Chinese Agron. J. 4: 173-181 (1994)

土壤特性對稻米品質之影響
(一)土壤母質對米飯食味之影響

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摘要：本試驗自1989年二期作至1992年一期作，連續三年六期作，於臺灣中部地區四個縣市108個地點進行田間調查及試驗，探討各種土壤性質對稻米品質之影響。試驗結果將米飯食味各項評分及米飯物理性之均衡度（－H／H）分別區分為較優、中等及較劣三組，比較生產較優及較劣品質稻米各種土壤性質之差異，包括土壤母質、土壤肥力、土壤物理及化學性質對稻米品質的影響。本文先探討不同土壤母質的影響。試驗結果顯示，生產於粘板岩新沖積土及粘板岩非石灰性沖積土之稻米，米飯食味總評有較好之趨勢，在外觀、香氣及均衡度上表現亦佳。米飯之口味及黏性則以砂頁岩新沖積土有較優的趨勢，但均衡度之表現較差。紅壤及混合沖積土則各項食味評分及均衡度皆表現較劣，得到較低的評價。新沖積土生產之稻米品質較佳，可能與滲漏速率較高，通氣較佳，以及交換性矽之釋放較快有關。粘板岩沖積土由於坋粒及砂粒雲母含量較砂頁岩沖積土高，鉀的釋放較高，而有助於米質的改善。根據試驗結果，建議規劃粘板岩新沖積土，為臺灣中部地區生產良質米的適栽土壤。

關鍵語：稻米、食味品質、均衡度、土壤。

Effects of soil characteristics on eating quality of rice I. Quality and balance of cooked rice as affected by soil parental materials

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Abstract. Field experiments were performed during the fall of 1989 to

the spring of 1992, including 108 paddy fields at central Taiwan, to investigate the effect of soil properties on rice quality. Results showed that rice produced from slate new alluvials have a better quality in appearance, aroma, balance (−H/H) and overall sensory evaluation, than that from other kinds of soils with different parental materials. Rice growing in sandstone-shale new alluvials have a better flavor and cohesion than others but with a poorer balance of cooked rice. On the other hand, rice produced from latosols and mixture alluvials of sandstone-shale and slate have poorer eating quality. It was suggested that slate new alluvials are the best paddy fields for production of high quality rice.

Key words: Rice, Eating quality, Balance, Soil.

前　言

稻米是台灣最重要的糧食，1976年曾有年產271萬公噸之紀錄。近年來由於消費型態改變，稻米消費量逐年減少，1972年臺灣每人每年消費稻米134公斤，到1990年每人每年只消費68公斤。消費量減少，加上我國生產成本太高，無法拓展外銷市場，使得稻米生產過剩。如何生產高品質的良質米，以鼓勵國人重視我國固有的米食文化，增加稻米消費，成爲目前重要的農業問題。影響良質米生產之因素除品種特性及氣候因素外，產地土壤性質及栽培管理技術也是重要影響因子（Horisue 1983, Kuo et al. 1985）。Chamura et al. (1972a)指出日本在沖積土生產之稻米，比黑火山灰土，及泥炭土生產者米質佳，顯示不同母質的土壤可能影響稻米品質，含腐植質，全氮較多土壤由於水稻生育後期吸收氮素太多，易於倒伏，米質不佳。稻米全氮及蛋白質含量較高時，則米質較差（Chamura et al. 1972b）。Chen et al. (1988)也指出臺灣新沖積土生產之稻米游離糖含量較高，米質較老沖積土爲優，顯示不同母質土壤，生產之稻米品質有差異。本省良質米栽培除需選定適合良質米生產之土壤及品種外，並極需建立正確之栽培方法。本試驗除了解不同土壤母質對良質米生產之影響，以爲選擇良質米生產區域之參考外，並進一步探討土壤肥力、物理、化學特性對米質之影響，以期運用土壤肥培管理技術，改進良質稻米之生產。

材料與方法

自1989年二期至1992年一期作連續三年六期作，於臺灣主要稻米產區之中部地區四縣市，共108處水田進行田間試驗。試驗土壤包括紅壤、砂頁岩沖積土、粘板岩沖積土及混合沖積土。水稻採用良質米品種—台農70號及臺中189號。

一、米飯食味評價

水稻成熟後，每分地逢機採三點，每一點100株水稻，三點混合後，乾燥調製至稻穀含水量14.5%，由臺中改良場米質品評員八人進行米飯食味品評，品評員進行米飯食味品評時，以彰化縣田中粘板岩沖積土生產之臺中189號爲對照，品評項目包括外觀、香味、口味、粘性、硬性，以及前述五項之綜合評估爲總評。在各項食味品評項目中，品評員根據上述的米飯各品評項目，作爲判別米飯優劣的依據（Carmen 1969），較對照佳者，評分大於零，與對照不分上下，評分等於零，若比對照差者，評分小於零。此外並以質地分析儀（Texturometer, Zenken）分析米飯物理性質之均衡度（—H / H）（Okabe 1979），以瞭解品評員官能品評與機械分析數值間之關係。

二、試驗資料整理

全部試驗結果進行對比，並以SAS套裝軟體（SAS Institute Inc. 1987）進行逐步迴歸分析，以了解各種土壤性質，包括母質、土壤肥力、物理及化學性質對米質的影響。本文先探討土壤母質之影響。依據各項食味及均衡度評分分別區分爲較優（評分較對照高），中等（評分與對照相同）及較劣（評分低於對照）三組，計算各種土壤母質所佔比例，以χ^2進行獨立性測驗。並將各項食味特性及均衡度以SAS套裝軟體之相關程序進行Spearman之相關分析，以瞭解各項米飯食味及均衡度間的相關性。

結果與討論

一、土壤母質對米飯食味之綜合影響：

米飯食味品評的總評結果，所表現的是整體感官的綜合判斷。由食味品評（以彰化田中粘板岩沖積土生產之台中189號良質米爲對照）之結果，根據總評得分，將米質區分爲較優（食味總評分數比對照高）、普通（與對照食味總評分數相同）與較差（食味總評分數比對照低）三個等級。粘板岩沖積土生產之稻米食味總評等級較優所佔的比例最高，其中有40.5% 屬於食味較佳者；砂頁岩沖積土、紅壤及混合沖積土生產稻米之米飯食味則有較差之趨勢（表一），砂頁岩沖積土只有26.7%評定食味較優，紅壤生產之稻米也只有25%食味總評被評定爲較優。粘板岩沖積土中又以新沖積土生產食味較佳之稻米部分所佔比例最大，共有73%食味總評較對照爲優。

二、土壤母質對米飯外觀之影響

米飯外觀包括米飯外形及明亮度，是重要視覺感官特性。對比結果顯示，粘板岩新沖積土生產的米飯外觀優於對照者佔91%，所佔比例最高（表二）。其他土壤母質生產之稻米，米飯外觀優於對照所佔比例皆小於30%，其中又以紅壤、砂頁岩沖積土及混合沖積土生產之米飯外觀較對照差所佔比例最高，皆超過60%，表現最差。

Table 1. Comparison for overall sensory evaluation of cooked rice produced from different soil materials (2nd crop 1989 ~ 1st crop 1992).

Overall sensory evaluation	Latosol	SA (New)	SA (Old)	SA (Non-Alk.)	SSA (New)	SSA (Old)	SA + SSA (Mix.)
Good	3(25)	8(73)	4(21)	3(43)	1(25)	7(27)	1(9)
Fair	1(8)	2(18)	2(11)	1(14)	0(0)	3(12)	1(9)
Poor	8(67)	1(9)	13(68)	3(43)	3(75)	16(61)	9(82)
Total	12	11	19	7	4	26	11

Classes of overall sensory evaluation for rice eating quality are significantly depended on soil materials by Chi-square test (contingency table) at $\alpha = 0.01$. Rating evalutated by panel tests in comparison with rice cultivar Taichung 189 cultivated in Tien-Chung, Chang-Hwa county, as the control. "good" = rating of eating quality is higher than the control, "fair" = rating is equal to the control, and "poor" = rating is lower than the control. SA:Slate alluvials; SSA:Sandstone-shale alluvials. Values in parentheses represent percentage of the total sample in each column.

Table 2. Comparison for appearance of cooked rice produced from different soil materials (2nd crop 1989 ~ 1st crop 1992).

Appearance	Latosol	SA (New)	SA (Old)	SA (Non-Alk.)	SSA (New)	SSA (Old)	SA + SSA (Mix.)
>0	2(17)	10(91)	5(26)	2(29)	1(25)	7(27)	1(9)
=0	1(8)	0(0)	4(21)	2(29)	0(0)	3(12)	3(27)
<0	9(75)	1(9)	10(53)	3(42)	3(75)	16(61)	7(64)
Total	12	11	19	7	4	26	11

Classes of appearance of cooked rice are significantly depended on soil materials by Chi-square test (contingency table) at $\alpha = 0.01$. Rating evaluated by panel tests in comparison with rice cultivar Taichung 189, which cultivated in Tien-Chung, Chang-Hwa county, as the control. ">0" = rating of eating quality is higher than the control, "=0" = rating is equal to the control, and "<0" = rating is lower than the control. SA:Slate alluvials; SSA:Sandstone-shale alluvials. Values in parentheses represent percentage of the total sample in each column.

三、土壤母質對米飯香味之影響

品評項目中米飯香味利用品評人員的嗅覺感官進行分析，米飯之香味乃由所含各種揮發性化合物的綜合表現（Lee et al. 1988）。就米飯香味而言，除粘板岩新沖積土生產之米飯香味達到45%，優於對照外（表三），其餘各種母質土壤生產之稻米，米飯香味優於對照所佔比例皆低，砂頁岩老沖積土僅有23%被評定香味較對照爲優，紅壤及其他土壤則不及20%。

前述各米飯品評項目，包括總評、外觀及香味，粘板岩新沖積土生產之米飯，表現皆相對優於其他土壤母質生產者。與Chen et al. (1988)曾指出粘板岩新沖積土稻米產量雖較老沖積土低，但游離糖含量較老沖積土高出25%，食味較佳，與本試驗結果相同，顯示粘板岩新沖積土確爲較適合生產良質米之土壤。

Table 3. Comparison for aroma of cooked rice produced from different soil materials (2nd crop 1989～1st crop 1992).

Aroma	Latosol	SA (New)	SA (Old)	SA (Non-Alk.)	SSA (New)	SSA (Old)	SA+SSA (Mix.)
>0	2(17)	5(45)	3(15)	1(14)	0(0)	6(23)	1(9)
=0	4(33)	4(37)	5(26)	3(43)	2(50)	11(43)	2(18)
<0	6(50)	2(18)	11(59)	3(43)	2(50)	9(34)	8(73)
Total	12	11	19	7	4	26	11

Classes of aroma of cooked rice are significantly depended on soil materials by Chi-square test (contingency table) at $\alpha=0.01$. Rating evaluated by panel tests in comparison with rice cultivar Taichung 189, which cultivated in Tien-Chung, Chang-Hwa county, as the control, ">0" = rating of eating quality is higher than the control, "= 0" = rating is equal to the control, "<0" = rating is lower than the control. SA:Slate alluvials; SSA:Sandstone-shale alluvials. Values in parentheses represent percentage of the total sample in each column.

四、土壤母質對米飯口味之影響

口味項目爲品評員依據米飯入口之口腔感覺，若以口味項目而言，除粘板岩新沖積土生產米飯優於對照超過50％外（表四），砂頁岩新沖積土亦可望生產較佳口感米飯（優於對照達75％），而米飯口感最差者爲混合沖積土所生產之稻米，其生產之米飯口感較對照差者高達91％。

五、土壤母質對米飯粘性之影響

粘性乃口腔感覺米飯粘稠性，在米飯粘性項目，砂頁岩沖積土生產之米飯粘性較對照強之比例高於其他母質土壤（表五），其中砂頁岩新沖積土生產稻米，粘性較對照米強之比例達到75％。其他如混合沖積土，粘板岩老沖積土及紅壤生產之米飯有70％以上，粘性較對照米弱，其中以混合沖積土所佔91％之比例最高，表現最差，可能最不合國人的口味。

Table 4. Comparison for flavor of cooked rice produced from different soil materials (2nd crop 1989～1st crop 1992).

Flavor	Latosol	SA (New)	SA (Old)	SA (Non-Alk.)	SSA (New)	SSA (Old)	SA+SSA (Mix.)
>0	3(25)	6(55)	3(15)	2(29)	3(75)	9(34)	0(0)
=0	1(8)	1(9)	2(11)	1(14)	1(25)	3(12)	1(9)
<0	8(67)	4(36)	14(74)	4(57)	0(0)	14(54)	10(91)
Total	12	11	19	7	4	26	11

Classes of flavor of cooked rice are significantly depended on soil materials by Chi-square test (contingency table) at $\alpha=0.01$. Rating evaluated by panel tests in comparison with rice cultivar Taichung 189, which cultivated in Tien-Chung, Chang-Hwa county, as the control, ">0" = rating of eating quality is higher than the control, "= 0" = rating is equal to the control, "<0" = rating is lower than the control SA:Slate alluvials; SSA: Sandstone-shale alluvials. Values in parentheses represent percentage of the total sample in each column.

Table 5. Comparison for cohesion of cooked rice produced from different soil materials (2nd crop 1989 ~ 1st crop 1992).

Cohesion	Latosol	SA (New)	SA (Old)	SA (Non-Alk.)	SSA (New)	SSA (Old)	SA + SSA (Mix.)
>0	2(17)	3(27)	3(16)	2(29)	3(75)	12(46)	0(0)
=0	1(8)	1(9)	1(5)	1(14)	0(0)	0(0)	1(9)
<0	9(75)	7(64)	15(79)	4(57)	1(25)	14(54)	10(91)
Total	12	11	19	7	4	26	11

Classes of cohesion of cooked rice are significantly depended on soil materials by Chi-square test (contingency table) at $\alpha = 0.01$. Rating evaluated by panel tests in comparison with rice cultivar Taichung 189, which cultivated in Tien-Chung, Chang-Hwa county, as the control, ">0" = rating of eating quality is higher than the control, "= 0" = rating is equal to the control, "<0" = rating is lower than the control. SA:Slate alluvials; SSA:Sandstone-shale allulvials. Values in parentheses represent percentage of the total sample in each column.

六、土壤母質對米飯硬性之影響

品評項目除口味、粘性外，硬性亦屬於一種口腔感覺，硬性是屬於口腔咀嚼時之壓力，國人普遍偏好質軟的米飯，硬性太高的米飯一般被認爲是口感較差者，較不易被民衆接受。硬性比較結果顯示，粘板岩沖積土，紅壤及混合沖積土生產米飯有偏硬的現象（表六），生產稻米之米飯硬性較對照米低的土壤母質則以砂頁岩沖積土所佔比例最高，其中砂頁岩新沖積土計有75%較對照米硬性低。

七、土壤母質對米飯均衡度之影響

綜合以上結果，粘板岩新沖積土生產之米飯，在總評、外觀及香味上，皆優於其他土壤母質所生產者；但就口腔的咀嚼而言，砂頁岩新沖積土生產的米飯，不論就口味上、粘性、硬性等似乎皆較適合國人的口感；而混合沖積土生產的米飯，則在各種感官上皆顯示較不受喜愛，米質有低劣的趨勢。新沖積土生產之稻米品質較佳，可能與滲漏速率較高（Chen et al. 1988），通氣較佳，以及交換性矽之釋放較快有關。粘板岩沖積土由於坋粒及砂粒中雲母含量較砂頁岩沖積土高，鉀的含量較高，可能有助於米質的改善。

但口腔咀嚼的感官應包括粘、硬度的整體均衡表現，本試驗除了利用品評員進行食味品評比較外，並另以質地分析儀測得米飯之均衡度（$-H/H$），作爲評估米質好壞之指標，並與評審團之官能品評結果比較。均衡度爲粘度（$-H$）與硬度（H）之比值，Okabe（1979）認爲均衡度在0.15到0.2之間米質最好，屬於A級。本試驗所調查之米飯均衡度均未達到A級之標準，此點可能與目前臺灣推廣品種，米飯均衡度尚未達到優良程度，或良質米栽培管理技術一般農民尚未純熟有關。故本試驗將B及C級（0.10-0.15）當作較佳均衡度，D級（0.05-0.10）爲中等，E級（低於0.05）視爲均衡度最差，以進行對比。在各種土壤母質中，以粘板岩沖積土生產之米質，具有較合適之均衡度（表七），其中又以粘板岩新沖積土生產之稻米均衡度達到B及C級所佔比例最高（45%）。

Table 6. Comparison for hardness of cooked rice produced from diffeent soil materials (2nd crop 1989～1st crop 1992).

Hardness	Latosol	SA (New)	SA (Old)	SA (Non-Alk.)	SSA (New)	SSA (Old)	SA+SSA (Mix.)
>0	9(75)	8(73)	15(79)	7(100)	1(25)	12(46)	10(91)
=0	1(8)	0(0)	0(0)	0(0)	0(0)	1(4)	0(0)
<0	2(17)	3(27)	4(21)	0(0)	3(75)	13(50)	1(9)
Total	12	11	19	7	4	26	11

Classes of hardness of cooked rice are significantly depended on soil materials by Chi-square test (contingency table) at $\alpha=0.01$. Rating evaluated by panel tests in comparison with rice cultivar Taichung 189, which cultivated in Tien-Chung, Chang-Hwa county, as the control, ">0" = rating of eating quality is higher than the control, "= 0" = rating is equal to the control, "<0" = rating is lower than the control. SA:Slate alluvials; SSA:Sandstone-shale allulvials. Values in parentheses represent percentage of the total sample in each column.

Table 7. Comparison for balance (−H/H) of rice produced from different soil materials (2nd crop 1989～1st crop 1992).

−H/H	Latosol	SA (New)	SA (Old)	SA (Non-Alk.)	SSA (New)	SSA (Old)	SA+SSA (Mix.)
B&C	3(25)	5(45)	2(11)	3(43)	0(0)	6(24)	1(9)
D	7(58)	6(55)	17(89)	4(57)	1(33)	10(38)	8(73)
E	2(17)	0(0)	0(0)	0(0)	2(67)	10(38)	2(18)
Total	12	11	19	7	3	26	11

Classes of balance (−H/H) are significantly depended on soil materials by Chisquare test (contingency table) at $\alpha=0.01$. Classified by the range of −H/H, i.e. A:0.15-0.20, B:0.13-0.15, C:0.10-0.13, D:0.05-0.10 and E:<0.05 (Okabe 1977). SA:Slate alluvials; SSA:Sandstone-shale alluvials. Values in parentheses represent percentage(%) of the total sample in each column.

甚多學者指出，食味總評與粘度及均衡度（−H/H）呈顯著正相關，但與硬度呈負相關（Chikubu et al. 1985, Juliano et al. 1985）。本試驗利用Spearman (Lehmann 1975)相關分析各食味品評項目及均衡度之關係，結果顯示除硬性與各項目呈極顯著負相關外，其餘各食味特性及均衡度之間呈極顯著正相關（表八）。此與前述各項特性於不同土壤母質下所呈現的結果頗爲一致，其中，食味總評與口味、外觀及粘性之相關係數，分別大於0.9，與硬性之相關係數亦呈極顯著負相關（−0.9），與香氣及均衡度的相關係數略低，分別爲0.69及0.74，但仍達到極顯著正相關。就均衡度而言，除了與香味之相關係數未達0.7（兩者相關係數=0.61）外，與其他品評項目之相關係數皆大於0.7及小於−0.7（硬性）。一般進行米飯食味品評，需具備多位受過長期訓練之合格品評員，因此，在考慮節省人力、物力，並可快速評估稻米食味之前提下，均衡度或可部分代替品評員之食味品評，以節省米質分析及食味品評過程中，大量人力、物力和時間的需求。

Table 8. Correlation analysis for some criteria properties of rice eating quality and balance.

	Overall*	Appearance	Aroma	Flavor	Cohesion	Hardness	Balance
Overall	1.00	0.90**	0.69**	0.97**	0.96**	−0.91**	0.74**
Appearance		1.00	0.65**	0.89**	0.88**	−0.90**	0.72**
Aroma			1.00	0.70**	0.68**	−0.61**	0.61**
Flavor				1.00	0.97**	−0.92**	0.75**
Cohesion					1.00	−0.93**	0.76**
Hardness						1.00	−0.73**
Balance							1.00

*: Overall sensory evaluation by panel test.
**: Signficantly different at $\alpha = 0.01$ by Spearman correlation analysis.

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收稿日期：83年 3 月30日，接受刊登日期：83年 4 月18日。
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