Low Cost,Labor Saving Cultivation of High Quality Rice(Oryza sativa L..cv Hitomebore)with Controlled Availability Fertilizer and No-tillage Transplanting System(良質米ひとめぼれ(Oryza sativa L.cv Hitomebore)の肥効調節型肥料と不耕起移植栽培による低コスト・省力栽培に関する研究)

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論 文 内 容 要 旨

Introduction

Recently rice cultivation farming in Japan has been besieged with a host of problems, both in the country and overseas. Nowadays, for farmers, low-cost, labor saving cultivation of rice is one of urgent problems. Therefore, it may be necessary to place much more emphasis on research of no-tilled direct seeding or transplanting to promote the development of a low-cost technology. However, there are still some technical problems in no-tilled direct seeding culture of the rice plant: low percentage of seedling establishment, low efficiency of applied N fertilizer, and difficulty for poorly drained soil. On the other hand, the combination of the no -tillage (NT) transplanting system of rice developed at the Ogatabranch of Agricultural station , and a total single basal application of controlled availability fertilizer (CAF) in a nursery box, developed by the Experimental Farm of Tohoku University, could improve labor cost to a great extent by eliminating tillage, puddling, top-dressing and the mid-summer drainage process. However, this system was practiced only in poorly drained gley soil, because this system is not suitable in highly percolated soil. However, there are no studies about this system for light textured soil.

On the other hand, nowadays for farmers the quality of rice is becoming a greater issue than quantity. However, currently, there is no high quality rice and low-cost, labor saving cultivation method, which is recommended for cultivation in cold regions.

Therefore considering the things mentioned above, the following experiments were conducted I) Establishment of the no-tillage transplanting cultivation of Hitomebore rice in different soil conditions and II) Establishment of cultivation methods of high quality rice "Hitomebore" in cold regions.

I) Establishment of the no-tillage transplanting cultivation of Hitomebore rice in different soil conditions.

No-tillage transplanting cultivation of high quality rice (*Oryza sativa* L.cv. Hitomebore) was conducted using controlled availability fertilizer (CAF) to reduce labor costs and environmental degradation on three different paddy soils. The purposes of this chapter are to study 1) effects of the no-tillage system on the oxidation- reduction condition of paddy soil, 2) nitrogen uptake of the rice plant and efficiency of fertilizer nitrogen from CAF, 3) growth characteristics and yield of rice, 4) effects of the no-tillage system on soil physico-chemical properties , and 5) improvement of the initial growth of the rice in no-tillage transplanting system. The results obtained are summarized as follows.

I-1) Effects of the no-tillage system on the oxidation- reduction condition of paddy soil.

Redox potentials at the 5 cm depth in the no-tillage system (NT) remained relatively higher than those in the conventional tillage system (CT) with or without straw at the early growth stage (Fig,I-1). Reflecting the difference of redox potential, the amounts of extracted Fe^{2+} and available P in NT were lower than those in the CT with or without straw. Considering the results of redox potential, extracted Fe^{2+} and available P, it was concluded that the oxidative condition in the NT system maintains for a longer time than that in the CT system.

I-2) Nitrogen uptake of the rice plant and efficiency of fertilizer nitrogen

The cumulative N release from the POCU S-100 was only 3-3.5% during the nursery stage. After transplanting, the rate of N release from POCU S100 gradually increased during the tillering stage and young panicle formation stage (Fig.I-2).

Nitrogen recoveries from POCU S100 in the NT and NTS system were 77-79% and 78-83%, 61-73% and 66-78%, and 74-76% and 80-81% for light clay soil, sandy loam soil and clay loam soil, respectively. Which is around 66-96% of the nitrogen released from CAF. On the other hand, nitrogen recoveries from ammonium sulfate applied as basal fertilizer in the CTS system were 35-43%, 20-29% and 23-32% for light clay soil, sandy loam soil and clay loam soil, respectively. Whereas those applied as top dressing were 50-83%, 49-73% and 40-65% (Fig.I-3). These data indicate that the application of POCU S100 in the nursery box for the NT and NTS system increases the recovery of nitrogen from fertilizer to a great extent in comparison with ammonium sulfate in the CTS system, and thus could reduce remarkably environmental degradation caused by fertilizer nitrogen.

I-3) Growth characteristics and yield of rice in three different paddy fields.

The tillering capacity of the rice plant in the NT transplanting system was smaller than that of the CT transplanting system. However, the percentage of productive tillers was larger in the NT transplanting system in all types of soil. The numbers of productive tillers per m^2 of NTS treatments of all types of soil were larger than those of NT treatments (Fig.I-4). The leaf color values of rice plant at early growth stage in NT transplanting system were lower than those of CT transplanting system.

The yields of brown rice of NT and CT treatments were 5.58-5.93 and 5.67-6.07 ton/ha, 5.47-6.35 and 4.68-6.60 ton/ha, and 5.18-6.34 and 4.13-6.74 ton/ha in light clay soil, sandy loam soil and clay loam, respectively (Fig.I-5). Comparing the averaged yield over two seasons, NT treatments produced -1%, 8% and 25 % higher grain yield than did CT treatments in light clay soil, sandy loam soil and clay loam soil, respectively.

I-4) Effects of the no-tillage system on soil physico-chemical properties.

The soil organic C at 0-2 cm depth in NTS treatments of light clay soil and clay loam soil after 2 years of the NT transplanting system were significantly higher than those in NT, CT and CTS treatments (Fig.I-6).Total N concentrations closely followed the pattern observed for organic C in all types of soil studied.

Soil penetration resistances (SPR)at the top 0-5 -cm and 5-10-cm layers in all types of soil were significantly higher in NT treatments than in CT treatments, which means in the NT system much more adequate machinery work could be done regardless of climatic conditions (Fig.I-7).

Percolation rates of the NT system were 4, 14 and 18 mm per day in light clay soil, sandy loam soil and clay loam soil, respectively. Whereas those of the CT system were 0, 7 and 12 mm per day (Fig.I-8). However, percolation rates of the NT system were still less than 20-30 mm per day, which is recommended as an adequate percolation rate for high yielding paddy soil.This lower percolation rate in sandy soil was verified by the results of the percolation rates of 8 representative sandy paddy fields located in natural levee of Eai river, Furukawa (Table I-1). It was found that the averaged percolation rate inside the cylinder was 7 mm per day, which was only one third of that outside the cylinder. A large portion of the irrigation water was lost due to surface runoff. However, they were still less than the value recommended. Therefore, it seems that after CT practice, the NT transplanting system by using CAF is highly feasible even in light textured sandy paddy fields.

I-5) Improvement of the initial growth of rice in the no-tillage transplanting system

POCU -10 or POCU -30 (short release type of CAF) in combination with POCU S100 was remarkably more effective in increasing the number of tillers than those in the POCU S treatments (Fig.I-9), reflecting the rapid release of N from POCU -10 or 30 at the initial growth stage.

The N recoveries from the linear type of POCU 10 and POCU 30 at the young panicle formation stage were 41 and 30 %, 35 and 27%, and 33 and 34%, in light clay soil, sandy loam soil and clay loam soil, respectively. At the harvest time, they were 53 and 53%, 69 and 53%, and 51 and 68% in light clay, sandy loam and in clay loam , respectively (Fig.I-10).

The yields of brown rice of NT 30 and NTS 30 were almost the same or higher than those of NT or NTS, whereas those of NT 10 or NTS 10 tended to be lower because of a fewer number of spikelets per m^2 (Fig.I-11).

From above results, it is concluded that the shifting from the CT system to the NT transplanting system of rice cultivation by using controlled availability fertilizer in a nursery box is highly feasible, not only in heavy textured soil, but also in light textured soil.

II) Establishment of cultivation methods of high quality rice "Hitomebore" in cold regions.

Establishment of cultivation methods of high quality rice (Oryza sativa L. cv. Hitomebore) in cold regions using pot mature seedling, was studied with special reference to quality of rice and labor saving, and following experiments were conducted at the Experimental Farm of Tohoku University (Kawatabi, Naruko, Tamatsukuri, Miyagi prefecture)

1) Improvement of the heading time of "Hitomebore" rice in cold regions.
2) Establishment of cultivation methods of "Hitomebore" rice in cold regions

3)Establishment of no-tillage transplanting cultivation of "Hitomebore" rice with a single basal application of CAF in pot seedling boxes in cold regions.

II-1) Improvement of heading time of high quality rice "Hitomebore" in cold regions.

The heading date of rice in pot seedling plots (4.8-6.2 of leaf age) was 5 days earlier than those in mat seedling plots (3.7-4.3 of leaf age). The cumulative temperatures for 40 days after the heading of rice in pot seedlings were 20-26 °C higher than those in mat seedlings (Table II-1). The early transplanting of pot seedlings of Hitomebore rice on the 7th of May, put forth its panicles 5 days earlier than that of the late transplanting on the 14th and 21st of May. Late transplanting of pot seedlings decreased the number of leaves per shoot (15.2 and 14.7 in 1992 and 1993, respectively) when compared to earlier transplanted ones (16.0 and 15.0 in 1992 and 1993 respectively) (Table II-2). The cumulative mean air temperature for the 40 days after heading of the rice in the pot seedlings plot was 9-32 °C greater in earlier transplanting than that in late transplanting (Table II-2).

Therefore, improvement of the heading date of Hitomebore in cold regions could be highly possible by early transplanting of pot mature seedlings.

II-2) Establishment of cultivation methods of high quality rice "Hitomebore" in cold regions by using pot seedlings.

The number of leaves per main culm was larger in the pot seedling plot than that of the mat seedling plot (Fig.II-1).The tillering capacity of pot seedlings was smaller than that of mat seedlings, but the percentage of productive tillers was larger in pot seedlings (Fig.II-1). The nitrogen percentages of each part of the rice grown in the pot seedling plot were lower than those in the mat seedling plot (Fig.II-1). The nitrogen percentages of both panicle and milled rice of the pot seedling plot were lower than those of the mat seedling plot (Fig.II-2), and therefore the quality of milled rice was improved on the basis of nitrogen content. Yields of rice in the pot seedling plot ranged from 4.45- 6.79 t/ha. The highest yield of the pot seedling plot was obtained in POCU dense planting cultivation, which was statistically similar to the highest yield of the mat seedlings (Fig.II-3).

Therefore, the yield and quality of Hitomebore rice in cold regions can be improved by pot mature seedling cultivation in combination with Polyolefin Coated Urea and dense planting.

II-3) Establishment of no-tillage transplanting cultivation of high quality rice "Hitomebore" with a single basal application of CAF in pot seedling box in cold regions.

The linear type of POCU 30, in combination with POCU S100 and POCU SS100 as a basal fertilizer, increased the number of tillers at the initial growth stage (Fig. II-4). The result of heading time of pot seedling was same as in 1992 and 1994. The brown rice yields of all the NT systems POCU (S100 +30), POCU S100 , POCU (SS100+30) and POCU SS100 were 5.23- 6.16 t/ha, which was quite a high yield compared to that of the POCU S100-CT system (4.52 t/ha) (Fig. II-5).

From above results , it was concluded that the no-tillage transplanting system of pot seedlings with a single basal application of POCU S100 or POCU SS100 in combination with POCU 30 in a nursery box, is a suitable method for improving both the quality and quantity of rice, and labor cost in cold regions.

Chapter-I: Establishment of no-tillage transplanting cultivation of "Hitomebore "rice in different soil conditions

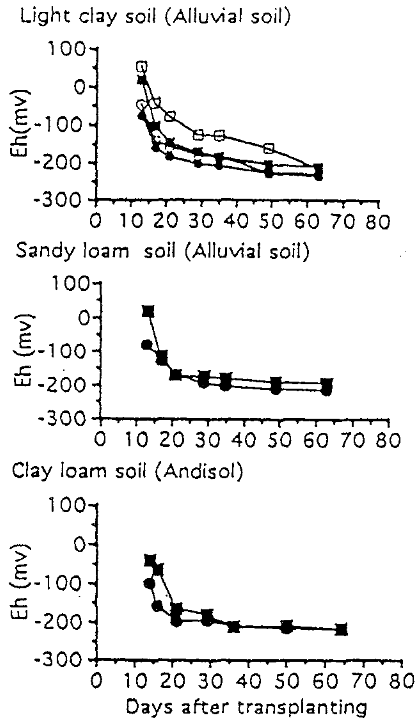

Fig.I-1. Effects of tillage system on redox-potential of soil —□— NT —■— NTS —○— CT —●— CTS
NT-No-tillage without rice straw; NTS-No-tillage with rice straw; CT-Conventional tillage without rice straw; CTS-Conventional tillage with rice straw

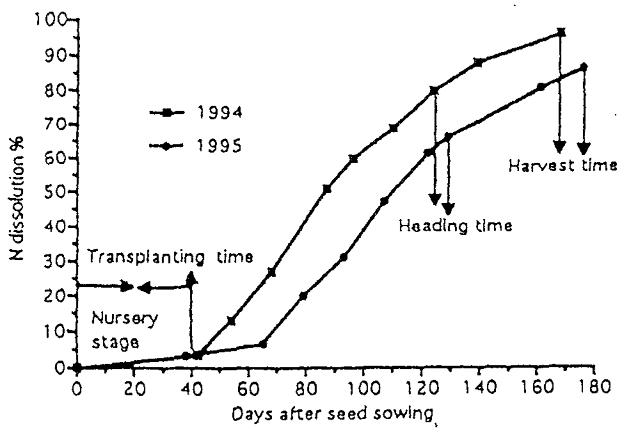

Fig.I-2. Cumulative nitrogen release from POCU S100 with days

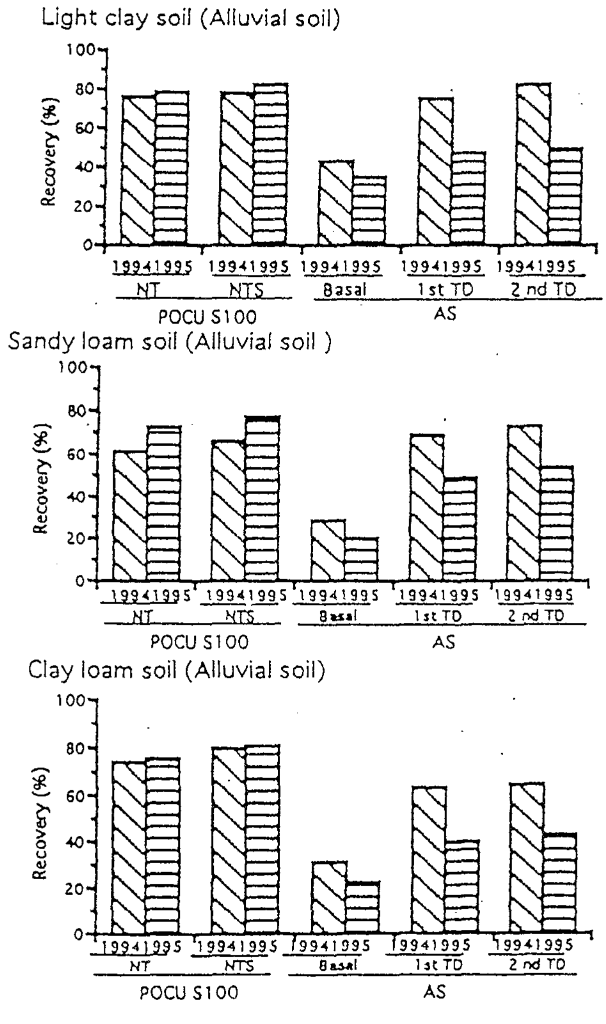

Fig. I-3 Recoveries of fertilizer nitrogen by rice plants at harvest time
NT-No-tillage without rice straw;NTS- No-tillage with rice straw; CTS-Conventional - tillage with rice straw; POCU S -Sigmoid type of Polyolefin Coated Urea; AS- Ammonium sulfate;TD-Top dressing

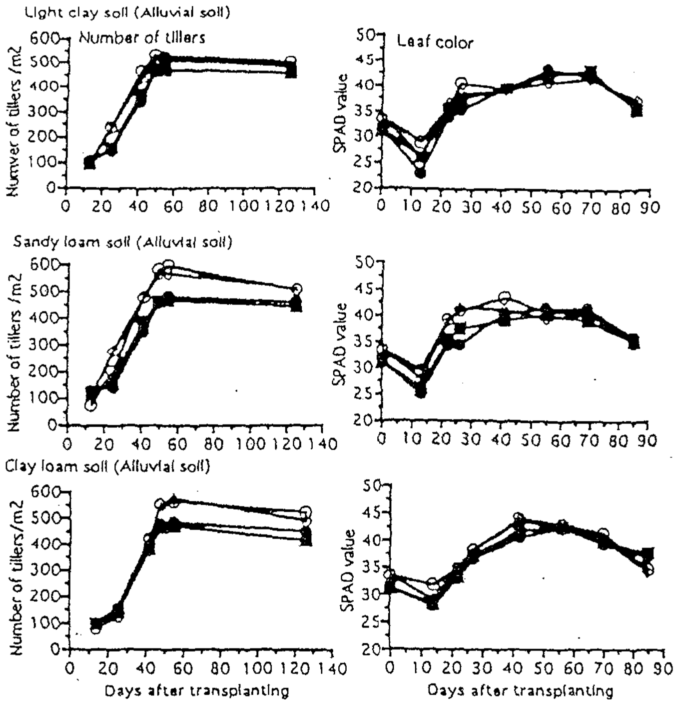

Fig.I-4. Effects of tillage system on growth characteristics of rice plant —■— NT —●— NTS —○— CT —⊖— CTS

NT-No-tillage without rice straw;NTS- No-tillage with rice straw

CT-Conventional tillage without rice straw; CTS- Conventional tillage with rice straw

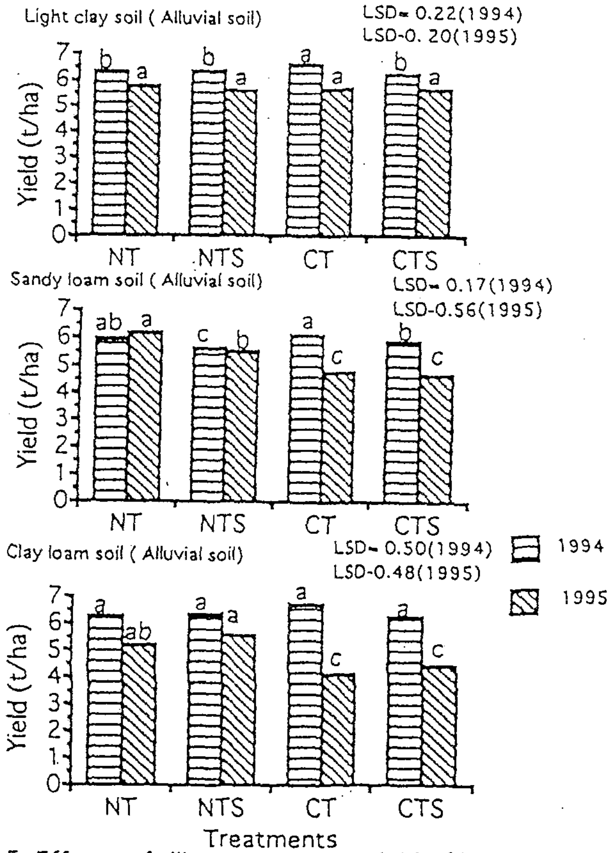

Fig.I-5. Effects of tillage system on yield of brown rice

NT-No-tillage without rice straw;NTS-No-tillage with rice straw;

CT-Conventional tillage without rice straw;CTS-Conventional tillage with rice straw .

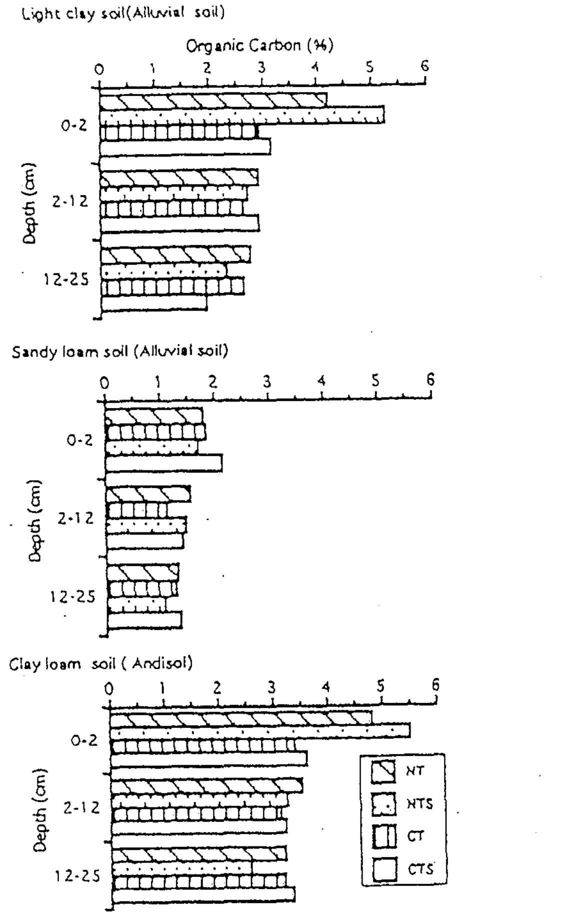

Fig.I-6. Effects of two years tillage system on organic carbon content at different depth of soil
NT-No-tillage without rice straw; NTS-No-tillage with rice straw; CT-conventional tillage without rice straw; CTS-Conventional tillage with rice straw

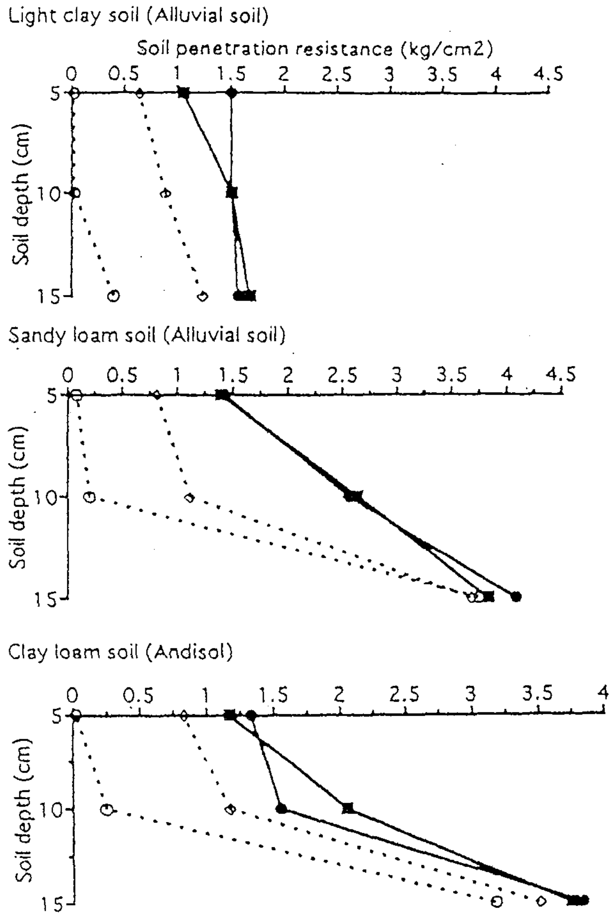

Fig. I-7. Effects of tillage system on soil penetration resistance.
NT-No-tillage;CT-Conventional tillage

NT(11 May) NT(20 Oct.) CT(11 May) CT(20 Oct.)

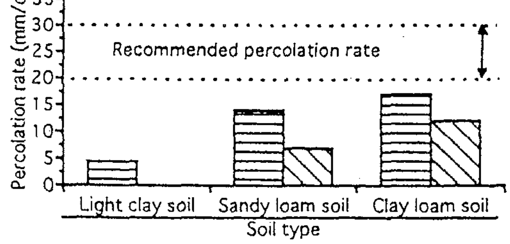

Fig.I-8. Effects of tillage system on water percolation rate. NT CT
NT-No-tillage;CT-Conventional tillage

Table I-1. Water percolation rate of sandy paddy fields at Shimiju, Furukawa, Japan

Field no.	Percolation rate (mm/day)	
	Inside the cylinder	Out side the cylinder
1	12.1(±4.6)	31.5 (±7.4)
2	4.4 (±2.0)	> 33.5 (±13.3)
3	7.5 (±4.3)	14.2 (±6.6)
4	7.9 (±6.1)	16.3 (±2.0)
5	2.5 (±0.6)	14.7 (±2.2)
6	7.5 (±4.7)	18.6 (±7.3)
7	4.6 (±1.7)	24.7 (±3.2)
8	11.1 (±6.2)	17.9 (±1.2)
Average	7.2	21.4

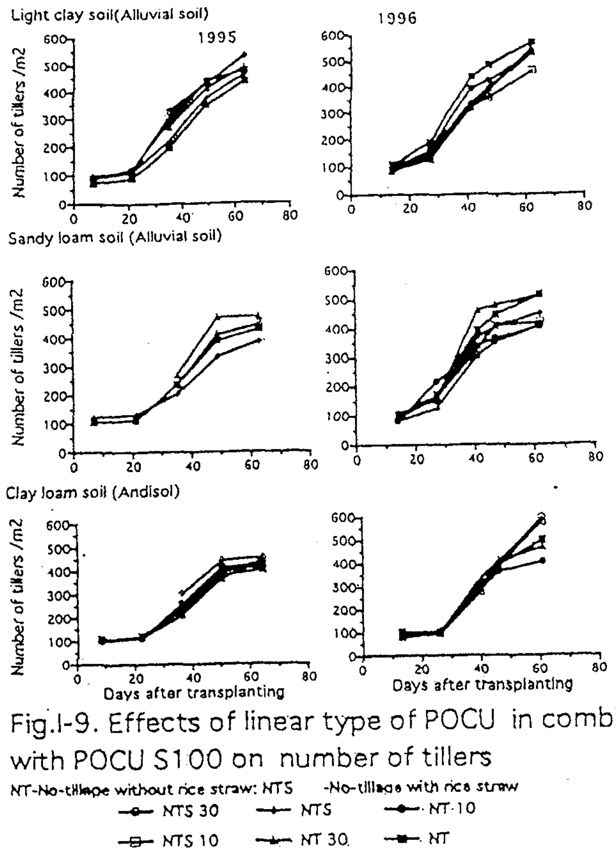

Fig.I-9. Effects of linear type of POCU in combination with POCU S100 on number of tillers

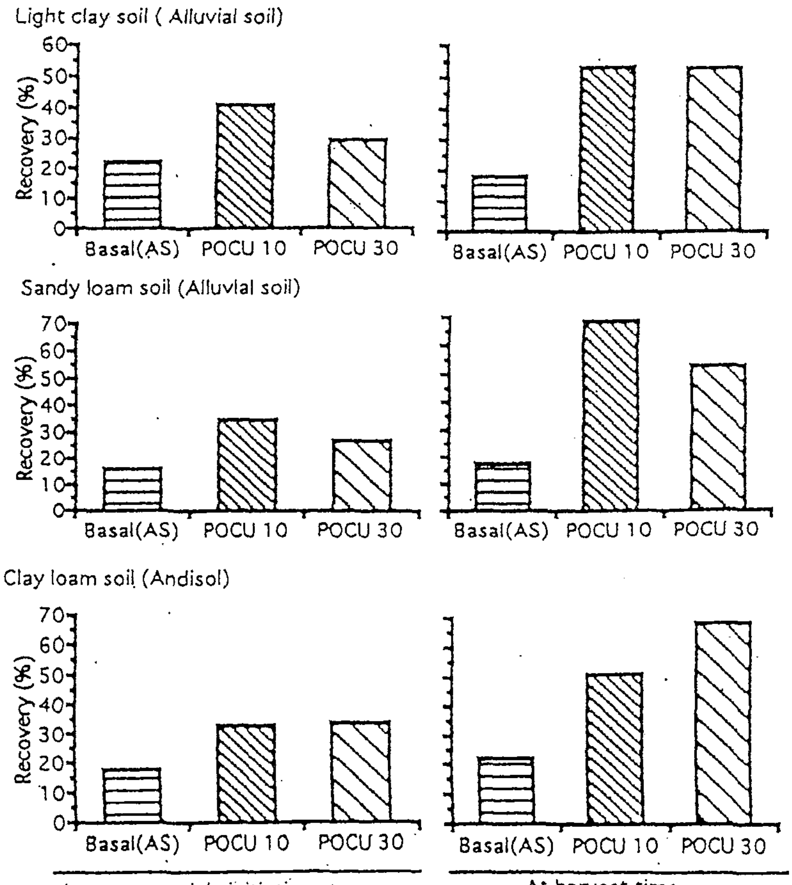

Fig.I-10. Recoveries of fertilizer nitrogen by rice plants

AS-Ammonium sulfate; POCU10 and 30 -Linear type of Polyolefin Coated Urea

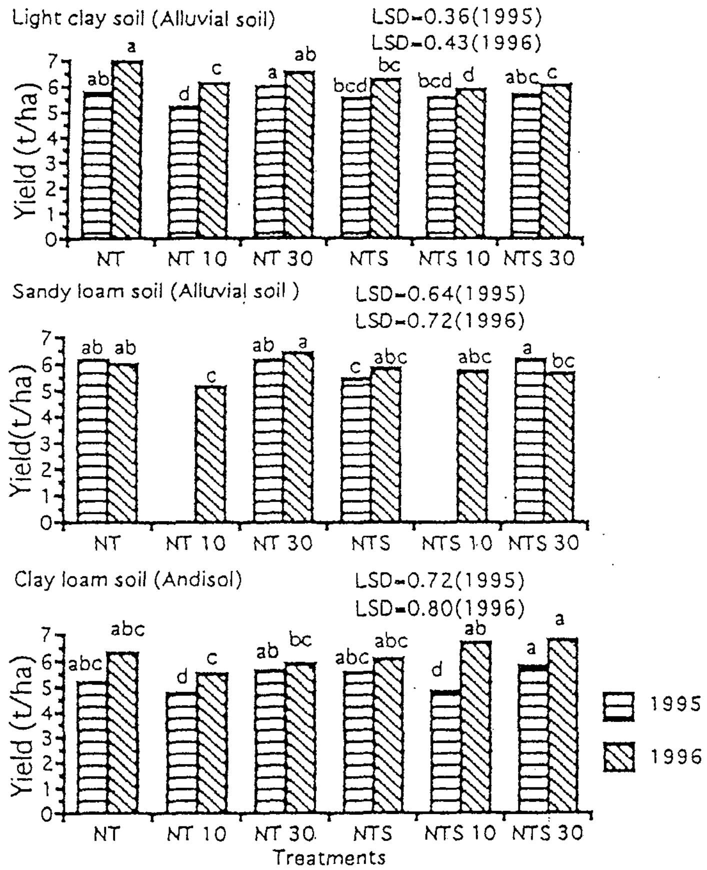

Fig.I-11. Effects of linear type of POCU in combination with POCU S100 on yield of brown rice

NT-No-tillage without rice straw;NTS-No-tillage with rice straw; CT-Conventional tillage without rice straw;CTS-Conventional tillage with rice straw .POCU-Polyolefin Coated Urea.

Chapter -II: Establishment of cultivation methods of high quality rice "Hitomebore" in cold regions.

Table II-1. Effects of leaf number at the transplanting time of different types of seedlings on number of leaves per shoot, heading date, and cumulative mean air temperature from transplanting to heading and for 40 days after heading.

Year	Type of seedlings	Leaf number at transplanting time	Total leaf number / main culm	Heading date	Cumulative mean air temperature (℃)		
					Sowing to transplanting	transplanting to heading date	For 40 days after heading
1992	Pot mature seedlings	4.8	16.0	9th Aug.	630	1667.1	847
	Mat seedlings	4.3	15.3	14th Aug.	532	1748.3	821
1993	Pot mature seedlings	5.7	15.0	18th Aug.	791	1742.3	768
	Mat seedlings	3.7	14.6	23th Aug.	561	1847.5	744
1994	Pot mature seedlings	6.2	15.8	31st July.	890	1540.0	987
	Mat seedlings	3.8	14.3	4th July.	600	1621.9	967

Table II-2. Effects of transplanting time of pot seedlings on number of leaves per shoot, heading date, and cumulative mean air temperature from transplanting to heading and 40 days after heading.

Year	Transplanting time	Leaf number at transplanting time	Total leaf number / main culm	Heading date	Cumulative mean air temperature (℃)	
					Transplanting to heading date	For 40 days after heading
1992	7th May	4.8	16.0	9th Aug.	1667.1	847
	14th May	4.8	15.2	10th Aug.	1614.0	838
1993	7th May	5.7	15.0	18th Aug.	1742.3	768
	14th May	5.3	14.7	22th Aug	1730.0	749
	21st May	5.3	15.0	24th Aug	1687.5	736

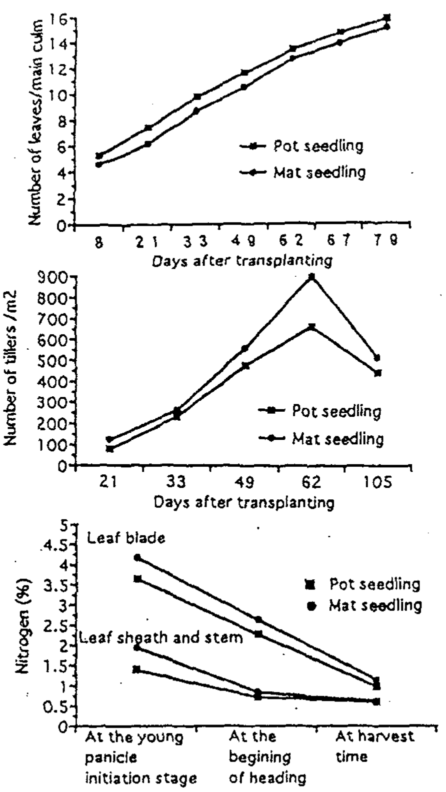

Fig.II-1.Growth characteristics of pot and mat seedling

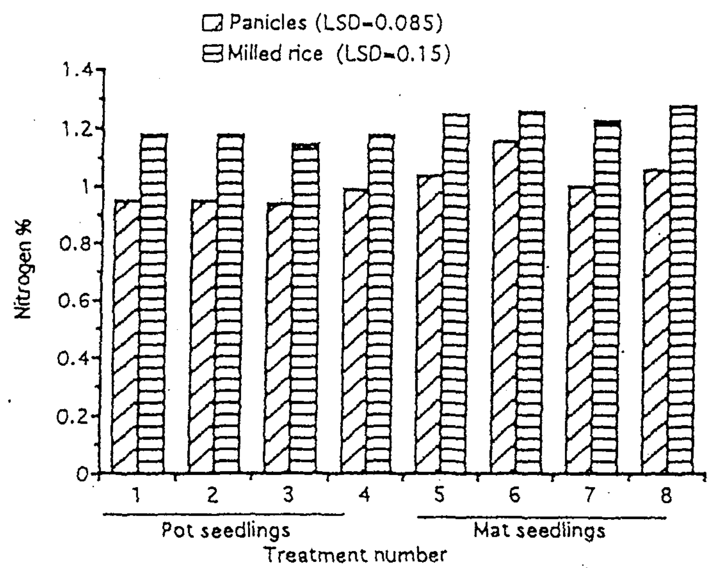

Fig.II-2. Nitrogen concentration of panicles and milled rice in pot and mat seedling plots

1-Pot POCU dense planting;2-Pot POCU sparse planting;3-Pot conventional dense planting;4-Pot conventional sparse planting;5-Mat POCU dense planting;6-Mat POCU sparse planting;7-Mat conventional dense planting;8-Mat conventional sparse planting. POCU- Poleolefin Coated Urea.

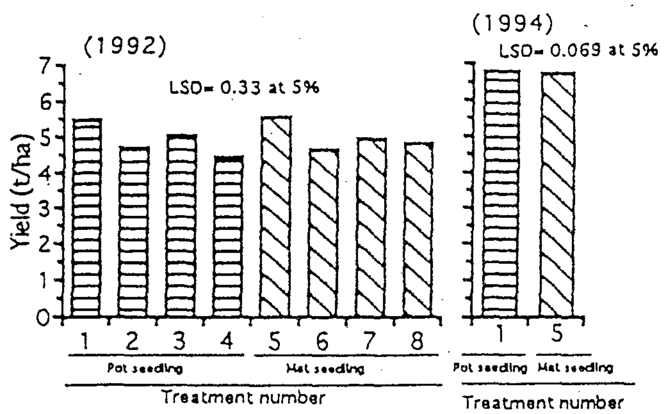

Fig.II-3. Brown rice yield of pot and mat seedling plots

1-Pot POCU dense planting;2- Pot POCU sparse planting;3- Pot conventional dense planting;4- Pot conventional sparse planting;5 -Mat POCU dense planting;6-Mat POCU sparse planting;7-Mat conventional dense planting;8-Mat conventional sparse planting. POCU- Poleolefin Coated Urea.

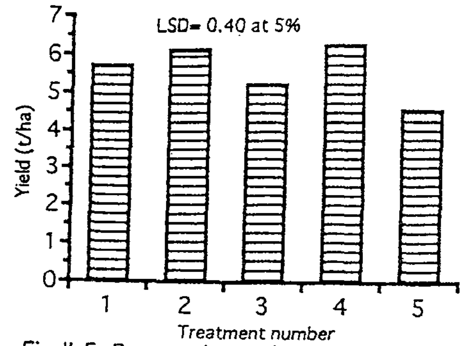

Fig.II-5. Brown rice yield of pot seedling

Treatment number; 1-POCU (S100+30)-NT;2 -POCU S100-NT;3-POCU (SS100+30)-NT;4 -POCU S100-NT;5 -POCU S100-CT; NT-No-tillage; CT-Conventional tillage; POCU-Polyolefin Coated Urea

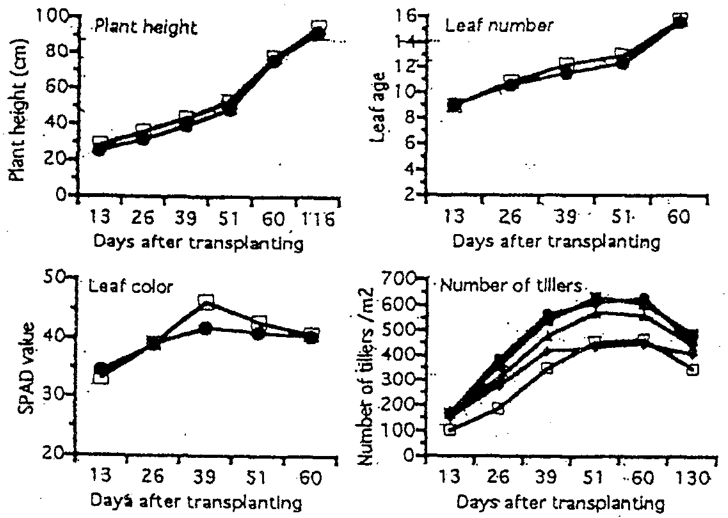

Fig.II-4. Growth characteristics of pot seedling

NT-No-tillage;CT-Conventional tillage

- POCU (S100+30)-NT
- POCU S100-NT
- POCU (SS100+30) -NT
- POCU SS100-NT
- POCU S100 -CT

論文審査結果要旨

本研究は肥効調節型肥料と不耕起栽培による良質米“ひとめぼれ”の環境に考慮した低コスト・省力栽培を土壌型に対する適用性と中山間地の栽培法の改善を中心として検討したものである。

まず第一に，異なる土壌型における良質米“ひとめぼれ”の全量苗箱施肥不耕起移植栽培を検討し，次の点を明らかにした。不耕起栽培の作土層はいずれの土壌型においても耕起土壌に比べて，より長期間酸化状態が維持され，このことが根の活性を生育後期まで維持していることを明らかにした。また，不耕起栽培の水稲の由来別窒素吸収量を重窒素トレーサー法で検討し，不耕起栽培の水稲は相対的に土壌由来窒素より肥料由来窒素を多く吸収すること，不耕起栽培に用いた時限式の肥効調節型肥料の利用率は，耕起栽培の硫安より著しく高い利用率を示すことより，本農法は窒素肥料による環境汚染を軽減することが可能であることを明らかにした。さらに，不耕起栽培の水稲は地力の発現が少なく初期生育が遅れるが，肥料の溶出特性を反映し，秋優り型の生育をするため収量的には耕起栽培と同じか，むしろ増収することを明らかにした。しかしながら，この初期生育の遅いことが農家への普及を妨げていると考え，溶出期間の短い肥料を移植直前に上乗せすることで初期生育を改善する方法を開発した。一方，従来，土壌型との関係では透水性の悪い湿田への適用のみが推奨されていたが，黒ボク土水田や自然堤防地帯の砂質水田の透水性を詳細に検討し，本農法は湿田のみならず，乾田を含めたいずれの土壌型にも適用できる方法であることを明らかにした。さらに，不耕起水田の貫入抵抗性を耕起水田と比較し，不耕起水田は栽培期間中を通じて地耐力に優ることを明らかにし，田植えや収穫などの機械作業が適期に可能な農法であることを明らかにした。

第2には寒冷地における良質米“ひとめぼれ”の栽培法を検討し，次の点を明らかにした。ひとめぼれの温度感応性を活用し，葉齢の進んだポット苗の早植えで出穂時期を改善できること，このことによって出穂後40日間の積算気温を高め寒冷地における良質米の生産が可能であることを明らかにした。また，ポット苗栽培はマット苗栽培に比べて最終的な葉数が多くなり，玄米の窒素濃度を低下させ米質を改善した。さらに肥効調節型肥料と密植栽培を組み合わせることによって収量性を改善すると共に，時限式の肥効調節型肥料と溶出の短い直線型肥料を組み合わせることによりポット苗の全量苗箱施肥不耕起移植栽培を開発した。

以上のように本研究では水稲の省力低コスト栽培である全量苗箱施肥不耕起移植栽培が土壌型を問わず，いずれの土壌にも適用できることを明らかにし，また初期生育の改善法を開発した。更に，中山間地における良質米の低コスト省力栽培技術を開発した。これらの結果はわが国の農業生産と環境保全に大きな貢献をするものと考えられる。よって，審査員一同は本論文提出者を博士（農学）の学位を授与するに値するものと判定した。