completed) to the maturation (ripening) stage is virtually free from fluctuation in Indonesia for all varieties because the atmospheric temperature and sunshine are stabilized during that period. Generally, it lasts 30 days for dry season cropping and 31 to 32 days for wet season cropping, and this duration is subject to little or no change for both short-culmed varieties and local long-culmed varieties.

However, it must be noted that the whole growth period from seeding to reaping or the growth period in the paddy field which lasts from transplanting to reaping varies by variety, area and cropping season. These two periods are subject to a wide variation depending on the cultural method and nursery duration of respective varieties. It is therefore necessary to know the accurate heading time before determining the reaping day.

Reaping tends to be delayed and often conducted in the deadripe stage in Indonesia. As described already, Indonesian varieties are featured by the fact that their growth tends to be deteriorated in the later stage of growth period, specially in the ripening stage, and that the yellow-ripe stage which is the optimum reaping time is very short due to the rapid maturation. Therefore, if reaping is delayed, deterioration is accelerated to decrease the weight of 1,000 grains, number of cracked grains increases, and grains become liable to drop off, which all lead to decreased yield.

Table 26 shows the correction factors to be applied to fresh grains harvested by early and late cutting.

It is advisable to conduct reaping from the beginning to middle of yellow-ripe stage when the lower part of rachis and the lower first primary rachis branch still retain some greenish colour (See Table 25).

Table 25 - Optimum Reaping Time Estimated from Transplanting Time (Growth Period in Paddy Field)

Cropping Season	Variety \ Nursery Duration	15 days	20	25	30	35	40
Dry Season Cropping	Pelita 1-1	115th day	111	107	103	100	98
	PB - 5	117	113	109	105	102	100
	Syntha	120	115	111	107	103	101
Wet Season Cropping	Pelita 1-1	122	117	112	108	104	101
	PB - 5	126	126	116	110	106	103
	Syntha	130	124	118	113	108	105

Notes:
1. A margin of ± 1 day may be allowed for each figure figure for practical purpose.
2. All figures are based on the standard cultural pattern (urea 200 kg/ha, 16.0 hills/m^2). Therefore, the reaping day should be delayed or expedited by 1.0 day for increase or decrease of each 4 hills/m^2 and each 50 kg/ha of urea.
3. The growth period in the paddy field varies by variety and district. It is therefore recommended that a similar table meeting the conditions of each district be prepared.
4. Number of days from transplanting to heading time can be obtained by deducting 30 from the figures shown.

Table 26 - Correction Factor of Weight of Fresh Grains (kg)
(Applicable to All Varieties)

Number of Days Before and After Optimum Reaping Day	1 day	2	3	4	5	6	7	8
Before Optimum Time (Early Reaping) – %	±0%	–2	–4	–6	–6	–4	–2	0
After Optimum Time (Late Reaping) + %	±0%	+2	+4	+6	+8	+10	+12	+15

Notes: 1. The correction factors can be applied to all varieties and districts.
2. Revision will be effected later to fill the minor gap between short-culmed varieties and long-culmed varieties.

20. Lodging of Paddy

Lodging of paddy has not presented any serious problem in Indonesia because the dosage of fertilizer application per unit area is still limited and the recommended varieties are of the short-culmed many tillering type. It is probable, however, that lodging of paddy will be increasingly observed as fertilizers will be applied at heavier dosages and yield target will be raised in future. The following table shows the causes of lodging arranged in the order of the degree of their influence.

Cause	Degree of Influence (100%)	Countermeasure
1. Long-culmed, heavy panicle type varieties.	70%	Extension of short-culmed many tillering type varieties.
2. Heavy dosage of nitrogen application.	70	Optimum dosage of nitrogen application.
3. Delayed first top dressing of nitrogen fertilizer after transplanting.	80	Completion of first top dressing of nitrogen by the 15th day after transplanting.
4. Too early ear m manuring.	85	Ear manuring to be conducted 20 to 17 days before heading time.
5. Deep flooding of paddy field.	60	Intermittent irrigation to keep water depth shallow.
6. Mid. drainge is omitted or conducted in an inadequate way.	65	Late starting of mid. drainage and late re-irrigation.
7. Excessive growth in the middle stage of growth period.	70	Adoption of concentrated nitrogen application in the latter half of growth period.
8. Use of overgrown and lean seedlings.	55	Use of healthy seedlings.
9. Use of young seedlings	40	Use of matured and healthy seedlings.
10. Deep planting.	45	Adoption of shallow planting.
11. Extreme thin or thick planting.	35	Setting the number of planted hills at $16.0 \sim 26.0/m^2$.
12. Shortage of phosphoric acid and potassium.	30	Balanced application of three fertilizer elements.
13. Diseases and insects (sclerotial disease, sheath blight, etc.).	60	Disease and insects control.
14. Irrational setting up of cultural system.	50	Establishing of rational cultural system.

Of all the causes listed above, the following three are known to be most responsible for lodging.

1) Dosage and distribution of nitrogen fertilizer.
2) Water management.
3) Seedling characters.

Paddy of any variety (including short-culmed variety) is liable to lodging if its plant height is too long, leaves present deep colour and spread, and leaf apex tends to droop in the tillering decrease stage during the middle growth period. Since paddy presenting such type is increasing in Indonesia with the increasing input of fertilizers, special care must be exercised in future.

It is generally believed that paddy is liable to lodging if its culm grows to excess and has large and heavy panicles in the later stage of growth period. This, however, is completely wrong. Actually, paddy of this type is resistant against lodging and exhibits high-yielding capacity.

Lodging is caused not by the mere apparent culm height or the size and weight of panicle, but it is closely related with the plant type. (See Table 10 and 34)

Any paddy which has been grown into "unhealthy type" by the middle stage of growth period is liable to lodging if its culm becomes higher in the later stage of growth period, but panicles of such paddy are usually short and light.

Good yield cannot be expected of such paddy even if it is not lodged. In contrast to such paddy, "healthy paddy" has light coloured leaves growing upright. In the middle stage of growth period, healthy paddy has the just right plant height, hard leaves and its growth is well controlled. Since its internodes are short and thick, growth of its culm and panicles in the later stage hardly makes it liable to lodging.

In brief, lodging is caused not by the plant height or culm length but solely by the length and stoutness of lower internodes.

Optimum length of lower internodes (N_4, N_5 and N_6) is 10 to 12 cm for Pelita 1-1 and PB-5, 7 to 8 cm for C_4, a short culmed variety, and 13 to 15 cm for Syntha, a long-culmed variety.

If the internode length becomes longer than these optimum values, fertility declines and liability to lodging increases even if the variety is short-culmed. If again, the internode length is too short (5~6 cm), it indicates poor growth in the early stage which inevitably leads to poor yield. Lodging can be prevented only by the constant effort to grow the paddy into "healthy type". Once the skill in growing healthy paddy is acquired, lodging decreases spontaneously and yield increases.

Degree of loding can be expressed by the lodging index shown in Table 27. As will be clear from the equation shown in this table, large denominator (large lower internode weight, specially large weight of the fourth internode per unit length), reduces the lodging index and provides a high lodging resistance even if the numerator is large (i.e., upper internode length is long and panicle is large and heavy).

Table 27 - Lodging Index

$$\text{Lodging index} = \frac{\text{Upper internode length (cm)} \times \text{Upper internode weight (g)} + \text{Panicle weight (g)}}{\text{4th internode weight (g/cm)} + \text{5th internode weight (g/cm)}}$$

$$= \frac{(N_1 + N_2)\ \text{cm} \times (N_1{}^{g} + N_2{}^{g} + P^{g})}{N_4{}^{g}/\text{cm} + N_5{}^{g}/\text{cm}}$$

Example of Calculation:

$$\text{Lodging index} = \frac{(34\ \text{cm} + 24\ \text{cm}) \times (1.0\ \text{g} + 2.4\ \text{g} + 2.8\ \text{g})}{3.0\ \text{g}/15\ \text{cm} + 4.2\ \text{g}/3\ \text{cm}}$$

$$= \frac{359.6}{1.6} = 224$$

21. Seed Setting Rate and Percentage of Ripened Grains

Yield increase calls for fulfillment of three conditions, i.e., large number of vigorous effective panicles per unit area, high seed setting rate and high percentage of ripened grains, and large weight of 1,000 hulled grains.

In the case of recommended short-culmed many tillering type varieties, the required number of effective (and not necessarily vigorous) panicles can be secured with relative ease, but their seed setting rate and percentage of ripened grains are low and the weight of 1,000 hulled grains is small and in addition, these minus factors are subject to a large variation by area and variety. Pelita 1-1 has recently been noted to sustain higher sterility than other varieties in West and Central Java, but the cause is not made clear yet. High sterility is caused by either of the following two reasons. First, the inherent physiological characteristics of the variety in question. Second, susceptibility to various morphological variations incurred by difference in the surrounding environmental condition and cultral condition.

If sterility is caused by the first reason, breeding is the only remedial means. However, it can be reduced by improvement of cultural condition if the morphological variration is the dominant cause.

The following are the major factors affecting the degree of sterility (which is directly related to the seed setting rate and percentage of ripened grains).

(1) Plant type during the middle growth period from the invalid tillering stage to the tillering decrease stage.
(2) Relationship between the nutritive condition and the climatic condition in the reduction division stage which takes place 15 to 7 days before heading.
(3) Nutritive and climatic conditions observed 5 to 6 days before or after the heading and flowering stage.

(4) Nutritive condition and climatic condition (specially temperature difference between days and nights and intensity of sunshine) during the ripening period which lasts about 20 days.

The seed setting rate is affected by the first three factors in the order of (1) > (2) > (3), whereas the percentage of ripened grains is influenced by the last three factors in the order of (4) > (3) > (2).

The plant type in the middle stage of growth period (which lasts from the invalid tillering stage to the tillering decrease stage) is the decisive factor that determines the crop condition in the subsequent stages. If growth is simulated to excess by too heavy a dosage of nitrogen application in this stage, it causes development of too many weak and small tillers, overgrowth of the lower fourth leaf, increase of secondary rachis branches, and greater ratio of poor quality grains in the inner and lower parts of panicle (See Table 10). This is the primary cause of high sterility rate. Whether the paddy is prone to overgrow into "unhealthy type" in the middle stage of growth period depends on the variety too. If paddy is grown under undesirable cultural condition such as excessive application of nitrogen basic fertilizer, excessively thin planting with young seedlings, delayed or excessive application of first top dressing, or constant flooding of paddy field at a large depth, its plant type is liable to vary to an extreme extent by variety. Many tillering type varieties like Pelita 1-1 which are more susceptible than other varieties to morphological variation due to the change in cultural condition are particularly prone to develop this tendency. Note must be taken of the fact that this tendency becomes more pronounced with the increase of fertilizer application.

If the paddy suffers malnutrition due to shortage of fertilizer or is subjected to drought injury, continued bad weather or deficient sunshine during the reduction division stage, growth of spikelets is hindered or completely stopped, giving rise to increase of degenerated grains. This is the second cause of high sterility.

If, again, the paddy is subjected to continued high temperature, rain, or shortage of sunshine during the heading and flowering period, spikelets with poor fertilization ability are not fertilized and tend to become sterile. This is the third cause of high sterility.

The percentage of ripened grains is expressed by the ratio of weight of complete grains (with a specific gravity of more than 1.06) to the total weight of grains per panicle or hill. In order to raise this percentage, the following conditions must be satisfied.

(1) Climatic condition is satisfactory, emergence of panicle neck-node is excellent, and heading is even during the heading and flowering period.

(2) Temperature difference between days and night is large, sunshine hours is long, and nutritive condition of paddy is good in the ripening period.

As described already, Indonesian short-culmed varieties are forced to present a growth pattern featured by degeneration of late growth because climate, location and cultural condition all work as minus factors in filling these conditions specially in flat areas.

In view of such unfavourable ripening condition, it is of great importance for future improvement of Indonesian rice culture to break out of the traditional cultural practices in which increase of panicles is given utmost attention and to establish a new cultural method in which emphasis will be placed on satisfactory late growth to mitigate depression in the late growth stage and increase the percentage of ripened grains and weight of 1,000 grains.

22. Combination of Cultural Techniques

In paddy cultivation, it is the common knowledge that cultural techniques do not always promise increased yield no matter how superlative they may be when examined individually. On the other hand, it is often noted that a technique which is generally regarded as being a negative element plays an active role in increasing the yield.

This is because the yield is brought about not by the accumulative effect of a single technique but by the integrated and overall effect of mutual restraint and interaction of all the techniques applied. Yield is also closely affected by the Plant type as already discussed. In this sense, "combination of cultural techniques" may be defined as the "organic and rational combination of individual techniques for the purpose of growing paddy into ideal or nearly ideal 'healthy and high-yielding type' ".

Each individual technique incorporated into the cultural system plays its own role in improving the plant type by interaction with (or under mutual restraint or) other related techniques, and the role it plays varies in degree according to the cultural environment and condition and how to construct a cultural system. Hence, there can be conceived many combinations of techniques whose roles differ from each other in degree. For instance, there may be a case where technique A plays a leading role in improving the plant type, but technique B only assists technique A, and technique C works as a minus factor in improving the plant type.

Any technique, no matter how suplerative, does not ensure yield increase if it is irrationally combined with other related techniques or embodies any minus factor because this makes it impossible for the said technique to display its effect on the improvement of plant type. Conversely, even if a technique generally considered to act as a minus element often

Table 28 - Number of Effective Panicles Required to Attain Yield Target

Yield Target (Kg/ha of fresh grains)	(a) Yield kg/m^2	(b) Weight of 1,000 Grains	(c)= $\frac{c}{a}$ Number of Complete Grains	(d) Percentage of Ripened Grains	(e)= $\frac{c}{d}$ Required Number of Spikelets	(f) Number of Spikelets per Panicle	(g)= $\frac{e}{f}$ Number of Effective Panicles	(h) Number of Planted Hills	(i)= $\frac{g}{h}$ Number of Panicles per Hill
t	Kg	g		%	(m^2)		(m^2)	(m^2)	
10	1.0	28.2	35.500	82	43,500	115	380	22.2	17.1
8	0.8	27.6	29.000	80	36,500	118	310	20.0	15.5
6	0.6	27.2	22.000	76	30,000	120	250	16.7	15.0

serves for yield increase because it could impose reasonable restraint on other related techniques depending on how all the techniques are combined.

Combination of cultural (technical) system produces little effect and need not produce any effect under light fertilization condition or if the yield production techniques are low. As the yield target is raised, however, rational combination of techniques becomes more essential and its effect becomes correspondingly higher.

While there are many traditional techniques which, when viewed individually, are appraréntly minus factors (such as thick sowing and deep planting), they have been skillfully employed by the farmers according to the environmental condition of respective areas through many years of their experience and have been incorporated in the traditional cultural practices. This could be considered a sort of combination of cultural (technical) system in the passive sense.

However, once any advanced technique is introduced and extended, it is almost sure to conflict with the corresponding single technique incorporated in the rraditional cultural practices. Such conflict arises from the lack of an unbiassed judgement on the effect of techniques. Trouble of this kind is caused, on the one hand, by the stress placed to excess on the plus effect of the introduced new single technique and on the minus effect the same technique would produce in the traditional cultural practices and on the other hand, by the preoccupied idea that such a new technique has a universal plus effect which is not true. Effect of any new technique is produced as a result of its interaction with other related techniques in the cultural system in which it is incorporated.

The discussion advanced above is substantiated by the examples shown in the following table.

	Effect of Independent Application of Single Technique		Effect Produced in Combined Cultural System	
(1)	Shallow Planting ++	Deep Planting –	Shallow Planting ++	Deep Planting +
(2)	Thick Planting +	Thin Planting –	Thick Planting +++	Thin Planting +
(3)	Young Seedling +	Matured Seedling +	Young Seedling –	Matured Seedling ++
(4)	Heavy Dosage of Basic Nitrogen Fertilizer +	Light Dosage of Basic Nitrogen Fertilizer –	Heavy Dosage of Basic Nitrogen Fertilizer ––	Light Dosage of Basic Nitrogen Fertilizer ++
(5)	Thin Sown Seedling +	Thick Sown Seedling ––	Thin Sown Seedling –	Thick Sown Seedling –+

Notes: + and – symbols indicate the degree of effect produced.

In extending cultural techniques, it is necessary to make a fair evaluation of both plus and minus effects of each individual technique and to exercise a prudent care when incorporating them into the cultural system so that their effect may be fully taken advantage of. This is an imperative because there is no new technique whose independent application results in 10 or 20% yield increase and also a new technique contributes to yield increase only when it is rationally incoporated in the cultural system.

Combination of Cultural System: (Short- and Long-culmed Varieties)

Since the effect of cultural techniques increases as the yield target becomes higher,combination of cultural system is of utmost importance.

Shown below is an example of cultural system intended to attain a yield of 9.0~10.0 t/ha of fresh grains for short-culmed varieties and a yield of 6.5~7.5 t/ha of fresh grains for long-culmed varieties.

Example of Cultural System

	(Short-culmed Variety)	(Long-culmed Variety)
1. Soil fertility		

Example of Cultural System

	(Short-culmed Variety)	(Long-culmed Variety)
1. Soil fertility	Fairly fertile.	Fairly fertile.
2. Area	Intermediate area.	Intermediate area.
3. Yield target	9.0~10.0 t/ha.	6.5~7.5 t/ha.
4. Variety	Pelita 1-1 or PB-5.	Syntha or Sentral.
5. Raising of seedling		
Seedling rate	70 g/m^2 of dry seeds.	70 g/m^2 of dry seeds.
Seedling rate	80 %.	80 %.
Number of matured seedlings	2,000/m^2.	2,000/m^2.
Required seed bed area	350 m^2/ha.	350 m^2/ha.
Seed quantity	24.5 kg/ha.	24.5 kg/ha.
Nitrogen quantity for application in nursery (urea)	8~10 g/m^2.	5~7 g/m^2.
Nursery duration	25~27 days.	30~35 days.
Leaf age	5.5 L ~ 5.8 L	6.0 L ~ 6.5 L
Plant height	25.0~27.0 cm.	30.0~35.0 cm.
6. Paddy field planting density	30 cm x 15 cm = 22.2 hills/m^2	25 cm x 20 cm = 20.0 hills/m^2.
Number of seedlings planted	3-plant planting.	3~4-plant planting.
7. Planting depth	3.0 cm.	3.0~4.0 cm.

8. Fertilizer		
Amount of application		
Urea	200~250 kg/ha.	120~150 kg/ha.
TSP	120~150 kg/ha.	80~100 kg/ha.
Nitrogendistribution ratio	{20% : 30% : 50% 25% : 25% : 50%	{30% : 30% : 40% 20% : 30% : 50%
Time of nitrogen top dressing		
1st	By 15th day after transplanting.	By 20th day after transplanting.
2nd	20~17 days before heading.	20~17 days before heading.
9. Water management	Intermittent irrigation every 3~4 days, with water depth kept shallow.	Intermittent irrigation every 3~4 days, with water depth kept shallow.
Mid-drainage	About 2 weeks during the period from maximum tillering stage to young panicle formation stage, (45~60 days after transplanting).	About 2 weeks during the period from maximum tillering stage to young panicle formation stage, (50~65 days after transplanting).
10. Reaping	30 days after heading time.	30 days after heading time.
Characteristics of Cultural System	1. Matured seedlings of small type.	1. Matured seedlings with optimum plant height.
	2. Small hill, thick planting, and shallow planting.	2. Medium size hill, thick planting, and shallow planting.
	3. Slightly heavy dosage for split application, with concentrated nitrogen application in the latter half of growth period.	3. Medium dosage for split application, with concentrated nitrogen application in the latter half of growth period.
	4. Growth control by mid-drainage.	4. Control of overgrowth of lower internodes by mid-drainage.

Notes: 1. Amount of nitrogen application in nursery is to be decreased in flat and fertile areas, and percentage of nitrogen basic fertilizer is to be limited in paddy field.

2. In mountainous and infertile areas, amount of nitrogen application in nursery and rate of nitrogen basic fertilizer in paddy field is to be increased, with nursery duration also somewhat extended.

3. If seedlings grow over 25 cm long at the transplanting time, they should be shortened to 25 cm long for being planted.

23. Judgement of Yield Increase Effect of a Cultural Technique

In the experimental cultivation of paddy, it is the common practice to judge the yield increase effect of any single technique on the basis of the significant difference between the yield of the experimental plot and that of the standard plot. It is to be noted, however, that there is marked tendency to arrive at the conclusion that the applied technique has the yield increase effect only when siginificant difference is detected. In order to pass a correst judgement on the results of any experiment dealing with living things, specially paddy, test of significance along does not suffice.

The test must be preceded by careful study of the results of experiment. In other words, it is necessary to determine if the values produced are consistent and comform with the purpose of the experiment and to check if the values themselves are accurate and reliable. This is necessary because assessment of techniques based only on yield comparison often leads to an entirely wrong conclusion.

When any new technique is introduced, careful attention must be paid to what changes it has brought about to the shape and type of paddy during the middle stage and maturation stage of growth period.

Some methods for judging the yield increase effect of a new technique are introduced below.

1) Attention should be directed to the growth condition and characteristics of the paddy in the "standard plot" provided for the purpose of comparison and control.

In order to pass a correct and unwarped judgement on the result of experiment, it is required to check if the values obtained from the standard plot represent the smooth and normal growth of paddy. It has often been the case that conclusion is reached by comparing such values with those of the experiment without any regard to the growth condition and shape of paddy in the standard plot. Even in case the experiment is conducted under the same cultural condition as applied to the standard plot, its results are not trustworthy if disturbance of plant type is liable to occur in the standard plot. In such a case, the yield increase effect is apt to be overrated.

Let us examine the experimental results shown in Table 29. A glance at the column of yield suffices to tell that the yield of the circulating irrigation plot is larger (by 27%) than that of the standard plot, so that the yield increase effect is conspicuous. But is this conclusion correct?

Then, let us take a closer look at the plant type in the standard plot. It is clear that the paddy in this plot was grown into "unhealthy type" with overgrown lower internodes and too long leaf blades. In addition, its percentage of ripened grains is very low and lodging degree is high. It is essentially a mistake to adopt such a standard plot for comparison with the experimental farm. It is therefore reasonable in this case to conclude that the experimental results shown in the table are not reliable.

Table 29 - Judgement of Effect of Circulating Irrigation

(1965) in Japan.

Irrigation Method	Yield		Percentage of Ripend Grains	Number of Panicles per m^2	Number of Grains per Panicle	Culm Length	Internode Length		Leaf Blade Length			Degree of Lodging
	Kg/10a	%					Upper	Lower	B_1	B_2	B_3	
			%			cm	cm	cm	cm			
Circulating Irrigation (Experimental)	589	127	96	312	81	92	58.7	16.4	33.8	45.7	48.5	0
Standard plot	463	100	70	335	92	98	56.9	22.5	34.4	49.8	53.2	IV

2) Account must be always taken of the effect exerted on the growth by other techniques then the ones to be tested.

Effect of the tested new technique is prone to be offset and not fully exhibited if any other techniques more capable of improving the plant type are incorporated in the cultural system. In such a case, one is apt to be confused by the yield into thinking that the tested technique has no effect at all, as will be well understood from Fig. 9.

Fig. 9 shows the results of a planting density experiment. If attention is given only to F plot (where nitrogen was applied concentrically in the first half of growth period), one would note that the thick planting employed in these conditions (20.0~26.7 hills/m^2 as against 16.7 hills/m^2 in the standard plot) produced no particular yield increase effect. Conclusion drawn only from this result would be that the dense planting has no yield increase effect, but this involves an unconscious technical mistake because a marked yield increase was achieved for both wet and dry season croppings in L plot where the fertilization method was varied to concentrated nitrogen application in the latter and not first half of growth period.

In F plot, the concentrated nitrogen application in the first half of growth period gave rise to overgrowth from the early to the middle stage of growth period and disturbance of plant type. In other words, the effect of thick planting was offset or decreased due to the fact that the plant type disturbing factor (a minus factor) was greater than the said effect.

In L farm, on the other hand, smooth growth was ensured and the effect of thick planting was exhibited fully because no such minus factor was included among the other techniques incorporated in the cultural system.

3) It must be noted that the yield increase effect of the tested technique is affected by whether other related techniques are applied rationally as supplementary yield increase means.

Even if any single technique is applied and incorporated in the cultural system according to the plan drawn up in advance, its yield increase effect is prone to be poorly manifested if other supplementary techniques are not applied in a proper way.

For example, yield increase by thick planting calls for the application of such other techniques as the use of healthy and matured seedlings in addition to the aforementioned nitrogen application techniques. Young seedlings are prone to lead to overgrowth and relatively smaller yield increase effect specially if nitrogen basic fertilizer is applied at a heavy dosage.

Decreasing the number of plants per hill is also effective as a supplementary means of increasing the yield by thick planting. A large number of plants per hill accelerates the disturbance of plant type and produces a low yield increase effect.

Note must also be taken of the fact that nitrogen application at the panicle formation stage does not always promise a high yield irrespective of season and variety. It displays a high yield increase effect only if it is conducted at the right time on healthy type paddy. The yield, however, could decline if the paddy is unhealthy type. The effect of nitrogen application at the panicle formation stage is thus influenced by whether the growth control technique is applied skillfully as a supplementary means to make the plant type "healthy".

24. Effect of Cultural Assembly Techniques under Low Dosage of Fertilizer Application (Long-culmed Varieties Inclusive)

Small dosage of nitrogen application usually works as a minus factor which makes a single technique hard to exhibit its yield increase effect. As will be clear from Table 30 and Fig. 10, the yield difference between respective plot is small if thin planting (13.3 hills/m^2) is employed and overgrowth in the

Table 30 - Relation between N-distribution and Planting Method under Light Nitrogen Application

(1 973)

Variety	N-distribution (Percentage of Basic Fertilizer : Percentage of First Top Dressing : Percentage of Second Top Dressing) \ Number of Plants per Hill \ Number of Hills per M²	Thin Planting (12.3 Hills/m²) 3-plant Planting t/ha	%	Thin Planting (12.3 Hills/m²) 5-plant Planting t/ha	%	Thick Planting (20.0 Hills/m²) 3-plant Planting t/ha	%	Thick Planting (20.0 Hills/m²) 5-plant Planting t/ha	%
Pelita 1-1	F 35 : 30 : 35	6.02	100	6.38	106	6.36	106	6.30	105
	L 20 : 20 : 50	6.33	105	6.58	110	6.90	115	6.80	112
	FF 50 : 50 : 0	5.80	96	5.56	92	5.91	98	5.67	94
	FL 50 : 0 : 50	5.94	99	6.50	108	6.26	104	6.62	110
Syntha	F 35 : 30 : 35	4.80	100	4.89	102	5.04	105	5.28	110
	L 20 : 30 : 50	5.08	106	5.17	108	5.70	109	5.82	121
	FF 50 : 50 : 0	4.34	90	4.51	94	4.96	103	4.78	100
	FL 50 : 0 : 50	4.89	102	4.93	103	5.60	117	5.40	113

Notes: Amount of fertilizer per unit area by variety.
Pelita 1-1 - 120 kg/ha of urea.
Syntha - 100 kg/ha of urea.

Table 31 - Effect of Cultural System of Long-culmed Varieties

(Sentral, 1973)

Number of Planted Hills / Number of Plants per hill / Nursery Duration and Planting Depth		16.0 Hills/m²				20.0 Hills/m²			
		3-plant Planting		5-plant Planting		3-plant Planting		5-plant Planting	
		Yield	Ratio	Yield	Ratio	Yield	Ratio	Yield	Ratio
		t	%	t	%	t	%	t	%
22-days Old Seedlings	3.0 cm	4.70	100	4.80	102	5.60	119	5.06	107
	6.0	5.01	106	4.82	103	5.54	117	5.32	113
32-days Old Seedlings	3.0	4.86	103	4.98	105	5.72	122	5.39	114
	6.0	4.96	105	4.78	102	5.80	123	5.55	118

Notes: 1. Amount of nitrogen application - 120 kg/ha of urea.
2. Nitrogen distribution - 30% : 30% : 40/.

early stage is liable to occur, while, thick planting for controlling the early to middle stage growth (20.0 hills/m^2) produces a considerablly big yield difference between plots for both short- and long-culmed varieties if assisted by heavy dosage (50%) of nitrogen application at the panicle formation stage, and by three-plant or five-plant planting method, the yield difference is negligible even if the number of planted hills or the nitrogen distribution method is varied. It follows, therefore, that the high yield increase effect obtained by the experimental cultural system incorporating low dosage of nitrogen application is an outcome of the interaction of effect is not clearly manifested by individual techniques such as nursery duration, planting depth, and number of plants per hill under the thin planting condition (16.0 hills/m^2) which is liable to lead to unsatisfactory plant type. It is also clear that the yield difference between plots is extremely small, and this can be explained by the liability to distrubed plant type of each hill due to thin planting.

Thick planting (20.0 hills/m^2) is apprarently more conductive to yield increase than thin planting, and matured seedlings (32-day old) also produce a higher yield increase effect than young ones (22-day old) in thick planting. As regards the planting depth of long-culmed varieties, however, virtually no yield difference can be observed between shallow planting and deep planting. This is because the plant type of long-culmed varieties is less influenced than short-culmed varieties by the planting depth. To be more precise, long-culmed varieties have a large plant height and panicles but an extremely small tillering ability, so that their yield is affected more by the main culm and number of primary tillers than by the number of tilled culms.

The following are the desirable techniques to be incorporated in the cultural system of long-culmed varieties.

(1) Planting of matured seedlings after a nursery duration of 30 to 35 days.

(2) Thick and rectangular planting at a rate of 20 to 22 hills per hill.
(3) Slightly greater dosage in the first half than in the latter half of growth period for split application of nitrogen.
(4) Control of middle stage overgrowth and enhancement of later growth for improvement of plant type.

Application of such cultural techniques as thin planting, use of young seedlings and concentrated nitrogen application in the first falf of growth period is not recommendable in long-culmed varieties and generally leads to a low yield because it gives rise to a large plant height and culm length.

III. METHOD OF SURVEY AND EXPERIMENT

25. Survey of Internode Length and Leaf Blade Length (Simple Method Resorting to Average Panicle Length)

In order to grasp the plant type on the basis of the internode length and leaf blade length, a suitable method must be adopted for sampling and survey. In this context, the method introduced below is commendable as being both simple and reliable.

1) Sampling of typical hills for survey

Ordinary quadrant sampling method is to be employed. In other words, two to three sampling places where the paddy shows the average growth condition should be selected for each experimental plot. Then, the growth condition should be examined by the culm length and number of panicles of 20 to 30 hills in each of the places thus selected without pulling out any hills. This should be followed by the careful pulling out of two to three hills representing the average or nearly average growth condition in each place. Thus, a total of six hills are to be sampled together with the root from each experimental plot. If the culm length and the number of panicles does not coincides with the average value, the latter should be given priority in selecting the typical hill.

2) Time of Survey

The six hills sampled in the yellow-ripe stage (seveal days before reaping) should be dried for several hours after washing their roots, thereafter keepting them in the room and taking them out whenever the survey is to be made. However, if the internode weight and panicle weight are to measured in time with the length measurement, the samples should be subjected to comlete air-drying in advance.

3) Method of Survey

At first, the "late-emerging panicles (panicle length or culm length is smaller than 70% of those of the longer culm in each hill)" should be sorted out and rejected. Then, the panicle length is to be measured for all the remaining panicles including those of the main culm, and a total of five culms (30 individuals for each plot) whose panicle length is close to the average value of each hill are to be selected for measurement of the internode length, leaf blade length, emergence length of panicle neck-node and other characters of all culms.

The average values of the sampled individuals (30 per plot) may be taken as the values representing the respective characters in each plot.

As can be seen in Annexed Table, the characteristic values obtained by the average panicle length method show a close approximation to those obtained by the measurement of all culms and panicles of a hill, although the number of individuals is small. Hence, the method is not only simple but also reliable, and moreover meets the practical purpose because it produces no significant error when actually applied for measurement of 20 individuals sampled from four hills in each plot. What counts most in employing this method is to sample respresentative hills correctly from each plot.

26. Leaf Age and Leaf Age Index

Seedlings suited to transplanting are often called by the leaf age, e.g., 5.1 L for 20-day old seedlings and 5.7 L for 25-day old ones. However, there are many cases where the seedlings are called incorrectly due to the lack of knowledge about the method of counting the leaf age.

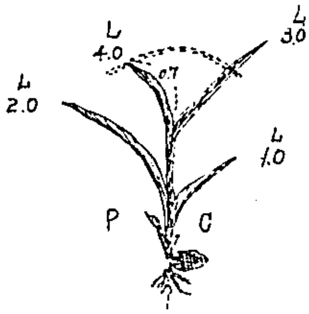
The first and tubular leaf shooting after germination is called coleoptile (C) (See Fig. 12). This is eventually ensued by the emergence of the incomplete leaf (P). It requires a period of 3.5 to 4.0 days after seeding for the first true leaf 1.0 L to emerge. Since an accumulated temperature of 120°C is required for each additional leaf to emerge in nursery, it may be said that leaves of seedlings emerge at a rate of 1 per 4 days in flat areas of Indonesia.

1) Counting of Seedling Age

A number of seedlings are to be pulled out together with the root in the middle stage of nursery period or on the day of transplanting, and seedling age is to be checked only for those seedlings retaining the original and complete external form of seed. Since the true leaves developing on the same side of the seed are given odd numbers (See Fig. 12), it is possible to obtain the correct leaf age by counting the number of leaves successively upward with the lowermost first true leaf taken as 1.0 L. The uppermost new leaf can be judged in comparison with the length of the leaf immediately below. Thus, the seedling shown in Fig. 12 has a leaf (a seedling age) age of 3.7 L.

2) Leaf Age Index and Leaf-emerging Time

Fig. 12 Seedling at leaf Age of 3.7 L



The "leaf-emerging time" and the "leaf age index" serve as most reliable criteria for judging the growth condition in the paddy field.

By the "leaf-emerging time" of a new leaf is meant the date on which the said new leaf starts emerging between the leaves immediately below.

The "leaf age index", on the other hand, indicates the ratio of the number of main culm leaves counted at the time of survey to that inherent to the variety. The number of main culm leaves (main culm internodes) is generally fixed for each variety and rarely changes due to the variation of the surrounding environmental condition (but the number of tilled culm internodes varies by the emerging positions in a hill and is susceptible to variation).

The number of main culm leaves ranges from 17 to 16 for short-culmed varieties such as Pelita I-1 and PB-5, and from 18 to 17 for long-culmed varieties like Syntha and Sentral.

If Pelita 1-1 is planted at a seedling age of 5.2 L (i.e., when the seedling is 20-day old), the leaf age index will be 76.2 (= 12 ÷ 16 x 100) at the time when the number of main culm leaves reaches 12.2 L (which is the turning pint of leaf emergence rate shown in Table 6). In the similar way, the leaf age index at the young paincle formation stage when the young paincle has a length of 2 mm is 90.

As a means to obtain the leaf age index correctly, four or five seedlings with medium and average growth condition are picked up as the samples in each experimental plot, and one of their true leaves, either 3.0 L or 5.0 L, is marked with red or yellow enamel before transplanting. Each of the seedlings thus marked is to be distributed to each four to five hills for 3-plant planting with other two seedlings. After planting, newly emerging odd-number leaves should be marked at least every 5 to 7 days until the flag leaf emerges. This can prevent the miscounting of the main culm leaf number during the growth period and serves to obtain the correct leaf age index at any desired time.

27. Estimation of Young Paincle Length

As described already, nitrogen application at the panicle formation stage produces a higher effect if conducted at the "spikelet differentiation end stage" which is little later than the time hitherto considered optimum. The spikelet diffieren-tiation occurs 20 to 18 days before heading time when the young panicle has a length of about 0.5~1.0 cm.

Method A: Method resorting to the measurement of the length of young panicle of main culm

In this method, the main culms or another equivalent culms in size in the hill of average growth condition are pulled out carefully from the ground every 4 to 5 days for direct measurement of their young panicle length starting from about five weeks before the estimeted heading time. This maeasurement is made in time with the early growth of lower internodes (N_4 and N_5) to 5.0~7.0 cm and with the hardening of culms which become round in shape. If the lower internodes are cut vertically with a razor blade or the like, the white and hairy young panicle can be seen at the apex of the uppermost internode.

This method involves the trouble of pulling out from the ground the sample each time.

Method B: Estimation based on the leaf age index

In this method, as discribed above, the leaf emerging time (or the number of emerged leaves) is noted down for several representative hills at intervals of five days starting from the transplanting stage for estimation of the young panicle length based on the leaf age at each time (See the separate table).

This method is not very recommendable because it resorts to main culms which are too small in number as samples. It is preferable to apply it as a supplementary means of other methods.

Method C: Estimation by "Nomograph of Young Panicle Length" devised by the author in 1972

Estimation can be quickly made fo: many samples in the field if the "Nomograph of Young Panicle Length (See Fig. 13)" is put to practical use.

1) Substantiation of validity of the nomograph

Generally, there exists a high degree of positive correlation between the young panicle length and the distance between the auricles of 3.0 L and 4.0 L of each culm ($Ac^{3\sim4}$) as will be clear from Table 2. The young panicle length can therefore be estimated quickly by measuring $Ac^{3\sim4}$ without pulling out the culms. If $Ac^{2\sim3}$ is also measured, it is possible to increase the accuracy of estimation.

2) How to estimate the panicle length by Method C.

Culms relatively large in size without sticking to main culm are to be selected 3~4 times from the desired number of respresentative hills showing the average growth condition during the period 30 to 17 days before heading, and their $Ac^{3\sim4}$ and $Ac^{2\sim3}$ are to be measured. Then, a plus or minus value is to be given according to the elongation of $Ac^{2\sim3}$ (plus if any small elongation is observed and minus if no elongation at all can be seen) by appling to the nomograph.

3) How to read the nomograph.

In Fig. 13, X-axis represents $Ac^{3\sim4}$ and Y-axis $Ac^{2\sim3}$, and the young panicle length can be obtained from the intersection of the two axes.

If the intersection comes between any two oblique lines, the difference in the panicle lengths indicated by the two lines is to be adjusted by the ratio obtained by comparing the distances from the intersection to the two lines.

Example :

a) If $Ac^{3\sim4}$= 5.0 cm and $Ac^{2\sim3}$= +1.0 cm, P ≑ 1.4 cm

b) If $Ac^{3\sim4}$= 5.0 cm and $Ac^{2\sim3}$= 1.0 cm, Q ≑ 0.62 cm

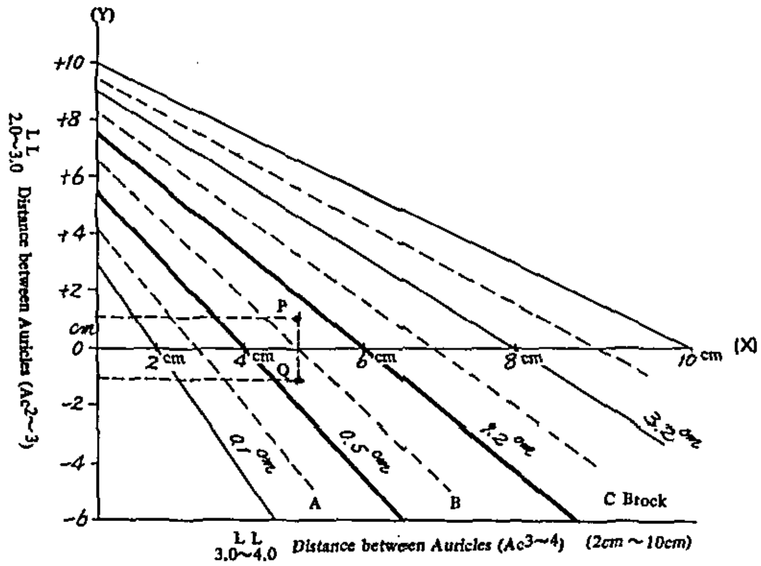
P and Q are respectively the young panicle length required.

Notes :

Block B delineated by two thick oblique lines in Fig. 13 indicates the optimum time for conducting top dressing at panicle formation stage.

The nomograph shown in Fig. 13 applies only to wet season cropping of Pelita I-1. However, the values for dry

Table 13 - Nomograph of Young Panicle Length
(Wet season cropping) (Pelita 1-1, 1972)



season cropping can be obtained with ease by substituting *the values for dry season cropping shown in Table 32 for the* basic young panicle length indicated by the oblique lines in Fig. 13.

Table 32~1 Conversion Table of Young Panicle Length (Pelita 1-1, 1973)

3.0 L ~ 4.0 L Distance between Auricles of 3.0 L and 4.0 L ($Ac^{3\sim4}$)			2.0cm	3.0cm	4.0cm	5.0cm	6.0cm	7.0cm	8.0cm
Wet Season Cropping	Young Panicle Length	(Multiplier) Basic Value cm	% (7) 0.1	% (10) 0.3	% (12) 0.5	% (15) 0.8	% (20) 1.2	% (28) 2.0	% (40) 3.2
Dry Season Cropping	Young Panicle Length	(Multiplier) Basic Value cm	% (12) 0.2	% (15) 0.5	% (20) 0.8	% (25) 1.2	% (30) 1.8	% (35) 2.4	% (40) 3.2

Notes: 1. The basic value is the value obtained when the dis- t tance between 2.0 L and 3.0 L ($Ac^{2\sim3}$) is zero(±0).
2. Plus adjustment is to be made if $Ac^{2\sim3}$ is a plus value and minus adjustment if it is a minus value.
3. Basic value is to be decreased to 70~80% for PB-5 and increased to 130~150% for C_4.

Table 32~2 Basic Value Correction Factors:

	Wet Season Cropping	Dry Season Cropping	Deep Leaf Colour	Light Leaf Colour
PB-5	-30%	-20%	-20%	+20%
C_4	+50%	+30%	-20%	+20%

Notes: The correction factors based on the leaf colour are applicable to Pelita, PB-5 and C_4, etc.

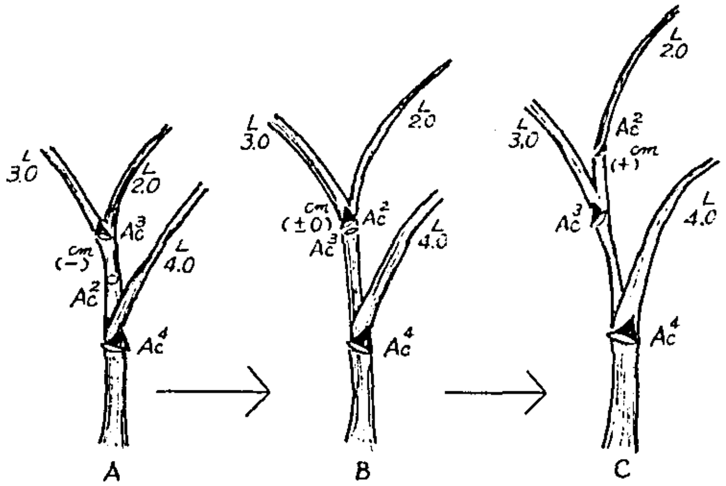
28. Method of Correct Measurement of Distance between Auricles

Each leaf has an auricle between its blade and sheath, and the distance between the auricle of an upper leaf and that of the leaf immediately below is called the "distance between auricles".

The distance between auricles is expressed in minus value (cm) if the upper leaf auricle is embraced in the sheath of the leaf immediately below, taken at ±0 if both auricles are on a level, and in plus value (cm) if the upper leaf auricle is emerging above the next lower leaf auricle (See Fig. 14).

When measuring the distance between auricles, care must be taken so as to be able to observe the leaf order position correctly. It is of particular importance not to confuse the upper 2.0 L with 3.0 L. During the period 30 to 18 days before heading, the uppermost new leaf which is in the course of emergence can be considered "2.0 L" because it is generally the case that the elongation of 3.0 L is completed but emergence of 1.0 L (flag leaf) does not start before that period (Flag leaf emerges 18 to 17 days before heading, see Table 6).

Fig. 14 - Elongation and Correct Observation of Distance between Auricles



Notes: 1. Elongation of $Ac^{3\sim4}$ and $Ac^{2\sim3}$ is illustrated.
2. Ac^3 - auricle of the third leaf, Ac^4 that of the fourth leaf, etc., $Ac^{3\sim4}$ - distance between auricles of the third and fourth leaves.

Strictly speaking, the relationship between $Ac^{3\sim4}$ and the young panicle length varies to an extent depending upon the cropping season, variety and intensity of leaf colour (nitrogen concentration). However, the basic values indicated by oblique lines in the nomograph can be made use of simply by applying the correction factors shown below to those corrected according to Table 32.

Example of Correction:

a. Wet season cropping of Pelita I-1 with light leaf colour and $Ac^{3\sim4}$ = 5.0 cm
0.8 cm x (100% + 20%) = 0.96% cm

b. Dry season cropping of PB-5 with light leaf colour and $Ac^{3\sim4}$ = 5.0 cm
1.2 cm x (100% - 20% + 20%) = 1.2 cm

c. Wet season cropping of C_4 with deep leaf colour and $Ac^{3\sim4}$ = 5.0 cm
0.8 cm x (100% + 50% - 20%) = 1.04 cm

29. Determination of Dosage of Nirogen Top Dressing at Panicle Formation Stage by Starch Reaction Test

a) Period of Diagnosis

Early, middle and later spikelet differentation stages and a number of subsequent days (28 days ~ 24 days ~ 20 days ~ 16 days before the heading time).

Diagnosis is to be conducted three to four times during the above period.

b) Sampling of Specimens

Several hills representing the average growth condition are to be selected, and three to four main culms or tilled culms with equivalent sige to it in a hill should be pulled out from the ground. Then, the third leaf sheath is to be sampled from each culm if its uppermost leaf is fully spread. If the uppermost leaf is not fully spread, the fourth leaf sheath is to be sampled for the purpose of test.

c) Treatment of Samples

The sampled leaf sheath is to be cut longitudinally with a razor blade along the vein with care, with iodine solution applied sufficiently on the cut section.

This will make the cut section turn into black colour, but the degree of this iodostarch reaction varies by the starch content of leaf sheath. When the reaction is completed in about five minutes after applying the iodine solution, the staining ratio (%) is to be calculated by the following equation to determine the amount of nitrogen top dressing at the panicle formation stage (N kg/ha) according to Table 33.

$$\text{Staining ratio (\%)} = \frac{\text{Blackened and stained length (cm)}}{\text{Leaf shath length (cm)}} \times 100$$

Table 33

Staining Ratio (%)	Amount of Nitrogen Top Dressing at Panicle Formation Stage
50%	20 Kg
60	30
70	45
80	60

Notes: 1. The amount of top dressing applied to short-culmèd valieties should be decreased to 50~60% of the indicated amount for long-culmed varieties.

2. If the staining ratio is lower than 50%, no top

dressing is to be applied.

d) Reagent

1) Preparation of iodine solution

Materials: 200 cc of water, 1.0 g of potassium iodide, and 0.5 g of iodine.

Dissolve potassium iodide in a small quantity of water and agitate it well after adding iodine. When iodine is dissolved well, add the remaining water.

2) Use of iodine tincture available on the market

Use 1.8 solution of iodine tincture prepared by adding water. The diagnosis discussed here is intended to determine the amount of nitrogen top dressing at panicle formation stage. When to apply the top dressing is to be decided by referring to the "Nomograph of Young Panicle Length". (Method C).

30. Measures and Steps for Realizing "Ideal Paddy Type"

The "ideal type of paddy" is the paddy which "has the characters and shape conductive to maximum production efficiency" and its realization calls for the following conditions.

1) Number of grains per panicle is large.
2) The ratio of complete grains is 100% (i.e., there are no withered or sterile grains at all).
3) Weight of 1,000 dried and hulled grains is heavy.

Future improvement of paddy culture hinges on whether such an ideal type paddy equipped with all the above conditions will be raised or not. To turn such an ideal into a reality, the paddy shape or type which can fill the three conditions must be made clear. Otherwise, endeavours for realizing the ideal type paddy will remain in the stage of "probing in the dark".

Table 34 - Relation between Quasi-ideal Type Paddy and Yield Components

(Pelita 1-1, 1972)

	Plant type							Yield Components					Estimated Yield (t/ha)
	Internode Length		Leaf Blade Length			Emergence Length of Panicle Neck-node	Number of Secondary Rachis Branches	Weight of One Panicle	Ratio of Complete Grains	Number of Complete Grains	Weight 1,000 Grains	Ratio of Withered and Sterile Grains	
	Upper	Lower	1 L	3 L	4 L								
		cm	cm	cm	cm	cm		g	%		g		t
A	59.6	11.2	26.0	36.9	34.1	+3.5	3.1	4.40	90.4	135	29.5	0.01	13.4
B	59.0	11.5	30.0	41.2	33.0	+3.5	3.2	4.90	91.8	155	29.2	0.02	14.0
C	52.0	14.4	21.6	35.8	43.2	+0.7	3.4	3.12	80.4	89	28.1	33.0	6.9

Notes : 1. A and B .... Quasi-ideal type paddy.
2. C .... Unhealthy type paddy.

Table 34 shows the data of the "quasi-ideal type paddy" found in Cihea Cianjur during the 1972 dry season cropping.

A close look at this table will elicit the surprising fact that as many as 135~155 grains ripened per panicle with only one withered grain and no sterile grains at all, although the number of plants or hills recording this excellent results was limited. The closer the reader examines this table, the better he will understand the characteristics of "quasi-ideal type paddy" and the validity of the discussion advanced in the foregoing pages.

Let us analyze the steps for improving rice culture as seen through the long-range perspective of technical development including, inter alia, the improvement of plant type.

(Steps for Improving Rice Culture)

Step F for phenomenal type paddy I →Step E for phonomenal type paddy II → Step D for healthy type paddy → Step C for healthy and high-yielding type paddy → Step B for quasi-ideal type paddy → Step A for ideal type paddy.

Step F for phenomenal type paddy I :

In this step, traditional cutlrual practices prevail with no advanced techniques introduced. The paddy shape is irregular and disturbed, yield level is low, and the gap between the highest and lowest yields is large.

Step E for phenomenal type paddy II :

Some yield increase is attained by the partical application of improved cultural techniques, but the increase is dependent solely on the effect of a single technique. Hence, the paddy shape is still irregular, crop condition varies by farmers and is not stabilized and calls for further technical improvement.

Step D :

Stabilized culture and uniform yield are set well afoot by the integrated technical extension and improvement and unification of cultural method. The paddy shape is improved and simplified, making it possible to take a step forward for improvement of paddy culture, but no positive effort is yet made in this direction.

Step C :

Adoption of the cultural system suited to respective areas produces a great integrated effect of techniques, whereby the yield increases considerably with little individual variation, and the gap between the highest and lowest yields is eliminated. In addition, the plant type is improved and the cultivation of the "high-yielding type paddy" becomes stabilized.

Step B :

Effort to attain the highest possible yield is continued in this stage, and the realization of at least "quasi-ideal" type paddy becomes possible.

Step A :

This is the stage when the "ideal type paddy" is to become a reality.

This step is to be taken one after another for improvement of rice culture not necessarily for the realization of the "ideal" paddy because it is a vision which will be entertained for generations to come by all persons concerned.

Notes: As some readers may already be aware, Dr. Matsushima gave a detailed account of "ideal type paddy" in his "Theory of V-shaped Type (1959)". The ideal type paddy discussed in this text book, however, has nothing to do with that of Dr. Matsushima.

As regards the ideal type introduced herein, the author submitted a report (1951) to the pertinent Japanese society. The author wishes to add that the theory of plant type he advanced in the said report proved to be true and acceptable in Indonesia just as in Japan.

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