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E. C. M No. 761 探空圖解之分析

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近年以來，高空測候之應用，日益發達，其測站日多，紀錄亦日益豐富，為便於計算，以資天氣預報，均利用圖解法。如 Refasdal 之 Emagrame, N. Shaw 之 Tephigrame, Rossby 之 Diagrame, Neuhoff 之 Diagrame 等均甚著稱，近法國氣象局有一新圖解法，極為適用，但非作解釋，不能知其原理，亦無由得以應用，故特為之詳細分析如次。

此圖為笛卡兒式圖解，用兩軸製之，一軸為氣壓具有氣壓對數，一軸為溫度，具有溫度標度。

設令 p 為氣壓，T 為絕對溫度，則圖上一點之兩坐標 x, y. 可以下列公式，以氣壓溫度表示之，即：

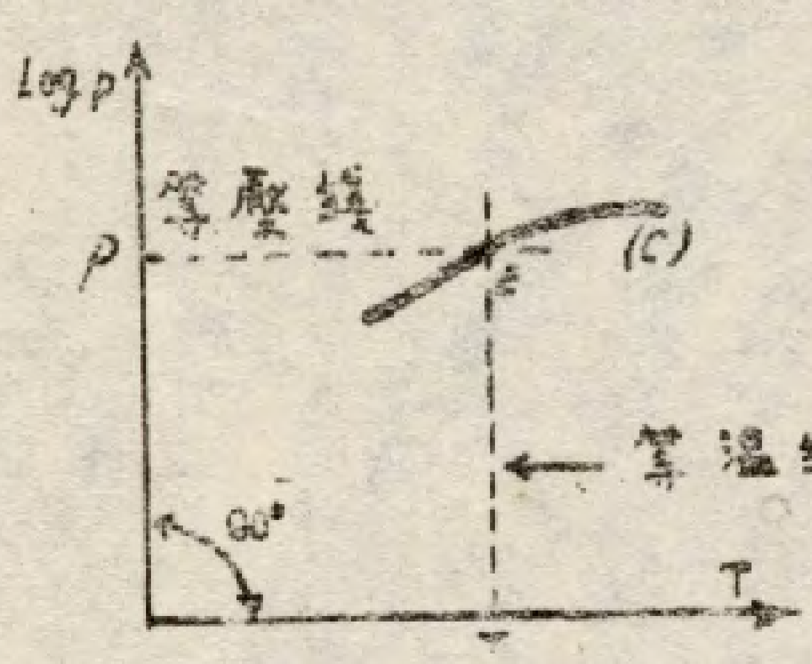
$$y = K\ (A - \log p) \qquad (1)$$

$$x = K'T \qquad (2)$$

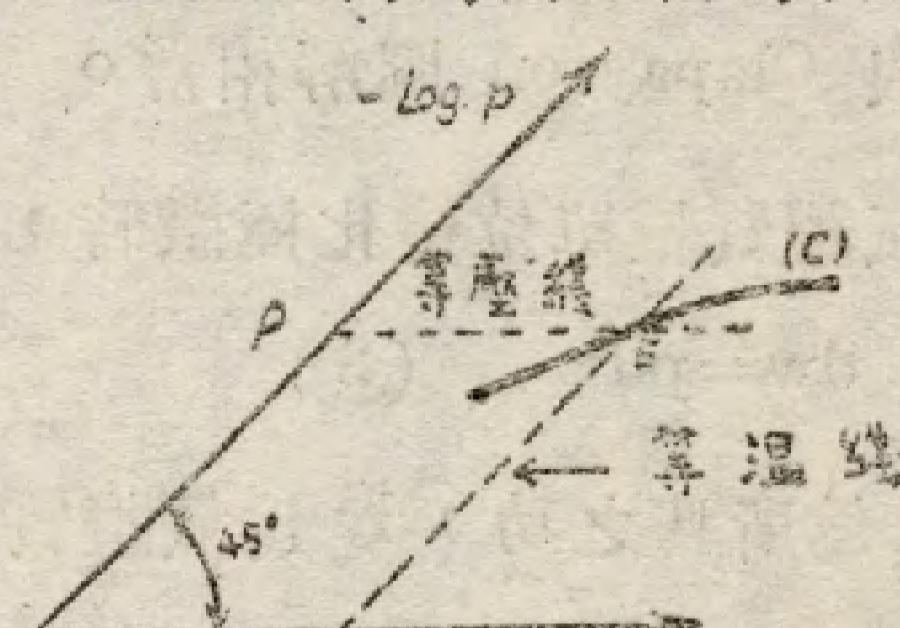
所以此圖解屬於 T－log p 圖解之一類，其中之典型者即 Refasdal 之圖解。

此圖共有兩型，其號數相同，第一型為長方形軸，直軸為氣壓橫軸為溫度（第一圖）（稱為舊型圖）

其第二型係用斜軸（第二圖）氣壓軸向左斜45°，溫度軸仍為橫軸稱為新型圖。



第一圖



第二圖

在探空測候網，所測之溫度濕度，探空圖解，有若干應用目標，略說如下：

（一）用圖解表示探空結果，即謂依探空儀器，上升時所測之數值，按氣壓以表示溫度濕度，而計算此各變數之量。

（二）用圖解表示一空氣質量所受之變化，此種表示，可便利於若干有用之討論，如大氣垂直平衡中之穩定性或不穩定性，或氣團之演進是也。

（三）用探空時所測溫度濕度，按氣壓計算高度。

茲先論此圖解對於表示空氣質點變化之狀態。

（I） 空氣變化及狀態之表示

若氣體之含分常定，則其狀況只與兩變數有關，故任何兩量圖解，均易於表示之，設所擇之變數，爲氣壓與溫度，此實爲氣象中最適用者，則全部圖解中，包括若干等壓線，及等溫線以資表示，此卽761號圖解中所用，此圖中有若干橫綫等壓線，有若干直線等溫線，在舊型圖等溫線爲垂直直線，而在新型圖，則爲斜45°之斜直線，若在此圖中表示氣體狀態，其氣壓爲p, 溫度爲T, 卽等壓線p及等溫線T之交點E是也，（第一圖）（第二圖）E點所得者，卽足以定空氣氣體狀態，故名此點爲氣體態點。

如連續變更氣體狀態，其代表此狀態之E點，卽在圖上作成曲線C。所以此C曲線卽代表氣體狀態之變化，其特別者，如氣壓常定（等壓變化）則E點在圖上作成等壓線，如溫度常定（等溫變化）則E點作成等溫線。

此種方法，依所選擇之變數定之，與 Clapayron 熱力學相似，能之觀念，在大氣學中有重要作用，故如用氣壓溫度爲變數，則似應選擇一標度，俾此圖解保藏Clapayron 圖解之基本性質，卽"某一氣體質量，於變化時廻復其原來狀態，所供給之功，與 Clapayron 圖解中，代表此變化合閉曲線內之面積有比例"。

若探討此類圖解之性質，則見凡爲（T－log p）式之圖解，若氣體爲理想氣體，則均與 Clapayron 圖解相當。

蓋氣體質量單位變化極微時，所有之功爲：

$$dw = pdv \qquad (3)$$

式中 dw 爲所具之功，dv 爲氣體質量單位體積之變差。

若計及理想氣體，其公式爲：

$$pv = RT \qquad (4)$$

R 爲關於所說氣體常數，若作微分式則有，

$$pdv - vdp = RdT \qquad (5)$$

或
$$pdv = RdT - vdp = RdT - \frac{RT}{p}dp \qquad (6)$$

則功之公式變爲：

$$dw = RdT - RT\frac{dp}{p} = RdT - RT\,d\log p \qquad (7)$$

以圖解之坐標表示 dT 及 d log p(1式2式)則有：

$$dy = K\,d\log p \qquad (8)$$

$$dx = K'dT \qquad (9)$$

或 $$-d\log p = \frac{dy}{K} \qquad (10)$$

$$dT = \frac{dx}{K'} \qquad (11)$$

則功之公式變爲：

$$dw = \frac{Rdx}{K'} + R\frac{xdy}{K'K} \qquad (12)$$

若在有窮變化中，使理想氣體自 A 狀態度變 B 狀態，則質量單位所給之功爲：

$$W_{AB} = \int_A^B dw = \int_A^B R\frac{dx}{K'} + \int_A^B \frac{R}{K'K}xdy \qquad (13)$$

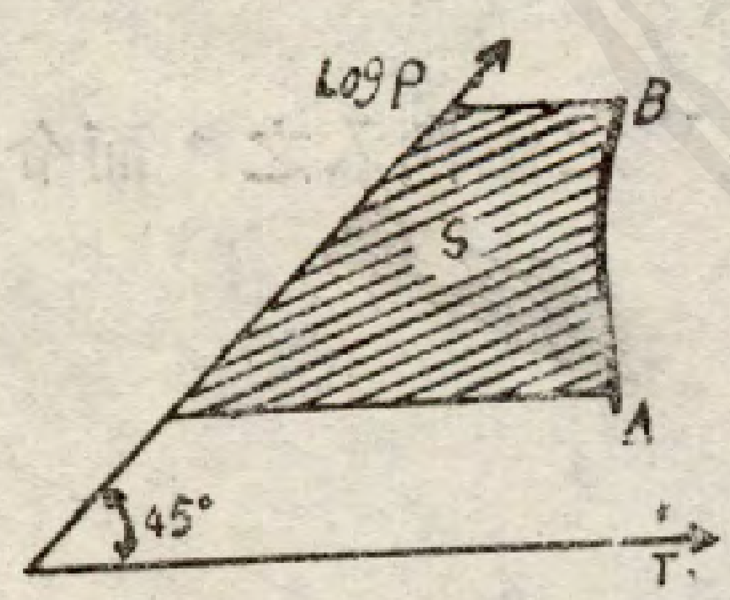
或 $$W_{AB} = \frac{R}{K'}(x_B - x_A) + \int_A^B \frac{R}{K'K}xdy \qquad (14)$$

所有積分，均依 AB 變化得之。

在第14式之第二項，可知積分可得含在 AB 曲線上 y 之軸及兩直線間之面積。

$$y = y_B \qquad y = y_A$$

設令 S 爲此面積(第三圖)則有：



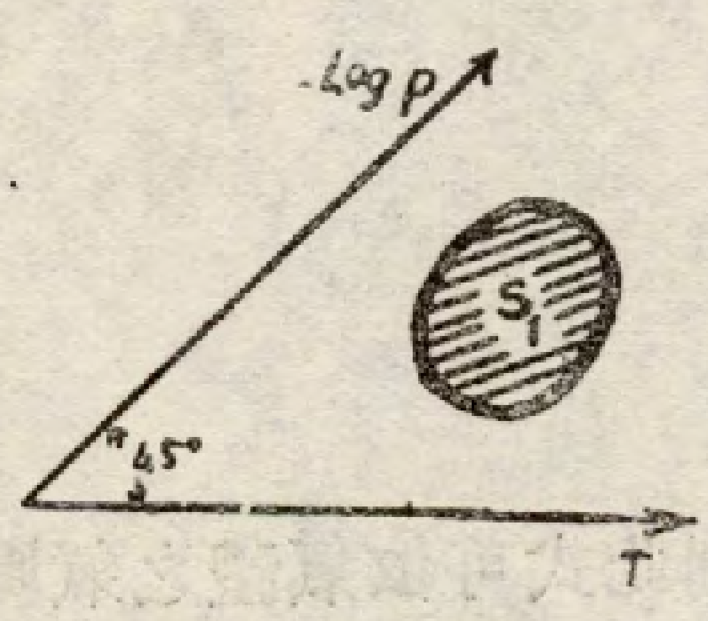
第 三 圖

$$\int_A^B xdy = S \qquad (15)$$

則可作 $$W_{AB} = \frac{R}{K'}(x_B - x_A) + \frac{R}{K'K}S$$

或以 T 代 $\frac{x}{K'}$ 則有：

$$W_{AB} = R(T_B - T_A)\frac{R}{K'K}S \qquad (16)$$



第 四 圖

若變化爲合閉變化，卽終態 B, 等於初態 A,(第四圖) 則有 $T_A = T_B$, 如此可將終溫與初溫間之一項消去，而關於 S 面積一項不爲零，則功之公式變爲：

$$W_{AA} = \frac{R}{K'K}S_1 \qquad (17)$$

此式中之 S_1 代表變化曲線以內之面積。

若 E 點所經行曲線之方向與時計針反向，則易於見功爲正。

但須知 Clapayron 圖解之基本性質，任何流動體，及此流動體狀態公式任何形式

，均能適用，而 T－log p 圖解，則只適用於理想氣體。且在 Clapayron 圖解上，計算功時，不參入流動體之性質，反之在 T－log p 圖解，則功與代表變化曲線內面積之比例，必須參入理想氣體之氣體常數 R，再若用 T－log p 圖解計算關於不合閉變化之功，則須計及 $B(T_B-T_A)$ 之項而在Clapayron圖解之計算，則無此類似之計算。

依熱力學第一原則，供給一氣體質量以成合閉變化之熱，應等於氣體所供給之功，設用此同一能之單位，以表示功及其熱量，則對於單位質量有：

$$Q=\frac{R}{K'K}S \qquad (18)$$

若用熱單位，則熱量當為：

$$Q=\frac{1}{J}\ \frac{R}{K'K}S \qquad (18')$$

絕熱變化

以上已說關於T－log p 圖解，如何表示等壓線及等溫線之變化，在大氣學中，尙加入其他之變化，其最重要者，為絕熱變化，卽在變化期間，氣體質量與外界無熱之交換也。

在極微之變化時，所取自外界，相當於氣壓與氣溫變差 dp 與 dT之熱，可用特定公式表示之，卽：

$$q=Cp\,dT-V\,dp \qquad (19)$$

式中 Cp 為氣體之定壓比熱，以理想氣體公式，(4) 求得 V 之值代入之，而令交換之熱量為零則有：

$$O=Cp\,dT-\frac{RT}{p}dp \qquad (20)$$

若以 T 及 Cp 除之，則有：

$$\frac{dT}{T}=\frac{R}{Cp}\ \frac{dp}{p} \qquad (21)$$

此公式極易積分，則有：

$$\frac{T}{T_o}=\left(\frac{p}{p_o}\right)^{R/C_p}$$

如已知氣體受絕熱變化，而初壓及初溫為 p_o 及 T_o，則此式可依氣體之氣壓求氣體之溫度。

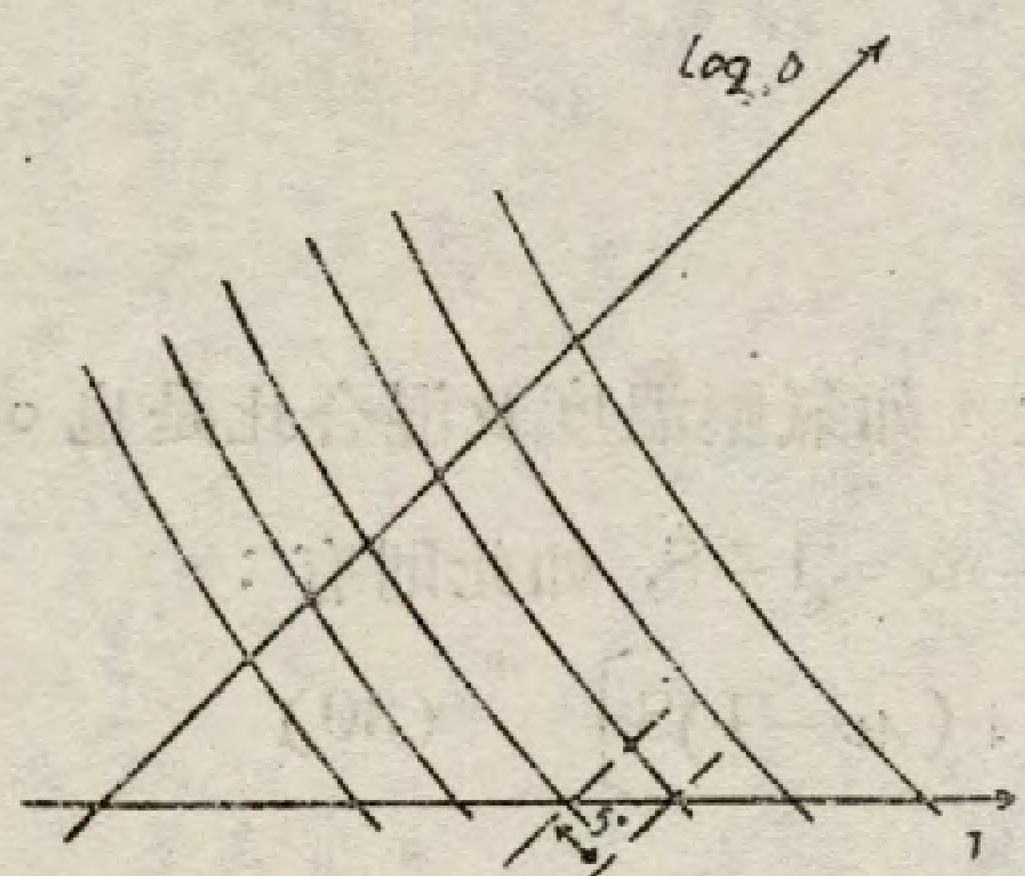
就他方面觀之，則 $\partial q=O$ 因有：

$$dS=\frac{\partial q}{T}=O \qquad (23)$$

可見絕熱變化，等於等熵變化，所以表示絕熱變化曲線，經過各點之表示同熵氣體

狀態者，是爲等熵線。

在探空圖解上，等熵曲線，其每線表示凡所有初態相當於所經過各點之氣體變化。(第五圖)



第 五 圖

就氣象言，則用位溫Θ定熵爲合宜，所謂位溫者，卽任何初態之氣體以絕熱引至氣壓爲1000毫巴時所得之溫度也。換言之，卽以同熵氣體狀態相當溫度，示氣體之熵，但其氣壓爲1000毫巴耳，爲便於讀位溫計，所有等熵曲線（常稱爲乾絕熱線）之畫法，以0°C兩旁相距5°，切斷1000 mb 等壓線，位溫以Θ爲符號，用攝氏度計。

空氣狀態之表示

大氣中空氣多含有水汽，可視爲兩氣體含分不同之混合。

乾空氣，含有氧，氮，氬及其他若干稀有氣體，其含分爲常定，在大氣常見之氣壓溫度條件中，此空氣可視爲理想氣體。

大氣中所含之水汽張力極微，故水汽亦可視爲理想氣體。

混合質量之含分，常以下列兩比值表示之：

(一)比濕：卽水汽質量 m_v 與混合全質量 m 之比，此比值常以 S 或 q 示之，卽有：

$$S=q=\frac{m_V}{m} \qquad (24)$$

(二)混合比，卽某一混合質量，水汽質量 m_V 與乾空氣質量 m_A 之比，此比值常以 r 示之，則有：

$$r=\frac{m_V}{m_A} \qquad (25)$$

近年以來，大多數氣象家，均主張用混合比。

濕空氣爲理想空氣之混合，亦同於理想氣體，故亦服從理想氣體公式，卽：

$$\frac{p}{\rho}=R'T \qquad (26)$$

式中 ρ 卽空氣之比重。

爲合於氣體常數定律，則其氣體常數 R' 爲：

$$R'=\frac{m_aR_a+m_vR_v}{m_a+m_v} \qquad (27)$$

R_a 爲乾空氣氣體常數，R_v 爲水汽氣體常數。

若 $m_a=1$, $m_v=r$, 則 27 式成爲：

$$R' = \frac{R_a + rR_v}{1+r} = R_a \frac{1+\frac{R_v}{R_a}r}{1+r} = R_a \frac{1+\mu r}{1+r} \quad (28)$$

假定 $\frac{R_v}{R_a} = \mu = 1.608$

則態之公式爲下式：

$$\frac{p}{\rho} = R_a \frac{1+\mu r}{1+r} T \quad (29)$$

觀此式可見參入者有四變數，其中三變數爲獨立，如氣壓溫度及混合比是也。

亦可用 $m = m_a + m_v = 1$, 因而 $m_v = S$, 而 $m_a = m - m_v = 1 - S$, 如此則有：

$$R' = (1-S)R_a + SR_v = R_a\left[1 + \left(\frac{R_v}{R_a} - 1\right)S\right] = R_a\left[1 + (\mu - 1)S\right] \quad (30)$$

將此值參入態之公式則有：

$$\frac{P}{\rho} = R_a\left[1 + (\mu - 1)S\right]T \quad (31)$$

式中有四變數 p, ρ, S, T 參入，而擇 $p, T, S.$ 爲獨立變數。

尙有須注意者，此三變數，p, T, s 或 p, T, r 各有不同作用，s 與 r 變數，以示混合氣體之含分，卽可以定此氣體之性質，氣體含分一定，則 p 與 T 兩變數之狀態，亦卽定矣，故須分別之，卽：

(一)含分變數 r 或 s

(二)狀態變數 p 及 T

在空氣變化途中，此兩集團變數，所處置方式，各不相同，其含分變數 r 或 s, 只隨水汽之增減變易其值，故只能在特殊條件中發生，且若空氣之含分變更，必與外界有物質之交換，則已在合閉系之熱力範圍以外矣。

既有此規定，則狀態變數，氣壓與溫度，極易在圖上、用點表示之，若圖只有兩量，則含分變數必須於態點附近，用記號註明之或用與態點有關之第二點。

吾人均知，在實用上，不直接量定混合比及比濕，但用計定之結果，或其他之量，亦易計算此值。

若欲計算單位容積之 s 或 r, 以 m_a 及 m_v 爲乾空氣及水汽比重 ρ_a 及 ρ_v 之質量，

則有： $r = \frac{m_v}{m_a} = \frac{\rho_v}{\rho_a} \quad (32)$

而乾空氣及水汽之狀態公式如下：

$$\rho_a = \frac{P_a}{R_a T} \text{ 及 } \rho_v = \frac{e}{ReT}$$

令 p_a 爲乾空氣部分氣壓，e 爲水汽張力，

若將此值，參入(32)式中，則變爲：

$$r=\frac{\dfrac{e}{R_eT}}{\dfrac{p_a}{R_aT}}=\frac{R_a}{R_e}\;\frac{e}{p_a}\qquad(33,)$$

設令　$v=\dfrac{R_a}{R_e}=\dfrac{1}{\mu}=0.622$

則有：　$r=\dfrac{ve}{p_a}$　　(33)

或計及混合理想氣體部分氣壓之增值，即 $p=p_a+e$ 則有：

$$r=\frac{ve}{p-e}\qquad(34)$$

若係比濕，則亦可爲：

$$s=\frac{ve}{p-(1-v)e}\qquad(35)$$

變化時功之計算

$T-\log p$ 圖解之基本性質，旣適用於理想氣體，亦適用於含分常定之濕空氣，但圖上所量定面積與功相比之因子，則須以適合之氣體常數計算之，即：

$$R'=R_a\left(\frac{1+\mu r}{1+r}\right)=R_a\Big[1+(\mu-1)s\Big]$$

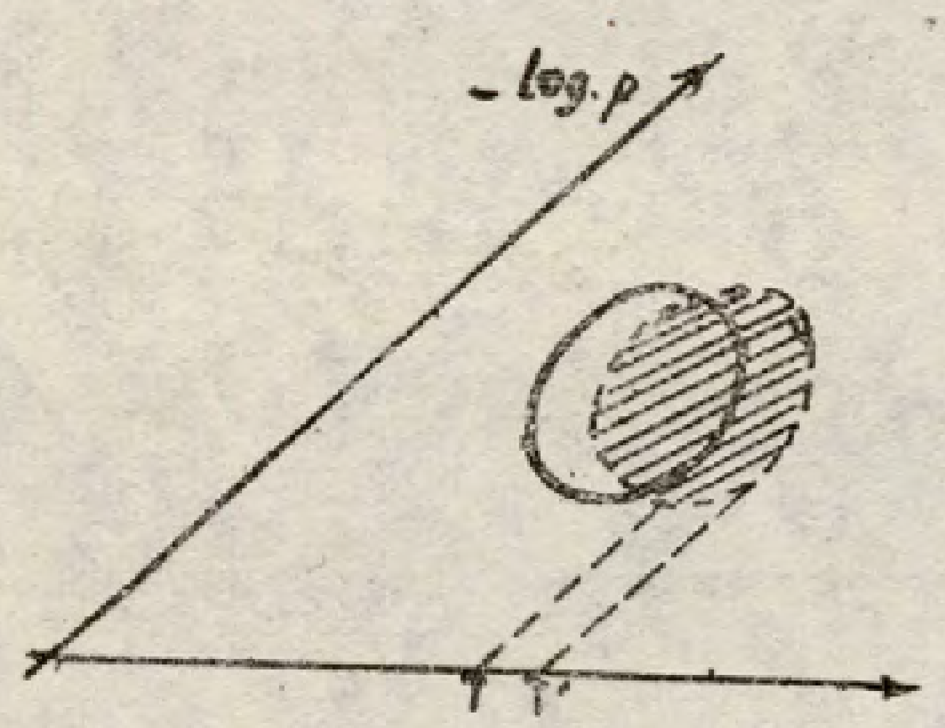
故此因子與空氣所含水汽成分有關，依此條件，則空氣含分變更而有變化時，其功之計算，甚爲複雜，爲避免此困難計，參入濕空氣之虛溫度 T', 則有：

$$T'=\left(\frac{1+\mu r}{1+r}\right)T=\Big[1+(\mu-1)s\Big]T\qquad(36)$$

若以上式參入狀態公式，(29)或(31)，則有：

$$\frac{p}{\rho}=R_aT'\qquad(37)$$

此式可使 s 或 r 含分濕空氣之 p, T 各狀態，相當於乾空氣之 p,T' 各狀態（第六圖）設仍用極微變化之功公式，即 $dw=p\,dv$　(3) 且重作以上之計算，以證明功與表示合閉變化曲線內面積之等值，而用下式，



第 六 圖

$$pv=R_aT'\qquad(38)$$

此與(37)式等值，則除以 T' 代 T 外，其式相同，此可證明可在圖上，以虛態點 V 代態點 E, 而計算功，但 V 亦在與 E 同一等壓線上，惟其溫度爲 T' 而非 T 耳。

在合閉變化期間，態點經行一合閉曲線 C, 而虛態點 V 經行一合閉曲線 C', 但須知必須變化終期，空氣之含分與初態相同，C' 始能合閉，設如此例，則空氣所成之

功，與 C' 曲線內之面積有比例，此比例係數卽適用於乾空氣者，卽 $\frac{R_a}{K'K}$ 也。

若 c' 不回復至其初點部位，則須加以等於 $R(T_1'-T_0')$ 之訂正數，其 T_0' 爲初態之虛溫度，T_1' 爲終態之虛溫度，此訂正數大概太小。

未飽和濕空氣之絕熱變化

在凝結現象或蒸發現象，未參入以前，卽謂空氣含分仍爲常定時，絕熱公式適用於理想氣體者，亦適用於濕空氣，但須用適合之氣體常數，此濕空氣之氣體常數爲

$$R'=R_a\frac{1+\frac{R_v}{R_a}r}{1+r}=R_a\left[1+(\mu-1)s\right] \qquad (28或30)$$

其與空氣定壓比熱 C_{pa} 及水汽定壓比濕 C_{pv} 有關之濕空氣定壓比熱 C'_p 可以下式表示之：

$$C'_p=\frac{m_a C_{pa}+m_v C_{pv}}{m_a+m_v}=C_{pa}+\frac{m_a+\frac{C_{pv}}{C_{pa}}m_v}{m_a+m_v} \qquad (39)$$

若設定 $\frac{C_{pv}}{C_{pa}}=\lambda=1.837$

則有： $C'_p=C_{pa}\frac{m_a+\lambda m_v}{m_a+m_v}$ (40)

設擇 $m_a=1$，則 $m_v=r$，而 C'_p 用混合比表示之爲：

$$C'_p=C_{pa}\frac{1+\lambda r}{1+r} \qquad (41)$$

設擇 $m=m_a+m_v=1$，則 $m_v=s, m_a=1-s$，而 C'_p 可以比濕表示之，爲：

$$C'_p=C_{pa}(1-s+\lambda s)=C_{pa}[1+(\lambda-1)s] \qquad (42)$$

若用混合比，則22式絕熱公式氣壓比之指數變爲：

$$\frac{R'}{C'_p}=\frac{R_a}{C_{pa}}\cdot\frac{1+\mu r}{1+\lambda r} \qquad (43)$$

設用比濕則有：

$$\frac{R'}{C_p}=\frac{R_a}{C_{pa}}\cdot\frac{1+(\mu-1)s}{1+(\lambda-1)s} \qquad (44)$$

因 r 與單位相比極小，故作下式亦無大錯誤，

$$\frac{R'}{C'_p}\#\frac{R_a}{C_{pa}}(1+\mu r)(1+\lambda r)\#\frac{R_a}{C_{ra}}\left[1+(\mu-\lambda)r\right] \qquad (44,)$$

其 μ 與 λ 之數值爲 $\mu=1.608$　$\lambda=1.837$

則有， $\frac{R'}{C'_p}\#\frac{R_a}{C_{pa}}(1-0.229\,r)$ (45)

可見，r 大概極小，故濕空氣絕熱所用指數與乾空氣所用者，無若何差異，所以可謂圖上曲線，表示乾空氣絕熱變化者，亦能用表示濕空氣絕熱變化，而無大錯

。F. C. M. 761圖上，卽有乾空氣絕熱曲線。

飽和濕空氣之表示

設濕空氣已飽和水汽，但不含有液體水，或僅屬於有雲空氣之氣體期，則空氣之含分，完全以兩度數定之，卽氣壓與溫度也，蓋水汽張力常等於飽和水汽張力 e_w, 此 e_w 卽依溫度而變化，在此條件，混合比有定值 r_w

$$r_w=\frac{Ve_w}{p-e_w} \qquad (46)$$

此值卽所謂，在氣壓 p, 溫度 T 之「飽和混合比」。

而比濕 s_w 之值則爲：

$$s_w=\frac{Ve_w}{p-(1-v)e_w} \qquad (47)$$

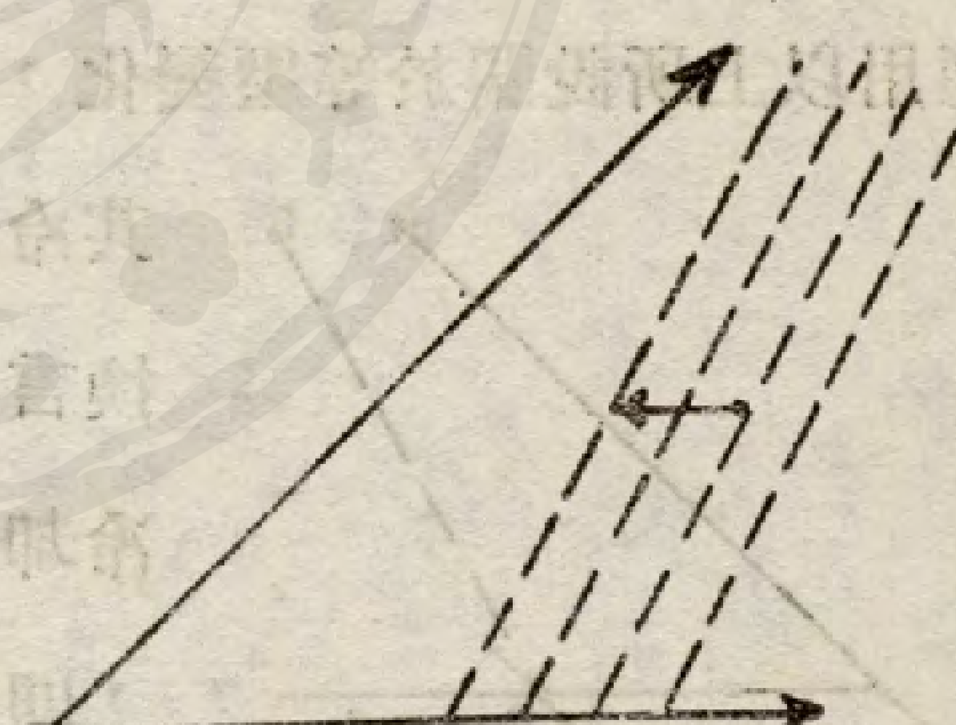
此值卽稱，氣壓 p, 溫度 T「飽和比濕」。

此兩量有極重要作用，故在圖中，常有等飽和混合比線或等飽和比濕線。

在舊型圖等飽和比濕線爲每仟克濕空氣含若干克水汽，以綠色聯線表示之。（第七圖）

在新型圖則等飽和混合比線爲每仟克乾空氣含若干克水汽用淡黃色斷線表示之（第八圖）

第七圖



第八圖

且此線與等溫線成銳角，設沿此線自高氣壓向低氣壓，則見溫度遞減，線之記數號，自低溫向高溫增加。

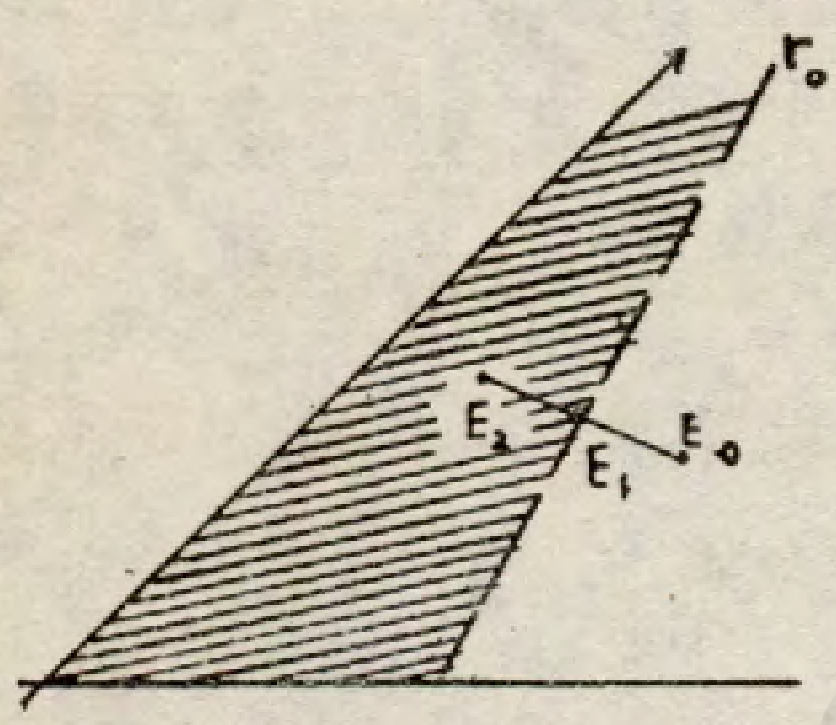
狀態變數 p 與 T, 既在圖上以 E 點表示之，設空氣之混合，爲已飽和，則亦以等飽和混合比線，直接連於 E 點，設圖上係等飽比濕線則亦如此聯之。

新型圖已取舊型代之，故比濕已不成問題，且比濕現已漸不用矣，且實用上，比濕之數值與混合比之數值，相差甚微，故相混亦無碍也。

常定含分空氣變化之界限

濕空氣不能飽和之條件，為其所有之水汽張力，e, 比其溫度所能有之飽和水汽張力 e_w 為小，凡一已知之氣壓值，其混合比依水汽張力而增加，所以欲令空氣不飽和，必其混合比較其相當氣壓溫度之飽和混合比為小。

設令 r_o 為濕空氣之混合比，此亦可謂其態點對於等飽和混合比線，以 r_o 為記號者，應在凡記數大於 r_o 之區中(第九圖)，即謂在圖上此線之右，所以凡含分 r_o 濕空氣之變化，於其代表曲線未切斷等飽和混合比線 r 之時，不能使之飽和。

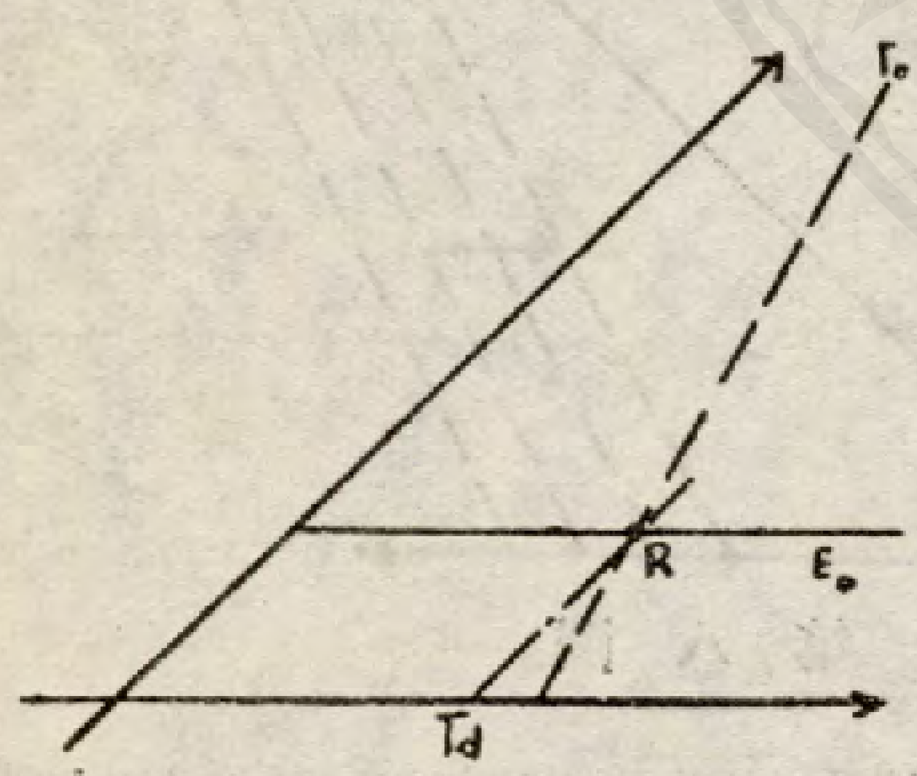


第九圖

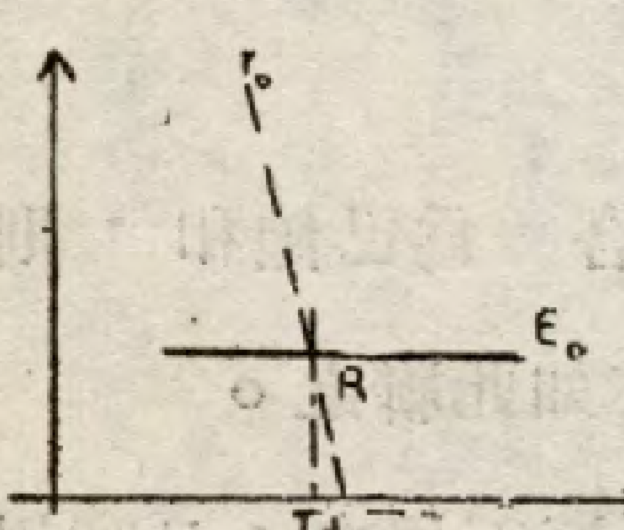
反之，若出乎飽和條件，一態點 E_2, 在等飽和混合比線 r_o 之左，(第九圖) 不能代表 r_o 含分濕空氣之狀態，所以在圖上記號 r_o 等飽和混合比線之左部，禁止混合比 r_o 濕空氣常定含分之變化，若有一變化，能使態點超越等飽和混合比線有 r_o 記號者，而至 E_1 點，即發動空氣在 E_1 點飽和，而發生凝結，在 E_1 及 E_2 之間，混合比均等於空氣狀態相當之飽和混合比，故此空氣之含分，除變化與等飽和混合比線相混之外，均常在無定狀況中。

露點

應用以上所說關於等壓變化，即可見空氣增熱，能以常定含分，無窮進行，則其冷却，可用等混合比線 r_o, 界之於 R 點。(第十圖) 換言之，凡空氣初態為 E_o 點，而含分為 r_o, 在定壓下冷却，當其到態點 R 時，即飽和。R 點所表示之狀態，即露點也。在 R 點所讀之度，即露點溫度 T_d,(第十一圖) 設冷却繼續進行，即有凝結參加，而空氣成雲性。



第十圖



第十一圖

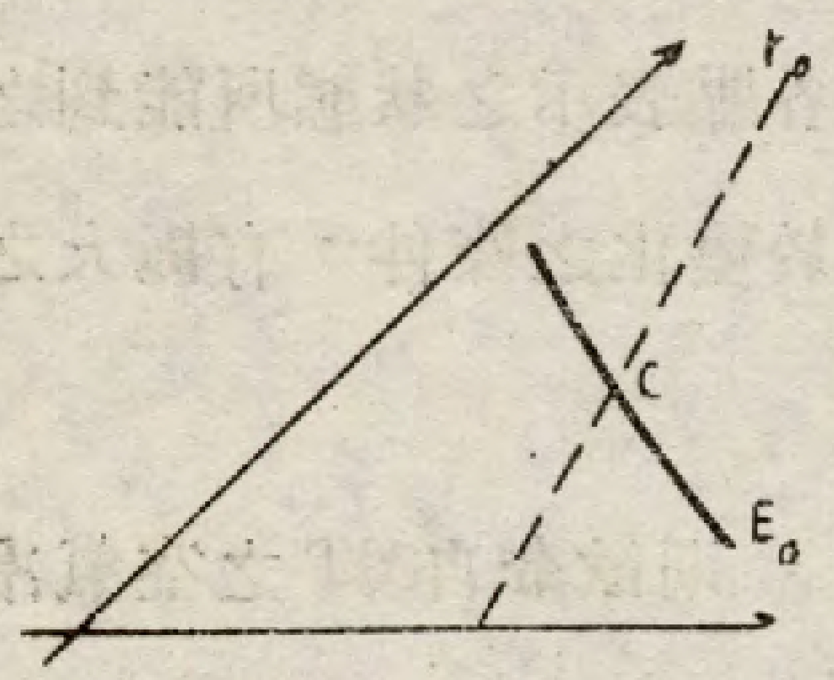
由此可見在新型 761 號圖上，如知混合比，即可用圖求露點溫度，反之，若知露點溫度，即謂在圖上作 R 點讀混合比，可知 r_o。

用舊型 761 號圖或其他任何圖解，有等含分線，等溫線及等壓線均可用比濕 s_o 求露點，第十一圖即以示在舊型圖上之計算法。

絕熱凝結點

混合比 r_0 之含分常定空氣絕熱變化，可用代表變化乾絕熱線，與有 r_0 記號等混合比線交點 C 爲界。(第十二圖)

從初態 E_0 起，在變化期間，其態點仍在乾絕熱部分，而其中之氣壓溫度均在 C 之上時，空氣仍爲未飽和。若變化期間，態點到達 C 點時，空氣卽成飽和，則名 C 點爲絕熱凝結點。如求其合理化，似應稱爲絕熱飽和點，但以絕熱凝結點較爲適合。



第十二圖

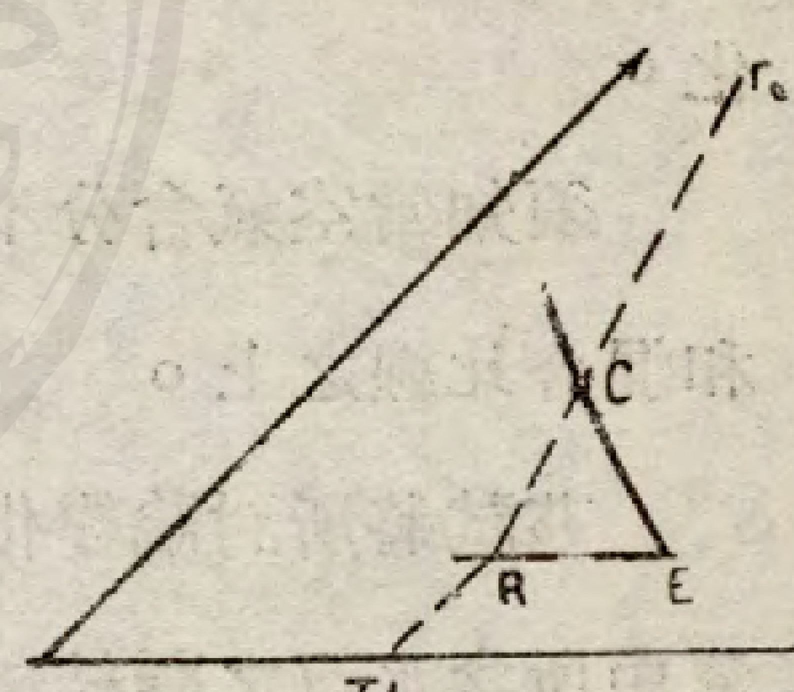
絕熱凝結點之得數，可以定空氣之含分，故可在圖上，以態點 E 及絕熱凝結 C, 定空氣之狀態及含分，露點亦可作此用，但以用絕熱凝結點爲上，因於討論空氣穩定性與不穩定性時，可以將其參入，而尤以定雲底之用爲最。

因此故常以 E, C, 兩點，表示空氣狀態及其含分。

絕熱凝結點之定法

若空氣含分，由其混合比得之，則定絕熱凝結點極易，卽取經過態點絕熱線與有混合比記號 r_0 之等飽和混合比線之交點可矣。

若空氣濕度，由露點得之，亦易於定絕熱凝結點，只從 E 點沿等壓線至有 T_d 記號等溫線之交點，既而循有 R 記號之等飽和混合比線，延至自 E 點來之乾熱線之交點，卽可定露點。(第十三圖)



第十三圖

若空氣濕度，由相對濕度得之則不同，如計及相對濕度標準界說則有：

$$h=100\frac{e}{e_w} \quad 或 \quad e=\frac{h}{100}e_w \qquad (47)$$

以 h 表示混合比，其公式相當複雜如：

$$r=\frac{v\frac{h}{100}e_w}{p-\frac{h}{100}e_w} \qquad (48)$$

但在此例，可用圖解法定凝結點。

國際氣象會議探空組，曾於1947年在 Toronto 議決定一相對濕度新界說，以 U 爲符號，以免混淆，有：

$$U=100\frac{r}{r_w} \quad 或 \quad r=\frac{U}{100}r_w \qquad (49)$$

如此則只須在 E 點讀 r_w, 乘以 $\frac{U}{100,}$ 卽得 r 矣。

此界說對於用舊型圖之用比濕，仍甚複雜，但此圖已日趨消滅：因氣象電碼已決定不用比濕矣。

參入凝結之變化期間

以上已云，凡空氣含分不變之變化，只能在圖上，以有濕空氣混合比爲記號之等飽和混合比線爲左界之範圍內發生，當然凡在此線左方各點表示之狀態所能到之變化，亦爲可能，但如比，則凝結參入，而所散之潛熱對於變化之條件，有極大之變更。

是則當等壓變化時，若自比露點較高之溫度發生冷却， 則欲令自 dT 之空氣冷却，只須自單位質量內取去熱量如：

$$dq = C'_p \ dT。$$

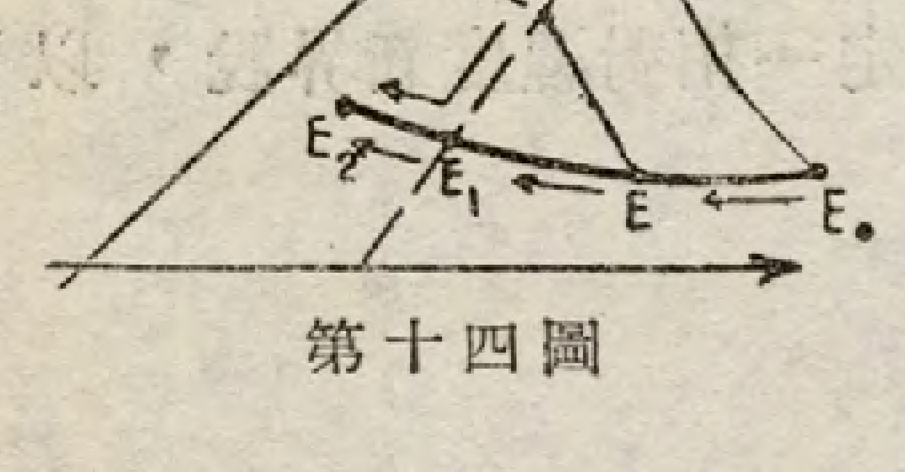
而在溫度小於露點溫度時則須取去凝結水之汽化潛熱，設 $d r_w$ 爲相當於空氣氣壓 p 溫度 dT 之飽和混合比差，則應取去之熱量，當爲： $dq = C'_p \ dT + L(T) \ d r_w$. 式中 L(T) 即氣溫 T 之汽化潛熱。

以態點 E 及絕熱凝結點 C, 表示濕空氣亦可用以表示含分有變或含分不變之變化。

須知當空氣含分不變之時，絕熱凝結點，仍在有 r_0 記號（不變混合比）之等飽和混合比線之上。

茲試將所討論變化問題，限於空氣含分之變更，僅由於下列兩方式，即或爲空氣中所含水汽之凝結，或飽和液體水空氣之蒸發（如此可以不涉及由震動擴散或分子擴散之含分變更）

凡變化能使空氣從未飽和之態點 E_0 點到達不凝結不能到達之態點 E_2, 可以分爲兩部(第十四圖）



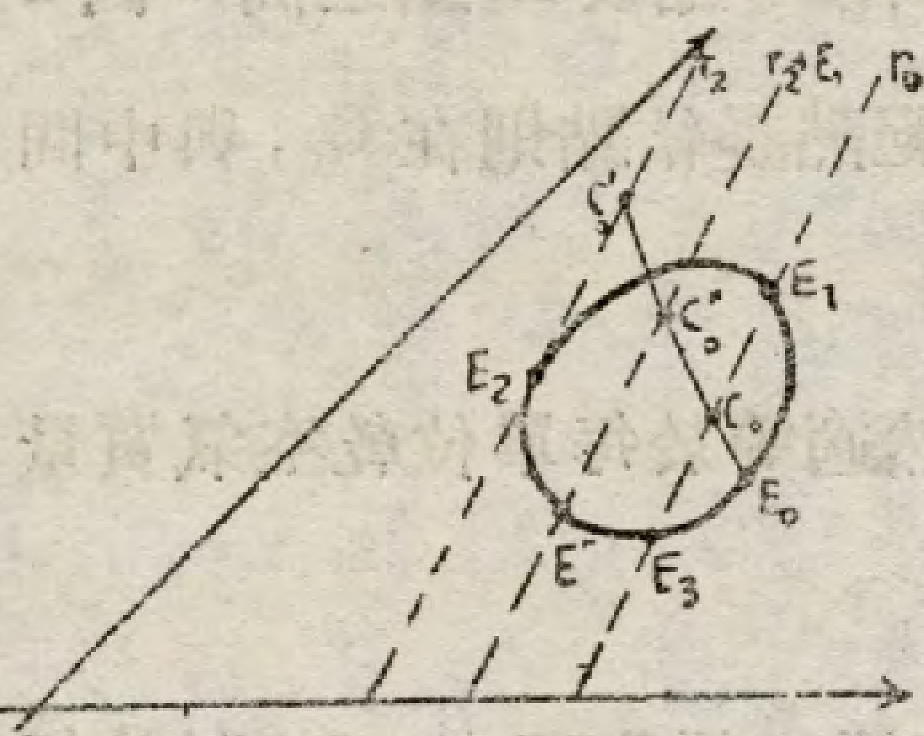
第十四圖

(a) 變化之部分爲 E_0E_1, 在此期間態點在有 r_0（濕空氣初混合比）記號之等飽和混合比線之右。

凝結不參入，空氣含分不變，及原在 C_0 點上之凝結點，移向有 r_0 記號等飽和混合比線之上，在每一時間，C 點均與 E 點在同乾絕熱線上。

若 E 在 r_0 線上移至 E_1, 因對於 E_1 態點，r_0 已飽和，故空氣飽和。所以其絕熱

凝結點與態點相混，而卽在 E_1 點。



第十五圖

(b) 變化之部分爲 E_1E_2, 在此期間，態點 E 在有 r_o 記號等飽和混合比線之左，空氣飽和而絕熱凝結點繼續與態點相混，相隨自 E_1 至 E_2。當變化期間凝結水之能力，能使濕空氣所含一部分之水汽凝結，此爲一要點，不可忽略也。

爲便利計，先設想一濕空氣所受之合閉變化 $E_o E_1 E_2 E_3 E_o$, 其初點爲未飽和，而初混合比爲 r_o(第十五圖)E_o 點代表初點狀態，E_2 點爲在變化期間，其飽和混合比爲最小值 r_2 之態點，E_1E_3 點爲代變化曲線，與有 r_o 記號等飽和混合比線之交點，令 C_o 爲初絕熱凝結點。

若態點自 E_1 至 E_2, 其絕熱凝結點，仍在 r_o 線上，而自 C_o 移至 E_1 卽在此與態點相混。

自 E_1 至 E_2 點，空氣飽和，其混合比常等於飽和混合比，而且低降，絕熱凝結點，仍與態點相混。在 E_2 點，其混合比非 r_2, 故有凝結，所以每單位質量有 (r_o-r_2) 之水汽凝結。

如此有三種不同狀之凝結水。

(a) 凝結水全份留存空氣中。

在此例，則當空氣到達 E_2 點時，含有 (r_2-r_o) 量之液體水，其變化隨飽和混合比之增進而進行，此水以漸蒸發，當態點到達 r_o 記號等飽和混合比線之 E_3 點時，空氣中無液體水，但仍爲飽和，在此變化全部份內，絕熱凝結點與態點相混，既而在最後部分 E_3 至 E_o 之變化間，空氣已不飽和，其含分常定，其凝結點重新移向 r_o 線上，若態點廻至其最初部位時，凝結亦廻至最初部位 C_o。

(b) 凝結所成之水，成爲降水，全部脫離空氣：

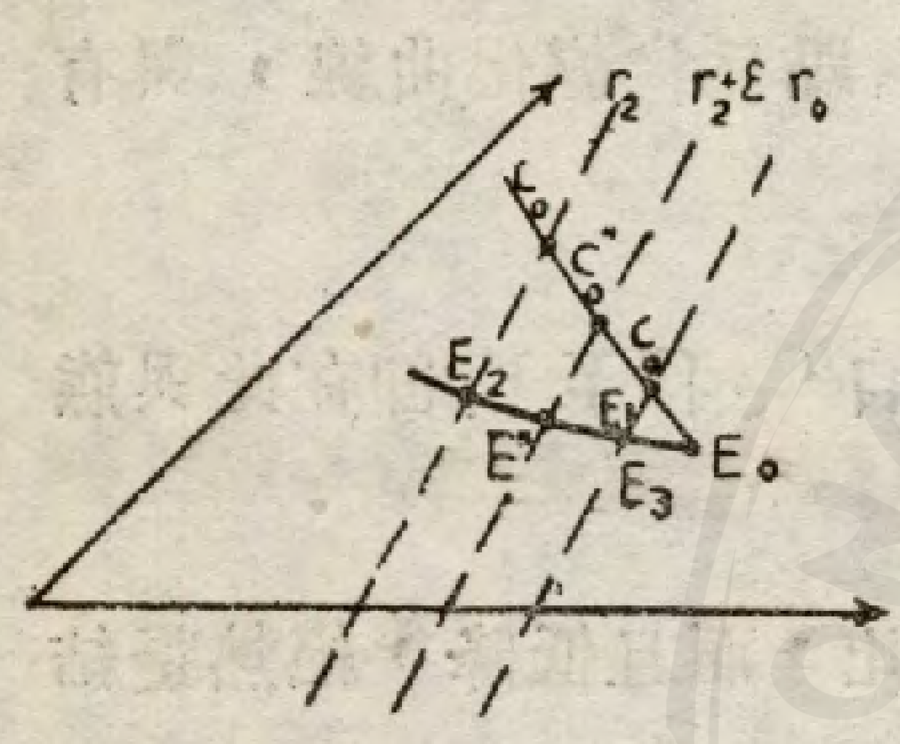
在此例則空氣到達 E_2 態點時，已不含有液體水，但仍飽和，設態點自 E_2 向 E_3, 空氣混合比仍等於 r_2，因其無可用之液體水也。所以空氣停止飽和，絕熱凝結點移向有 r_2 記號之等飽和混合線上，若態點廻至其最初部位 E_o, 絕熱凝結點在 C'_o 上，與 C_o 相差甚多，空氣不回至其初態。

(c) 只有一部份凝結水脫離空氣(此爲最常見者)。

設令ε爲態點在F_2,而變化進行時，留在空氣中之水分，此水蒸發，直至到達$r+\varepsilon$等飽和混合比線上之E''點，仍爲飽和，此E''點必在E_2點及E_3點之間，因ε必小於r_o與r_2間之差。若態點回至其初點E_o之部位，絕熱凝結點則在C_c,與中間之C''_o上。，空氣不回至其初態。

自變化起點至終點，在態點E_o,各混合比之差，當然適等於每單位乾空氣質量所降水之質量。

設假定E_2, E_3, E_o之變化，爲反變化，則就E_oE_1態點之變化觀之，其討論仍相同(第十六圖)



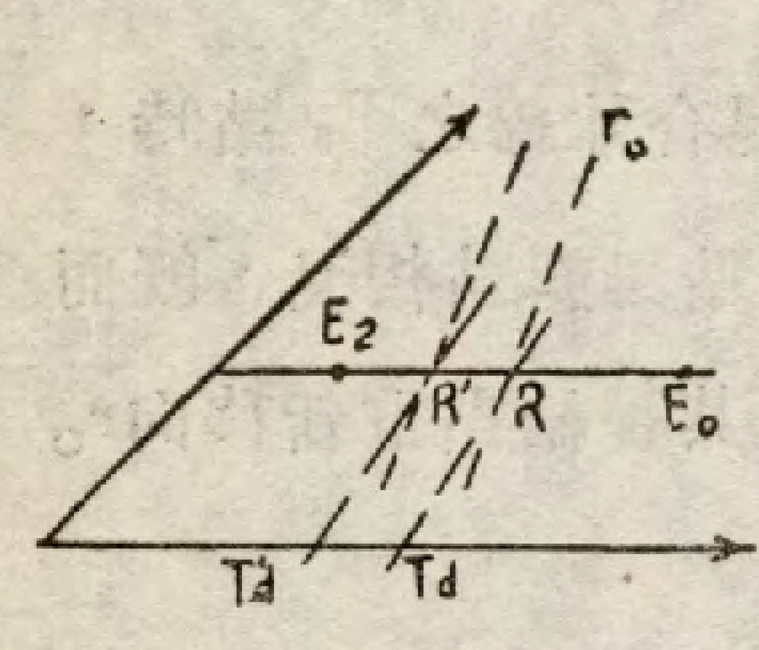
第十六圖

欲使絕熱凝結點，回至其初位置C_o,必所有凝結水均留在空氣中，此名爲「氣象的迴復變化」

設一部份之水下降，則凝結點不廻復其初部位C_o,是名「氣象的不廻復變化」。設在特別狀況，所有凝結水均成降水，則飽和凝結點乃至態點到達最低之等飽和混合比線上之C'_o點，其最普通者，爲絕熱凝點，到達從E_o所作乾絕熱線上C_o及C'_o間之C''_o點。

須知所稱氣象的不廻復變化，就熱力觀點，不一定爲不廻復，因可假設以熱力的廻復方法，增加或減小極微之水量於空氣中也，至其擧例當見於後。

有凝結之等壓變化



第十七圖

以上所說，極易應用於在露點R參入凝結之等壓變化。(第十七圖)當溫度仍高於露點T_d時，絕熱凝結點沿經過R之等飽和混合比線而移動。

設既經冷却至E_2,而空氣增熱，除非有一部份之凝結水脫離，空氣卽在R停止飽和。若在凝結水脫離之例，空氣在R'點停止飽和，其溫度T'_d比初露點溫度T_d爲低。

假絕熱變化

凡氣壓與溫度變化，合於22式$\left(\frac{T}{T_o}=\frac{p}{p_o}\right)^{R'/C'P}$者，在氣壓溫度，小於凝結點氣壓溫度者，非絕熱變化，因計及所散之汽化潛熱也。設承認大氣中質點熱量之交換微弱，必須於凝結參加時，研究如何規定合此條件之變化。

因凝結之水，不能全份以水滴形留在空氣中，故此項研究頗有困難，蓋雲性空氣中，氣體相與液體相間熱之交換，不易略去，而事實上欲知雲性空氣實際所發生係何狀況，亦不易知也，現時均謂：

凝結水即在造成時，全份降水，而不與外界有熱之交換時，定其膨脹爲較有益，所以此並非合閉變化，因其質量不斷變更也。

則其絕熱條件應作式如下：

$$\delta q = dU + p\,dv = 0 \quad (50)$$

式中 U 爲空氣之內能，而輸入全熱。

$$I = U + pv \quad (51)$$

若作微分式則有 $dI = dU + pdv + vdp$ (52)

所以有 $dU + pdv = dI - vdp = \delta q = 0$ (53)

設承認 Gibbs 關於氣體之假設，而計及全熱，爲一位熱力，雲性空氣全熱之變象，爲其組成體全熱變象之和。dp 與 dT, 之氣壓與溫度變象，一克乾空氣之全熱，依下式而變，即： $dIa = Cpa\,dT$ (54)

設由溫度 T, 計算其 r_w 克水汽之全熱，假定在此溫度，能使有 r_w 克之液體水，旣而使之在定溫度下蒸發，令水爲液體時之溫度爲 T_o 則有：

$$I_v = r_w C(T - T_o) + r_w L(T) \quad (55)$$

式中 C 爲水之比熱，L(T) 爲溫度 T 之汽化潛熱，則水汽全熱之變象爲：

$$dI_v = r_w CdT + CTdr_w + d(r_w L(T)) \quad (56)$$

液體水全熱之變象爲： $dI_w = -CT\,dr_w$ (57)

若作其總值，則 1+r 克飽和空氣全熱變象，爲：

$$dI = dIa + dI_v + dI_w = (Cp_a + r_w C)dT + d(r_w L) \quad (58)$$

如此則(53)式可改爲

$$dI - vdp = (Cpa + r_w C)dT + d(r_w L) - vdp = 0 \quad (59)$$

加入組成氣體之部份氣壓，則有：

$$vdp = vdp_a + vde_w = R_a \frac{T}{p_a} dp_a + vde_w \quad (60)$$

而對於 r 克水汽，Clapeyron 公式可作爲：

$$vde_w = L\frac{dT}{T} r_w \quad (61)$$

亦可作爲： $vdp = Ra\ T_d \log p_a + r_w Ld \log T$ (62)

則59式之絕熱條件可作爲：

$$(Cp_a + r_w C)dT + d(r_w L) - Ra\ T\ d\log p_a + r_w L\ d\log T = 0 \quad (63)$$

以T除之，則有：

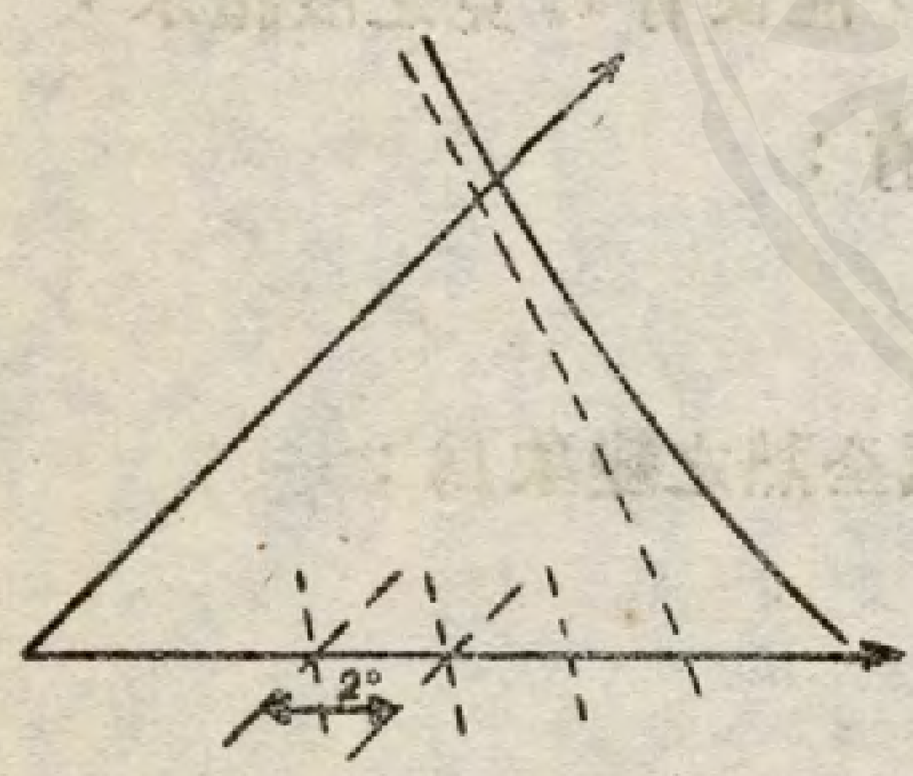
$$(Cp_a + r_w C)\ d\log T - R_a\ d\log p_a + d\left(\frac{r_w L}{T}\right) = 0 \quad (64)$$

惜乎此公式不能積分，而爲假絕熱膨脹之微分式，至此所謂假之意義，卽謂此處之變化系，質量不常定，而與外界有物質之交換也。

此變化亦稱無廻復絕熱膨脹變化，以就氣象觀點，因液體水，以漸造成，亦以漸脫離，故其方式非廻復也。

就熱力觀點，則亦可設想其爲一相反變化，因在此變化期間，可以設想其能陸續補充適當水量，使空氣維持其飽和也。

用漸進近似法，可以極長而極困難之計算，求若干假絕熱變化之數値，在新型761圖解，以1000mb氣壓及每差2°C, 作初態，造成曲線(第十八圖)以表示此變化。此線在圖上，卽成綠色點線，而按溫度記其初點於等壓線1000mb線上。



第十八圖

若硏究各曲線，卽見向低壓及低溫、假乾絕熱線有趨向與乾絕熱線平行之趨勢。此平行形之理由，至爲易見，因溫度低時飽和混合比，亦轉成極小，則對於某一溫度之變差，其沿絕熱線之差，亦必極小，(64)式，含有 r 或 dr 項爲可省略，則此公式可改爲下式：

$$C_{pa}\ d\log T + R_a\ d\log p_a = 0$$

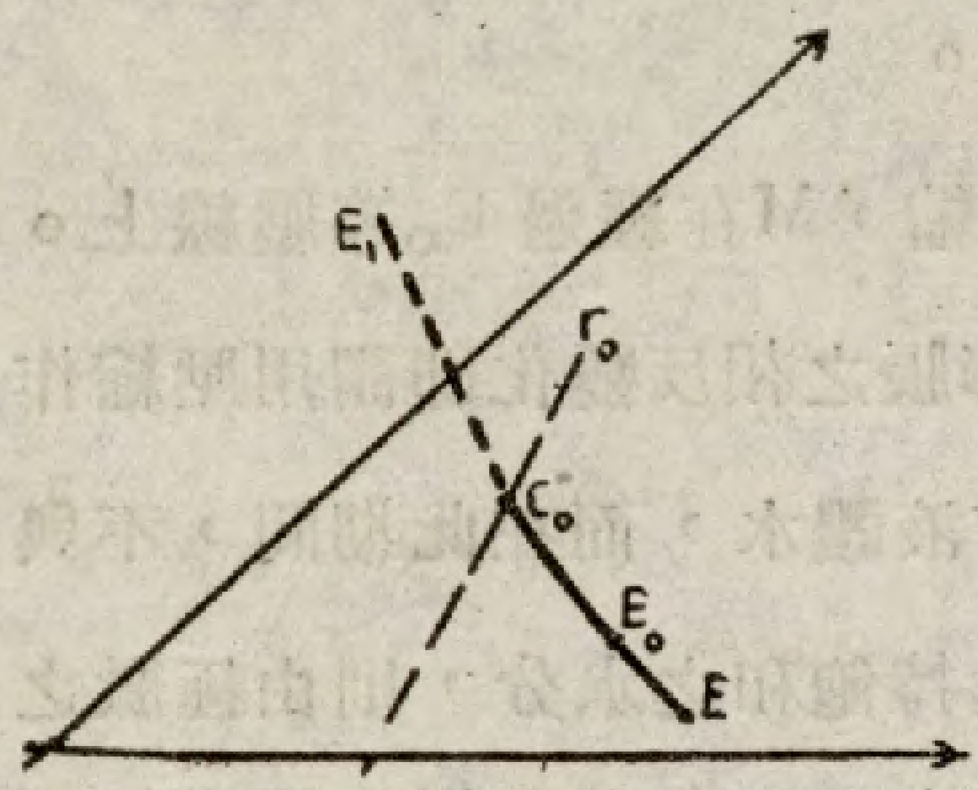
此卽乾絕熱之微分式也。

在假絕熱變化期間，空氣旣爲飽和，當然絕熱飽和點常與態點相混。

舊型圖上，亦可作此假絕熱曲線，其不同之處，爲此曲線係用漸近式計算，而俾每線與絕熱線漸近，而以與此絕熱相當之位溫，作其記號。

絕熱變化之表示

如有濕空氣，其初態點 E_o, 混合比 r_o, 其凝結點在 C_o(第十九圖)設令此空氣受一絕熱壓縮，則其態點E在經過 E_o 及 C_o 乾絕熱線上移動，在此壓縮期間，其絕



第十九圖

熱凝結點，同時在有 r_0 記號之等飽和混合比線上，因其含分不變，亦在經過 E_0 乾絕熱線上，因其態點仍在此絕熱線上也。

所以 C_0 點仍在此兩線相交之原部位。

設令空氣受一絕熱膨脹，則當態點未到達有 r_0 記號等飽和混合比時間，絕熱凝結點，仍在 C_0。

在如此變化期間，絕熱凝結點，常在經過 C_0 之假絕熱線上，換言之，卽凡所有變化，無空氣熱量之交換，其初態以 E_0 表示，而其混合比為 r_0 者，無論凝結參入與否，經過 C_0 之假絕熱線為不變。設假絕熱線在圖上成有記號之網，則在 C_0 記號之線上，所讀之 C_0 值亦不變。在新型761圖上，所有假絕熱線，其與 1000mb 等壓線之交點均有 Θ'_w 之記號。Θ'_w 溫度在經過 C_0 點之假絕熱線上讀得者，或由極相近假絕熱線揷補讀得者，為與濕空氣相關聯之量，此量在無外界熱之交換之全部變化中為不變。

在舊型圖上，假絕熱線以其漸近之乾絕熱線位溫 Θ' 為記號，因此處僅為記數之不同，故此假位溫之數值，在空氣與外界無熱交換之變化期間仍為不變，至假位溫之界說如下：

所謂假位溫者，為空氣與外界無熱之交換，受膨脹之作用，直到氣壓為零時，其在此期間，所凝結之液體水，以漸造成，亦以漸脫離，乃又重新壓縮至 1000mb 所有之溫度是也。

由以上之界說，可見其能在圖上，用態點之移動解析之。

(a)在經 E_0 至 C_0 乾絕熱線上，自 E_0 到 C_0。

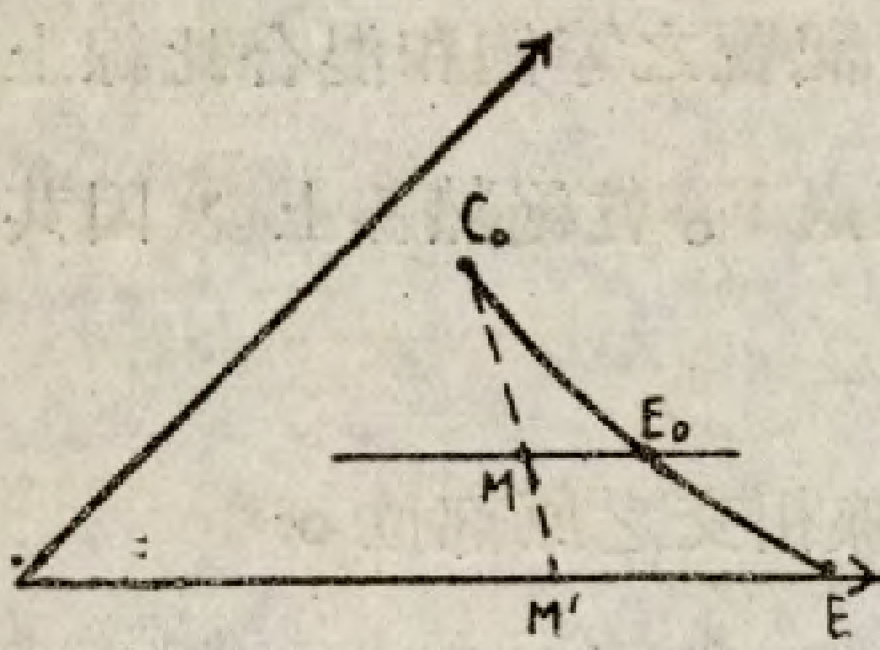
(b)自 C_0 點無窮的沿經過 C_0 點之假絕熱線，而有窮的與乾絕熱線相混。

(c)無窮的 1000mb 沿乾絕熱線漸近於經過 C_0 之假絕熱線。

在(a)類變化時，凝結點在 C_0 點不動，在(b)類變化時，則與態點無窮離開，在(c)類變化時，則無窮的滯留，因空氣仍絕對乾也。

濕球溫度表之假絕熱溫度

玆再論一濕空氣，在其初態時，態點為 E_0，凝結點為 C_0（第二十圖）相繼的受下列之變化。



第二十圖

(a)自 E_0 至 C_0 絕熱膨脹。

(b)自 C_0 至 M, 假絕熱壓縮，M在經過 E_0等壓線上。假絕熱壓縮，爲假絕熱膨脹之相反變化卽謂用壓縮作用於飽和濕空氣，不含有液體水，而在此期間，不與外界有熱之交換，至此維持飽和之水分，則由極微之量供給之，但永不過剩，若以此界說與假絕熱膨脹界說相比，卽見此變化服從(64)微分公式，所以在此變化時，態點及絕熱凝結點，均在經過 C 之絕熱線上，移向高氣壓。

爲態點及絕熱凝結點所佔之M點，在此變化之終期，表示飽和濕空氣與初期濕空氣同氣壓者，可由於在此回復熱力方式期間，如水而與外界無熱之交換得之。此M點相當之溫度，名曰「濕球濕度表假絕熱溫度」，以 T'_w 爲號，如此可見，在適合於所說變化條件，及能到達濕球溫度表熱力溫度之變化間，有共相類之處，至其不同之事實，爲其限在等壓線內耳。

濕球溫度表之位假絕熱溫度

設假想有以 E_0 及 C_0 表示初態之空氣絕熱壓縮，以達 1000mb 之氣壓，旣而從新初態 E_0，作與上節相同之變化。(C_0不動)卽可得一新 M'點，M'點之溫度，實爲以上已見之 Θ_w, 其記號在經過 C_0, M, M' 之假絕熱線上，則可以名之爲濕球溫度表位假絕熱溫度表，其性質已如上述。

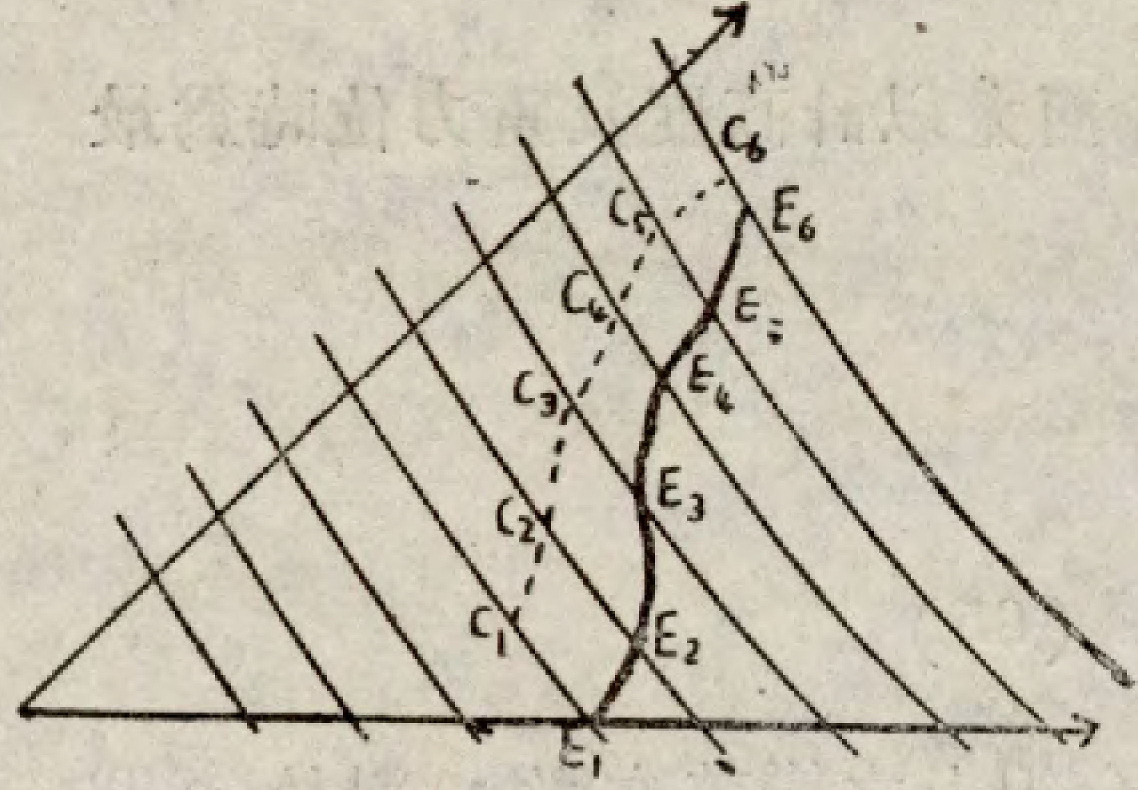
(Ⅱ) 探空要素之表示法

用兩點在 761 號圖解上(或其他探空圖解)表示濕空氣之狀態及含分，卽謂態點及絕熱凝結點，極易於表示探空所得之氣壓，溫度，及濕度。

探空時，所用探測高空氣象重要儀器，由汽球或其他探空器，繼續經過氣壓漸減，溫度濕度變更之各氣層之狀態及其含分，可在探空圖解上，用態點E 及絕熱凝結點 C 表示之，每一探空可得若干E 點，及若干C 點，各 E 點之集合，成一曲線名曰態曲線，各 C 點之集合，成一曲線，名曰絕熱凝結曲線或簡稱凝結曲線。

同層兩曲線上，有關係各點間之相當，應在依各絕熱線上爲之，因任一層上有關係之E 點 C 點，均在同乾絕熱線上也。

凡作此線者，大概態曲線爲滿線，凝結曲線爲斷線(第二十一圖)



第二十一圖

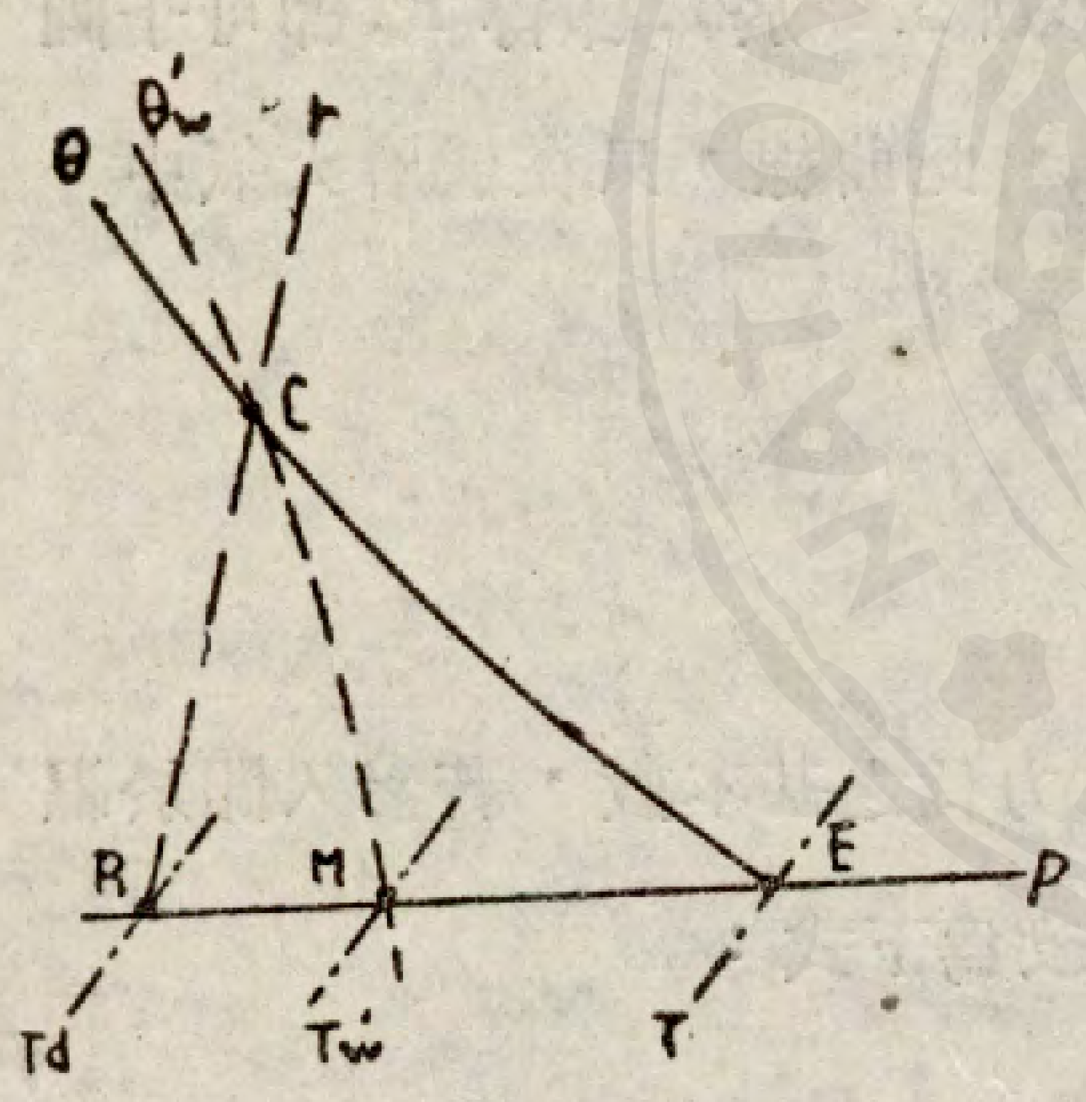
用電報所得之報告，極易造成此項探空表示，其態點卽可用若干地點之氣壓溫度定之，在其中作插補可矣。凝結點，則可按上述各法計算之，設電報有混合比，則更易矣，現時電報已均有此混合比一項矣。

二十一圖，係用新型圖解，若用舊型者，亦不難，因用比濕亦非難事，蓋以數字言，兩者之差，大可不計也。

探空圖解之讀法

凡此所說之圖解表示法，可用以讀空氣狀態及其含分，各變數，及其與此類變數有關之若干數。

設所注意者爲一氣壓曲線，第二十二圖，則可讀下列各數。



第二十二圖

(一)溫度　卽在態曲線及等壓線交點 E 之等溫線上讀之。

(二)位溫Θ卽在乾絕熱記號網之 E 點讀之。

(三)乾絕熱凝結點在 C, 卽經過E之乾絕熱線與凝結曲線之交點也。

(四)混合比 r 於 C 點讀之，在各等飽和混合比線之網上。

(五)露點溫度 Td, 卽在經過 C 等飽和混合比線與爲等壓線之交點 R 讀之。

(六)濕球溫度表假絕熱溫度 T'_w 在經過 C 之假絕熱線與等壓線之交點 M 上讀之。

(七)濕球溫度表位絕熱溫度，在有假絕熱線網記號 C 上讀之，此爲舊型圖，而在新型圖，則在經過 C 假絕熱與 1000mb 等壓線之交點讀之。

(八)假位溫，在舊型圖上，卽在有假絕熱記號線上 C 讀之，而在新型圖，則應隨經過 C 向低氣壓之假絕熱線直至距乾絕熱線相當遠之任一點及各假絕熱線實際平行處爲止，而卽在此點讀位溫。

虛溫度之計算法

計算虛溫度或虛溫度與實溫度之差，至爲重要，而尤以計高度及重力位時爲最，其公式爲(32)式之。

$$T'=T\left(\frac{1+\mu r}{1+r}\right)$$

及 $$\triangle T'=T'-T=T\left(\frac{(\mu-1)r}{1+r}\right)=\frac{0.608rT}{1+r} \qquad (65)$$

$\triangle T'$ 超過數度者甚少，而溫度 T, 則沿等飽和混合線上之變差亦微，對於 $\triangle T'$ 之相對誤差可以頗大，但其絕對誤差則極微，故可以將經過絕熱凝結點之等混合比上之平均與態點上所讀溫度相混，設令 T(r) 爲此平均溫度，以與混合比有關，則可有下式：

$$\triangle T' \# \frac{0.608\,rT(r)}{1+r}=f(r) \qquad (66)$$

除非極精密之計算，可置一刻有 $f(r)$ 之標尺，於等飽和混合線之網上，而讀 $\triangle T'$ 之近値，於經過 C 點之等混合線與標尺之交點，加 $\triangle T'$ 於T, 卽得 T', 卽可于圖上作虛態點 V, 集合 V 點成一曲線，名爲虛溫度曲線，此曲線，只在低層大氣中，與態點曲線有頗顯著之分別。

重力位之計算

按靜水力公式爲 $dp=-\rho g dz \qquad (67)$

式中 z 爲高度，g 爲重力加速度，均爲計算高度或重力位之基本數，若參入關於濕空氣狀態公式之(37)式，$\rho=\frac{p}{RaT'}$ 卽可將靜水力公式改爲下式：

$$dp=-\frac{p}{RaT'}gdz \qquad (68)$$

解之以 gdz 之比，而參入重力位 Φ 按下式所定之重力位，卽，

若 $z=0 \qquad \Phi=0$

而有： $$d\Phi=gdz \qquad (69)$$

卽得下式爲： $$d\Phi=gdz=-RaT'\frac{dp}{p}=-RaT'\,d\log p \qquad (70)$$

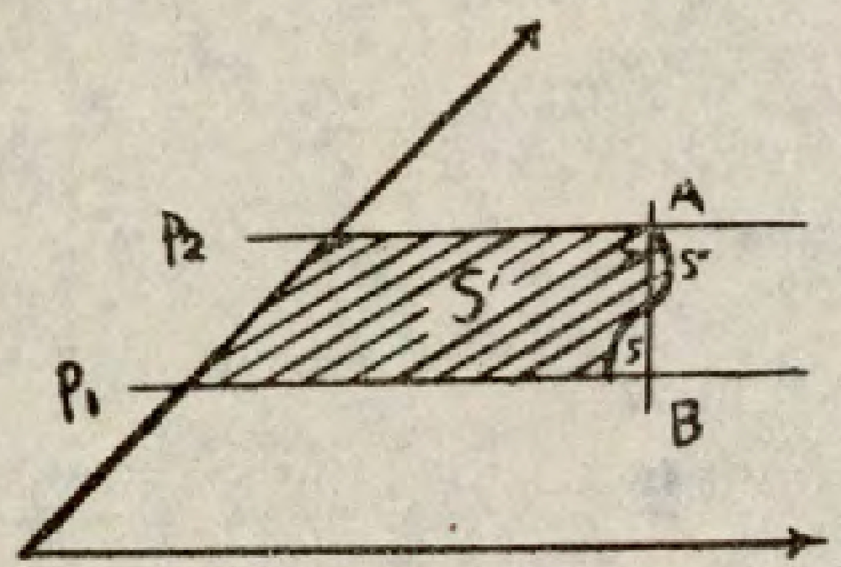
令 x' 及 y 爲圖解上虛點 V 之坐標，而用(2)及(10)式，則此公式變爲：

$$d\Phi=\frac{R_a}{K'K}\,x'dy \qquad (71)$$

欲計算氣壓 p_1 與氣壓 p_2 ($p_2>p_1$) 兩層間重力位之差，只須積分相當 p_1 之 y_1 與相當 p_2 之 y_2 可矣，故有：

$$\Phi_2-\Phi_1=\frac{Ra}{K'K}\int_{y_1'}^{y_2'}x'dy \qquad (72)$$

此第二項積分，在圖上者爲含有等壓線 p_1，p_2，等溫線 T＝0°K 及虛溫曲線間之面積。



第二十三圖

則量此面積，乘以適用因數，卽可得兩層間重力位之差。

如此可用下式方法，約定此 S' 面積。

(a)作一直線 AB（第二十三圖）切斷等壓線 p_1 及 p_2 而使其在 AB 直線，0°K 等溫線及等壓線 p_1，p_2 間之面積，等於 S' 面積，卽使在 AB 直線及 AB 左右等虛溫線VV'間之 S', S'' 兩面積相等。

(b)量定如此造成梯形之平均底，而乘以高度，及比例係數 $\frac{Ra}{K'K}$ 以此高度常相同，故重力位之差與平均底有比例，故可置一刻有重力位標尺於 p_1 p_2 等距離之間，卽可在此標尺與 AB 直線之交點，讀重力位差。

高度曲線

用以上所說方法，可以直接計算各標準等壓線間之重力位差，如已知 1000mb. 與 700mb. 間之重力位差，及已知 1000mb. 等壓面之重力位（此爲氣象電報所有或用表計算）只須加 1000mb. 與 700mb. 之重力位差，卽可得700mb. 面之重力位，如此以漸計算，可得 700mb.，500mb.，300mb.，100mb. 各面之重力位。

爲便於表示與氣壓有關之重力位，可在圖上作一曲線，名曰高度曲線，爲作此曲線，應用圖上之氣壓標，而用之如重力位標。

在舊型圖，Θ相當於＋40° 溫度標以每重力位仟籵十度計，重力位向溫度低減方增加。

在新型圖上，零度在等溫線＋30°上，溫度標以重力位仟籵十度計，重力位向溫度低減方增加。

用圖計算可從此曲線得若干相當於標準氣壓，應用時，可在此各點間作直線補挿法。

曲線成後，欲讀氣壓 p 層之重力位，只須讀疊於溫度標上之重力位標尺，卽在高度曲線與 p 等壓線之交點。

結　論

以上所述，關於此新探空圖解，均已詳盡，按圖索驥，大有益於天氣預報，因近代天氣預報，必須應用此立體圖解也。

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大粒及小粒種落花生若干性狀之比較研究

第　一　報

Studies in Certain Differentiating Characters of Small and Large seeded Varieties of Peanuts (Arachis hypogaea L.)-First report

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一、緒　言

落花生(Arachis hypogaea L.)之分類，迄今尚無完善之方法及基準，如Waldron (1919) 氏依其植株生長習性，大別為二亞種，直立者稱為 fastigiata，匐伏者稱為 procumbens，並謂此二者之淵源各異；Hutcheson 及 Wolfe (1924) 二氏則分之為大莢或大粒種(large seeded, large poded, macrocarpa)及小莢或小粒種(Small seeded, Small poded, microcarpa)，前者復分為匐伏性及直立性二系，後者均屬直立性；熊澤(1950)氏依據產地之不同，分落花生為 Spanish、Valencia、Virginia 及 Southeast runner 四型(types)。四者似均非妥善之方法。

落花生之染色體數及其主要性狀，如葉之大小，厚薄，形狀及顏色，毛茸，花青素之着色程度，葉綠素含量；莖之生長習性，主莖長度，分枝數，枝之粗細，側枝長度；開花期，成熟期；莢果大小，種子大小，種皮色澤，一莢粒數，脂肪含量，不稔實率及耐病性等，究竟在所謂大粒與小粒種二族群(Populations)間差異程度若何？吾人如能從事精密觀察與比較研究，其中二、三特性或可作為二者之鑑別基準，以作分類根據。作者等舉行此項試驗，其目的卽在於斯。試驗中對於性狀之測定，儘可能以具體數字表明，並加以分析，力避多少、深淺、高矮、早晚、大小、長短、厚薄、强弱等含糊字眼，以期得一明確概念。

禾穀類作物之分類，往往以芽生器官為根據。如稻及大麥，卽以中莖(mesocotyl)、鞘葉(coleoptile)及初生葉(primary leaf)等作為屬、種及品種之特徵。惟在雙子葉作物方面關於此類研究，猶屬罕見。最近竹崎 (1951) 氏研究菜豆 (Phaseolus vulgaris L.) 胚軸 (hypocotyl) 長度與品種間之關係，結果頗爲圓滿。筆者等對落花生之胚軸，亦加以測度，期能有助於分類上之應用。

本文係本項工作之第一報，計包括染色體數目形狀及行爲、胚軸長度、小葉大小及厚度、葉綠素含量及休眠之有無與長短等。至於其他性狀之觀察研究，當視完成之先後，於他日陸續發表。

二、試驗材料及方法

甲、試驗材料

大粒種計有千葉大粒、千葉中粒、大冇、大豆、臺南二號、欅枝仔豆、達磨、瓜哇大粒一號及 Virginia 等九品種；小粒種計有東京小粒、Maleys、印度四號、印度六號、爪哇小粒二號、爪哇小粒六號、油豆、紅仁土豆、Kart、Valencia、Indo-spanish、玉林、白仁土豆、懷遠花生、番地24號、爪哇種及臺南白油豆等十七品種。

臺灣之落花生大粒種不若小粒種之普遍，因此徵得之大粒種品種亦較少。又供試品種係分別自各地徵來，種子旣有新陳，發芽力自參差不一，間在試驗中某一時期全不發芽者。故舉行試驗時往往無法皆將全數品種加入，不得不減少參加試驗之品種數。此類根據少數品種而測得之結果，是否足以代表整個族群之特性，不無考慮餘地。

乙、試驗方法

1. 染色體數　試驗材料(根尖或花粉母細胞)經Carnoy's fluid 固定後，用smear method 鏡檢。惟根尖於固定之前，先以2% 之 Para-dichlorobenzenene處理三小時。

2. 胚軸長度

a. **曝光區**　播種於溫室苗床內，深度(1cm.)力求均勻，以免影響胚軸之伸長度，迨第二張眞葉之小葉完全展開時，每品種逢機取樣十株，度量其胚軸之長度，重複二次。

b. **遮光區**　播種後立卽用黑紙遮蓋，不使日光透入，其他處理與曝光區同。

3. 小葉大小及厚度　利用2a(胚軸長度曝光區)之材料外加爪哇種，測定第一眞葉頂端右邊小葉之長寬度，再計算其長寬積，然後將此葉作成橫切面，鏡檢其厚度。

4. 葉綠素含量 每日上午十時以前，每品種逢機剪取第四眞叶上之小葉 3gr.爲材料(葉綠素之含量隨葉位而有差異)，以鹼化法抽出葉綠素α及β後，用比色計測定其含量。標準溶液爲 Guthric 之 Stable Colorimeter Standard，其調製法：(A)純粹硫酸銅結晶($CuSo_4 \cdot 5H_2O$)11.4gr.，溶於 1000c.c. 蒸餾水中，(B)精製重鉻酸鉀 20gr. 溶於 1000c.c. 蒸餾水中，(C)氫氧化錏(NH_4OH) 2mol. 溶液。以上三種溶液配成後，取(A)液 25c.c.；(B)液 50c.c. 及(C)液 10c.c. 混和後，加水至 100c.c.，卽相當於 1000c.c. 中含葉綠素 85mg.

5. 休眠性之有無及其催醒 以民國40年 9 月25日收穫之落花生，曝晒五天後舉行室內發芽試驗。休眠尙未終止者每隔十天舉行發芽試驗一次。凡發芽率超過60%者，卽作爲休眠終止論。每品種之供試種子數20粒，半數去掉種皮，半數則否。催醒法爲高溫(40°、45°C)、變溫(高溫40°、45°C；低溫5°C)、2, 4—D (0.001、0.002,0.003、0.004、0.005%)、硫酸(0.2、0.15、0.1、0.05%)、Heteroauxin (30、40、50%)及 Uspulun(0.2、0.15、0.1、0.05%)等處理，處理時間各分成若干級。

三、試驗結果

甲、染色體數 觀察花粉母細胞結果，除爪哇小粒六號，Indo-spanish、白仁土豆及爪哇種(均小粒種)未及鏡檢外，小粒種各供試品種之染色體數均爲 n=20；大粒種品種之染色體數(內臺南二號及Virginia二品種係觀察根端細胞)亦爲n=20。所有各品種間(包括大粒種及小粒種)之染色體形狀均無差異。惟在減數分裂 metaphase I，anaphase I 時，若干染色體呈鍊狀排列(chain form)或染色體聯接(chromosome association)現象；又大有(大粒種)、印度六號、玉林、油豆及 Maleys(均小粒種)諸品種在 ananphase I時，偶有 lagging chromosome 發現。

乙、胚軸長度 除欅枝仔豆(大粒種)，Indo-spanish及爪哇種(均小粒種)3品種外，其他23品種均行測定。測定單位爲mm.

表一 曝光區胚軸長度變方分析

變因	自由度	平方和	均方	F 值
品種	22	785.7787	35.7172	10.227**
機差	23	80.3250	3.4923	
總計	45	866.1037		

表二　曝光區胚軸長度變方再分析

變　　因	自 由 度	平　方　和	均　　方	F　　值
大粒種對小粒種	1	539.31	539.31	154.428**
大 粒 種 內	7	46.54	6.648	
小 粒 種 內	14	199.9287	14.280	3.272**
機　　差	23	80.3250	3.4923	
總　　計	45	866.1037		

表三　曝光區胚軸長度梯形比較

大　粒　種 32.612mm.	
小　粒　種 25.423mm.	7.189mm.**

$\overline{D}_1=1.6922$　　$\overline{D}_2=2.2958$

根據上列三表，可知大粒種與小粒種二族群間胚軸之長度差異甚大(7.189mm.)。又小粒種族群內諸品種間之F值亦甚顯著，大粒種則不然。據此，兩族群間胚軸長度上之差異，可視作其固有之分類特徵之一。

表四　遮光區胚軸長度方分析

變　　因	自 由 度	平　方　和	均　　方	F　　值
品　　種	22	2030.1332	92.2787	7.526**
機　　差	23	281.9858	12.2602	
總　　計	45	2312.1190		

表五　遮光區胚軸長度變方再分析

變　　因	自 由 度	平　方　和	均　　方	F　　值
大粒種對小粒種	1	794.789941	794.789941	64.8268**
大 粒 種 內	7	781.383515	111.626216	9.10476**
小 粒 種 內	14	453.959762	32.4256973	2.64479*
機　　差	23	281.9858	12.2602	
總　　計	45	2312.1190		

附註：*示5%之差異顯著水準；**示1%之差異顯著水準，以下仿此。

表六　遮光區胚軸長度梯形比較

小　粒　種	59.953mm.	
大　粒　種	45.534mm.	14.419mm.**

$\overline{D}_1 = 3.1707$　　$\overline{D}_2 = 4.3017$

根據表四至表六之數字，可知遮光區之胚軸長度，其族群間差異雖不及曝光區者顯著，但仍達 1 % 之差異顯著水準。故落花生之胚軸長度，不論其生長期之光線遮斷與否，均可作爲二族群之分類根據。但在曝光時，大粒種之胚軸長於小粒種，而黑暗處適相反，可見光對於胚軸伸長之抑制作用，小粒種所感受者更甚於大粒種。

丙、小葉大小及厚度

1. 小葉長寬積　在本項測定中，Indo-spanish(小粒種)及攀枝仔豆(大粒種)2品種未行參加。

表七　幼小時小葉長寬積變方分析

變　因	自由度	平方和	均方	F 值
品　種	23	142421.4505	6192.2366	7.6551**
機　差	24	19410.1479	808.7561	
總　計	47	161831.5984		

表八　幼小時小葉長寬積變方再分析

變　因	自由度	平方和	均方	F 值
大粒種對小粒種	1	88067.2664	88607.2664	10.889**
大粒種內	7	20393.4085	2913.3400	3.5153**
小粒種內	15	33960.7756	2264.0517	2.799*
機　差	24	19140.1479	808.756	
總　計	47	161831.5984		

表九　幼小時小葉長度長寬積梯形比較

小　粒　種	311.7131 (mm)²	
大　粒　種	186.1963 (mm)²	125.5169**

$\overline{D}_1=20.7493$　　$\overline{D}_2=28.1182$

由表八及表九，可察知落花生小葉之長寬積，在同族群內諸品種間，並無差異，而二族群間之差異則非常顯著。此一特性，卽肉眼亦能明辨，可作爲族群間分類之基準。

上述數字係就第二眞葉頂端右邊小葉在未完全發育時測定者。爲明瞭小葉成長後差異情形，作者等更於子實將收穫當時復作一次測定。除 Indo-spanish 與爪哇種(均小粒種)外，其他諸品種均有參加。結果如下列諸表所示：

表十　成長後小葉長寬積變方分析

變因	自由度	平方和	均方	F值
品種	23	22573882.4590	981473.1503	31.4108**
機差	24	749911.3211	31246.3052	
總計	47	23323793.7801		

表十一　成長後小葉長寬積變方再分析

變因	自由度	平方和	均方	F值
大粒種對小粒種	1	20471175.5168	20471175.5168	655.155**
大粒種內	8	4508603.0911	57325.38638	
小粒種內	14	1644103.8511	117435.9893	3.7583**
機差	24	749911.3211	31246.3050	
總計	23	22573882.4950		

表十二　成長後小葉長寬積梯形比較

小粒種	2841.7373(mm)^2	
大粒種	1521.4027(mm)^2	1320.3346**

$\overline{D}_1=231.2868$　　$\overline{D}_2=313.7855$

由上列三表得知大粒種與小粒種二族群間及同一族群諸品種間，均有顯著差異。故小葉之長寬積，不拘在幼小或長大時，大粒與小粒種之間，有甚大之差別，似無疑義。

2. 小葉厚度　供試品種與丙1(小葉長寬積)者相同。

表十三　小葉厚度變方分析

變　因	自由度	平方和	均方	F值
品　種	23	35430.9592	1540.4764	7.034**
機　差	24	5255.8138	218.9923	
總　計	47	40686.7730		

表十四　小葉厚度變方再分析

變　因	自由度	平方和	均方	F值
大粒種對小粒種	1	17038.5846	17308.5846	79.037**
大粒種內	7	7214.2278	1030.6039	4.706**
小粒種內	15	10908.1468	727.2097	3.320**
機　差	24	5255.8138	218.9923	
總　計	47	40686.7730		

表十五　小葉長度梯形比較

大粒種	281.2262μ	
小粒種	241.3537μ	39.872**

$\overline{D}_1 = 10.7971$　　$\overline{D}_2 = 14.6316$

根據表十五，可判斷幼小時小葉厚度，在族群間確有明顯差異，卽大粒種者大於小粒種。此項特性憑肉眼亦可察出。又據表十四，同一族群內諸品種間，亦有顯著差異。

丁、葉綠素含量　供試品種名稱見表十八。

表十六　葉綠素含量變方分析

變　因	自由度	平方和	均方	F值
品　種	17	866.307802	50.959282	3.1004*
機　差	18	295.853732	16.4363185	
總　計	24	1162.161534		

表十七　葉綠素含量變方再分析

變　因	自由度	平方和	均方	F值
大粒種對小粒種	1	0.097136	0.097136	
大粒種內	8	450.531504	56.316438	3.4263*
小粒種內	8	415.679162	51.959895	3.1612*
機　差	18	295.853732	16.4363185	
總　計	24	1162.161534		

表十八　葉綠素含量梯形比較　(mg./l.)

印度四號	44.590																	
玉林	48.380	1.210																
大有	48.308	1.282	0.072															
千葉大粒	46.100	3.490	2.280	2.208														
Maleys	45.850	3.740	2.530	2.458	0.250													
達磨	45.317	4.273	3.063	2.991	0.783	0.533												
千葉中粒	44.059	5.531	4.321	4.249	2.041	1.791	1.258											
臺南二號	43.590	6.000	4.790	4.718	2.510	2.260	1.727	0.469										
東京小粒	42.271	7.319	6.109	6.037	3.829	3.579	3.046	1.788	1.319									
爪哇大粒一號	42.174	7.416	6.206	6.134	3.926	3.676	3.143	1.885	1.416	0.097								
油豆	38.726	10.864*	9.654*	9.582*	7.374	7.124	6.591	5.333	4.864	3.545	3.448							
Valencia	38.220	11.372*	10.160*	10.088*	7.880	7.630	7.117	5.839	5.370	4.051	3.954	0.506						
Kart	37.918	11.672**	10.462*	10.390*	8.182	7.932	7.399	6.141	5.672	4.353	4.256	0.808	0.302					
番地24號	37.604	11.986**	10.776*	10.704*	8.496	8.246	7.713	6.455	5.986	4.667	4.570	1.122	0.616	0.314				
欅枝仔豆	36.925	12.665**	11.455*	11.383*	9.175*	8.925*	8.392	7.134	6.665	5.346	5.249	1.801	1.295	0.993	0.679			
爪哇小粒二號	36.094	13.496**	12.286**	12.214**	10.006*	9.756*	9.223*	7.965	7.496	6.117	6.080	2.632	2.126	1.824	1.510	0.831		
大豆	35.693	13.897**	13.287**	12.615**	10.407*	10.157*	9.624*	8.366	7.897	6.578	6.481	3.033	2.527	2.225	1.911	1.232	0.401	
Virginia	32.922	16.668**	15.458**	15.386**	13.178**	12.928**	12.395**	11.137*	10.668*	9.349*	9.252*	5.804	5.298	4.996	4.682	4.003	3.172	2.771

$\overline{D}_1 = 8.517$　　　　$\overline{D}_2 = 11.667$

品種名下有———者爲小粒種

由上三表可知葉綠素含量，在品種間差異固甚顯著，但在族群間否則。就肉眼觀察鮮葉時，大粒種之葉色呈濃綠，而小粒種者爲淺綠，其差別似頗爲顯明。但據實測葉綠素含量結果，若干小粒種之葉綠素含量反遠較大粒種者爲多。此項情形可能由於大粒種之葉片較厚，故外觀上色澤亦較濃。又本試驗之材料取樣時係以重量計算，若以面積計算，則在同一單位面積之小葉內葉綠素之含量，大粒種者或多於小粒種者。

戊、休眠性之有無、長短及其催醒 就本試驗之材料而言，小粒種全無休眠現象，大粒種之休眠期間如表二十所示：

表二十　大粒種之休眠期

品　　種	休眠期(日數)	品　　種	休眠期(日數)
爪哇大粒一號	0	欅枝仔豆	65
千葉大粒	55	達磨	65
千葉中粒	55	大有	65
Virginia	55	臺南二號	75
大豆	65	—	—

由上可知，在供試之大粒種品種中，不特其休眠期長短不等，且亦有無休眠現象者(爪哇大粒一號)。往昔學者以爲大粒種均具休眠性，似有未當。即在小粒種中，可能亦有若干休眠性品種。

又以高溫、變溫、2, 4—D、硫酸、Heteroauxin 及 Uspulum 等作催醒處理，或無效，或發芽率甚低，而發芽後之幼根呈不正常狀態。惟Uspulun(處理1,2或3小時)成績特優；在處理1小時或2小時者，置床後24小時內發芽率達100%者六組；其他六組自75至95%不等，惟均在48小時內全部發芽。對照區之發芽率僅5%。詳見筆者等另一試驗報告(1952)。

四、結　　論

1. 根據比較研究26個品種之結果，落花生之大粒及及小粒二族群，可以胚軸長度，小葉長寬積及厚度三者作共分類上基本性狀。

2. 不論在有光或無光環境下，胚軸之長度在族群間確有差異(有光區尤甚)。但

在有光時之胚軸以大粒種者爲長，在黑暗處則適相反，蓋由於光對於小粒種胚軸伸長之抑制作用甚於大粒種。

3. 小葉之長寬積從數值而言，族群間差異極爲顯著。在幼小時，卽使以肉眼觀察亦可判知。其時同一族群內諸品種之差異未達5%的顯著水準，故在幼小時檢別最爲妥善。

4. 小葉厚度之族群間的差異，無論肉眼觀察或實測分析，均殊爲顯著。

5. 在供試之21品種中，染色體數均爲N=20，與往昔學者（Kawakami 1930，Husted 1931, 1933, Kihara，Yamamoto，及Hosono 1931）觀察結果相若。染色體之形狀亦彼此相若。又在本試驗中之大粒種9個品種間，休眠性之有無及長短頗不一致，且有無休眠性者。以筆者等推測，如收集之小粒種，品種數增加甚大時，或可能發現在小粒種中亦有具休眠品種存在。故染色體數暨休眠性二項性狀似不適爲族群間分類之準繩。

6. 在同一單位重量之小葉內所含葉綠素量，族群間差異固不顯著，惟同一單位面積之小葉內所含葉綠素，大粒種以葉片較厚，其含量甚可能多於小粒種者，此一推斷有待日後證實。

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English Summary

1. By the length of hypocotyl as well as the size and thickness of leaflet, the 26 varieties of peanuts used in the present study can be segregated into 2 well-defined groups, the large-seeded and small-seeded.

2. When the plant is exposed to sunlight, the hypocotyl in the large-seeded varieties is distinctly longer than that in small-seeded ones; and when kept in darkness, it is reversely so. In both cases, however, the differences between the groups are very significant, particularly when exposed.

3. The size of the leaflet in the small-seeded varieties is distinctly larger than that in the large-seeded ones. In its younger developmental stage, the recognition of these two groups can be made even by naked eyes.

4. The thickness of the leaflet is also markedly distinctive between the groups, either by macroscopic observation or microscopic measurement.

5. The number (N=20) and shape of chromsomes in the varieties studied are similar to one another. On the other hand, the nature of seed dormancy is different for individual varieties belonging to the same group. Consequently, both of these cannot be safely used for the differentiation of the groups.

6. The chlorophyll content per unit weight of leaflet in the large-seeded varieties is practically the same as that in small-seeded ones. There might be some difference for groups when the content per unit area of leaflet is taken into consideration.

English Summary

1. By the length of hypocotyl as well as the size and thickness of leaflets the 20 varieties of peanuts used in the present study may be segregated into 2 well-defined groups, the large seeded and small-seeded.

2. When the plant is exposed to sunlight, the hypocotyl in the large-seeded varieties is distinctly longer than that in small seeded ones; and when kept in darkness, it is [illegible]. In both cases, however, the differences between the groups are very significant, particularly when [illegible].

3. The size of the leaflets in the small seeded varieties is [illegible] than that in the large seeded ones [illegible]. The recognition of these two groups can be made [illegible].

4. The thickness of [illegible] leaflets [illegible] between the groups either [illegible].

5. The number of [illegible] 20 [illegible] varieties [illegible] are similar to one another [illegible] may be different for individual [illegible] cannot be safely used for the differentiation of the groups.

6. The chlorophyll content [illegible] in the large-seeded varieties is practically the same as that in small-seeded ones. There might be some difference for groups when the content per unit [illegible] is taken into consideration.

亞麻田間試驗技術之研究

葉 樹 藩

Studies on the Field Technique in Experiments with Flax.

By Shu-Fan Yeh

目　　錄

Ⅰ 引　　言

臺灣紡織原料之缺乏為人所共知，據民國三十七年統計，全省棉產僅約二十六萬餘公斤，苧麻產額約七十六萬公斤，兩者合計僅一百餘萬公斤。今臺省人口已增至八百餘萬，如按每人每年消耗纖維原料一公斤計，每年需要八百餘萬公斤，照上

述之產額言，相差至鉅，亟宜謀補救之道。亞麻爲良好之纖維原料，其紡織品除供衣被之用外，更可作航空機翼，營幕，砲擔架及消防用水管等；且亞麻仁油可供油漆，印刷，顏料及醫藥上之應用；亞麻仁粕可用作肥料及飼料，其產物無一爲廢棄品。又亞麻生長期短，需要溫度不高，可作水稻兩季栽培田之冬季裏作，在農家經濟上佔極有利之地位。在日据時代，曾一度推廣，面積達一萬公頃以上，並由日政府以高價收購亞麻纖維，運往日本本土紡織，是以推廣甚爲順利。光復以來，因臺灣缺乏亞麻纖維紡織工廠，農家所植亞麻無人收購，亞麻事業乃突然中卒。際茲衣被原料極形缺乏之秋，提倡栽培亞麻，擴大推廣區域及增設亞麻紡織工廠，實爲臺灣農業建設亟宜復興之事。茲鑒於亞麻栽培事業推廣之先，關於優良品種之育成，施肥，栽培及防除蟲病災害等技術上之種種問題，皆有待於田間試驗，予以解決；而田間試驗結果之可靠性，涉及試驗技術問題，例如田間取樣之最小單位，試區之大小，形狀及在區集內之排列情形等是否適當，重復次數最少需要幾次，及試驗地究應如何選擇等皆宜詳細研究。故本研究之目的，卽在解決此等問題，以謀獲得在臺灣舉行亞麻試驗之合理有效之規劃，俾供亞麻試驗者設計試驗之參考。

研究某農作物之試區大小，形狀，重複次數及某試驗設計之效能等問題，常利用均度試驗（Uniformity trials, 或稱空白試驗 Blank tests）資料，均度試驗者卽在一試驗地上栽植同一作物品種，給以同樣之栽培管理，於作物成熟時期，將全試驗田劃成等大之許多小區，分別收穫，測定其擬研究之性態；且所得測定之數字記錄可前後左右合併，造成各種大小形狀之試區（Plots）記錄，俾供研究。細查是項記錄，可知其爲下列四類因子共同作用所產生之結果：一爲作物本性，二爲土壤差異，三爲氣候及栽培環境，及四爲不明原因之機差因素。故某種作物，在某地域及某種栽培環境下所得之均度試驗分析結果，常不能應用於另一作物及另一環境之試驗，此項事實早經學者如 Harris (1920) Lander 及其他諸氏 (1938) 所公認。查亞麻均度試驗經作者遍查臺大各研究室之農業文献在臺灣素未舉行，卽歐美各國作此研究者亦爲數極少，此乃作者作是項研究動機之二。

Ⅱ 試驗材料方法及經過

本試驗於民國三十九年冬季在臺灣臺北市國立臺灣大學農學院農藝分場舉行。

試驗地爲毗鄰之田兩坵，土層爲淡水河冲積土，土壤屬泥沙質壤土，有機質頗丰，排水灌漑均極方便，前作物爲普通栽培之水稻，生育頗爲整齊。每坵地之面積約5公畝，分作四畦，畦寬6.30公尺，畦長18公尺，畦與畦間之溝寬0.5公尺，每畦植亞麻14行，行距0.45公尺。試驗種子係由臺灣省農業試驗所供給，爲經多年栽培之優良純種——Ireland，經發芽試驗，發芽率在70%以上。於十一月二十三日播種，每公尺用種子一克，分段播下。播種前，先在播種溝施用基肥，十公畝用硫酸錏7.5公斤，及過磷酸石灰8.0公斤，每行除兩端各一公尺外，中間16公尺均分四段，照比例稱量施用。播種後五日出苗，出苗後三週，照每公寸留苗六株之標準舉行間拔一次，以後行除草兩次，於四十年二月十九日開始見花，以後花數逐日增多，至四月中下旬方漸見減少，四月二十八日，分段扣牌收穫，段長一公尺。全試驗除每畦之兩端，共得 $(8\times14\times16=)$ 1792 個收穫單位，若再除去每畦之兩邊行，則留 $(8\times12\times16=)$1536 個收穫單位，按單位調查收穫株數，乾株重（帶根及蒴果）乾莖重(去根及蒴果)及種子重等四項性狀。而今先擇乾莖重爲研究之對象，由收穫單位之記錄，配合成各種大小形狀之試區收量，分別進行分析，所得結果簡報如後。

Ⅲ 結果分析與討論

（一） 田間取樣最小單位之選定　田間試驗處理間差異顯著性測驗，需以常態機差作爲判斷之尺度，例如吾人常用之 t, z, F 及 X^2 測驗皆以常態機差分布爲理論根據，故一試驗之機差分布必須檢定其符合常態之後，方可應用上述各法測驗。查田間試驗所得小區產量，吾人已知其除由純質機差作用之外，尙受作物特性，土壤差異及各區所在環境差異等偏性因素之影響，故所造成之機差，不能肯定其爲常態，有時成爲混雜之多項分布，有時成爲偏歪分布。凡小區越小，離常態之程度越遠，小區越大，則越近常態分布，區小則區內包括之作物株數少，區大則株數多，故前者爲較小之樣品，而後者爲較大之樣品。根據統計理論，偏態變値如樣品達相當大時，其平均或總和可趨向於常態分布，吾人可利用此項特性，及均度試驗之資料，將基本之收穫單位產量，合併成各種大小形狀之試區，以常態離軌度測驗法檢定試區產量之常態性。如該試區經檢定結果，知其成爲常態，卽表明該樣品之大小，已足够使偏態機差成爲常態機差，根據全部檢定結果，可選擇試區最小，而機差

成常態者，作為田間取樣之最小單位。

用上法測定之主要作用有二：一為某作物特性成為常態分布時需若干大小之樣品，二為該試驗地之土壤差異成為常態分布時所應有之面積為何。二種作用，無法分離，故其應用有時遭遇限制。設試驗地甲區土壤肥沃，所得各小區產量均高，乙區土壤瘠薄，所得小區產量均低，如兩者合併測驗其頻度分布必成雙頂分布，故試區增至十分大時仍不能成為常態，例如本試驗 I II 兩地所得結果，即係如是。欲使均度試驗結果，能適合於各種試驗地之應用，最好能考慮土壤差異，事實上各地域各試驗地之土壤差異程度決不能一致，其成為常態分布時所需之面積亦各不相同，今若同時考慮作物及土壤兩種特性，問題趨於複雜，故不如以作物特性為主，而土壤差異為副，為免除土壤差異之擾亂，則均度試驗之地，必須選擇土壤差異微小之地用之。若已知試驗田之土壤差異頗大，補救之法，可應用變方分析 (Analysis of variance) 之雙分類法，先減除橫行及直行之土異，計算各收穫區之剩餘機差，再檢定此項機差之常態性，如本研究行長 4 公尺 2 行區即利用此法檢驗者。

常態性測驗法今用 Fisher 氏創用之 γ_1 及 γ_2 介量 (Parameters)；其估值為 g_1 及 g_2，計算公式如下：

$$g_1=\frac{k_3}{k_2^{3/2}} \qquad S.E.\ g_1=\sqrt{\frac{6n(n-1)}{(n-2)(n+1)(n+3)}}$$

$$g_2=\frac{k_4}{k_2^{2}} \qquad S.E.\ g_2=\sqrt{\frac{24n(n-1)^2}{(n-3)(n-2)(n+3)(n+5)}}$$

式中 k_2, k_3 及 k_4 為累差估值，n 為觀測個數，S. E. g_1 及 S. E. g_2 為 g_1 及 g_2 之取樣標準機差。

g_1 為測定歪度(Skewness)之介值(Statistic)，$Eg_1=\gamma_1=0$時為對稱分布，$Eg_1>0$ 為正偏態 (Positive Skewness), $Eg_1<0$ 為負偏態 (Negative Skewness), $g_1>2\times S.E.\ g_1$ 即表明本資料所由來之族群 (Population) 有偏歪存在；g_2 為測定峯度 (Kurtosis) 之介值$Eg_2=\gamma_2$，$Eg_2=0$ 時為常態峯度 (Mesokurtic), $Eg_2>0$ 為尖峯 (Leptokurtic), $Eg_2<0$ 為扁峯 (Platykurtic)，$g_2>2\times S.E.\ g_2$ 表示族群分布之峯度與常態峯度有顯著區別。

茲將本試驗單行及二行之小區收量測驗結果列如表一：

表一　各種取樣單位常態離軌度測驗表

Table 1. Tests of departure from normality on the air-dried stems of flax harvested within different size of sampling units.

(1) 試驗地坵號	(2) 取樣單位 行長×行數	(3) 取樣單位 個數	(4) $g_1 \pm$ S. E. g_1	(5) $g_2 \pm$ S. E. g_2	(6) 常態性
I	3×1	240	0.9429 ±0.1571	1.2425 ±0.3130	非常態
I	4×1	192	0.5559 ±0.1754	0.1352 ±0.3491	非常態
II	4×1	192	−0.4346 ±0.1754	−0.2418 ±0.3491	非常態
I	5×1	144	0.9496 ±0.2020	1.1450 ±0.4014	非常態
I	8×1	96	0.3551 ±0.2462	0.3022 ±0.4877	常態
II	8×1	96	−0.3041 ±0.2462	0.1835 ±0.4877	常態
I+II	8×1	192	0.4336 ±0.1754	−1.0480 ±0.3491	非常態
I	16×1	48	−0.1470 ±0.3431	0.7454 ±0.6744	常態
II	16×1	48	−0.6531 ±0.3431	0.7676 ±0.6744	常態
I+II	16×1	96	0.3232 ±0.2462	−0.8970 ±0.4877	常態
I	4×2	96	0.5804* ±0.2462	0.1017* ±0.4877	非常態

*estimates of g_1 and g_2 after elimination of rows and columns soil variation.

係減除橫直行土壤差異後求得之 g_1 及 g_2

(1) No. of division of experimental land.

(2) Sampling units (row length in meters × No. of rows)

(3) No. of Sampling units

(4) Values of $g_1 \pm$ S. E. g_1　　(5) Values of $g_2 \pm$ S. E. g_2

(6) Normality (normal and non-normal)

由表一之測驗結果，知本研究所用之兩坵試驗地，其肥沃度有明顯之不同，例如行長八公尺之單行區，I、II 兩地分別測驗，試區收量已趨常態，而合併測驗則為扁峯，此因兩試驗地，有兩個型量（Modes），合併則呈雙頂分布，行長增至16公尺扁峯現象雖在統計立場可不予承認，但 g_2 與 S. E. g_2 之比（=1.84）已接近顯著界限，故兩試驗地之結果理應分別測驗。

又視 I、II 兩地分別測驗結果中，行長在 5 公尺以下單行區之試區收量，均非常態分布，而行長達 8 公尺以上單行區試區收量方成常態分布，故田間取樣之最小

單位不宜小於行長 8 公尺之單行區。

又查 8 公尺單行區之面積等於 4 公尺長二行區之面積，理應同樣可為取樣之單位，但經測驗指示，知其並非常態，即按變方分析之雙分類法減除橫直行之土壤差異後測驗其機差之分布，結果仍非常態，此則由於該項機差攙雜橫直行土壤差異與作物特性之交感作用所致。如試驗地中肥地、中庸地及瘠地呈塊狀散布，且其面積不等時，行長過短之試區立於此三種不同肥度區域中之個數亦有差別，故其分布難成常態，若試區行長增加，試區跨搭肥瘠土壤之機會大，故試區產量均匀，易趨於常態分布。凡一試驗地其土壤差異愈成大塊分布，試區行長愈應增長，田間試驗取樣之最小單位不宜採用短行多行區者即此理由，試觀表二行長在 5 公尺以下多行區之變異係數與行長 8 公尺以上單行區者比較亦可予以證明。

（二） 試區規劃之選定　選定試區規劃為田間試驗之首要工作，其大小形狀隨試驗之種類及性質而異，一般栽培或肥料試驗適用之試區宜大，作物性態或遺傳研究需用之試區可小。選定試區之原則，第一必需使試驗結果準確，故試驗機差應小；第二試驗所用之勞力經費宜少，故選擇之試區效率宜高。為符合以上原則，今乃將均度試驗資料計算各種試區大小形狀之變異係數（Coefficient of variation）及相對效率（Relative efficiency），以供研討。

據上項取樣最小單位之研究得知本試驗行長 8 公尺以下之試區，產生之機差不呈常態，本可不必考慮，惟為研究其變異大小及與 8 公尺以上試區變異比較起見，仍不放棄。又Ⅰ、Ⅱ兩試驗地所得產量記錄，其分布位置及分散度均不相同，例如8公尺一行區試驗地Ⅰ之平均為 551.042克，標準機差為 52.9298克，試驗地Ⅱ之平為 675.375克，標準機差為 85.4316克（均係分組計算結果，與不分組計算結果略有出入），似不宜合併研究，以下之結果皆係根據試驗地Ⅰ之資料計算而得。

試驗地Ⅰ共分四畦，今作為四區集（Block），應用變方分析法求出剔除區集間土壤差異之單區標準機差（Standard error of single determination），而後以 $\bar{x}$ 除之得變異係數；相對效率應用 R. A. Fisher 氏所提倡之法，其公式如下：

$$\text{相對效率} = \frac{(n_1+1)(n_2+3)s_2^2}{(n_2+1)(n_1+3)s_1^2}$$

式中 s_1^2 及 s_2^2 為比較均方（Comparable mean square）即相等面積下之均方，今

用試區中之收穫單位數除均方而得，n_1 及 n_2 分別爲第一均方及第二均方之自由度 (Degrees of freedom)， 上式係定 s_2^2 試區之相對效率爲 100，以計算 s_1^2 試區相對效率之公式。本試驗以行長 8 公尺單行區之比較均方爲 s_2^2，計算各種試區之相對效率如表二所示：

表二　亞麻試區大小形狀分析結果表

Table 2. Analyses of uniformity trial on flax for estimating size and shape of experimental field plots.

(1) 試區組合	(2) 收穫單位數	(3) 重複次數	(4) 機差自由度	(5) 比較均方	(6) 相對效率	(7) 變異係數
3× 3	9	4	76	586.3439	50.74	11.8850
3× 4	12	4	56	730.5916	40.41	11.4892
3× 6	18	4	36	1003.5142	28.86	10.9943
3×12	36	4	16	2026.7911	13.47	11.0483
4× 2	8	4	92	531.4678	56.22	11.8329
4× 4	16	4	44	941.7233	31.03	11.1383
4× 6	24	4	28	1298.7502	21.99	10.6801
4×12	48	4	12	2759.4556	9.59	11 0080
5× 2	10	4	68	591.1194	49.04	11.3687
5× 3	15	4	44	842.7231	34.68	11.0367
5× 4	20	4	32	614.8457	46.81	8.1642
5× 6	30	4	20	1466.9331	19.00	10.2965
5×12	60	4	8	3832.4885	7.49	10.9737
8× 1	8	4	92	298.8031	100.00	8.8729
8× 2	16	4	44	543.0634	53.81	8.4583
8× 3	24	4	28	739.7240	38.60	8.0602
8× 4	32	4	20	875.2604	31.84	7.5930
8× 6	48	4	12	1144.1592	23.12	7.0883
8×12	96	4	4	2952.2570	7.38	8.0512
10× 1	10	4	44	195.8839	149.19	6.7648
10× 2	20	4	20	308.5251	90.33	6.0032
10× 3	30	4	12	353.0980	74.92	5.2438
10× 4	40	4	8	345.2425	72.34	4.4904
10× 6	60	4	4	172.8433	126.14	2.5942

12×1	12	4	44	234.7761	124.48	6.6205
12×2	24	4	20	376.4606	74.03	5.9280
12×3	36	4	12	465.0386	56.88	5.3795
12×4	48	4	8	442.7532	56.40	4.5458
12×6	72	4	4	173.3636	125.76	2.3225
16× 1	16	4	44	277.7115	105.23	6.0486
16× 2	32	4	20	465.1666	59.91	5.5354
16× 3	48	4	12	543.1149	48.71	4.8836
16× 4	64	4	8	493.7791	50.58	4.0327
16× 6	96	4	4	75.6939	288.03	1.2892

(1) Combinations of plots (row length × No. of rows)

(2) No. of harvested units per plot (3) Replications

(4) Degrees of freedom for error (5) Comparable mean squares

(6) Relative efficiency (7) Coefficient of variation

甲、試區行數　研究表二之結果，行長5公尺以下各行區之變異係數與行長8公尺以上各行區者比較，有明顯增加之現象，此與常態離軌度測驗之結果完全一致，皆顯示5公尺以下行長之試區不宜用於田間試驗。

行長八公尺以上之試區，行數增多，變異係數有一致降低之趨向，試觀表三自1至6行等試區之各平均變異係數，幾成直線下降，換言之，即行數增加，試驗準確度提高。在本試驗中，試區行數以4行及6行區準確度最高。（差異顯著性測驗見附錄三。）

表三　試區行數與變異係數之關係表

Table 3. Coefficient of variation for different No. of rows per plot

(1) 試區行數	(2) 試區長度 (公尺) 8	10	12	16	(3) 平均及遞差	
1	8.8729	6.7648	6.6205	6.0486	7.0767	
						0.5955
2	8.4583	6.0030	5.9280	5.5354	6.4812	
						0.5894
3	8.0602	5.2438	5.3795	4.8836	5.8918	
						0.7263
4	7.5930	4.4904	4.5458	4.0327	5.1655	
						1.8419
6	7.0883	2.5942	2.3225	1.2892	3.3236	
平　均	8.0145	5.0192	4.9593	4.3579		

(1) No. of rows. (2) Row lengths in meter.

(3) Averages and sequent differences.

茲再研究試區行數之相對效率，如表四所示，試區行數增多，用地面積加大，故相對效率低減，但因試區面積增大，試區間肥力趨向均匀，均方(Mean square)因此減小，即用少數之重複，亦可穫得準確之比較，相對效率亦有提高之情形，如本研究中四行區之平均相對效率幾與三行區相同，六行區之平均相對效率反比一行區者爲高，即爲明顯之例。

表四 試區行數與相對效率之關係表

Table 4. Relative efficiency for different No. of rows in per plot

(1) 試區行數	(2) 試區長度 (公尺)				(3) 平均
	8	10	12	16	
1	100.00	149.19	124.48	105.23	119.73
2	53.81	90.33	74.03	59.91	69.52
3	38.60	74.92	56.88	48.71	54.78
4	31.84	72.34	56.40	50.58	52.79
6	23.12	126.14	125.76	288.03	140.76
平均*	49.47	102.58	87.51	110.49	

註(*) 表三及表四中之變異係數及相對效率，皆爲相對數值，本不可以直接平均，今爲說明方便起見乃差强用之。但其結果仍不失其準確性。合理分析法，請參看附錄三。

綜合變異係數及相對效率研究之結論，亞麻試驗之試區，以用行長8公尺以上之四行區或六行區最爲有利；試驗項目既可獲得準確之比較，且相對效率亦高。行長8公尺以上而行數在四行以下之試區，亦可採用，惟準確程度稍低耳。

乙、試區長度 據最小取樣單位研究結果，行長不宜短於8公尺，但適宜之區長，究需若干，亦值得考慮。試觀表三及表四，同一區長之平均變異係數隨區長之增加而降低，平均相對效率則隨區長增加而提高，變異係數可代表試驗準確度，而相對效率可表試驗之經濟性，故增加區長對試驗之準確性及經濟性皆屬有利。然區長8公尺之平均變異係數與10、12、及16公尺者比較，均有顯著之差別，而後三者

之間，差異至微(參看附錄三)。相對效率亦然，卽區長 8 公尺者與其他三者比較亦有明顯區別。故用 8 公尺之試區不如採用行長10—16公尺之試區爲佳，尤以10—12公尺之試區在實用上比16公尺者方便，可謂最適當之試區長度。

丙、試區面積　試區行數及試區長度決定之後，試區面積亦隨之決定。惟因各試驗所選用之試驗地，其土壤差異之情況決不能與本試驗地完全相同，試區行數及長度，有時因實際需要，而有變更，變更之範圍，必須給以適當之限制，最確當者卽決定適合之試區面積以限定之。決定試區面積之法，可由增加行長及增加行數二方面綜合研究之。據以上各節研究結果，可充爲田間試驗之試區行長爲 8—16公尺，行數爲1—6行，以此可配合成各種試區。茲擇一行區，四行區及六行區表出其面積之變異範圍，如表五所示，卽自3.6平方公尺至43.2平方公尺，若以最適合之行長10—12公尺及行數4—6行，配合成最適合之試區面積，其變異範圍自18平方公尺，至32.4平方公尺，惟在此等範圍內，不適合之試區如行長 5 公尺 12行區等，亦包括在內，用者必需注意。

表五　試區面積與變異係數及相對效率之關係表

Table 5. Coefficient of variation and relative efficiency for different size of plot.

(1) 試區面積 (平方公尺)	(2) 試區組合 行長×行數	(3) 變異係數 %	(4) 相對效率 %
3.60	8×1	8.8729	100.00
4.50	10×1	6.7648	149.19
5.40	12×1	6.6205	124.48
7.20	16×1	6.0486	105.23
14.40	8×4	7.5930	31.84
18.00	10×4	4.4904	72.34
21.60	12×4	4.5458	56.40
28.80	16×4	4.0327	50.58
21.60	8×6	7.0883	23.12
27.00	10×6	2.5942	126.14
32.40	12×6	2.3225	123.76
43.20	16×6	1.2892	288.03

(1) Plot size

(2) Row length × No. of rows

(3) Coefficient of variation

(4) Relative efficiency

試區面積與變異係數之關係，照公式言，面積愈大，變異係數愈小，而事實上因試驗地之土壤差異及所選試區形狀不適，亦有呈相反之現象者。如表五中8×4式試區面積爲14.40平方公尺，變異係數等於7.5930，而16×1式試區面積爲7.20平方公尺，變異係數反爲6.0486，從此二列數字中，並可表出在本試驗地之土壤差異情形以增加行長比增加行數爲有利，亦表出本試驗之行長方向，恰與土壤差異方向竝行，符合正常之試區規劃法。

試區面積與相對效率之關係，類似變異係數，卽面積大，相對效率小，實際上亦因土異情形呈相反之現象者，例如表五中一行區各試區與四行區各試區比較爲正常現象，而一行區各種試區間及四行區各種試區間比較，則爲反常現象，此卽因行長方面土壤差異大，而行間方面土異變異小之故也。

試區面積亦可根據表六硏究之，觀表六第二欄及第四欄，則知面積增大平均變異係數逐漸降低，面積在9平方公尺以下，降低之速度甚快，而面積在13.5平方公尺以上，則平均變異係數降低緩慢，其中雖有一段增高，係受不適合試區形狀之影響，如將此等試區提出，平均變異係數仍低，故最適合之試區面積在13.5平方公尺以上，此結果與上法硏究結果大致相似。

丁、試區形狀　試區形狀隨試驗地土壤差異狀況而定。一般言之，用狹長形者比近方形者爲佳；且狹長之方向應與土壤肥瘠變異方向平行，方有效果，若狹長之方向與土壤肥瘠變異方向直交，適得相反之效果，試驗者必須注意。在均度試驗中，比較試區形狀之法有三：一爲同面積不同形狀比較；二爲同行數不同長度、面積及形狀之比較；及三爲同行長不同行數、面積及形狀之比較。下表六甲表係根據第一種比較法而列之表式。

表六　甲、　試區形狀與變異係數及相對效率之關係表（根據試區面積之大小順序排列）

Table 6.　A: Coefficients of variation and relative efficiencies for various shapes of plot (arranged according to plot size)

(1) 試區形狀 長：濶	(2) 試區面積	(3) 行長×行數	(4) 變異係數	(5) 相對效率
4.44：1	3.60	4×2	11.8329	56.32
17.78：1	3.60	8×1	8.8729	100.00
平均			10.3529	78.16
5.56：1	4.50	5×2	11.3687	49.04
22.1：1	4.50	10×1	6.7648	90.33
平均			9.0668	69.69
2.22：1	7.20	4×4	11.1383	31.03
8.89：1	7.20	8×2	8.4583	53.81
35.56：1	7.20	16×1	6.0486	105.23
平均			8.5484	63.36
2.78：1	9.0	5×4	8.1642	46.81
11.11：1	9.0	10×2	6.0032	90.33
平均			7.0827	68.57
1.48：1	10.80	4×6	10.6801	21.99
5.93：1	10.80	8×3	8.0602	38.60
13.33：1	10.80	12×2	5.9280	74.03
平均			8.2228	44.89
1.58：1	13.50	5×6	10.2965	19.00
7.41：1	13.50	10×3	5.2438	74.92
平均			7.7702	46.96
4.44：1	14.40	8×4	7.5930	31.84
17.78：1	14.40	16×2	5.5354	59.91
平均			6.5642	45.88
0.74：1	21.60	4×12	11.0080	9.59
2.96：1	21.60	8×6	7.0883	23.12
6.67：1	21.60	12×4	4.5458	56.40
11.85：1	21.60	16×3	4.8836	50.58
平均			6.8814	34.92

0.93 : 1	27.00	5×12	10.9737	7.41
3.70 : 1	27.00	10× 6	2.5942	126.14
平　　均			6.7840	66.78
1.48 : 1	43.20	8×12	8.0512	7.38
5.93 : 1	43.20	16× 6	1.2892	288.63
平　　均			4.6702	148.01

(1) Plot shape(Ratio of $\frac{\text{length}}{\text{width}}$)　(2) Plot size (Square meters)

(3) Row length in meters × No. of rows

(4) Coefficient of variation　(5) Relative efficiency

試觀上表，得知在等試區面積下，形狀愈狹長者，其變異係數愈小，相對效率愈高，愈近方形者，變異係數愈大，相對效率愈低；若以同行數不同行長比較時，亦以狹長形者爲佳；若以等行長不同行數比較時，則得與上相反之結果，而以近方形者比狹長形者爲佳，其原因由於行長方向土異固定，增加行數，面積擴大，足使試區間土異差異降低，故造成近方形試區比狹長形試區爲優。由上種種事實證明試區形狀狹長之程度，不能給以一定之限制，必須明瞭土壤差異方向，方可決定；若行長方向，順土壤差異方向，則增加行長比增加行數爲佳，此時試區形狀便趨狹長；若行長方向與土異方向直交，則增加行數比增行長爲佳，此時試區形狀便趨近方形。若勉强地決定試區狹長程度，可用以上第二法研究最佳，即固定行數增加行長，使試區形狀由近方形趨向長形。茲將本研究結果列如表六乙表。

表六　乙、　試區形狀與變異係數及相對效率之關係表(隨行長之長短次序排列)

Table 6. B: Coefficients of variation and relative efficiencies for various shapes of plot (arranged according to row length and fixed No. of rows.)

(1) 試區長濶比	(2) 行長×行數	(3) 變異係數	(4) 相對效率	(1) 試區長濶比	(2) 行長×行數	(3) 變異係數	(4) 相對效率
17.78 : 1	8×1	8.8729	100.00	13.33 : 1	12×2	5.9280	74.03
22.10 : 1	10×1	6.7648	90.33	17.78 : 1	16×2	5.5354	59.91
26.67 : 1	12×1	6.6205	124.48	2.22 : 1	4×4	11.1383	31.03
35.56 : 1	16×1	6.0486	105.23	2.78 : 1	5×4	8.1642	46.81
4.44 : 1	4×2	11.8329	56.32	4.44 : 1	8×4	7.5930	31.84
5.56 : 1	5×2	11.3689	49.34	5.56 : 1	10×4	4.4904	72.34
8.89 : 1	8×2	8.4583	53.81	6.67 : 1	12×4	4.5458	56.40
11.11 : 1	10×2	6.0032	90.33	8.89 : 1	16 : 4	4.0327	50.58

2.96 : 1	8×6	7.0883	23.12	4.44 : 1	12×6	2.3225	125.76
3.70 : 1	10×6	2.5942	126,14	5.93 : 1	16×6	1.2892	228.03

(1) Plot shape (2) Row length × No. of rows
(3) Coefficient of variation (4) Relative efficiency

觀上表，符合行長8－16公尺及行數 1—6 行各種試區之長濶比自 2•96：1 至 35,56：1，符合行長8－12公尺及行數4－6行各種試區之長濶比 自2.96：1至6.67：1，但不適合試區亦包括在此變異範圍內，故用時應注意之。

（三） 區集規劃之選定 區集大小及形狀，固由試區面積，區集內之試區數及區集內試區排列方法而決定，然僅就一地一次之均度試驗研究結果，便作為其他各地任何試驗設計之根據，不免使試驗結果陷於錯誤；蓋有時因試區在區集中之排列失當，常使結果不適用統計方法分析；或則因土壤差異錯亂試項效果，使試項無法比較。緣適合之區集規劃，主要因素決定於當時所用試驗地中土壤肥瘠之分布狀況及差異程度；若土壤差異不大，等肥區域分布面積廣大，肥力變異之方向成一定規則順序之變動，則可適合大面積區集之應用；反之若等肥區域面積狹小，且呈斑狀之特殊分布時，常不適合試驗區集之設置；是以擬用作試驗地之土地，其肥力變異方向，必須預先明瞭，而後按照肥力之變異方向，列入適合此肥力變異之適當區集規劃，方足以使試驗結果準確。

測定土壤肥力變異方法，可就該試驗地之前作物，粗放地劃成方格形之等面積區收穫之，以收穫物之測定記錄、應用連續相關係數公式，分橫、直兩個方向分別測定變值間連續相關程度；如連續相關係數，橫向大而顯著，直向小而不顯著，則表明橫向之土壤肥力，大致一致，而直向肥力變動不定，規劃試驗時，試區之長邊應順直向，試區排列應以長邊相隣而成區集，區集內試區數多少，可視連續相關係數之大小決定，連續相關係數愈大，區集內容納之試區數可愈多；反之如連續相關係數直向顯著而橫向不顯著，以上試驗規劃之方向，亦應倒置；如橫向及直向連續相關係數均不顯著，則表明試驗地之土壤差異係逢機分布，試區之排列橫直均可，而區集之形狀則用近方形者最佳。玆以本試驗地 I 行長 4 公尺12行區之乾莖產量記錄測定其橫直兩向之連續相關係數如下，並藉此說明連續相關係數 (Serial Correlation) 之計算法。

連續相關係數之計算式　$R=\dfrac{Sx_ix_{i+1}-(Sx_i)^2/_N}{Sx_i^2-(Sx_i)^2/_N}$

試中 x_ix_{i+1} 爲鄰接兩變值之乘積， N 爲變值個數及 $x_{N+1}=x_1$

表七　行長4公尺12行區乾莖產量表

Table 7. Yield of air-dried stems of flax in kilograms (the deviation from assumed mean 2.4 kgs) per plot of 12 rows wide and 4 meters long.

0.83	1.59	0.74	0.65
0.86	0.90	0.55	0.43
0.82	0.61	0.57	0.79
1.23	1.24	1.18	1.52

表七爲試區乾莖收量減去假定平均2.4公斤後之離差在試驗地之分布位置圖，茲順直向按次每兩變值配對計算連續相關係數如下：

$$Sx_ix_{i+1}=0.83\times0.86+0.86\times0.82+0.82\times1.23+12.3+1.24+1.24\times0.61+\cdots\cdots$$
$$+0.43\times0.65+0.65\times0.83=13.412$$

$$\frac{(Sx_i)^2}{N}=\frac{(0.83+0.86+\cdots+0.43+0.65)^2}{16}=\frac{210.5401}{16}=13.158756$$

$$Sx_i^2=(0.83)^2+(0.86)^2+\cdots\cdots+(0.65)^2=14.9709$$

$$R_c=\frac{13.412-13.158756}{14.9709-13.158756}=\frac{0.253244}{1.812144}=0.1392$$

同例橫向之連續相關係數 $R_r=0.3370$， 今查 Anderson 氏所製正及負兩向單尾機率 0.01 及 0.05 連續相關係數分布表，當 N=15(N爲觀察值個數，因表中無16，故用15。) P=0.05 時之 R=0.328， P=0.01 時之 R=0.475，今實際計算得之 $R_r=0.3370>0.328$，已達顯著水準，卽表明橫向之肥力變異小，而直向之肥力變異大，故試區在集內之排列，應順着橫向，試區之長邊應與橫向垂直，如此庶可收設置區集之功效。

茲再將行長 8 公尺之二、三及四等行數試區之乾莖收量，用變異係數及區集內之組內相關係數研究區集大小及形狀，得結果如表八所示：

表八　區集大小形狀與變異係數及組內相關係數之關係表

Table 8. Coefficient of variation and intraclass correlation for different size and shape of blocks

(1) 試區組合 行長×行數	(2) 區集內之試區數	(3) 重複次數	(4) 區集大小 長×濶 公尺 公尺	(5) 區集形狀 長濶比	(6) 變異係數	(7) 組內相關係數
8×2	1× 4= 4	12	8× 3.6	2.22 : 1	6.2850	0.4931
	2× 2= 4	12	16× 1.8	8.89 : 1	8.5395	0.0735
	1× 6= 6	8	8× 5.4	1.48 : 1	6.3064	0.4947
	2× 3= 6	8	16× 2.7	5.93 : 1	8.8110	0.0187
	1× 8= 8	6	8× 7.2	1.11 : 1	7.8384	0.2194
	2× 4= 8	6	16× 3.6	4.44 : 1	8.4692	0.0887
	1×12=12	4	8×10.8	0.74 : 1	7.2140	0.3388
	2× 6=12	4	16× 5.4	2.96 : 1	8.4583	0.0918
8×3	1× 4= 4	8	8× 5.4	1.48 : 1	5.7100	0.5348
	2× 2= 4	8	16× 2.7	5.93 : 1	8.6422	−0.0663
	1× 8= 8	4	8×10.8	0.74 : 1	6.6771	0.3635
	2× 4= 8	4	16× 5.4	2.96 : 1	8.0602	0.0724
8×4	1× 4= 4	6	8× 7.2	1.11 : 1	6.9541	0.2103
	2× 2= 4	6	16× 3.6	4.44 : 1	7.7699	0.0142
	1× 6= 6	4	8×10.8	0.74 : 1	6.0208	0.4081
	2× 3= 6	4	16× 5.4	2.96 : 1	7.5930	0.0585

(1) Combinations of plot (Row length in meter × No. of rows)

(2) No. of plots within block

(3) Replications

(4) Block size (length$_{m.}$ × width$_{m.}$)

(5) Block shape $\left(\text{Ratio of } \frac{\text{length}}{\text{width}}\right)$

(6) Coefficient of variation

(7) Intraclass correlations

組內相關係數係利用 Harris 氏之公式：

$$r_{p_1p_2}=\frac{\{[S(C_p{}^2)-S(p^2)]/_{mn(n-1)}\}-\overline{p}}{\sigma_p{}^2}$$

式中 C_p 爲各區集之總收量，p 爲區集內之各試區收量，$\overline{p}$爲全試驗試區收量平均，n 爲區集內之試區數，m 爲區集數及 $\sigma_p{}^2$ 爲試區產量變方。茲爲計算工作方便計，改用汪厥明教授及張魯智教授之轉變式，即

$$r_{p_1p_2}=\frac{n^2S(\overline{x}_b-\overline{x})^2-S(x-\overline{x})^2}{(n-1)S(x-\overline{x})^2}=1-\frac{nSSE}{(n-1)SST}$$

式中 $\overline{x}_b$ 爲每區集中試區收量平均，x 爲試區收量，n 爲區集內試區數，SSE爲機差平方和及 SST 爲總平方和。

茲以行長 8 公尺 2 行區，$1\times4=4$ 式之區集爲例，計算其組內相關如下：先由變方分析結果得

SST＝459,235.3998　　　SSE＝172,855.1225

$n=4$　代入上式得

$$r=1-\frac{4\times172,855.1225}{3\times459,235.3998}=1-0.5019=0.4981$$

r 大表明區集內試區收量之相關大，換言之即區集內各處之肥力均勻，設置區集之效率高。組內相關係數與變異係數之數值，常呈相反之變異，組內相關係數大，變異係數小。變異係數之大小，表明試驗機差之大小，試驗機差小，試驗結果精確。

今由表八結果得知區集擴大變異係數增大，組內相關係數減小，此明示擴大區集有降低控制土壤差異之效能；惟亦受區集內試區排列狀況之影響，而緩和其降低程度者，例如行長 8 公尺 2 行區，每區集內包含 4 試區成2×2雙排排列者，其變異係數爲8.5395，而每區集內包含12試區成1×12單排排列者，其變異係數爲7.2140，此與擴大區集，降低控制土壤差異效能之結論相反。是以設置區集控置土壤差異之效能不在區集之大小，而在是否能預知當時所用試驗地之土壤肥力變異方向，及配合之試區排列法是否適當。查本試驗地前經連續相關係數測驗之結果，知橫向之肥力變異小，直向之肥力變異大，上例 1×12式區集內試區之排列，係與橫向平行，區集內肥力平均，故設置之區集效率高，而2×2式違反上之原則，故設置區集之效率低。若以同數試區之區集比較其排列不同之效果，其差異更爲明顯，觀表八即知。

區集內試區排列情形涉及區集形狀，據表八所示，在等面積下愈近方形之區集，其效能愈高，此與過去研究結果一致，故不再詳細討論。

（四） 重複次數之選定　增加試項之重複次數，爲增進試驗準確度之有效處置，惟因人力物力及材料之限制，不能儘量增加，但爲使試項確實能表達其效果起見，必須有適當之重複。

田間試驗常用之完全逢機區集法，或不完全逢機區集法，測定試項間之差異顯著性多用 t 法，t 之公式如下：

$$t_1=\frac{\bar{x}_1-\bar{x}_2}{S.E._{(\bar{x}_1\sim\bar{x}_2)}}=\frac{d}{\sqrt{\frac{2s^2}{r}}}\cdots\cdots\cdots\cdots\cdots\cdots(a)$$

(a) 式中 s^2 爲單區均方，由變方分析法中得來，r 爲重複次數，d 爲兩平均之差數，今若以顯著時之 t 值代入 (a) 式，可得顯著之平均差異數；所謂顯著之意義，卽表明此 d 值與平均差異等於零有顯著之區別，換言之，此 d 值在兩處理之平均差異爲零之族群變値頻度分布中，發生之機率很小，故可大膽地否認此 d 係屬於零族群中之變值，而承認此 d 值確實存在，兩處理既有差異存在，必有一眞正的差異數 δ 值，在 δ 值族群中逢機取樣而求得之 d 值，必亦發生取樣變異，故欲測驗實際 d 值與 δ 值有無顯著差異，因此產生 t_2，

$$t_2=\frac{d-\delta}{\sqrt{\frac{2}{r}}\,s}\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(b)$$

(b) 式中 $\sqrt{\frac{2}{r}}s$ 本爲估計平均差異等於零族群中之取樣平均差異標準機差，而今則兼作 δ 族群中之取樣平均差異標準機差，隨着 s^2 之估算，有其相當之自由度 n, 亦兼作爲 δ 族群之取樣機差自由度，根據 n 檢查一般之 t 表，可得落於 $\pm t_2$ 以外之雙尾機率 p_2，若 t_2 由與零有顯著差異之 d 值代入 (b) 式求得，則此 d 值旣與零有顯著區別，必爲 δ 族群中之取樣值，故可以 $1-\frac{1}{2}p_2=P$ 作爲獲得與零有顯著差數之最高適當機率。

又以與零有顯著差異之 $d=t_1\sqrt{\frac{2s^2}{r}}$ 代入 (b) 式，移項化簡可估計 δ 值，卽

$$\delta=\sqrt{\frac{2}{r}}s(t_1+t_2)\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(c)$$

。由 (c) 式再移項，可以求得與零有顯著差數之最少重複次數 r, 卽

$$r \geq 2\left(\frac{s}{\delta}\right)^2 (t_1+t_2)^2 \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (d)$$

(d) 式中　δ＝兩試項間之眞正差異，吾人可由普通觀察獲得之差異數代入。

s＝單區標準機差，本應爲 δ 族群中眞正之標準偏差 σ，今可用均度試驗或以前試驗之單區標準機差代替。

t_1＝兩試項平均差異顯著性測驗時之 t 值，爲零族群下之 t 值。

P＝獲得與零有顯著差數之最高適當機率，可以吾人所期望者代入。

t_2＝2 (1－P) 時之 t 值，根據 n 可由一般之 t 表中查得。

應用 (d) 式，首先可大約地指定試驗中估計 s^2 之自由度 n, 根據 n 查出 t_1 及 t_2，代入 (d) 式可求得近似之 r，再以此 r 推算擬作試驗中發生機差之正確自由度，再查出 t_1 及 t_2，仍由 (d) 式計算出可獲得與零有顯著差異之最少重複次數。

應用上法估計 r, 因 $s^2 \neq \sigma^2$, 在理論上略有缺點，惟實際上 s^2 一般比 σ^2 爲大，估得之 r 亦比理論者稍大，故應用時尙屬合式。是以 Cochran 和 Cox 諸氏主張採用此法。

今假定有八處理之全完逢機區集試驗，機差自由度 n＝7(r－1)，測定試項間平均差異顯著水準用 p_1＝0.05，期望獲得與零有顯著差異之最高適當機率 P＝0.90，由前期試驗結果得單區標準機差百分率爲 5.5%，今由普通觀察中獲得兩處理之平均差異爲處理總平均數之20%，問最少應用重複幾次？

解此問題先假定 n＝30，根據 n 查 t 表得 p_1＝0.05 時之 t_1＝2.042，及 p_2＝2(1－P)＝2 (1—0.90)＝0.2時之 t_2＝1.310，則$2(t_1+t_2)^2=2(3.352)^2=22.4718$，故 $r \geq 2\left(\frac{s}{\delta}\right)^2(t_1+t_2)^2=\left(\frac{5.5}{20}\right)^2 \times 22.4718=1.7 \simeq 2$

在試驗中2次重複之自由度 n＝7(2－1)＝7，而非爲 30，故應檢查 2 次重複是否足够，當 n＝7，t_1＝2.365，t_2＝1.415，$2(t_1+t_2)^2=2(3.78)^2=28.5768$，則 $r \geq \left(\frac{5.5}{20}\right)^2 \times 28.5768=2.16$，知 2 次重複尙不足够，故最少重複次數應爲3次。

據前項均度試驗結果得各種試區之單區標準機差百分率在 2.0%－12% 之間，今卽在此變域內，仍照上例設計，並假定兩處理平均差數百分率爲5%、10%、15%及20%，顯著水準用 p_1＝0.05及 0.01 兩種，獲得與零有顯著差數之最高適當機率 P 用0.9及0.95兩種，照上法計算得各種試區應有之最少重複次數如表九所示，俾供試驗者設計試驗時之應用。

表九　在一定機率下獲得顯著結果應有之重複次數表

表中上排數字　根據顯著性測驗所用$p_1=0.05$及最高適當機率$P=0.90$

表中下排數字　根據顯著性測驗所用$p_1=0.01$及最高適當機率$P=0.95$

(皆為雙尾機率測驗)

Table 9.　Number of replications required for a given probability of obtaining a significant result.

Upper figure　Test of significance at 5% level, probability 90%

Lower figure　Test of significance at 1% level, probability 95%

two-tailed tests

(1)	(2) 單區標準機差百分率														
平均差數%	12	11	10	9	8.5	8.0	7.5	7.0	6.5	6.0	5.5	5.0	4.0	3.0	2.0
5						54	48	42	36	31	26	22	14	8	4
										52	44	36	23	14	6
10	31	26	22	18	16	14	13	11	10	8	7	6	5	3	2
	52	44	36	29	26	23	20	18	16	14	12	10	6	6	3
15	14	12	10	8	7	7	6	6	5	5	4	3	2	2	1
	23	20	16	14	12	11	10	8	7	6	6	5	4	3	1
20	8	7	6	5	5	4	4	4	3	3	3	2	2	1	1
	14	12	10	8	7	6	6	5	5	4	4	3	3	2	1

Notes: In Constructing the table, it was assumed that the number of degrees of freedom for error is $7(r-1)$this would apply in a randomized blocks experiment with 8 treatments. No entries are given where more than 60 replications are required.

(1) True difference (δ) as percent of the mean.

(2) Standard error per unit as percent of the mean.

例如行長八公尺四行區之單區標準機差為7.59%，若兩處理間之平均差數百分率為20%，查上表應用重複4—6次，若兩處理間之平均差數百分率僅5%，則應重複48次。

(五)結論　根據本試驗研究結果，亞麻田間試驗取樣之最小單位不宜小於行長八公尺之單行區，即行長在八公尺以下之多行區亦不宜採用，適合試區面積之變域為3.6—32.4平方公尺，試區形狀以狹長形者較佳，但狹長之方向應與土異方向平行

，適合此等條件之試區，如行長 8－16 公尺，行數 1—6 行等試區皆是，而其中以行長10－12公尺，行數 4—6 行者最佳。試區在區集內之排列，必須與土壤差異方向垂直。區集之大小及形狀，必須根據當時所用試驗地之土壤差異方向而決定，測定土壤差異方向之法，可用連續相關係數或組內相關係數，縱橫測定前作物等面積之收量，卽可明瞭。重複次數視試驗所需要之準確度及試項間差異之大小而決定，可應用 $r \geq 2\left(\frac{s}{\delta}\right)^2(t_1+t_2)^2$ 式估計之。總上所述，無論任何作物任何試驗，必須慎重試驗地之選擇，尤其對土壤差異方向應預先查明，然後設置適當之區集及決定試區在區集內之排列法，使成爲一良好之試驗設計，照設計按步進行，方克獲得正確之結果。

Ⅳ 摘　　要

1. 本研究之試驗目的，爲尋求亞麻田間試驗取樣之最小單位，適合試區之大小及形狀，妥善區集之設置及適當之重複次數，以冀增進試驗之準確度。
2. 本試驗於民國三十九年冬季在國立臺灣大學農學院農藝分場舉行。試驗地爲毗鄰之田兩坵，每坵面積約五公畝，分作四畦，畦寬6.30公尺，畦長18公尺，每畦植亞麻14行，行距0.45公尺。亞麻品種爲 Ireland, 收獲時以單行行長一公尺爲收獲單位，除每畦之兩邊行及兩端外，全試驗共得1536個收獲單位，分別測其乾莖重量，作爲分析研究之材料。
3. 取樣單位之決定用 Fisher 氏創立之 $g_1 \pm S.E.g_1$ 及 $g_2 \pm S.E.g_2$ 介值，測驗各種行長之一行及二行試區收量之常態性，結果得行長 8 公尺以上之單行區，始合常態分布，故亞麻田間試驗取樣之最小單位面積，不宜小於行長 8 公尺之單行區。
4. 亞麻試驗適合之試區規劃，區長應在 8 公尺以上，試區形狀以狹長形者較佳，其狹長之方向應與土異方向平行，試區長濶比之變域，自2.96：1至35.56：1，適合試區面積之變域（Range），爲3.60—32.4平方公尺，例如行長 8—16 公尺，行數1—6行等之試區，皆爲適合之試區規劃，其中以行長10—12公尺，行數4—6等試區最佳。
5. 區集規劃應視所用試驗地土壤差異之大小及變異方向而決定之，可利用前作物收量，計算試田縱、橫連續相關係數或組內相關係數，如縱向連續相關係數大

而顯著，區集內試區排列方向應與縱向平行，反之，則應順着横向排列。

6. 重複次數應視試驗項目之多少，應用之試驗方法，試項間差異之大小，及測定差異顯著性所用之水準而定，可利用公式 $r \geq 2\left(\frac{s}{\delta}\right)^2(t_1+t_2)^2$ 推算。茲設有8處理之逢機區集試驗，處理間之差異大小設為平均數之5%、10%、15%及20%等，獲得差異顯著結果之最高適當機率為 0.90及0.95，顯著性測驗之軌範為0.05及0.01，今計算單區標準機差百分率自2%—12%應有之重複次數，列如表九所示，以供試驗者設計試驗時作參考之用。

本試驗蒙前任臺大農學院院長陳振鐸，現任農學院院長周楨，前任農藝系系主任湯文通及現任農藝系系主任顧元亮等之讚助，以及生物統計研究室汪厥明教授之領導，得以順利進行，陳達權先生及農藝分場諸同仁在田間工作方面諸多協助，試驗設計之時，本校張魯智教授及農業試驗所張拔倫技正，予以許多指示，文成之後又承汪厥明教授斧正，謹此一併誌謝。

Summary

1. The aim of the present research is to find out some useful field plot techniques of flax trials such as size, shape, number of replications of sampling unit i.e. the plot and its arrangement within a block, in order to provide a guide to experimental design.

2. The uniformity trial with flax variety "Ireland" was conducted at University farm of National Taiwan University in 1950. The field experimental plan was laid out in a site of two joint pieces of cropland, each 5 ares in area, which was divided into four blocks of the same size and shape. Each block was 6.3 meters wide and 18 meters long within which 14 rows of flax were planted 0.45 m. apart from each other. At harvest time, each one-meter-section of every single row was taken as a harvest unit while flax crops on the borders of block were discarded. Hence, in the whole experiment, 1536 units were obtained. The air-dried stems of the harvest crops from each unit were weighed and entered for statistical analysis.

3. To test, for normality, the distribution of yields from various sizes and

shapes of plot, Prof. Fisher's criterions of g_1 and g_2 were employed. From statistical analysis of the numerical data, it may be concluded that the smallest sampling unit in flax experiments should be not less than 8-meter long in a single row in a plot, because the yield from a row of 8 meters long or still longer is distributed normally as verified by evidence from data.

4. As a result of further statistical analysis, it is shown that a plot which is longer than 8 meters and the ratio of length/width of which ranges from 2.96:1 to 35.56, consequently its area varying from 3.6 to 32.4 sq. m. may be recommended. From this, it follows that either plots of 1-6 rows and 8-16 m. in length, may be regarded as adequate for the purposes. Of course, the experimenter may choose a suitable plot in accordance with his own aim of experiments.

5. As to block planning, the author employed serial correlation coefficient to express the direction of the variation of fertility in field. If the serial correlation calculated along vertical direction of the field is shown as statistically significant, the arrangement of plots within block should be distributed in this direction. On the other hand, if serial correlation in horizontal direction is significant, the plots should be arranged in horizontal direction.

6. The formulus $r \geq 2\left(\frac{s}{\delta}\right)^2(t_1+t_2)$ may be employed to estimate number of replications, but it needs to consider the following conditions: (1) Number of treatments, (2) The design of experiment, (3) The true difference between treatments that we desire to detect, (4) level of significance at t-test and (5) the highly likely probability that a significant difference would be found in the experiment, in order to induce the smallest number of replications. If, for example, in a 8-treatment experiment of randomized blocks, a difference of 5 %-20 % of the mean we may expect to detect and if the significant levels of 0.05 and 0.01 at t-test and probabilities of 90% and 95% for obtaining significant results (under 5th condition) are chosen, then the smallest number of replications of plot can be estimated from the experimental errors which range from 2% to

12% in this uniformity trial. A table for this benefit has been made as shown in Table 9.

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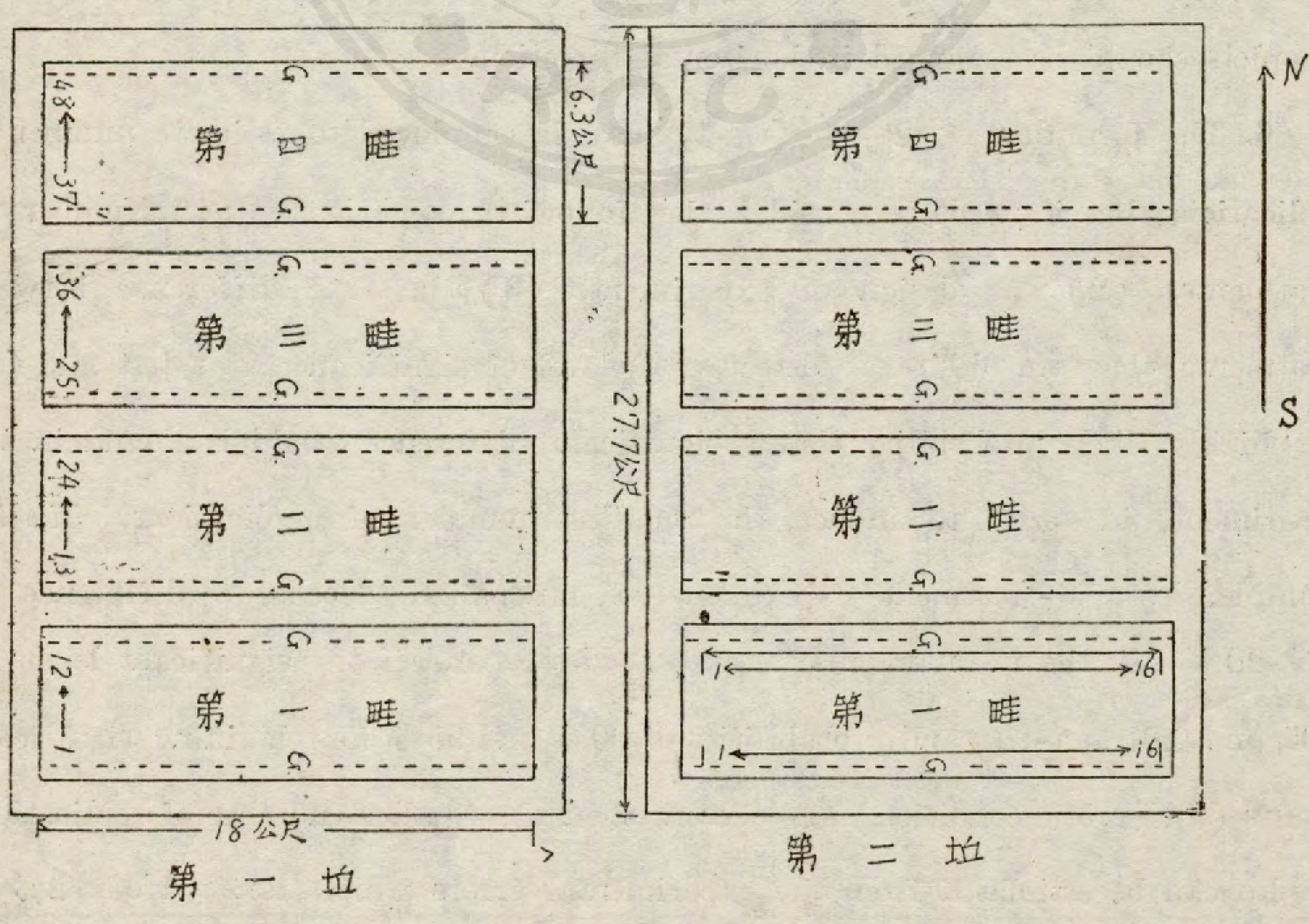
附錄(一)　亞麻均度試驗田間種植圖



附錄二：亞麻均度試驗行長一公尺單行區乾莖收穫量表

第 一 坵　　第 一 畦

段號＼行號	1	2	3	4	5	6	7	8	9	10	11	12
1	82.3	75.2	80.6	72.8	62.0	79.0	59.0	74.5	94.5	70.5	71.0	64.1
2	62.8	67.9	67.5	61.4	64.0	62.2	65.1	69.1	59.1	65.9	56.3	60.5
3	63.5	64.0	60.5	62.2	70.5	62.9	80.0	77.4	83.0	70.1	75.5	69.5
4	51.9	62.7	69.5	65.1	68.9	56.0	56.9	75.0	59.7	65.0	59.9	54.5
5	56.9	66.4	65.5	61.0	74.9	79,0	99.9	87.0	84.0	70.6	69.0	65.5
6	54.0	53.9	61.9	61.5	67.2	71.2	81.5	65.6	71.5	73.1	78.0	64.1
7	62.2	57.9	56.0	57.3	63.7	66.5	79.5	78.4	76.2	64.4	60.9	53.0
8	64.0	56.2	70.0	70.0	71.0	72.9	76.5	67.7	70.4	68.7	56.5	60.2
9	59.5	55.5	57.4	66.3	67,7	61.0	66.9	68.8	58.4	63.0	55.3	52.2
10	61.8	72.0	78.1	67.5	65.0	83.5	70.3	72.3	68.0	69.1	69.7	59.4
11	72.1	78.0	76.1	72.5	59.7	91.0	77.4	61.8	54.5	64.2	58.8	58.7
12	67.4	70.1	78.2	65.4	76.5	74.0	64.8	62.8	67.8	69.0	64.5	61.2
13	74.1	73.7	85.7	82.9	69.8	76.5	84.0	82.0	78.7	69.0	60.7	56.9
14	69.0	74.8	70.9	75.7	68.0	78.5	90.0	67.7	70.9	73.3	76.6	63.0
15	75.2	62.0	88.2	79.9	90.0	71.5	71.0	76.7	64.0	72.7	60.4	55.5
16	86.8	93.5	83.3	91.8	75.2	75.6	66.5	81.8	89.0	86.1	87.7	75.0

第 一 坵　　第 二 畦

段號＼行號	13	14	15	16	17	18	19	20	21	22	23	24
1	74.0	72.0	83.5	93.8	99.3	87.0	96.0	86.5	75.0	83.8	78.5	85.6
2	62.0	71.5	74.7	76.9	92.9	92.0	93.4	89.4	91.7	83.2	88.9	81.5
3	75.2	77.0	81.7	91.4	91.5	97.7	94.2	100.0	89.0	80.0	73.1	76.9
4	69.4	70.9	83.4	88.0	88.1	95.6	79.5	83.7	85.6	65.7	73.5	69.7
5	80.0	81.0	88.0	82.0	107.5	84.0	89.4	71.2	67.7	80.7	77.4	65.0
6	67.9	74.0	69.4	70.8	78.7	74.4	75.6	66.4	65.9	74.5	74.9	63.6
7	54.2	59.5	59.4	49.4	66.7	79.5	53.0	47.0	59.7	47.4	50.9	54.9
8	59.0	68.0	63.2	65.7	67.0	75.2	66.5	63.9	70.2	65.2	55.7	64.4
9	52.3	57.5	58.0	65.6	67,0	61.9	65.7	62.3	59.4	60.7	54.0	53.9
10	56.5	68.9	65.7	67.2	74.2	65.0	65.4	58.2	67.4	59.6	62.9	56.7
11	53.9	66.9	62.9	65.7	78.5	67.5	59.9	69.2	73.2	69.0	65.2	69.2
12	49.7	49.0	63.8	64.4	62.3	67.4	58.8	72.0	60.1	55.8	59.1	55.5
13	59.8	73.8	56.0	78.0	76.5	68.5	68.9	63.9	72.5	59.2	72.2	64.4
14	80.9	79.7	75.6	80.7	85.4	80.4	74.0	83.0	84.7	75.2	76.7	76.2
15	65.7	70.7	74.3	75.0	73.3	66.5	63.9	68.3	77.9	75.5	66.0	63.9
16	62.3	81.5	84.0	84.2	83.0	88.2	86.0	92.7	94.1	90.2	99.2	87.2

第一坵　第三畦

段號＼行號	25	26	27	28	29	30	31	32	33	34	35	36
1	82.7	84.2	78.5	67.1	59.0	51.0	51.1	61.8	61.2	69.5	67.0	60.0
2	71.0	74.5	73.2	71.5	69.0	68.9	57.5	59.5	66.5	65.4	62.1	62.9
3	69.6	80.8	63.5	61.0	52.7	62.4	48.7	62.0	64.2	67.0	57.4	55.9
4	57.7	81.5	70.2	76.7	54.6	65.0	68.5	65.4	61.9	76.2	61.5	55.5
5	58.0	65.0	63.9	68.0	55.0	68.7	61.9	69.0	70.0	63.0	60.5	65.9
6	59.9	60.0	66.7	56.9	58.2	59.4	71.2	68.4	70.5	75.0	67.4	50.8
7	54.4	53.0	60.9	51.5	55.9	57.0	66.1	57.0	57.5	57.4	50.4	58.5
8	58.0	62.5	60.0	63.5	52.4	63.2	57.9	54.7	68.4	71.2	64.0	56.7
9	54.7	52.7	59.2	51.5	50.2	52.5	53.5	62.5	66.5	63.5	51.5	51.0
10	60.2	74.5	61.5	55.2	57.2	72.2	64.5	58.6	64.2	70.4	57.0	54.6
11	66.4	67.5	82.2	69.9	60.9	66.5	65.7	66.4	72.5	65.9	61.7	61.2
12	64.1	67.0	62.0	64.9	61.2	56.9	71.2	57.2	48.5	66.4	59.9	65.6
13	61.6	72.7	72.2	65.5	58.5	58.0	60.0	62.2	69.4	67.4	61.9	69.5
14	83.2	77.0	80.0	77.5	67.0	75.7	67.0	70.4	79.0	83.9	64.0	63.5
15	77.0	73.9	62.7	69.9	67.5	72.8	69.7	72.3	83.9	84.5	83.6	71.3
16	79.5	93.7	77.7	80.2	77.0	85.9	78.5	99.0	99.5	89.5	84.2	80.9

第一坵　第四畦

段號＼行號	37	38	39	40	41	42	43	44	45	46	47	48
1	64.6	70.9	59.0	71.2	74.8	63.5	71.2	73.0	67.3	76.9	70.5	44.0
2	60.0	65.5	67.5	64.0	72.2	65.5	69.5	66.0	66.0	63.5	65.5	58.0
3	59.0	62.2	61.8	48.2	56.0	57.2	59.0	63.5	65.0	54.5	56.0	51.5
4	66.9	62.9	68.8	68.2	76.0	62.7	73.3	61.2	56.8	57.7	52.3	57.3
5	60.0	52.4	58.0	63.0	64.0	67.0	67.5	61.5	49.0	63.5	67.9	55.0
6	58.2	64.2	62.9	57.2	65.6	52.7	65.0	55.1	58.5	58.5	62.2	53.9
7	49.0	44.0	47.8	60.0	56.9	42.4	52.7	45.4	59.5	65.5	60.0	51.5
8	60.7	57.0	69.1	62.5	59.9	64.0	68.9	68.9	61.5	69.9	59.0	54.0
9	54.5	51.9	55.5	50.0	50.0	52.1	65.6	58.5	63.4	63.9	57.4	47.2
10	77.8	61.2	64.3	65.0	58.6	64.2	79.8	59.4	76.4	73.5	63.1	61.5
11	59.5	68.0	64.7	72.5	77.0	77.4	95.5	797	67.0	76.0	69.5	56.0
12	69.0	67.5	68.9	70.5	69.2	49.8	80.5	80.2	84.5	75.3	85 2	53.5
13	73.2	71.7	76.2	77.7	71.9	82.8	101.9	80.4	80.5	73.2	83.5	67.2
14	82.7	84.8	72.7	97.7	94.2	89.3	103.0	94.9	103.2	85.6	84.2	61.7
15	74.5	79.0	74.8	80.4	71.3	74.5	93.5	85.4	98.0	99.7	71.4	69.0
16	88.5	84.0	79.7	79.5	90.0	77.0	81.0	89.7	74.2	76.7	59.5	70.5

第二坵　　第一畦

行號 / 段號	1	2	3	4	5	6	7	8	9	10	11	12
1	64.1	62.7	66.9	59.5	62.0	57.8	65.2	70.5	61.2	62.8	68.2	61.9
2	61.8	62.1	72.4	62.3	67.5	57.2	62.0	63.0	54.9	65.8	57.5	51.7
3	56.5	60.0	63.8	64.9	55.0	57.4	61.0	60.0	45.3	60.0	56.2	40.0
4	50.6	55.2	55.5	55.4	73.7	58.0	60.0	53.5	85.5	51.0	65.5	45.6
5	51.8	59.7	57.3	71.0	77.5	80.5	80.2	72.8	71.2	73.6	74.6	64.0
6	70.0	66.7	61.7	60.0	81.4	74.0	63.0	67.8	76.7	82.5	84.0	70.5
7	54.7	57.7	58.5	81.5	84.0	84.0	81.9	87.8	93.7	87.5	89.3	75.5
8	57.2	53.5	57.2	62.0	87.2	96.0	89.0	97.2	87.7	93.7	104.5	80.5
9	51.8	62.0	62.5	79.1	86.6	89.5	87.8	106.0	101.2	90.0	90.0	84.8
10	60.1	61.4	76.8	73.2	90.7	105.5	82.7	101.0	111.0	100.0	99.3	98.7
11	68.0	65.0	72.5	71.5	93.2	89.0	92.5	86.2	89.2	96.7	94.5	88.3
12	57.8	75.6	77.8	78.8	82.3	92.5	83.0	85.5	94.5	75.9	86.0	77.4
13	49.2	74.5	78.0	90.5	87.5	101.5	93.6	107.0	93.7	81.8	96.3	82.4
14	65.0	83.0	81.3	83.5	77.3	85.0	74.9	72.7	88.9	79.0	92.8	95.6
15	80.2	100.5	91.0	78.0	96.5	88.2	90.0	93.3	78.3	92.5	100.2	97.2
16	60.0	68.6	80.8	100.0	90.2	106.9	105.8	108.9	111.8	118.5	126.9	107.9

第二坵　　第二畦

行號 / 段號	13	14	15	16	17	18	19	20	21	22	23	24
1	65.4	60.5	72.8	71.5	70.0	85.8	95.5	81.5	76.3	84.8	62.6	72.5
2	53.3	75.5	77.4	68.6	97.0	70.2	81.4	87.4	72.1	75.3	63.0	82.3
3	64.5	71.2	61.0	54.7	53.5	76.0	85.2	75.8	75.0	67.0	63.5	65.0
4	57.2	67.3	77.4	68.5	75.7	79.7	83.0	79.7	78.5	66.4	77.4	79.7
5	83.0	77.0	86.9	86.0	70.0	87.0	96.5	89.0	87.5	89.7	86.1	89.8
6	82.9	70.0	87.5	80.6	71.5	92.5	86.0	100.5	102.0	89.7	89.5	91.9
7	87.4	84.0	95.7	84.0	99.0	92.7	100.0	93.6	103.2	104.0	90.5	101.4
8	93.5	86.0	103.8	83.4	105.4	88.7	105.9	113.7	107.0	110.5	90.4	103.2
9	100.2	99.3	110.0	93.0	94.7	110.0	86.0	91.0	89.9	100.5	94.8	90.0
10	89.0	99.0	94.9	97.0	107.4	105.5	108.7	120.8	98.5	100.0	98.0	104.5
11	92.7	94.0	99.2	106.5	79.2	93.2	98.0	109.7	101.0	96.0	94.3	97.5
12	80.5	79.0	100.0	82.5	96.5	98.4	104.2	86.0	96.4	104.0	88.8	72.0
13	90.0	85.2	95.0	86.8	93.9	71.0	96.9	123.4	105.8	111.7	105.0	95.0
14	113.0	83.2	104.2	106.0	99.2	115.7	104.8	102.7	96.8	104.5	113.0	101.4
15	110.0	94.9	110.5	92.3	100.0	89.7	89.7	114.7	87.8	102.0	79.1	79.3
16	100.0	89.2	91.4	105.0	116.9	111.5	139.0	125.0	115.7	101.8	107.2	92.5

第 二 坵　　第 三 畦

段號＼行號	25	26	27	28	29	30	31	32	33	34	35	36
1	63.6	67.0	68.7	72.2	60.2	66.0	67.2	77.0	74.0	67.2	62.5	56.2
2	72.5	81.3	75.4	76.8	72.3	75.1	81.5	90.6	75.5	69.7	80.6	69.3
3	68.6	74.5	70.9	71.5	77.5	64.5	85.0	94.4	65.0	84.5	86.4	77.0
4	85.4	94.0	89.0	110.8	89.5	96.6	89.7	90.5	82.0	94.7	88.4	82.0
5	85.1	102.5	87.0	87.6	83.7	103.6	93.0	111.2	88.9	90.0	90.1	100.1
6	89.0	104.7	94.5	91.9	72.6	91.5	97.0	93.5	80.5	85.0	93.0	88.2
7	106.4	110.3	81.9	87.5	82.5	79.0	86.7	95.5	82.7	93.5	86.0	77.5
8	96.0	103.5	116.8	89.0	92.4	105.3	104.4	86.9	79.2	80.5	83.8	88.4
9	88.0	88.8	79.2	90.7	79.0	84.0	77.5	91.0	86.7	86.2	77.0	84.5
10	117.5	110.0	98.7	90.0	102.0	89.0	103.0	109.0	98.3	100.7	105.7	90.7
11	89.2	98.7	90.7	86.4	81.2	94.5	93.7	87.7	89.5	92.2	87.5	78.8
12	71.9	84.6	82.2	81.0	78.7	77.0	78.5	78.5	64.8	82.2	86.2	78.5
13	78.0	86.3	93.7	89.7	94.6	100.0	90.0	95.4	98.5	79.3	75.9	75.1
14	78.7	94.3	87.8	87.0	73.0	93.0	100.7	110.0	90.8	95.0	88.9	84.9
15	90.6	100.3	88.2	92.8	85.8	106.5	77.9	104.1	83.4	72.3	92.8	83.6
16	108.0	118.7	117.3	93.9	92.4	117.0	88.9	101.6	83.2	98.2	108.5	99.0

第 二 坵　　第 四 畦

段號＼行號	37	38	39	40	41	42	43	44	45	46	47	48
1	71.5	65.2	62.3	73.7	74.0	59.0	81.4	77.0	79.9	71.5	59.7	78.4
2	66.8	63.2	62.6	80.5	74.7	79.2	92.2	84.0	82.0	71.1	69.8	65.0
3	72.0	75.9	64.5	84.0	100.7	95.5	85.0	71.0	74.0	73.0	55.2	51.8
4	76.5	76.7	74.2	78.0	78.9	89.0	93.9	89.2	78.2	74.7	69.5	70.0
5	91.5	80.9	84.0	87.9	97.9	105.1	98.9	81.1	75.5	86.6	78.5	65.2
6	91.2	85.8	74.7	81.2	88.5	101.3	105.2	98.0	109.5	100.0	93.7	79.5
7	77.7	89.9	76.7	89.5	84.0	106.5	98.7	80.0	92.2	98.0	90.5	70.0
8	88.4	75.9	81.4	102.9	91.2	103.8	103.5	94.2	94.8	90.5	89.4	75.0
9	81.5	79.0	82.7	91.0	77.5	87.9	104.5	87.0	82.5	72.7	72.9	71.5
10	80.9	80.4	98.2	90.9	95.0	107.4	103.0	95.8	88.3	75.4	72.0	62.3
11	72.4	81.6	83.9	80.5	90.0	96.0	77.7	53.6	63.5	79.0	66.5	73.0
12	70.5	61.5	64.1	74.9	117.0	87.4	82.1	76.0	76.0	74.5	69.8	55.5
13	78.8	78.2	98.9	86.5	84.6	100.9	101.2	93.9	88.5	79.0	85.5	77.2
14	81.3	78.0	92.7	82.0	90.2	95.2	101.2	88.2	86.7	76.7	72.7	63.0
15	91.5	82.5	80.2	83.5	81.5	94.9	90.4	88.4	108.1	85.6	63.1	73.4
16	93.2	77.0	88.3	83.0	81.6	82.0	84.7	85.8	85.6	74.6	66.2	55.5

附錄三：各種試區長度及試區行數下亞麻乾莖產量變異係數之差異顯著性測驗法

變異係數爲標準機差（Standard Error）與平均數（Mean）之比值，係一無測定單位之百分數，百分數之平均有時受大分母小分子或小分母大分子之影響，而使平均結果失眞，且該等百分數如應用變方分析進行 F 及 t 值測驗，其求得之機差均方，係與原用之平均及標準機差發生聯繫，違背 F 及 t 值測驗之機差獨立擬說，故應加以變形（Transformation），變形之法， C. I. Bliss（1937）創議將百分數轉成角度，根據角度進行變方分析，可能求得獨立之機差，百分數轉變成角度之公式如下：

$$\text{angle} = \text{arc } \sin\sqrt{\text{Percentage}}$$

茲卽應用上列公式將表三中之變異係數轉變成角度，而後進行變方分析，F 值測驗及 t 值測驗，分析步驟及其結果，今敍述如下：

1. 變異係數轉變成角度表

試區行數	試區長度（公尺） 8	10	12	16	總計
1	17.33	15.08	14.91	14.24	61.56
2	16.91	14.18	14.09	13.61	58.79
3	16.49	13.24	13.41	12.77	55.91
4	15.99	12.23	12.31	11.59	52.12
6	15.44	9.28	8.77	6.52	40.01
總計	82.16	64.01	63.49	58.73	268.39

2. 變方分析表

變因	自由度	平方和	均方	F 值	P=0.05時之F P=0.01時之F	顯著性
行數	4	70.6205	17.65512	10.2054	3.84 7.01	極顯著
行長	3	63.8881	21.29605	13.5163	4.07 7.59	極顯著
機差	8	12.6047	1.57559			
總數	15	147.1133				

據上表分析結果知行數間及行長間均有極顯著之差異存在，故有繼續進行 t 值測驗之必要。

3. t 值測驗　$t=\dfrac{\bar{x}_1-\bar{x}_2}{S.E.(\bar{x}_1\sim\bar{x}_2)}$，以顯著之 t 值代入上式，可得平均差異之顯著數 $=t\times S.E.(\bar{x}_1\sim\bar{x}_2)$, $S.E.(\bar{x}_1\sim\bar{x}_2)=\sqrt{\dfrac{\text{機差均方}}{\text{重複數}}\times 2}=\sqrt{\dfrac{M.S.E}{n'}\times 2}$，以重

複數n'乘平均差異顯著數，便得總數差異之顯著數，卽 $t\times\sqrt{M.S.E\times2\times n'}$；若實得總數差異數大於總數差異顯著數，卽表明兩處理之間，有顯著之差異存在。

A. 行數間差異顯著數性測驗：茲據機差自由度 $n=8$，查 t 表，得 $p=0.05$ 時之 $t=2.306$ 及 $p=0.01$ 時之 $t=3.355$。因重複數 $n'=4$ 及 $M.S.E=1.57559$ 故

$p=0.05$ 時之總數差異顯著數 $=2.306\sqrt{1.57559\times2\times4}=8.1870$

$p=0.01$ 時之總數差異顯著數 $=3.355\sqrt{1.57559\times2\times4}=11.9113$

總 數 差 異 數 表：

行數	行數	1 行	2 行	3 行	4 行
	總數	61.56	58.79	55.91	52.12
2 行	58.79	2.77			
3 行	55.91	5.65	2.88		
4 行	52.12	9.44*	6.67	3.79	
6 行	40.01	21.55**	18.78**	15,90**	12.11**

表中數值有*者達5%顯著點，有**者達1%顯著點

觀上表六行區與其他各行區比較，均有極顯著之差別；四行區與一行區有顯著差別而與二、三行區則無顯著差別；又二、三行數之間差異均不顯著。

B. 行長間差異顯著性測驗　　重複數 $n'=5$

$p=0.05$ 時之總數差異顯著數 $=2.306\sqrt{1.57559\times2\times5}=9.1534$

$p=0.01$ 時之總數差異顯著數 $=3.355\sqrt{1.57559\times2\times5}=13.3172$

總 數 差 異 數 表：

行長	行長	8 公尺	10公尺	12公尺
	總數	82.16	64.01	63.49
10公尺	64.01	18.15**		
12公尺	63.49	18.67**	0.52	
16公尺	58.73	23.43*	5.28	4.76

據上測驗結果，行長八公尺區與其他各行長區比較均有極顯著之差異，其他各種行長區之間差異均不顯著。

以上測驗獲得之結論，與直接用變異係數平均之普通觀察法求得之結論完全一致，此因本試驗之資料爲連續變數，表三中之變異係數皆根據全試驗地試區求得，各種試區之均數雖不相同，但其單位面積之均數，可說完全相等，故其變異係數不受大分母小分子，或小分母大分子之影響，直接平均，亦不致使結果失眞，以是本研究中仍採用之。

農業化學系

慣用土壤水分常數與水分性能曲線之研究

A Study on the Conventional Moisture Constants and the Moisture Characteristics Curves of Soils

陳　振　鐸

C. T. Chen

引　　言

植物之優良生產有賴於土壤供應適量之水分，空氣與礦物質營養料，而在多數乾旱與濕潤農地以土壤水分之合理管制爲首要，蓋在此種環境之下，倘能施以適期適量之灌溉與排水，則可改善土壤之通氣與植物營養料之供給，而提高植物單位面積之產量。

查土壤水分中，僅有一部分水分可供植物利用。土壤學者與植物生理學者曾就土壤中可利用的水分，加以解釋如下：1. 凡土壤水概受水與土粒間產生之表面張力及土壤溶液中溶質滲透壓的影響，故表現張力並具有不同之自由勢力値。土壤水之張力或自由勢力値，乃以普通水(自由水)之張力或勢力値作爲零點而起算，故爲負値者。

2. 土壤水張力乃管制該水分之保持與移動的性能，故各種土壤，在同一水分張力下，含有共同性能的水分，但其水分含量則不一，例如在各種土壤中，植物呈現永久凋萎現象時之土壤水分張力概爲15氣壓左右，但其水分含量則視土壤質地及其他性質而有甚大之差異。

水分張力一含量曲線或水分性能曲線乃指示土壤水分，自飽和以至乾燥間張力與含量之變化以及彼此間的關係，因而得以獲悉供試土壤水分在任何張力下所具有之性能與含量。

3. 土壤水分中可供植物利用者，必須其具有的張力小于植物吸收水分的吸力而大於重力的引力，因此得向植物根部移動並抵抗重力的吸引而保留於土壤中。該水分之張力約在0.1至15氣壓之間，亦卽田間容水量 Field capacity 與永久凋萎點

Permanent wilting point 間之水分，通常稱此部份的水分爲土壤的有效水分。

綜上可知闡明各種土壤的水分張力，水分性能與含量的關係及在植物生育中維持土壤的有效水分爲管制水分之重要措施。唯目前在臺灣尚缺少關於本省土壤水分張力與含量之研究及諸水分常數；如永久凋萎點，田間容水量，水分當量等資料。作者鑑及其對於臺灣農地之灌溉，排水，水分管制以及有效水分測定之重要性，近年間曾利用各種測定方法測驗本省若干土壤之水分張力一含量曲線及各種土壤水分常數。本文記載其實驗經過，並就測定方法與測定值之應用問題亦加以討究。

本文實驗部分，承魏金塗先生熱心協助，至爲銘感，謹此誌謝。

供試土壤與試驗方法

本試驗所用之土壤(表士)係自國立臺灣大學農學院農場，臺灣省農業試驗所農場，臺灣省糖業試驗所屏東分所農場，屏東糖廠崇蘭農場與六塊厝農場等五處採取。

供試土壤之生成方式與重要理化學性質列於第一表中：

第一表 土壤型與其性狀

Table 1 Soil types and characteristics

No.	採樣地點 Location	生成方式 Mode of formation	土系 Series	土型 Type	機械組成分 Mechanical composition Sand 2—0.05 mm	Silt 0.05—0.002 mm	Clay < 0.002 mm	風乾土含水量 Pw of air dry soil	眞比重 Real density	假比重 Apparent density dense	loose	容水量 Water holding capacity	pH	有機物 Organic matter	土壤溶液電導度 Conductivity mho × 10⁻³	滲透壓 Osmotic pressure Atm.	滲透度 Permeability *
					%	%	%	%				%		%			
1	臺大農場	冲積	臺北系	砂質壤土	55	36	9	2.15	2.70	1.37	1.19	34.2	5.25	1.57	0.84	0.266	0.485×10^{-6}
2	臺北農業試驗所農場	冲積	臺北系	泥沙壤土	33	58	9	3.56	2.64	1.30	1.11	34.7	5.55	2.15	2.16	0.729	0.083×10^{-6}
3	屏東糖業試驗所分所農場	冲積	屏東系	泥沙壤土	14	72	14	1.64	2.71	1.22	0.96	40.8	6.75	2.87	2.06	0.693	0.053×10^{-6}
4	屏東崇蘭農場	冲積	崇蘭系	泥沙壤土	40	54	6	2.67	2.74	1.73	0.97	30.5	7.40	1.44	12.85	4.869	0.123×10^{-6}
5	屏東六塊厝農場	冲積	高樹系	砂土	90	6	4	0.58	2.75	1.71	1.50	19.0	8.00	0.74	2.64	0.903	0.689×10^{-6}

* 單位面積，單位位能，單位重量，單位時間。Per unit area, unit total potential gradient, per unit mass, per second.

上表中機械組成分乃用 Bouyoucos 氏法，有機物則用 Schollenberger 氏法，

pH 使用玻璃電極法，容水量用 Hilgard 氏法，至於土壤溶液電導度，滲透壓與滲透度測定中所採用之方法如下：

土壤溶液之電導度：加水于土壤中，俟達容水量時，吸取其溶液，然後照 Wilcox(29)氏法測定其電導度。

滲透壓：參照 Campbell 氏法(9)，由電導度計算之。

滲透度：參照 Bodman 氏法(3) 利用公式 $P_s = Ql/At\overline{\underline{\Phi}}$ 計算水分飽和狀態下之滲透度 P_s(單位面積，單位位能，單位重量，單位時間)， 式中 Q 爲流水量(cm^3)，A：土柱橫斷面積(cm^2)，t：滲透時間(sec.)，$\overline{\underline{\Phi}}$位能，l：土柱高度(cm)

一、土壤水分常數與其測定法。

1. 永久凋萎點。

栽培在盆中之植物，因缺少土壤水分，呈現凋萎現象後，移置之於飽和濕度之暗室中經過12小時，如果植物葉部仍呈現凋萎狀態，則該凋萎現象實由於土壤水分之不足而引起者。此時土壤之水分含量稱爲永久凋萎點，但若植物開始凋萎，而移置于暗室中後，葉部可回復正常膨脹狀態則其土壤含水量乃稱爲凋萎點，俾與前者加以區別。Briggs，Kramer, Lewis 氏等前後發表永久凋萎點之測定法，據其試驗結果，在同一類土壤中各種植物之永久凋萎點略爲一致，唯通常採用向日葵作爲供試植物。Furr, Reeve 氏(13)、在其研究中謂，植物在凋萎限界內呈現凋萎現象，其所稱的凋萎限界乃指限界之起點與終點間之土壤水分量，而限界起點者乃當向日葵之底葉，呈現凋萎現象時之土壤含水量、終點者乃向日葵的葉全部呈凋萎現象時之土壤含水量。該氏等又稱，植物不能利用凋萎限界內之水分供爲生長之用，唯可藉之以維持生命。據悉凋萎限界內水分大約佔土壤有效水分之11~30%。最近 Henderson 氏 (15) 測定同一土壤之永久凋萎點，而所得測定値間之差異甚大。因而該氏在其結論中稱，永久凋萎點之限界頗廣，致難以單一水分位能 moisture potential 表示其水分常數。該氏又示；土壤中鹽類之含量高時，永久凋萎點限界有擴大之趨向。Richards 氏(22)謂土壤水分在永久凋萎點時之張力多爲10~20氣壓平均爲15氣壓。

在本實驗中係採用 Veihmeyer 與 Hendrickson (3) 兩氏所提倡之向日葵法，

以測定永久凋萎點。其方法乃使用 No. 2 罐頭、在温室中栽培向日葵 (Helianthus Annus)，俟植物第三葉呈凋萎狀態後，移置之於飽和濕度的暗室中，經過12小時，而第三葉仍然維持凋萎狀態，則以此時供試土壤之水分量，卽爲其永久凋萎點。

2. 水分當量及其測定法。

水分當量爲 Briggs, McLane 氏等引用之土壤水分係數，卽土壤經受1000倍于重力的遠心力 (1000g) 後，所能保持之水分量。而其水分張力則略等於1/3氣壓。Veihmeyer, Oserkowsky, Tester 氏等 (26) 曾研究水分當量測定法與應用問題。水分當量爲在人爲管制條件下測得之水分常數，但田間容水量，永久凋萎點則爲在自然情況下測得者。故前後兩者之用意自有不同，但水分當量之測定較爲準確，方便，而不受自然環境之影響，故多數學者曾尋求水分當量與田間容水量及永久凋萎點間之關係。如 Veihmeyer Hendrickson (27)氏等謂：細粒土壤之水分當量約爲14%時，水分當量與田間容水量極爲接近，但在粗粒土壤則不然。Browning 氏 (7)則謂：水分當量爲21%時，田間容水量與水分當量之比率爲 1，但水分當量大或小於21%時，該比率則大或小於 1，卽示該兩值之比率乃受土壤質地，水分量等影響而變化者。

至於水分當量與凋萎點之關係，曾經 Briggs，Shantz，Veihmeyer，Hendrickson, Ducan (11)諸氏討究。Briggs，Shantz (6)氏於1911年發表水分當量測定法，後經各方改進被廣爲採用，而在本實驗則採用 Veihmeyer 與 Bodman (5) 氏之修改法。

3. 田間容水量與其測定法。

田間容水量爲土壤中重力水業經排出，而微管水移動達於極緩慢狀態時之土壤含水量也。田間容水量又稱毛細管水容量 capillary capacity，在多數土壤，降雨或灌漑後數小時乃至二三日間，含水量卽達於田間容水量。Veihmeyer, Hendrickson 氏等謂：田間容水量非爲一種平衡值，但當達該水分量時土壤水分之移動極爲遲慢，故水分含量幾無變化。田間容水量爲田間測定值，故直接受土壤剖面性質及地下水位高低之影響。Richard, Weaver 氏 (22) 曾用張力計 Tensiometer 測定田間容水量之水分張力，據示約等於0.1氣壓，相當於水高 100cm. 之壓力。P. W. Thorne 氏等之實驗結果則示約等於 25—60cm. 水高。在本實驗中使用 Browning 氏法(7)

測定田間容水量。本法乃在測定地點埋沒規定型式之圓筒，加入定量水分，經過48小時後，自表面下6吋處採取土壤而測定其含水量。

4. 正常水分容量與其測定法。

正常水分容量Normal moisture capacity 爲 C. F. Shaw 氏(23) 提出的土壤水分常數，卽放置土壤於定型圓筒中，加入定量水分後密封之，經過123日後，土壤表層所含之水分量也。Shaw 氏曾謂：土壤在正常水分容量時，水分之移動幾乎停止，而到達於平衡狀態，故此時僅有蒸氣之移動。Shaw 氏在其試驗中測定土壤之正常水分容量與水分當量之比率而得 1.057，故可知兩者數值極接近。本實驗乃參照 Shaw 氏法測定供試土壤之正常水分含量。

二、土壤水分張力與含量之測定。

1. 低張力土壤水含量之測定。

Richards, L. A. (18)(19)(20)(22)，Jamison, V. C. 諸氏(14) 曾研究低張力(0—2Atm.) 土壤水之含量測定法，該氏等設計吸氣計 Suction apparatus，加壓計 Pressure-plate apparatus 與矽藻土張力計 durable asbestos table 等而均得良好的結果。查低張力水分佔有土壤有效水分之大部分，而低張力水分供應植物利用之效率乃視其張力與移動量而定，故吾人通常求出水分張力一含量曲線，而檢定其水分性能與含量後，再測定毛細管傳導度 Capillary conductivity 與滲透度 permeability 以決定水分移動量。本試驗之低張力水分含量測定，除採用 Richards 氏(18) 設計的加壓計外，並曾稍作更改：使用吸壓並添加壓力計，以及利用濾紙代用磁製孔板等。

2. 高張力土壤水含量之測定。

在本試驗中，高張力土壤水之含量乃依照 Bodman, G. B. 氏 (2)(3) 法測定，該法之操作如下：放置供試乾燥土與濕潤土(水分含量約爲水分當量者)於裝有不同濃度硫酸的乾燥器中，然後將乾燥器放置於 30°C 定溫箱中，經過二星期後，取出土壤而秤量之。其後復放置土壤於乾燥器與定溫箱中，經過一星期後再秤量之，迄至土壤重量達於恒量爲止。於是測定水分含量，而求出相對濕度或蒸氣壓與土壤水分含量之關係。至於各蒸氣壓下之土壤水分張力值與微管(毛細管)位能 Capillary potential，則用 Bodman 氏所提之公式 $\pi = \ln\frac{P}{Po} \times \frac{Po}{\sigma}$ 計算之，本式中 π 爲微管

位能、Po 爲自由水面之蒸氣壓 mm. P 爲土粒表面之蒸氣壓 mm., σ 爲蒸氣密度。

3. 低張力與高張力間土壤水分含量之測定。

氷點降下度測定法：Schofield 與 Botelho da Costa 氏(24) 曾使用 Beckman 溫度計，測定土壤在不同水分含量下之氷點降下度，並引用下列公式計算自由勢力減少值。

$H=\frac{Lj}{T.g}t$ 式中 H ：爲水柱高度 (cm.)，相等於自由勢力減少值，而土壤中可溶性鹽類含量小時相等於土壤在保持水分中所表現的吸力。Lj ：水之溶解潛熱，3.336×10^{9}erg gm^{-1}。 t ：土壤中水分之氷點降下度 (°C) ，T：純水之結氷點，273.18°C 絕對溫度。 g：重力加速度 981cm. sec^{-2}。Schofield 式中之 H 與張力計測得高度 cm. 在標準溫度與氣壓下相符， 又 Schofield 氏法 H 值與自由勢力減少值僅在供試土壤之遊離鹽類含量低，而滲透壓少時相接近，否則反是。 G. B. Bodman, P. R. Day 氏 (4) 曾使用 thermocouple. 測定土壤水分之氷點降下度。氏等在其研究中注意及壓力，溫度，溶質等對於土壤水分自由勢力値之影響，並將 Schofield 氏 H 値改爲水分位能 α 値，藉以表示該値與氷點降下之關係。最近 Richards, Campbell (21) 兩氏使用 14—B Thermister 測定土壤水分張力。在本試驗中，因受設備限制，乃採取 Schofield 氏 A 法 (24)，使用 Beckman 溫度計，而測定供試土壤在各種水分含量之氷點降下度，實驗中並曾測定容器，土壤及溫度計之水當量、而得平均值 12.9，此值與 Schofield 氏所用者12.1略同。

本文中採用若干土壤水分勢力值用詞，茲將該詞等用意略爲補充說明加下：

一、微管(毛細管)位能 Capillary potential。

土壤所以能保持水分者，乃藉於土粒表面之吸力 attractive force，而吸力之大部份則由毛細管引力 capillary force 產生者。故欲使水分由土粒表面分離，則須由外部加以功而此功量則相當于毛細管引力所作之「功量」後始可。Buckingham 氏 (8) 使用微管位能以表示自水分含量不同的土壤中取出單位重量水分時所需要之功量。此功量乃與另一功量，卽自地下水面，將單位重量水分移動至土壤系統 Soil system 的 H 高度處所需要的功量 Hg 相符、故微管位能除以功之單位 erg/gr.表示外，尙能以水柱高度 H 表示之。通常以自由水之微管位能作爲零點算起，故普

通土壤水分（飽和點以下）之微管位能爲負值，而土壤水分減少時其絕對値則增加。Buckingham 氏的微管位能中含有水分張力與滲透壓所作之功，故其與水分張力之用意自有不同之處。

二、自由勢力 Free energy。

Edlefsen, Anderson 氏等（12）更改微管位能爲自由勢力值，又使其單位同爲 erg/gr, 而應用於土壤水分研究中。凡土壤水分自由勢力之轉移，均根據於熱力學法則，故應用之後在解釋上更有明瞭與利便處。土壤水分之勢力值仍以自由水之勢力值作爲零算起，實際上應爲自由勢力差異值 free energy deficit，故其符號爲負。自由勢力受兩種位能之管制，其一爲土壤水分之各種張力，如土粒與水分間之表面力 surface force, 重力 gravitational force，靜水力 hydrostatic force 等；另一爲由土壤溶液滲透壓 Osmotic force 產生者。

三、水分張力 moisture tension。

土粒藉其表面之負壓力保持水分，故由外界若以同大壓力吸引水分，則該水分卽離開土粒表面。學者等稱此負壓力爲水分張力，而以單位面積上水柱高度，重量或氣壓等表示之。水分張力中包括表面張力，重力，靜水力等，但不包括滲透壓在內。土壤水分張力可用張力計，吸引器等直接測定之。

四、水分應力 moisture stress.。

Wadleich 與 Ayers 氏(28)曾使用水分應力於其土壤水分研究中。水分應力中乃包括兩種張力：卽水分張力與滲透壓是也。通常以氣壓爲單位表示之。

試驗結果與討論

一、土壤水分常數：

1.永久凋萎點(向日葵法)

使用向日葵法測定供試土壤永久凋萎點之結果列於第二表中。試驗成績示除崇蘭土壤外，其他供試土壤之永久凋萎點在兩次試驗中均得近似數值。A. D. Ayers 與 R. B. Campbell 氏（1）在其研究中曾示，當土壤溶液的濃度高，卽滲透壓大時，同一土壤永久凋萎點間之變異特大。查崇蘭土壤溶液之濃度獨高，因之其凋萎點間之變異亦大，此與 Campbell 氏之結果相符。

第二表　永久凋萎點(向日葵法)

Table 2　Permanent wilting point (Sunflower method)

No.	採樣地點 Location	第一次試驗 1st experiment			第二次試驗 2nd experiment		
		Mean *	S. D.	C. V.	Mean *	S. D.	C. V.
1	臺大農場	8.90 %	±0.502 %	5.64 %	9.81 %	±0.264 %	2.69 %
2	臺北農業試驗所農場	9.90	±0.121	1.22	10.09	±0.563	5.58
3	屏東糖業試驗所分所農場	8.44	±0.210	2.49	8.22	±0.374	4.55
4	屏東崇蘭農場		—	—	7.46	±1.123	15.05
5	屏東六塊厝農場	2.79	±0.125	4.48	2.31	±0.318	13.77

* 5個重複之平均值 Average values of five replicates, S D.: 標準偏差 Standard deviation, C.V.: 變異係數 Coefficient of variation

2. 水分常量

水分當量之測定，係在規定條件下處理，因此重複測定值間之差異甚少。其結果列於第三表中。供試土壤中 No. 2, 3, 4, 均爲泥沙壤土，其永久凋萎點尙相接近，但各土壤間水分當量之差異則大，卽示在水分張力低時，除質地外土壤之其他若干性質；如有機物含量，滲透度等，對于水分當量值產生顯著的作用，卽有機物含量高，質地細微，滲透度小時水分當量大也。作者檢討本試驗結果後，就水分當量之測定法與應用，提出下列意見：1. 水分當量測定法之缺點尙少，但必須取得代表性試料。2. 水分當量非爲田間測定值，故應用之於實際問題時，應注意各種自然環境因子之影響。

第三表　水分當量

Table 3　Moisture equivalent

No.	採取地點 Location	水分當量 Moisture equivalent		
		Mean *	S. D.	C. V.
1	臺大農場	16.38 %	±0.191 %	1.17 %
2	臺北農業試驗所農場	24.26	±0.273	1.13
3	屏東糖業試驗所分所農場	30.82	±0.150	0.49
4	屏東崇蘭農場	16.58	±0.291	1.76
5	屏東六塊厝農場	5.17	±0.122	2.36

* 四個重複之平均值 Average values of four replicates

3. 田間容水量

田間容水量乃按照 Browning 氏法（7）係于三個不同時期分別在採樣地點舉行，每期行四次重複之測定，結果列於第四表中。該表示各種土壤田間容水量測定值之變異係數概大於其凋萎點，水分當量，與正常容水量之變異係數。其中尤以砂質土壤 No. 4,5 之變異係數特大，故不無減低測定值之準確性。查砂質土壤之田間容水量原來就少，而少量的水分變異更易形成大的變異係數，故今後應行多數砂質土壤田間容水量之測定，而就其變異係數範圍加以討究之必要。

田間容水量為田間測定值，受自然環境：諸如地形，地下水位之高低，非毛細管孔度，濕度，作物種類以及生長情形等之影響甚大，而此等因子在測定中不易加以控制，即使加以控制，在實用上則却欠少意義，故將某種土壤之田間容水量與別種土壤者相較時，應注意及各種環境因子之影響。

本試驗結果又示，田間容水量概大於水分當量，茲將後者對前者之比率列於第四表中。Browning 氏(7) 與 Veihmeyer 氏(27)曾研究水分當量與田間容水量之比率，共結果似不適用於本試驗之農田土壤。此可能因於供試農地之地下水位高，而影響及田間容水量之測定值也。

第四表　田間容水量

Table 4　Field capacity

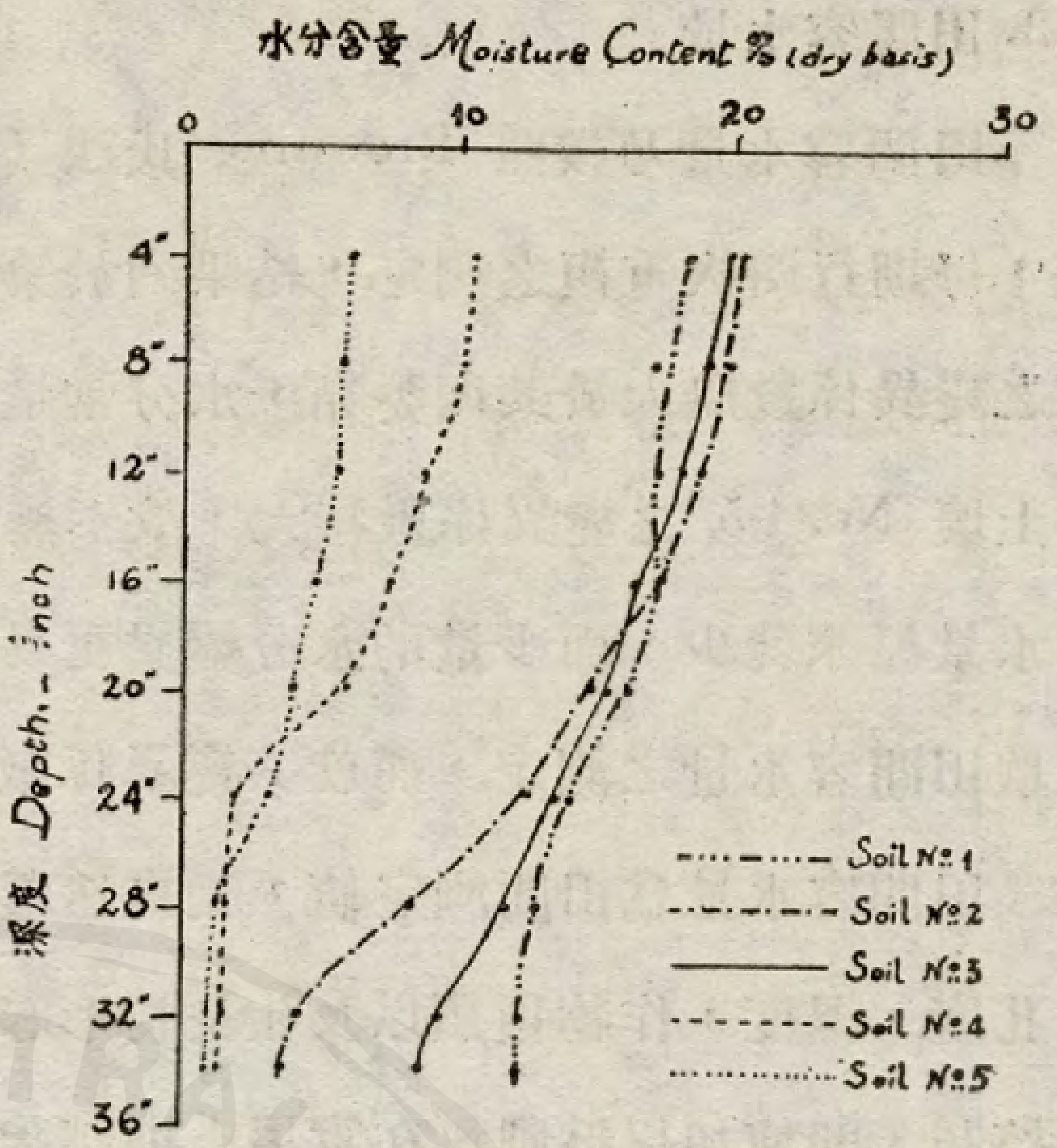
No.	採取地點 Location	第一次試驗 1st experiment			第二次試驗 2nd experiment			第三次試驗 3rd experiment			平均 Average	田間容水量 / 水分當量 Field capacity / moisture equivalent
		Mean*	S. D.	C. V.	Mean	S. D.	C. V.	Mean	S. D.	C. V.		
		%	%	%	%	%	%	%	%	%	%	
1	臺大農場	26.31	± 2.36	8.97	25.59	± 1.50	5.86	25.90	± 1.24	4.79	25.93	1.58
2	臺北農業試驗所農場	33.73	± 1.06	3.14	33.56	± 3.67	10.94	33.30	± 1.73	5.19	33,53	1.38
3	屏東糖業試驗所分所農場	37.00	± 2.19	5.92	40.90	± 2.30	5.62	41.90	± 1.41	3.36	39.93	1.29
4	屏東崇蘭農場	19.87	± 4.49	22.59	21.25	± 2.91	13.69	21.80	± 6.59	30.22	20.97	1.26
5	屏東六塊厝農場	13.67	± 3.43	25.09	14.97	± 3.39	22.64	11.75	± 2.35	20.00	13.46	2.60

* 四個重複之平均值 Average values of four replicates

No. 3, 4, 5 土壤之田間容水量測定乃承糖業試驗所屏東分所楊宗錫先生協助，謹此誌謝。

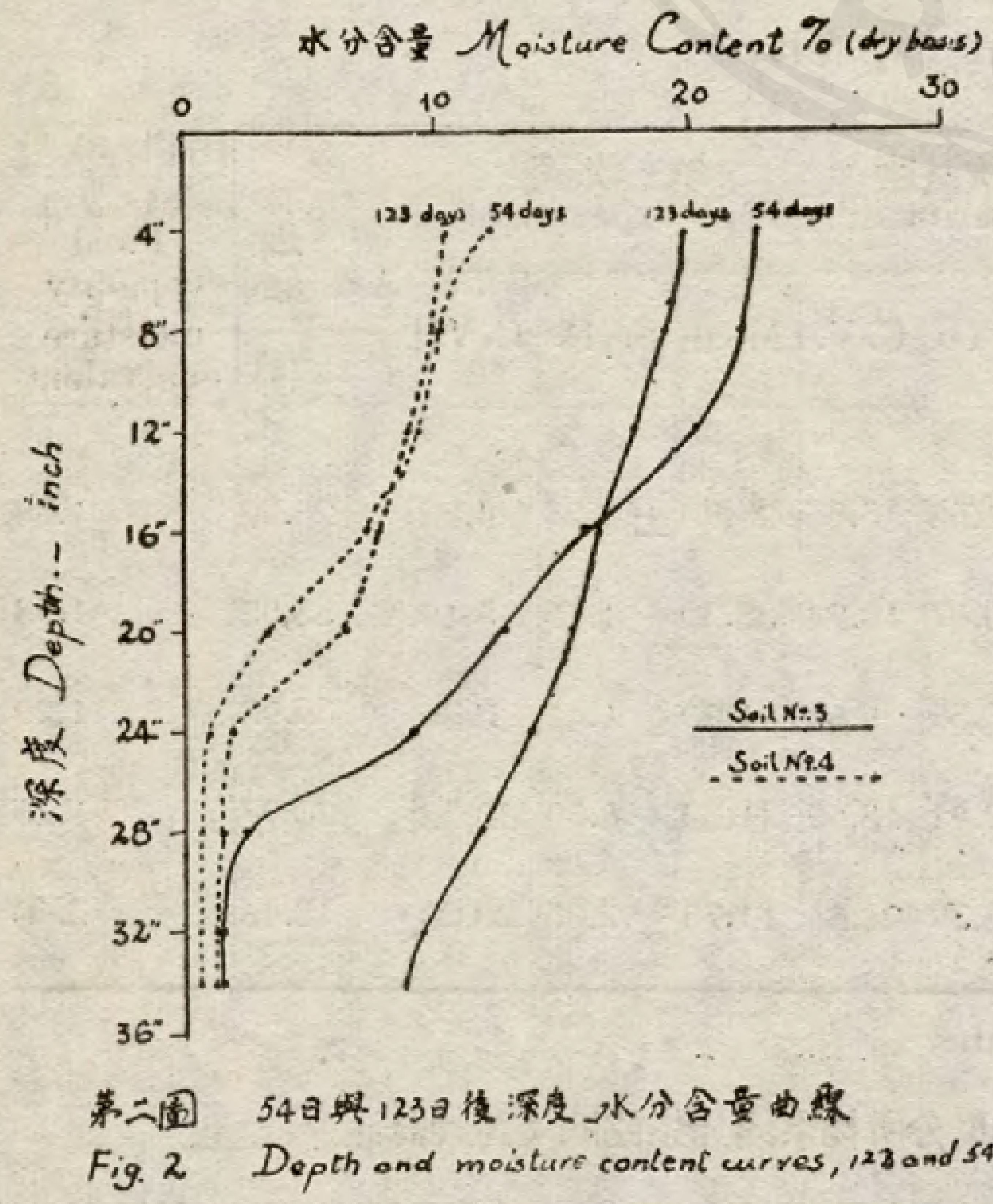
4. 正常容水量

依照 C. F. Shaw 氏法(23)按期測定圓筒中各深度土層之水分含量，而在123日後，取其表面下4"深度處之含水量作爲正常容水量。各供試土壤之表面下 4"，8"，12" 深度的水分含量與變異係數統列於第五表中。至於本試驗間所得深度 36" 土層中每隔 4" 土層的水分含量平均值，則示於第一圖中。參閱本圖便知，各土壤的深度一水分含量曲線，在深度 12" 以上的土層中，約略形成直線，即示在該層中，水分移動幾達於平衡狀態者也。此項現象，曾經 Shaw 氏在其研究中證實之。實驗結果又示，除土壤No. 1, 4, 5 外，其他土壤之測定值變異係數尚小，均在慣用土壤水分常數變異係數範圍以內。茲將水分當量對正常容水量之比率亦列於第五表中，就中 No. 1, No. 5 土壤之比率大於 1，餘者則小於 1。Shaw 氏之試驗示兩者之比率爲 1.05，Shaw 氏僅用一種土壤以測定其比率，故未便將本試驗結果與 Shaw 氏者相較，唯由本試驗可知，水分當量可能大或小於正常容水量，兩值之比率即視土壤之種類而異。



第一圖 深度—水分含量曲線(123日後)
Fig. 1 Depth—Moisture content curves (123 days later)

土層中液體水分之流動，在正常容水量時，幾達於平衡，故自試驗開始至結束，即自注水於土壤中開始試驗，迄至水分移動達於平衡狀態爲止，需要長久時間。Shaw 氏曾規定其時間爲 123日，在本試驗中曾將放置時間縮短爲54日，以觀察土層深度與水分含量之關係究竟如何，該結果列於第二圖中。由該圖可知，在54日後，土層中水分之移動，尚未



第二圖 54日與123日後深度—水分含量曲線
Fig. 2 Depth and moisture content curves, 123 and 54 days later.

達於平衡狀態也。

正常容水量之測定，需要長久時間，此為應用上不便之點。又其係在管制條件下之測定值，故對於試料，自然比重，溫度，加水量等等，應加以詳細規定方可，唯目前尚缺少是項之研究，故在處理本法中，應就以上各點，予以注意自不待言。

第五表 正常容水量

Table 5 Normal moisture capacity

以4吋深度之水分量作為正常容水量。Pw at 4" depth is regarded as the normal mois ure capacity

No.	採取地點 Location	4" depth				8" depth				12" depth				正常容水量 水分當量 n. m. c. / m. e.
		Mean	S. D.		C. V.	Mean	S. D.		C. V.	Mean	S. D.		C. V.	
		%		%	%	%		%	%	%		%	%	
1	臺大農場	18.37	±	0.621	3.38	17.11	±	0.402	2.35	17.41	±	1.216	6.98	1.12
2	臺北農業試驗所農場	20.36	±	0.188	0.92	19.90	±	0.223	1.12	18.83	±	0.369	1.96	0.83
3	屏東糖業試驗所分所農場	19.95	±	0.393	1.97	19.08	±	0.346	1.81	18.17	±	0.246	1.35	0.64
4	屏東崇蘭農場	10.31	±	0.982	9.52	10.08	±	0.195	1.93	8.94	±	0.283	3.17	0.62
5	屏東六塊厝農場	6.17	±	0.519	8.41	5.98	±	0.237	3.96	5.48	±	0.221	4.03	1.19

* 四個重複之平均值 Average values of four replicates

二、土壤水分張力與含量

1. 低張力土壤水之含量。

供試土壤在張力1/3氣壓，2/3氣壓與1氣壓之水分含量，列於第六表中，又將其水分含量一張力曲線示於第三圖中。

第六表 不同水分張力下之水分含量

Table 6 Moisture conten at various moisture tention.

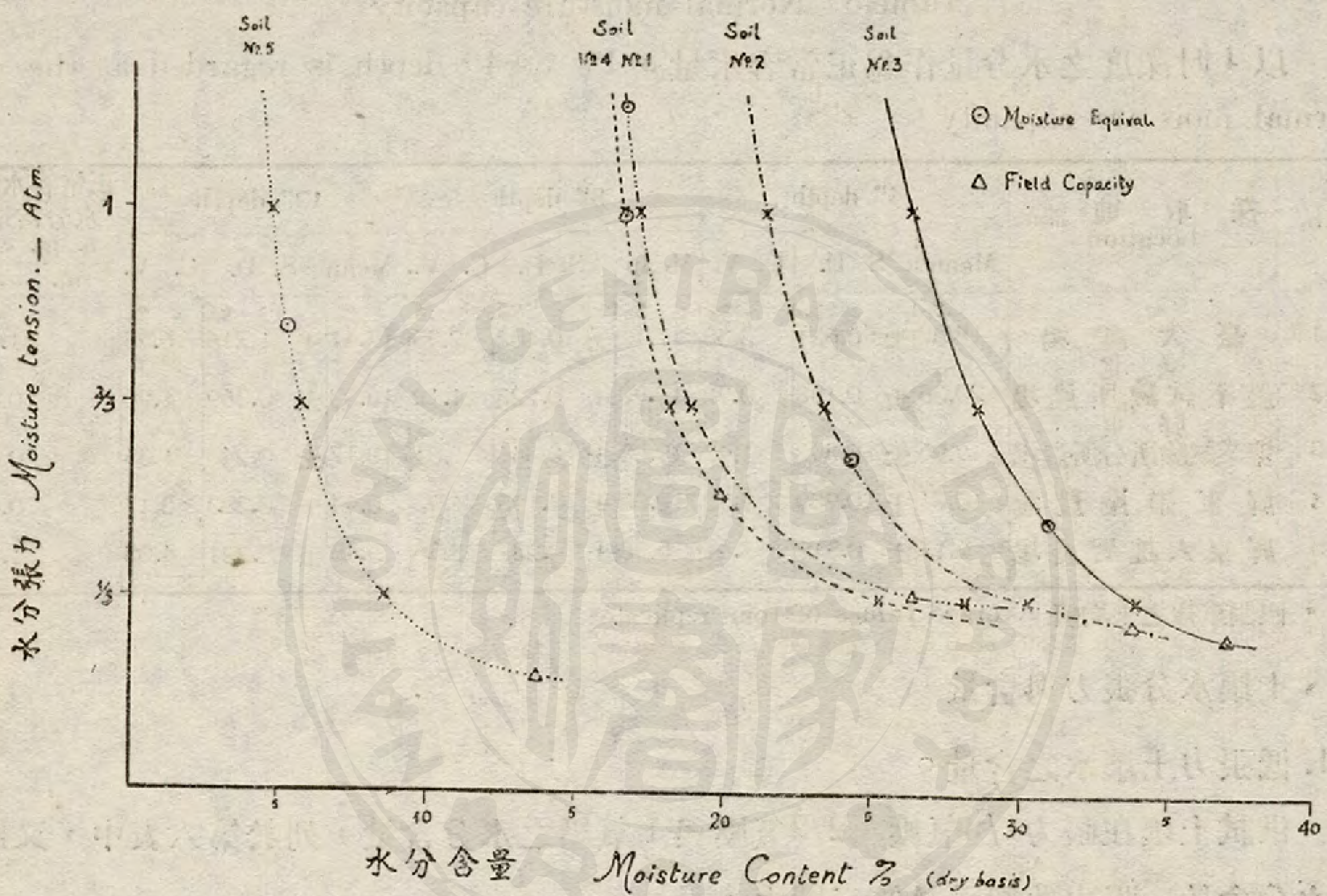
No.	採取地點 Location	水分張力 Moisture tensiom											
		1氣壓 Atm.				2/3氣壓 Atm.				1/3氣壓 Atm.			
		Mean	S. D.		C. V.	Mean	S. D.		C. V.	Mean	S. D.		C. V.
		%		%	%	%		%	%	%		%	%
1	臺大農場	17.02	±	0.348	2.04	18.83	±	0.241	1.28	28.13	±	0.485	1.72
2	臺北農業試驗所農場	21.35	±	0.311	1.46	23.33	±	0.645	2.76	30.23	±	0.807	2.67
3	屏東糖業試驗所分所農場	26.19	±	0.222	0.85	28.47	±	0.165	0.58	33.92	±	0.301	0.89
4	屏東崇蘭農場	16.55	±	0.543	3.28	18.07	±	0.437	2.12	25.21	±	0.651	2.58
5	展東六塊厝農場	4.68	±	0.058	1.24	5.70	±	0.237	4.16	8.51	±	0.366	4.30

* 四個重複之平均值 Average values of four replicates

在四次重複測定中，每種試料所得差異係數均小，此乃由于測定法管制嚴密之

故。

經由第三圖水分張力—含量曲線求出供試土壤在水分當量與田間容水量之張力，其結果示於第七表中。由此可知，使濕土乾燥時水分當量之張力在 1.1~0.5氣壓間，田間容水量則在 0.5~0.2氣壓間，兩者張力差異相當廣濶約為 0.8~0.2氣壓。又由本試驗結果可知土壤構造，質地，粘土性質，有機物含量等等影響於遠心力法水分當量之張力值，其數值在有機物含量缺少，單粒構造的土壤中較高。



第三圖　水分張力——水分含量曲線

Fig. 3　Moisture tension —— Moisture Content Curves

第七表　水分當量與田間容水量之水分張力

Table 7　Moisture tension at moisture equivalent and field capacity.

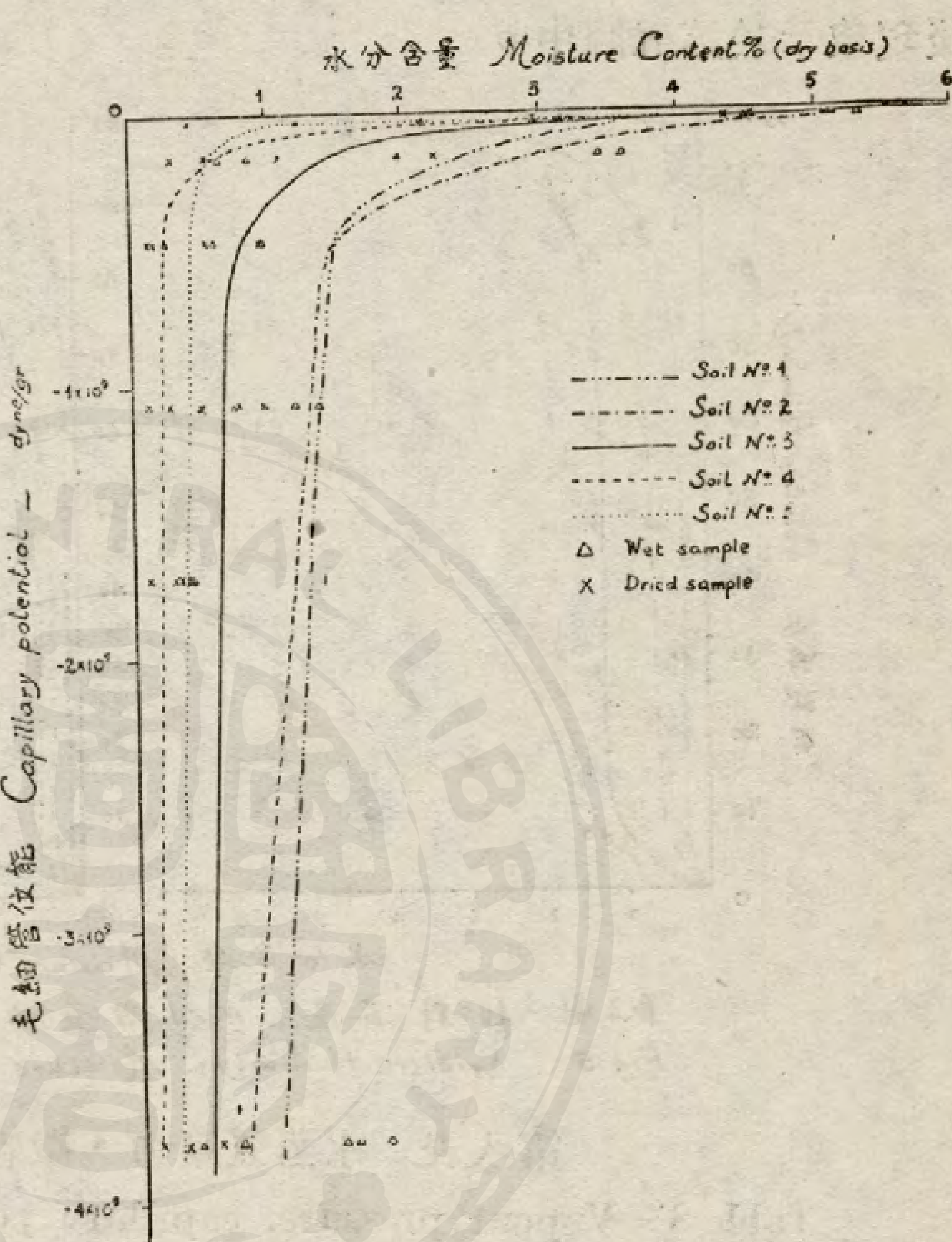
No.	採取地點 Location	水分當量 Moisture equivalent		田間容水量 Field capacity	
		Pw	水分張力 Moisture tension	Pw	水分張力 Moisture tension
		%	Atm.	% *	Atm.
1	臺大農場	16.38	1.18	26.31	0.34
2	臺北農業試驗所農場	24.26	0.57	33.73	0.29
3	屏東糖業試驗所分所農場	30.82	0.47	37.00	0.27
4	屏東崇蘭農場	16.58	0.99	19.87	0.51
5	屏東六塊厝農場	5.17	0.79	13.67	0.20

* 根據第一次試驗　　Results of the 1st experiment.

參閱第三圖便知，各供試土壤的水分張力一含量曲線之位置與形狀至爲明顯，而第六圖中利用氷點降下度法測得低張力部份之曲線形狀與位置，則無本法之明顯，故可知本法卽 Richards 氏法 (18)，適合於土壤低張力水分含量之測定，而能補救氷點降下度測定法之缺陷。

2. 高張力土壤水之含量

高張力土壤水爲凋萎點以上之水分。在本試驗中使用蒸氣壓力調整法而測定供試土壤乾土與濕土（水分含量爲水分當量）在各種水蒸氣壓力與相對濕度下之水分含量。共結果統列於第八表中。表中重複測定數值尙互相接近，而水分含量有隨水蒸氣壓力之減少而遞減之傾向。其微管位能與水分含量之關係乃示於第四圖中。查閱該圖便知圖中各曲線之位置與形狀亦甚爲明瞭，若將此組曲線與第六圖中利用氷點降下法測定之高張力部分一組曲線相較時便知前者位置與形狀較後者明顯多矣。由此可知在土壤水分張力及其水分含量測定中，視張力高低，而採用不同的測定法，以發揮各法之優點爲宜。例如在高張力時宜使用水蒸氣壓調節法，而自低張力至高張力間，則宜採用氷點降下法，但在低張力則使用吸氣法等。Richards 氏等之研究示，在高張力亦可用吸氣法或壓氣法，但就目前本省實驗室設備情形而言，甚難求得固定的高壓或低壓故在其利用上不無困難之處。第三圖中所示，低張力下曲線排列之順序，若自接近 Y 軸（水分張力）者算起，則爲 No. 5, No. 4, No. 1 No. 2, No. 3 但在第四圖中高張力下者，則爲 No. 4, No. 5, No. 3, No. 2, No. 1 可知各土壤的曲線位置與形狀，在低張力與高張力間有頗大的變異，就中其位置與形狀變化較大者爲 No. 4 與 No. 3, No. 3 土壤之有機物含量多，滲透之條件佳良，而 No. 4 者則滲透壓大，故以上性質可能在

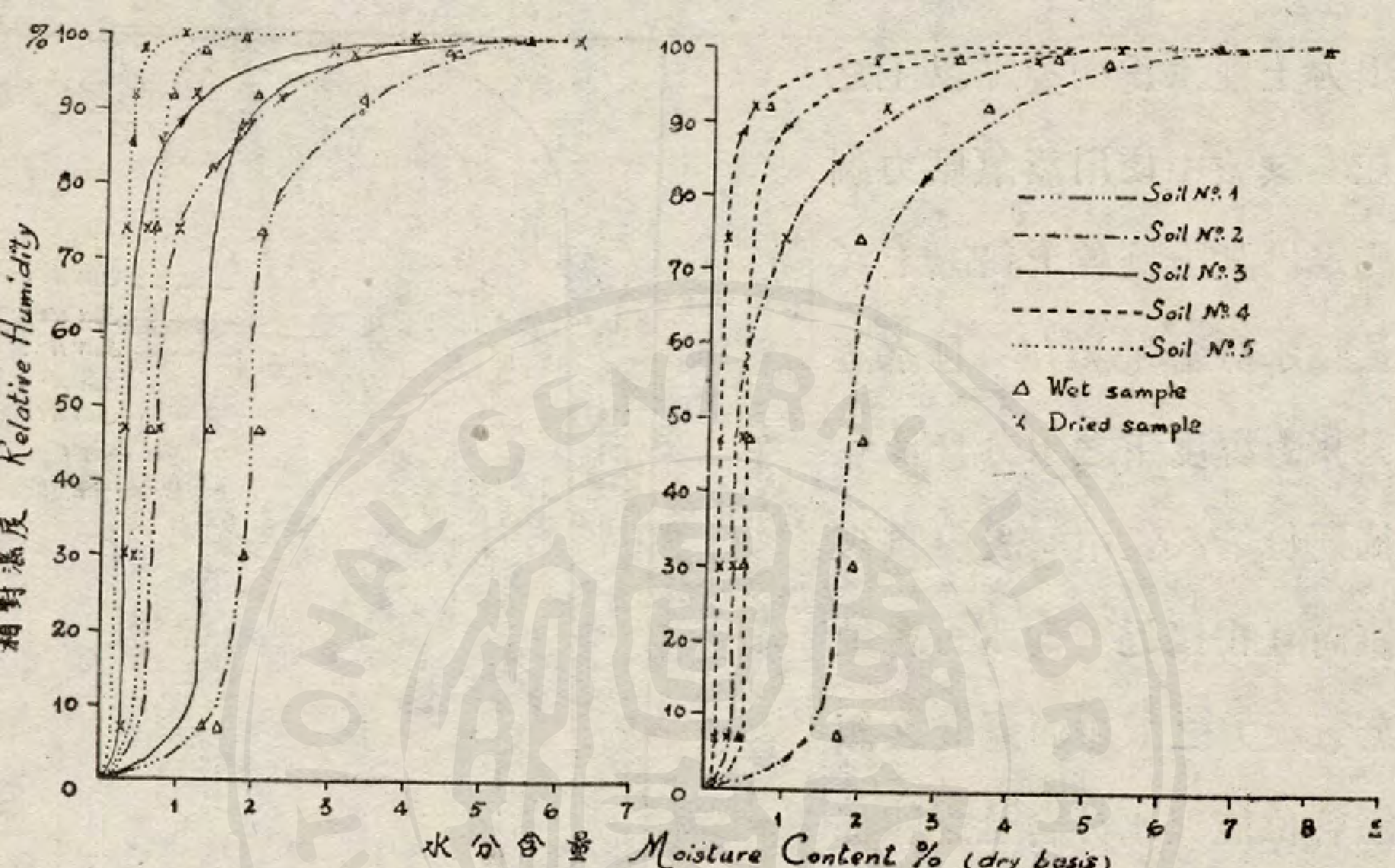


第四圖 毛細管位能—水分含量曲線

Fig. 4 Capillary potential — Moisture Content Curves

低壓力及高張力表現特異的影響。

在高張力下行相對濕度一水分含量曲線之測定結果示，曲線之位置與形狀，依供試土壤爲乾土抑或濕土而不同，因此產生滯後現象 Hysteresis 。各土壤中 No. 1 No. 2 特爲顯著而砂質土壤則微少，茲將各土壤之相對濕度一水分含量曲線的滯後現象示於第五圖中。



第五圖 相對濕度—水分含量曲線
Fig 5 Relative Humidity – Moisture Content Curves

第八表 水蒸氣壓力，微管位能與水分含量

Table 8 Vapour pressure, capillary potential and moisture content.

水蒸氣壓力 Vapour pressure Hg mm	相對濕度 Relative humidity %	微管位能 Capillary potential dyne/gm	No. 1 臺大農場				No. 2 臺北農業試驗所農場				No. 3 糖業試驗所分所農場				No. 4 屛東崇蘭農場				No. 5 屛東六塊厝農場			
			Dried Soil Wetting		Wet Soil Drying		Died Soil Wetting		Wet Soil Drying		Dried Soil Wetting		Wet Soil Drying		Dried Soil Wetting		Wet Soil Drying		Dried Soil Wetting		Wet Soil Drying	
			M	D*	M	D	M	D	M	D	M	D	M	D	M	D	M	D	M	D	M	D
			%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
32.0	100		4.04	0.4	5.59	3.7	5.38	9.2	8.17	0.3	6.20	4.6	9.40	5.1	6.02	0.3	6.64	7.2	1.00	1.0	1.78	0
31.5	98	-0.02×10^9	2.98	18.4	4.54	2.6	4.28	3.9	5.21	4.4	3.18	6.6	4.53	3.0	—	—	3.20	2 1	—	—	—	—
29.0	92	-0.14×10^9	2.25	0.4	3.44	4.6	2.28	1.3	3.61	3.3	1.14	0.8	1.99	6.5	0.57	3.5	0.65	3.0	0.33	6.0	0.88	2.2
23.0	74	-0.46×10^9	0.99	11.1	—	—	0.97	6.1	—	—	0.57	1.7	—	—	0.17	23.5	—	—	0.13	15.3	—	—
15.0	47	-1.06×10^9	0.76	14.4	2.11	2.8	0.50	o	2.15	6.9	—	—	1.40	0.7	0.11	o	0.50	24.0	—	—	0.72	9.7
9.5	30	-1.70×10^9	0.42	14.2	1.90	6.8	0.33	o	1.93	17.6	—	—	—	—	—	—	—	—	—	—	0.72	0
2.3	7	-3.78×10^9	0.57	14.0	1.55	9.0	0.29	27.5	1.78	4.4	0.31	3.2	1.46	6.8	0.11	18.1	0.43	16.2	—	—	0.71	15.4

*M : Mean

D : Percentage of difference between duplicate samples

3. 氷點降下度測定法

供試土壤在各種水分含量之氷點降下度測定結果，以及兩次重複間差異百分率，水分應力，水分張力等列於第九表與第六圖中。

第九表　氷點降下度，水分應力與水分張力

Table 9　Freezing point depression, moisture stress and moisture tension.

No.	採取地點 Location	水分含量 Pw	氷點降下 △T	重複間差異 % of difference between duplicate samples	水分應力 Moisture stress	水分張力 Moisture tension
		%	°C	%	Atm.	Atm.
1	臺大農場	3.15	3.51	1.99	42.38	42.06
		9.17	1.66	2.40	20.01	19.75
		9.24	1.37	2.19	16.52	16.25
		9.73	1.14	0.88	13.74	13.48
		9.93	0.95	6.31	11.45	11.19
		10.61	0.88	5.70	10.61	10.34
		15.26	0.24	8.33	2.89	2.62
		23.01	0.09	11.70	1.08	0.81
2	臺北農業試驗所農場	3.12	3.59	1.67	43.29	42.56
		9.18	1.41	2.83	17.00	16.27
		9.52	1.29	2.33	15.55	14.82
		9.89	1.05	1.90	12.66	11.93
		13.58	0.43	2.30	5.18	4.45
		23.61	0.07	28.5	0.84	0.12
3	屏東糖業試驗所分所農場	1.61	3.39	5.02	40.88	40.19
		7.67	1.59	2.51	19.17	18.48
		8.71	1.39	0.72	16.76	16.07
		8.92	1.28	0.78	15.43	14.74
		9.49	1.19	—	14.35	13.65
		9.58	1.17	—	14.11	13.41
		13.57	0.66	1.52	7.95	7.26
		21.80	0.31	12.9	3.73	3.04
		27.87	0.27	3.77	3.25	2.56
4	屏東崇蘭農場	2.68	3.61	1.10	43.53	38.66
		4.78	1.87	2.68	22.55	17.68
		5.96	1.33	0.75	16.03	11.17
		6.36	1.24	—	14.95	10.08
		8.77	0.80	1.25	9.64	4.77
		10.66	0.49	1.22	5.90	1.04
5	屏東六塊厝農場	0.60	3.65	1.37	44.01	43.11
		2.45	1.61	3.11	19.41	18.51
		2.84	1.38	5.09	16.64	15.74
		2.98	1.13	1.86	13.62	12.72
		3.40	1.10	5.56	13.26	12.36
		4.73	0.70	1.43	8.44	7.53
		8.33	0.26	4.87	3.13	2.33

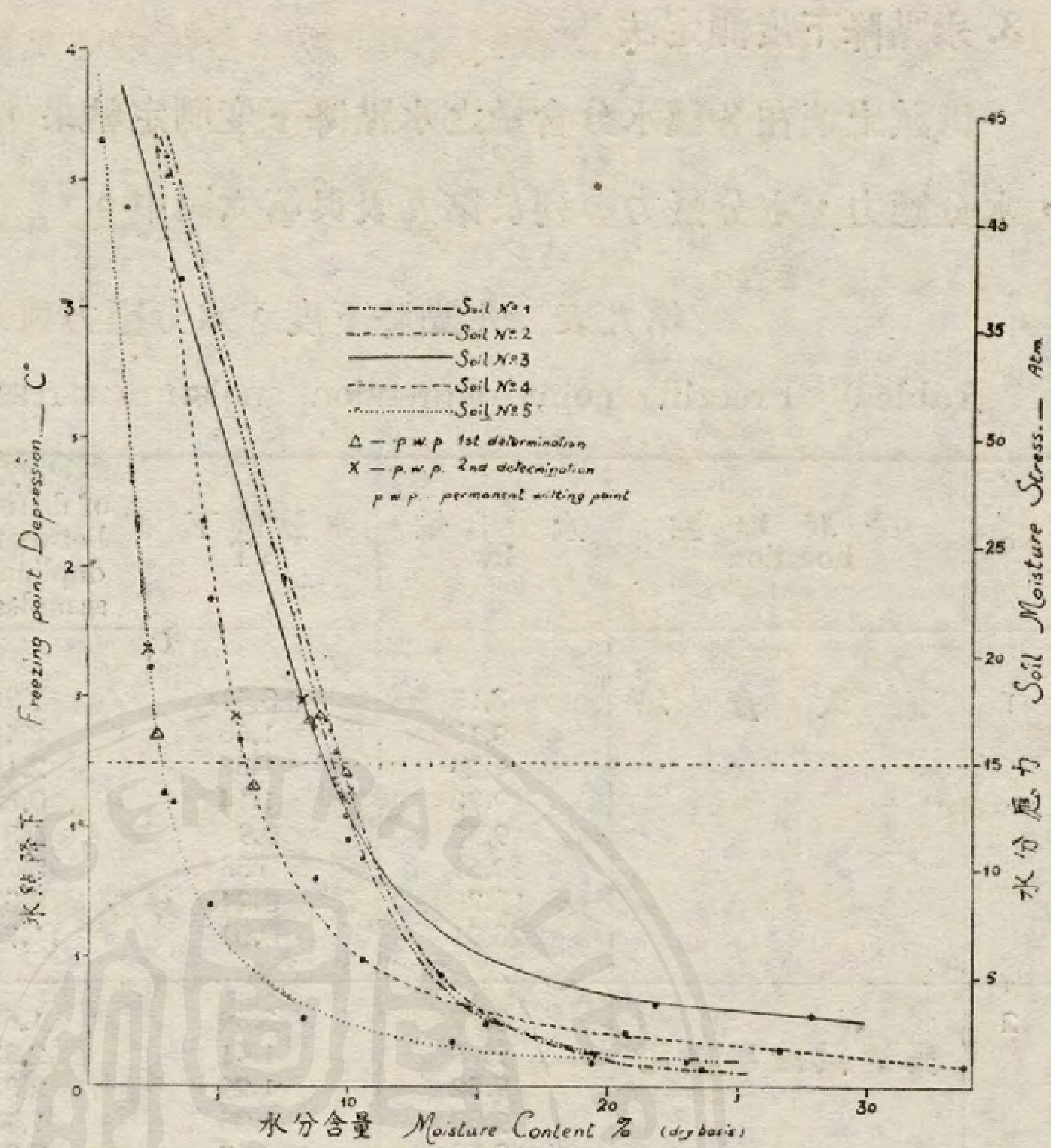
Moisture stress (0°C) $= 12.06 \times \triangle T$ (10)

Moisture tension (0°C) $= 12.06 \times \triangle T -$ osmotic pressure (10)

試驗結果示，土壤水分含量與氷點降下度之關係相當明顯。氷點降下度測定值之重複間差異百分率，在凋萎點附近尚小，但在氷點降下度 0.5°C 附近，或水分張

力在 6 氣壓以下者則大。

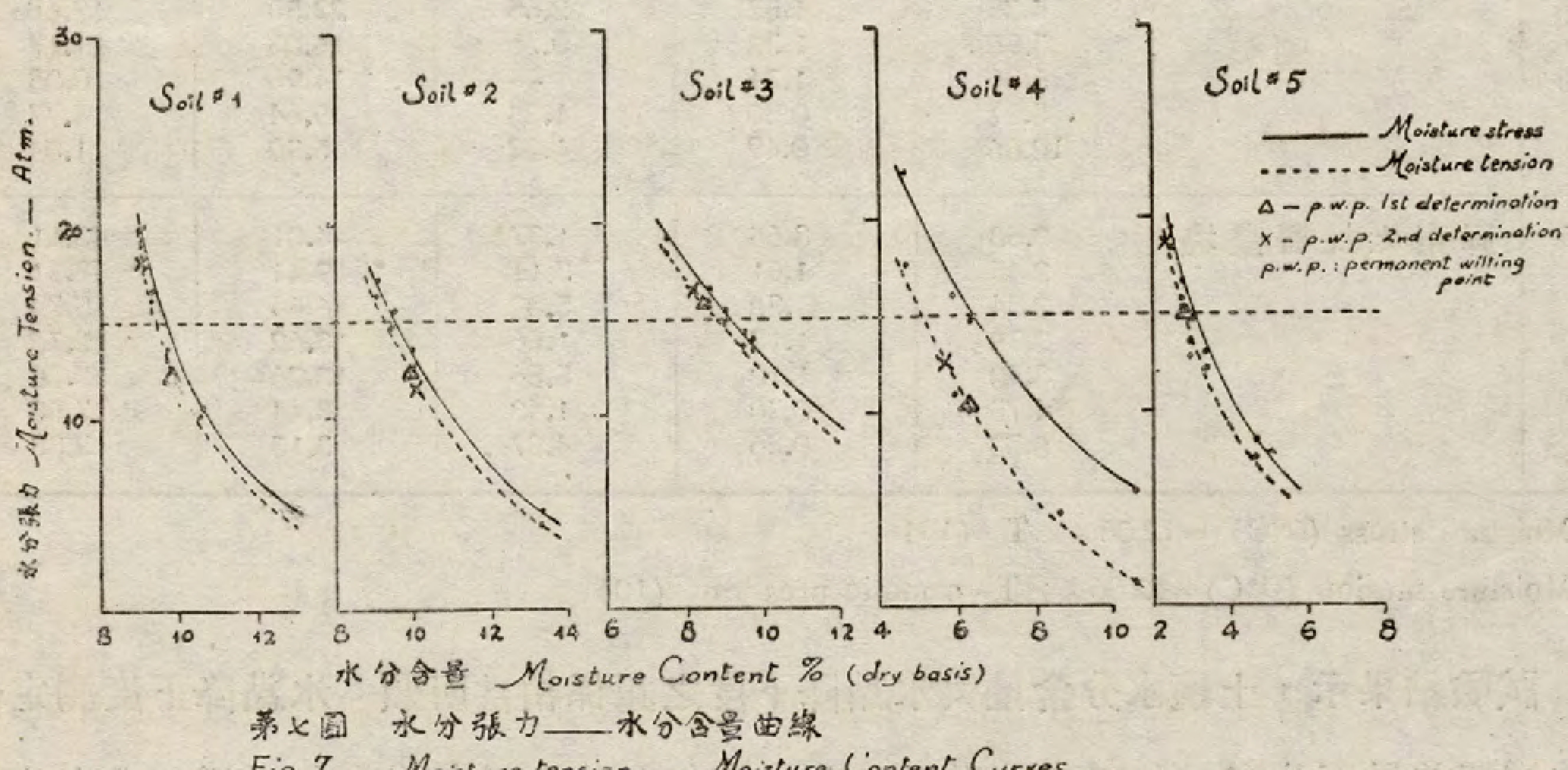
由本試驗可知，土壤水分冰點降下度之測定，在凋萎點附近之高張力尙爲準確。參照第六圖便知，No. 2, 3, 土壤同爲泥沙壤土，但就中 No. 3(糖業試驗所屏東分所農場土壤)之水分含量在低張力下特高，此爲本土壤之優良性能，推其原因似在於有機物含量高，質地細密，而構造優良所致。



第六圖　冰點降下——水分含量曲線

Fig 6　Freezing-point depression — Moisture Curves

供試土壤在15氣壓水分應力及水分張力之含水量與向日葵法所測定永久凋萎點列於第十表與第七圖中。由第十表可知，除 No. 4 崇蘭土壤以外，其他土壤在 15 氣壓水分張力之水分含量與向日葵法之永久凋萎點相近。崇蘭土壤溶液之滲透壓獨高，故其水分張力與水分應力之差異大而15氣壓水分應力較接近於永久凋萎點，在理論上亦然。



第七圖　水分張力——水分含量曲線

Fig. 7　Moisture tension — Moisture Content Curves

第十表　永久凋萎點與15氣壓水分張力，水分應力之水分含量

Table 10 Permanent wilting percentage and moisture content at 15 atmosphere moisture tension and moisture stress.

土壤號碼 No. of Soil	1	2	3	4	5
永久凋萎點 Permanent wilting percentage.	9.35 %	9.99 %	8.33 %	7.46 %	2.55 %
15氣壓水分張力之水分量 Moisture content at 15 Atm. soil moisture tension	9.4	9.3	8.8	5.2	2.9
15氣壓水分應力之水分量 Moisture content at 15 Atm. soil moisture stress	9.6	9.4	9.2	6.4	3.2

三、供試土壤中有效水分之範圍。

土壤的有效水分量爲永久凋萎點與田間容水量兩者間之水分含量，故一種土壤有效水分量之可靠性乃與其永久凋萎點及田間容水量測定值之準確性有關。

由本試驗已知，向日葵法測定永久凋萎點之管制條件較周密，故在壤土類可能獲得可靠之結果(砂土類測定值之變異係數在15—13%)，此外倘採用冰點降下法，先尋求土壤水分含量與水分張力之關係，再由永久凋萎點之水分應力(大約15氣壓)，求出永久凋萎點，則在測定法上更爲準確而簡捷。

田間容水量爲田間測定值；其測定值除受測定法本身之誤差影響外，兼受自然環境之影響，故若將同一型土壤在甲地點某季節之田間容水量，與在乙地點他季節之田間容水量相較，兩者間差異相當的廣大。

水分當量之測定法則有嚴密規定，故測定值之可靠性大，此者曾經本文中試驗報告之。倘以土壤物質 Soil material 爲主體，而檢討其有效水分之性能，則雖土壤在水分當量時之水分張力略大於田間容水量，致減少有效水分範圍，但在準確性上言，却勝於田間容水量。由于永久凋萎點與水分當量測定值之可靠，故 Lyon, Buckman (16)， Veihmyer (25) 與 MacGillivray (17) 諸氏指定永久凋萎點與水分當量間水分量爲植物有效水分範圍 optimum moisture zone 而稱兩者之比率爲有效比率 availability ratio ，藉以比較各種土壤之有效水分量。

根據作者之推測，各氏所提之土壤有效水分量，植物有效水分範圍，有效比率等各有其意義與用處，唯當應用之前認清其用意似爲重要。爰將供試土壤之有效水分量，有效水分範圍，有效比率等示之於第十一表中。在表中土壤 No. 2 與 No. 4

間之有效水分量差異頗大，但兩者之有效比率則極近，又No.1土壤之有效水分量大於No. 5，但前者之有效比率却小於後者。故可知土壤有效水分係數之間尙缺少聯關。

土壤有效水分範圍之決定乃根據水分張力爲妥。供試土壤水分張力與含量之關係已列舉於第三、四、六圖及第六、十表中外，特將各種水分張力下之水分含量與其在容水量 Water holding capacity Hilgard 法中之百分率示於第十二表中。

第十一表　有效水分量與有效比率

Table 11 Available moisture content and availability ratio

No.	採取地點 Location	有效水分量 田間容水量—永久凋萎點 Available moisture content Field capacity-permanent wilting percentage	有效水分比率 水分當量/永久凋萎點 Availability ratio	在100cm 土層中 有效水分量 Readily available water per 100cm. depth
		%		* cm.
1	臺大農場	16.58	1.75	9.6
2	臺北 農業試驗所農場	23.54	2.42	18.5
3	屏東 糖業試驗所分所農場	31.60	3.69	27.4
4	屏東崇蘭農場	13.51	2.22	15.7
5	屏東六塊厝農場	10.91	2.02	4.4

* 以水分當量與永久凋萎點間水分量作爲有效水分範圍而計算者 In this calculation, the readily available water is considered to be that included in the range from moisture equivalent down to the permanent-wilting percentage.

第十二表　水分張力與水分含量

Table 12 Moisture tension and moisture content

採樣地點 Location	臺北臺大農場			臺北 農業試驗所農場			屏東糖業試驗所 分所農場			屏東崇蘭農場			屏東六塊厝農場		
No.	1			2			3			4			5		
水分含量 Moisture content / 水分張力 Moisture tension	水分範圍 moisture range %	Pw %	%	水分範圍 moisture range %	Pw %	%	水分範圍 moisture range %	Pw %	%	水分範圍 moisture range %	Pw %	%	水分範圍 moisture range %	Pw %	%
>15 Atm.	<9.40	9.4	27.5	<9.30	9.3	26.8	<8.80	8.8	21.6	<5.20	5.2	17.0	<2.90	2.9	15.3
15—1.01 Atm.	16.99—9.40	7.6	22.2	21.39—9.30	12.1	34.9	26.19—8.80	17.4	42.6	16.59—5.20	11.4	37.4	4.69—2.90	1.8	9.4
1.00—0.33 Atm.	28.09—17.00	11.1	32.5	30.19—21.40	8.8	25.3	33.89—26.20	7.7	18.9	25.19—16.60	8.6	28.2	8.49—4.70	3.8	20.0
<0,33 Atm.	34.20—28.10	6.1	17.8	34.70—30.20	4.5	13.0	40.80—33.90	6.9	16.9	30.50—25.20	5.3	17.4	19.00—8.50	10.5	55.3
計 Total		34.2	100.0		34.7	100.0		40.8	100.0		30.5	100.0		19.0	100.0

摘　　要

1. 本試驗中使用五種土壤行諸水分常數（如永久凋萎點，水分當量，田間容水量，正常容水量等）之重複測定。其結果示，永久凋萎點與水分當量之測定，倘按照規定處理，則可獲得可靠之測定值，唯在永久凋萎點測定中，土壤溶液滲透壓大的土壤示較大的變異係數。田間容水量爲田間測定值，受環境因素之影響甚大，故在多次測定中，似難獲得一致之數值。但田間容水量之應用價值大，因之在測定中，須就測定環境，條件等詳爲記載，以備查考爲妥。正常容水量重複測定值之準確度大於田間容水量，但正常容水量測定法尙缺少周密規定，且其測定時間甚長，不無缺陷，故在實用之前似尙須加以討究。

2. 本試驗中曾測定供試土壤水分張力－含量曲線或水分性能曲線 Soil moisture characteristics curves，蓋由該曲線之形狀與位置，可知土壤供給水分與植物利用水分之效率。土壤水分在各張力下之水分含量則用：－1. 水蒸氣壓調節法，2 Schofield 氏氷點降下度測定法及，3 吸氣法等分別測定。試驗結果示，Schofield 氏氷點降下度測定法，宜用於水分張力在40氣壓至 6 氣壓之範圍，並適合於永久凋萎點之測定，而水蒸氣壓調節法與吸氣法則分別使用於高張力與低張力水分含量之測定爲宜。三法在重複測定中，均得可靠之測定值。

3. 若干土壤的水分性能曲線之位置與形狀，自高張力以至低張力間，與其他土壤比較時有較大之變異，究其原因，似由于該土壤之若干性質，在不同張力下有特殊表現所致。由本試驗結果可舉出者爲質地，有機物含量，及滲透壓等。

4. 測定結果示，供試土壤永久凋萎點之水分張力約爲 15氣壓，水分當量約爲 0.5—1.1氣壓(使濕土乾燥時)，田間容水量爲 0.2－0.5氣壓。就中水分當量之水分張力較文獻中所示者爲高，尙須行多數土壤之測定，以求土壤性質與變異限界之關係似爲重要。

5. 由土壤水分常數之測定值求出有效水分量 available moisture，有效水分範圍 optimum moisture zone，及有效比率 availability ratio 等而均列於本文中，檢討本試驗結果後，作者認爲選取有效水分範圍(水分當量與永久凋萎點間之水分量)爲比較值，以比較各土壤保持之有效水分量似較爲妥善。因水分當量與永久凋萎

點之測定均為準確可靠。有效水分量或植物可利用性水分量（田間容水量與永久凋萎點間之水分），則由于田間容水量測定值間之差異大，而影響其準確性，故在處理上需要愼重。而有效水分量之應用得當與否，似乎有賴于當地環境條件之詳細調查。土壤水分性能曲線乃顯明的表示土壤有效水分範圍，含量與性能故其利用自優越於各種有效水分係數之應用。

6. 在本文中，就土壤水分性能曲線與各土壤水分常數之意義與測定方法，亦曾加以討究。

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English Summary

A Study on the Conventional Moisture Constants and the Moisture Characteristics Curves of Soils

by

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1. By using the sunflower method, the centrifugal method, Brown's method and Shaw's method, determination of the permanent wilting point, the moisture equivalent, the field capacity and the normal moisture capacity of the five different types of soil were made.

It was observed that both the permanent wilting percentage and the moisture equivalent gave a consistant and reliable result, when a well standardized procedure had been used in the measurement. However, if we want to make the result more applicable, it seems necessary to obtain a representative soil sample and to make a general survey on the field conditions.

Field capacity is usually determined in the field. Its value is, therefore, not only affected by the method used in the measurement, but also influenced by the environmental conditions, such as the height of water table, humidity, growth of crop, etc. It was shown in this experiment that the dissimilarities of the field conditions in respect to time and location of measurement had induced a wide range of field capacity value. Nevertheless, the study of the field capacity has had a wide use; it is, therefore, suggestive to have a detailed account of the conditions, which may be used as a reference. The ratio of field capacity to moisture equivalent was found 1.2-2.6.

It was indicated in this experiment that the determination of normal moisture capacity also gave a reproducible result. The ratio of normal moisture capacity to moisture equivalent was 0.6-1.1. The determination of normal moisture capacity takes a long time. It requires 123 days and, further-more, a detailed procedure of measurement, such as, the compaction of soil sample, the temperature during storage, the amount of water addition etc., all of which have not yet been prescribed. A particular study of this method seems necessary.

2. It is known that the availability of soil moisture to plant is determined by two factors: the ability of a soil to supply water to a plant root system and the readiness with which the soil conducts water. The former factor can be indicated by the moisture characteristics curves or moisture tension-moisture content curves while the latter one, by capillary conductivity or unsaturated permeability.

In this paper, the moisture characteristics curves and the related data of the five types of soil are presented. The moisture release data were secured by using the following methods, namely: 1. the method of controlling vapour pressure, 2. the freezing point method of Schofield and Da Costa, 3. the suction method. These methods may be used in the least equipped soil and fertilizer laboratories, where a supply of constant high or low pressure is lacking. It was found in the multiple measurements by using these methods a consistant result was obtained.

The freezing point method may be applicable within the range from six to forty atmospheres. It is also applicable in measuring the moisture in the plant wilting range. The suction method is fit in the low tension range; while the method of controlling vapour pressure, in the high tension range.

3. The moisture characteristics curves obtained in this investigation show no segment of rapidly changing slopes; however, some soils have changes more significant than others especially in respect to the shape and position of the curve, when the tension has increased from a low range to a high one.

It was observed in this experiment, that some soil properties: texture, organic matter content, permeability, osmotic pressure of soil solution etc. are the prominent factors in determining the shape and the position of the moisture characteristics curves.

4. The agreement between the two values, the permanent wilting percentage and 15 atmosphere percentage for each sample, is exceptionally close. The soil moisture tension at the moisture equivalent was found in the range of 0.5-1.1 atmosphere, when the wetted sample was dried while soils with field capacity were at tensions varying from 0.2-0.5 atmosphere.

It is known that the soil moisture tension at the moisture equivalent is approximately 0.3 atmosphere. The results obtained in this experiment gave higher figures. It is also known that fine texture and high organic matter centent lead to high moisture equivalent values. In this experiment, it was observed that at themoisture eguivalent, the coarse soils with low organic ma ttergave high moisture tension values

5. The readily available moisture, the optimum moisture zone and the availability ratio of each soil were calculated from the moisture constants measured in this experiment. It is evident that the measurement of permanent wilting percentage and moisture equivalent are accurate and reproducible, while the determination of field capacity gave a wide range of value; therefore a precaution may be taken in using this value. The optimum moisture zone which is obtained by subtracting the wilting percentage from moisture equivalent indicates a more comparable and reliable figure than the available moisture does. The latter is obtained by subtracting wilting percentage from the field capacity. As mentioned above, a detailed description of the experimental conditions during the measurement of field capacity may increase its use and value. It was observed in this

experiment that a wide discrepancy exists between the available moisture content and availability ratio when these are used as indexes to indicate available moisture range (table 11).

6. A general review on the moisture characteristics curve, the definition of the conventional moisture constants and their methods of determination was made in this investigation.

關於木耳多糖類之研究
第一報：關於熱水可溶性多糖類之基礎的研究

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I 緒　　言

木耳（Auricularia auricula-Judae（Linn.), Schroeter）屬於擔子菌類，第一類，多胞子擔子菌，第二亞類，木耳科。寄生於種種濶葉樹類之枯木或生活力衰退的生木上，四季都能生育。

木耳在水中加溫時全體膨潤而變爲洋菜質，其色如飴稍透明，乾燥就變爲堅質的薄葉，且顏色加深。一般風乾木耳的表面呈赤褐色，裏面灰色。形態爲圓形的薄片，徑 1~3cm，但常常多數小片融合而呈不整形。胞子白色，曲玉狀，其大小略爲16—20×6—9μ。

已往關於木耳之研究只有 Ten-Han Tang[1] 氏之關於一般組成及營養價的報告及井上氏[2] 之關於分解木耳 Chitin 質之腸內細菌出現之頻度而做的營養學的考察而已，而如關於木耳多糖類之研究則未曾聞有之。因此著者等計劃木耳水溶性多糖類之研究。

II 實　　驗

1）預備考察：

以熱水抽出木耳細片時，可得到褐色粘稠的抽出液，這抽出液在高溫下亦不能通過濾紙，擬是一種膠質溶液，又這抽出液不能還元 Fehling 氏液，但對此抽出液加酒精，或酒精及 Fehling 氏液，或苛性鈉與酒精時，都能得到沈澱，而此等沈澱如加水分解，則有顯著的還元力，由此等性質推定以熱水抽出的膠質物爲多糖類。

2）供試料之製備及一般分析：

供試木耳係于1947年 8 月在臺北市內販賣的臺灣產品，將此木耳水洗三次而除去土砂等夾雜物後晒陽光而乾燥半天後，以 40°~50°c 的熱風乾燥機乾燥一晝夜。乾燥木耳粉碎後，通過 3mm 篩而供於試驗用。

供試料之一般分析結果如下

	水分	灰分	粗蛋白	粗脂肪	粗纖維	Pentosan	可溶性無氮物
風乾物 %	11.46	4.72	5.87	1.34	16.87	6.69	53.04
無水物 %		5.33	6.62	1.51	19.05	7.55	59.94

3) 多糖類之抽出：

放 35gm 木耳於 1L 水中，在沸騰水浴中抽出十小時，以濾布及紙漿層減壓濾過，就得到稍帶褐色的抽出液。加90% alcohol 或 Fehling's solution-alcohol 或 NaOH-alcohol 於抽出液就能使多糖類沈澱。單用 alcohol 時就需抽出液之 3~4 倍量之90% alcohol 如加用 Fehlings' solution 則需與抽出液同量之90% alcohol 及其半量之 Fehling's soln. 如加用苛性鈉，則需等量90% alcohol 及半量35% NaOH 溶液。依後兩者沈澱法則 alcohol 之消費量少，且容易沈澱，但如用 Fehling's solution 就多糖類中可能含銅而對酸酵試驗發生阻害作用，故專採用 NaOH-alcohol 沈澱法。

將沈澱下來的 gum 狀沈澱以2% alcoholic HCl 液處理數次而除去 Na ion 如此精製則初爲黑褐色的沈澱漸變爲灰白色，繼以 80~90% alcohol 洗去 HCl 而在眞空 Desiccafor 中乾燥就得到脆弱的 gum 狀多糖類，由 300gm 的風乾物多糖類的收量約爲 20gm。

4) 多糖類之化學的性質

A) 水分：6.83%

B) 灰分：2.73%

C) Uronic acid：

Uronic acid 使用 Burkhart, Bauer and Link[2] 之微量定量法之改良裝置而定量。即將試料與以 NaCl 飽和的12% HCl 煮沸，而將所發生的 CO_2-gas 以 $Ba(OH)_2$ 溶液吸收，以1/50 N-H_2SO_4 滴定殘存 $Ba(OH)_2$ 的量（以 Phenolphthalein 爲指示

藥）而計算 CO_2 的量。對 CO_2- gas 的量乘 4 而算出 Uronic acid 無水物之量。其結果如下：

試　　料 mg	CO_2-gas mg	Uronic acid 無水物 gm	Uronic acid* 無 水 物 %
173.0	8.67	34.66	22.15
115.0	5.52	22.07	21.22

*爲無水無灰物%
以下都用此表示法。

平均21.69%

D）Pentose 及 methyl pentose 之定量：

以常法測定的結果如下：

	試料 mg	Furfurol-phloro-glucide gm	Methylfurfurol-Phloroglucide gm	Pentose gm	Pentose %	Methyl Pentose gm	Methyl Pentose %
No. 1	1.6835	0.1610	0.0085	0.1831	12.01	0.0226	1.48
No. 2	1.2588	0.1188	0.0090	0.1360	11.93	0.0230	2.10

平均11.97　　平均1.79

然而 Uronic acid 亦在定量 Pentose 之條件下能生成 Furfurol 故所得到的 Phloroglucide 爲由 Pentose 及 Uronic acid 所生成的 Furfurol 而形成的。因此以 Ehrlich and Schubert[4] 氏使用於 Galacturonic acid 之 Factor 2.67 而由所定量之 Phloroglucide 之量算出 Uronic acid 無水物之相當量。

	Uronic acid 無水物 gm	Uronic acid 無水物 %
No. 1	0.4299	28.23
No. 2	0.3172	27.86

平均28.05

即 Uronic acid 之量由 Furfurol phloroglucide 之量算出者爲 28.05%，而由 CO_2-gas 之量算出者爲21.69%，而其相差應由於 Pentose 之存在而發生。由此逆算 Pentose 之存在量則有3.13%。

5）加水分解：

A〕加水分解度之測定：

0.3gm 之多糖類以 0.1, 0.2, 0.3, 0.4, 0.5, 及 1% 之各種濃度稀硫酸 50 c.c. 在 Autoclave 中加壓加水分解，（加熱條件爲費20分鐘將 Autoclave 之溫度由 100°C 提

高到 150°C 而保持於 150°C 30分鐘）。中和後除去 Humin 物質而稀釋為 200c.c. 取其 20c. c. 以 Bertrand 法測定其還元糖而以 glucose 計算之。

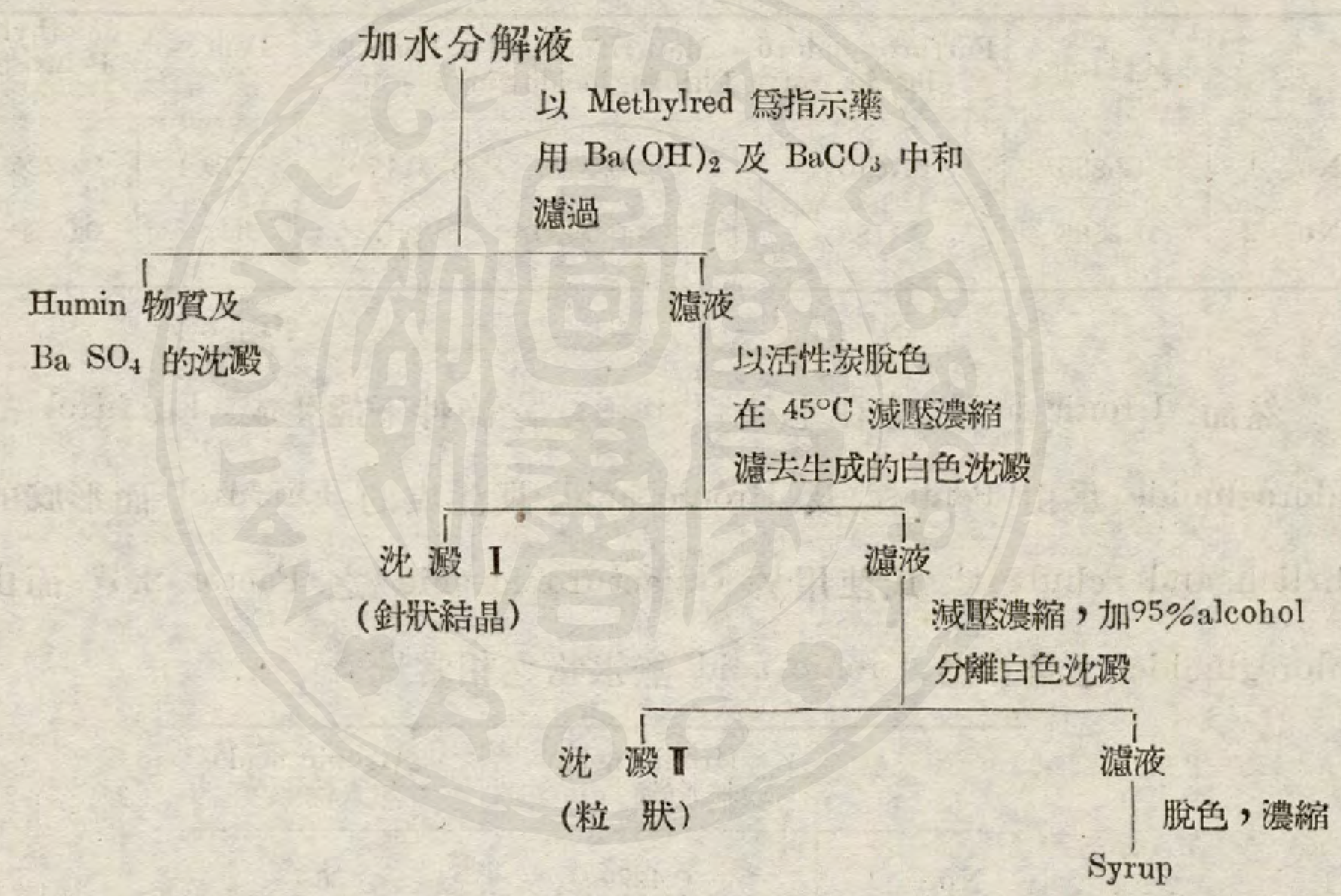
其分解度以無水無灰物百分比表示則如下：

硫　　酸　%	0.1	0.2	0.3	0.4	0.5	1
分　解　度　%	70.4	83.5	91.5	92.5	95.6	94.7

卽 H_2SO_4 0.5% 時加水分解度最大。

B] Syrup 之調製：

以 0.5% H_2SO_4 加壓加水分解之糖類經過如下處理而成為 Syrup：



a）沈澱 I：在 Crucible 中强熱也不黑化，判明為無機物。

b）沈澱 II：量甚少，在濃 alcohol 中呈白色粒狀，但在濾紙上減壓濾過時急激地吸濕溶化而變為橙色。味苦，有還元力。擬是 Uronic acid 但其量大少而不便確認，當待於後日之研究。

C] Syrup 之試驗：

Surup 稍帶甜味，脫色後為無色，但在 H_2SO_4-desicator 中減壓乾燥，就慢慢增加褐色，而且增加粘稠性。

a）醱酵試驗

i）定性試驗

稀釋 Syrup 爲 29.2mg glucose/0.5 c. c. 而用此糖液以 micro method (Lindner 氏[5]) 試之。酵母用更新後24小時之 Sacch. cereviceae 。作五個平行試驗結果都是陽性，故確認 Zymohexose 之存在。

ii) 定量試驗

因定性試驗爲陽性故，製備醱酵液而做可醱酵糖之定量。卽添加 Henneberg[6] 氏之 Buffer solution 而保持醱酵液之 pH 爲 5.4~5.6。使用更新過的 Sacch. ceretiviceae。等到CO_2-gas 之發生停止後（約需七天），測定醱酵液之殘存糖量而算出糖消費率如下：

（但糖量是以醱酵前後之糖液各 2c. c. 所呈之還元力以 glucose mg 所表示者）

糖量 / No.	醱酵前 mg	醱酵後 mg
1	31.30	5.15
2	31.30	5.10
	平均 31.30	5.13

$$糖消費率=\frac{31.30-5.13}{31.30}\times 100=83.5\%$$

b) 對 Syrup 之稀釋液施行 Ketose[7] 之種種反應如下；

Pinoff's Reaction (—)

Seliwanoff's Reaction (—)

Ihl Pechmann's Reaction (—)

Pieraert's Reaction (—)

由此結果推定無 Ketose 之存在。

c) Syrup 之硝酸氧化

以比重1.15的硝酸，照常法氧化 Syrup，但並無 mucic acid 之生成，故推定無 d- 及 l-galactose 及 d-galacturonic acid 之存在。

d) Uronic acid 之定性

將醱酵後的殘留粘液減壓濃縮而除去無機物後，用此 Syrup 作 Naphthoresorcin Reaction[9] 時，有顯著的反應。因此與前做的定量試驗結果比較考察，就可能斷定 Uronic acid 之確實存在。但究竟其爲何種 Uronic acid 則尚未能決定。

e) Pentose 及 methyl pentose 之定性[10,11]

用釀酵後的 Syrup 做 pentose 及 methyl pentose 之定性，結果如下：

i) Pentose 之定性

Wheeler and Tollens' phloroglucin Reacton	(—)?
Schiff's aniline acetate Reaction	(++)
Van der Haar's improved orcin Reaction	?
Rosenthaler's Resorcin Reaction	Trace
Bial's orcin Reaction	(—)

ii) methyl Pentose 之定性

Rosenthaler's Resorcin Reaction	(—)
Widtsoe and Tollens' Reaction	Trace
Oshima & Tollens' Reactions	(—)
Maquene's Reaction	(—)

綜合以上結果，Pentose 之定性如以特別銳敏的反應（如 Schiff's Reaction）就呈陽性，而其他反應則示陰或 Trace。然在定量試驗認有約 3% 之 Pentose 之存在，且供試液是不可醱酵糖液故可能推定少量 Pentose 之存在。而在本試驗有陰性者可能係被他種糖類阻害的，methyl pentose 也如此推想而推定其少量之存在。

f) Phenylhydrazine Der'vatives

i) Phenylhydrazone;

對糖液加 phenylhydrazine 之醋酸溶液(phenylhydrazine 壹部對25% 醋酸兩部)不久就有沈澱之生成。放置一夜後，濾取而先用水，再用80% alcohol 再結晶，再結晶三次的結晶用微量融點測定裝置測定融點，而與以 Takeda Chemicals (Japan) 的 mannose 製備的 phenylhydrazone 測定結果比較如下：

	融　點	性　質
由 Syrup 製備的 phenylhydrazone	186~188°C	無色，菱形
由 Takeda 製 mannose 製備的 phenylhydrazone	188~190°C	無色，菱形
Tollens and Gans [2]	188°	
Reiss[3]	185~186°C	

Fischer and Hirschberger[3]　　195~200°C

ii) Phenylosazone:

對 Syrup 加過剩量之 phenylhydrazine 醋酸溶液，而在水浴上加熱一個半鐘，將所生成的黃色針狀結晶先由 50~60% alcohol，再由水再結晶，而測定融點，其結果與由 Takeda Chemicals 的 mannose 製備的 Osazone 的測定結果比較如下：

	融　點	性　質
由 Syrup 製備的 phenylosazone	201~202°C	黃色，針狀
由 Takeda 製的 mannose 製備的 Osazone	202~203°C	黃色，針狀

iii) Phenylhydrazon 之定量

由上述結果知道有 mannose 之存在，故依 Bourquelot, Herrisey 氏法[4] 定量 mannose. 另外用 Bertrand 法測定供試中之還元糖之量（以 glucose 計算之）而由此兩個結果計算糖類中之 mannose 含有率如下：

由糖溶液 15 c.c. 所得到的 mannose phenylhydrazone gm	No. 1	0.4490
	No. 2	0.4455
	平均	0.4473

然而由 Igm. mannose 可得到 1.490[4]gm 之 mannose-phenylhydrazone, 故 0.4473 gm 之 mannose-phenylhydrazone 相當於 0.3000gm 的 mannose. 又原糖液之還元糖量爲0.452gm glucose/15c.c. 故 mannose 含有率爲

$$\frac{0.300}{0.452} \times 100 = 66.4\%$$

因此知道糖類之過半爲 mannose.

Ⅲ 討　　論

著者等雖由定量定性結果推定有少量的 Pentose 及 Methylpentose 之存在，但如謂其爲此多糖類之構成基體之單糖，則未免言之過早，因供試驗的材料擬是不甚純粹的。

又定量 Zymohexose 之結果知該多糖類中含有83.5%的 Zymohexose, 而 mannose 之定量結果知有66.4%之 mannose。此兩者之差有18%以上，即顯然的有 mannose

以外之 Zymohexose 之存在。又著者等由定性試驗結果知道無 Ketose 及 Galactose 之存在故推想該未明 Zymohexose 為 Glucose, 但尚無確實證據可供證明。

以上所做的試驗結果只能明瞭木耳熱水可溶性粗多糖類的全貌，而其更定量的研究則要待於將來的努力。

Ⅳ 概　　要

研究木耳 Auricularia auricula-Judae (Linn.) Schroeter. 之熱水可溶性多糖類的結果如下：

1) 以熱水抽出木耳，而用 NaOH-alcohol 使多糖類沈澱，用 2 % alcoholic HCl-Solution 精製：由300gm 供試料得到灰白色多糖類約20gm.

2) 精製的多糖類，有水分6.83%，灰分2.73%，最大加水分解度95.6%，就其加水分解液檢索單糖類結果，以 Phenylhydrazone 確認 mannose 之存在，但不能確認 Ketose 及 galactose. 定量結果 mannose. 66.37% Uronic acid 21.69%，且推定少量之 Pentose 及 methyl pentose 之存在。

3) 由上述結果推定該多糖類為一種複合 mannan.

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English summary.

Muar—Auricularia auricula-Judae (Linn.) Schroeter—is widely distributed in East Asia and is very commonly used as food. For the lack of its chemical studies, the authors attempted to undertake its study especially on its carbohydrate constituents.

The sample was extracted with hot water and then, the crude polysaccharide was precipitated by NaOH and alcohol. The yield of the crude polysaccharide was about 20 gms. from 300 gms. of the sample. The polysaccharide obtained was pale white colored gummy substance.

The polysaccharide was purified, but it still contains 6.83% moisture and 2.73% ash. The maximum degree of hydrolysis is 95.6%. On the qualitative determination, mannose was identified as its phenylhydrazone and osazone. The test for ketose and mucic acid test were negative. And by the results of quantitative determination of zymohexoses (83.5%) and mannose (66.4%), the authors supposed the existence of glucose, but the positive proof is still not obtained.

By both quantitative and qualitative tests, the authors supposed the existence of small amounts of pentose and methylpentose in the hydrolysate, but it is still doubtfull that both sugars are the building stones of the chief water soluble carbohydrate of Muar.

The authors also indicated the existence of uronic acid, but the more quantitative determination should be subjected to the further researches.

11) Ibid. to 72 S. 48—57.

12) Tollens u. Gans: Ber. 21, 2150 (1888)

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The polysaccharide was purified, but it still contains 8.83% moisture and 2.73% ash. The maximum degree of hydrolysis is 88.5%. On the qualitative determination, mannose was identified as its phenylhydrazone and osazone. The test for ketose and mucic acid test was negative, but by the results of quantitative determination of synthohexoses (8.33%) and mannose (60.4%), the authors supposed the existence of glucose, but the positive proof is still not obtained.

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植物病蟲害學系

A Preliminary Study With Stored Rice Insect Pests and Their Control in Taiwan

(Contribution No. 5, Entomological Laboratory)

Ching-Sing Li

I. Introduction

Rice is the most important agricultural product in Taiwan. The annual yield of the crop is approximately 1,4000,000 tons in 1950 and the annual losses caused by insect pests were estimated more than 5 percent of the total crop value.

The climatic conditions of Taiwan are highly favorable for the development of insects. The warm season is rather long and the winter in not severe enough to interfere with the insect activity.

The purposes of this study are to make a survey of the present statas of the stored rice insect pests in Taiwan and to study the toxicity of three kinds of insecticides upon the rice weevil, Sitophilus oryzae Linn. and the red flour beetle, Tribolium ferrugineum Fab.

II. The Present Status of the Stored Rice Insect Pasts

A general survey of the insect pests of stored rice was carried out at the middle of December, 1949 to the end of march, 1950. Granaries and mills of four districts namely, Taipei, Taichung, Tainan and Kaohsiung were generally examined. Data concerning the identified species of insect pests and degrees of infestation were listed in Table 1.

Table 1. ······Degrees of Infestation of Stored Rice Insect Pests on Taiwan Granaries and Mills.

Species of Insect Pests	Infested Rice	Degrees of tInfestation	Locality
Black fungus beetle (Alphitobius diaperinus Fab.)	Paddy rice Milled rice	++	Taipei, Tainan, Kaohsiung, Taichung
Small-eyed flour beetle(Caenocrse ratzeburgi Wissm.)	Milled rice	++	Taipei, Taichung
Corn sap beetle (Carpophilus dimidiatus Fab.)	Milled rice	+	Taipel
Small rice weevil (Calandra sasakii Takahashi)	〃	+	〃
Flat grain beetle (Laemophloeus minutus Oliv.)	Paddy rice Milled rice	+	Taipei, Taichung, Tainan, Kaohsiung
Saw-toothed grain beetle Oryzaephilus surinamensisL.)	〃	+	Taipei, Tainan, Kaohsiung
Lesser grain borer (Rhizopertha dominica Fab.)	〃	+++	Taipei, Kaohsiung, Tainan, Taichuug
Rice weevil (Sitophilus oryzae Linne)	〃	+++	〃
Angoumois grain moth (Sitotroga cerealella Oliv.)	〃	++	Taipei, Kaohsiung
Cadelle (Tenebrioides mauritanicus Linne)	〃	++	Taipei, Tainan, Kaohsiung

Confused flour beetle (Tribolinm confusum Duval)	Milled rice	+	Taichung
Red flour beetle(Tribolinm ferrugineum Fab.)	Paddy rice Milled rice	+++	Taipei, Taichung, Tainan, Kaohsiung

Among the above-named insect pests three species are of more predominant, i. e. ……Sitophilus oryzae Linn., Tribolium ferrugineum Fab. and Rhizopertha dominica Fab. to both paddy and milled rices. The damage caused by any one of the above named three species to milled rice was seriously infested in the storage within 4-6 months. Almost all the present granaries and mills are in poor conditions. They are not enough to permit successful mass fumigation with fumigants. They are arranged in such a confused way that it is difficult to separate the infested and the uninfested one. All these situations provide opportunity for the insect pests to migrate from one place to the others. Great attention has been paid to the insect pests of the rice field since 1946. However, nothing has been done for the storage. This enable stored rice insect pests menace seriously in the present time.

Ⅲ. Insecticide Tests for Rice Weevil and Red Flour Beetle.

Materials. ……Three kinds of impregnated dust were prepared as follows:

5% DDT Dust. ……2.55 grams of technical DDT(97%)dissolved in 25 cc. of acetone and ground up with 47.45 grams of gypsum.

5% gamma… BHC Dust. …… 83 cc. of BHC solution (3% of gammaisomer) were incorporated in 47.51 grams of gypsum.

1.5% Rotenoid Dust. ……20 grams of derris root powder (2.65% of rotenone) were extracted by acetone. The total extracts were then ground up with 34 grams of gypsum. This derris root powder was produced and ground by Taiwan Suger Corporation.

All these three above named mixtures were thoroughly dried in an incubator until keeping for a constant weight. The temperature was maintaining about 40-60 degrees C, and passed through a 200 linear mesh of sieve.

Methods. ……400 gams of paddy rice were weighed for each treatment. Each of the tested material was mixed with 25, 50, 100 and 250 milligrams of each kind of the toxic ingredients respectively. They were separately placed in a mixer which was rotated in a rate of approximately 100 r. p. m. for 5 minutes, until the paddy rice was uniformly coated with the particles of insecticide. After mixing, each lot of paddy rice and 130 insects (100 Tribolium ferrugineum Fab. and 30 Sitophilus oryzae Linn.) were placed in a cylindrical glass container(7.5 cm. in diameter and 13.5 cm. in height). The mouth of the container wes glued by some vaselin to prevent the tested insects from escaping. Each test was replicated four times and records were taken separately for each container. Untreated lots were run with the same number of the insects. Usualy the insects were examined at weekly intervals.

Results. ……This experiment was carried on five weeks and results obtained are summarized in Table 2. The latter shows that gamma-BHC requires rather shorter time to kill Sitophilus oryzae Linn. and Tribolium ferrugineum Fab., whereas DDT and rotenoid require longer.

Table. 2. …… Summarized data on toxicity of various insecticides to S. oryzae Linné and T. ferrugineum Fab.

Insecticides	Species of Insects	Length of Time in Weeks	Average mortatily (%) Dosages of Insecticides per 400gm. of Paddy Rice 25gm.	50gm.	100gm.	250gm.	Check
5% gamma-BHC dust	Sitophilus oryzae Linne	1	95.69	98.30	100.00	100.00	39.21
		2	2.87	1.70			6.08
		3	0.96				3.95
		4					4.26
		5					0.91
	Tribolium ferrugineum Fab.	1	79.18	94.94	100.00	100.00	5.47
		2	9.67	5.05			3.08
		3	3.72				1.20
		4	2.23				0.34
		5	2.60				0.17
5% DDT dust	S. oryzae Linne	1	85.21	86.23	89.36	91.33	39.21
		2	3.52	4.19	7.98	8.67	6.08
		3	2.46	4.72	2.02		3.95
		4	2.35	3.15	2.06		4.26
		5	2.70	2.78			0.91
	T. ferrugineum Fab.	1	47.03	37.93	44.41	80.82	5.47
		2	12.79	32.02	39.32	18.08	3.08
		3	8.22	21.68	4.75		1.20
		4	1.83	4.33	1.16		0.34
		5	1.83	2.05			0.17
1.5% Rotenoid dust	S. oryzae Finné	1	35.42	50.36	50.34	50.89	39.21
		2	2.78	8.63	7.48	8.28	6.08
		3	2.08	1.44	2.72	3.55	3.95
		4	2.08	4.32	1.36	2.96	4.26
		5	1.39	0.72	1.36		0.91
	T. ferrugineum Fab.	1	10.35	19.92	7.25	10.60	5.47
		2	3.45	6.10	6.16	5.96	3.08
		3	0.77	1.22	1.63	1.99	1.20
		4	1.15	0.41	0.36		0.34
		5	0.38	0.81		1.66	0.17

The differences (the average actual per cent mortality) of the average per cent mortality of treatments (different insecticides and different dosages) and that of untreated checks were 38.0(92.6-54.6) and (65.3) (78.9-13.6) for S. oryzae Linné and T. ferrugineum Fab. respectively. The average per cent mortality of untreated checks of S. oryzae Linné was rhighe than that of T. ferrugineum Fab. so that the average actual per cent mortality of S. oryzae Linné was reversely lower than that of T. ferrugineum Fab.

The data was calculated by converting percentages into angles (angle=are sin $\sqrt{\text{percentage}}$) for test of significance in Table 3-5.

Table 3. ……Analysis of Variance.

Species of Insects	Source of Varation	Degree of Freedom	Sum of Squares	Mean Square	F-Value
Sitophilus oryzae Linné	Treatments vs check	1	2602.1016	2602.1016	87.8521**
	Insecticides	2	15722.1085	7861.0543	265.4049**
	Dosages	3	589.5843	196.5291	6.6352**
	Interaction	6	233.0516	38.8419	1.3111
	Error	39	1155.1444	29.6191	
	Total	51	20301.9918		
Tribolium ferrugineum Fab.	Treatments vs check	1	6185.4043	6185.4043	77.4427**
	Insecticides	2	34668.6100	17334.3150	245.0540**
	Dosages	3	1617.5317	339.1770	7.6220**
	Interaction	6	850.2391	14.1707	0.2003
	Errnr	39	2758.7331	70.7367	
	Total	51	46080.5182		

Table. 4. ……Comparative toxicity of various insecticides to S. oryzae Linné and T. ferrugineum Fab.

Species of Insects	Insecticides	Weighted mortality	X Difference		
S. oryzae Linné	gamma-BHC	99.99	89.4313		
	DDT	99.03	84.3538	5.0775*	
	Retenoid	56.50	48.7531	40.7772**	35.6007**
T. ferrugineum Fab.	gamma-BHC	99.65	86.63		
	DDT	94.25	76.13	10.497**	
	Rotenoid	18.00	25.10	61.529**	51.031**

Table. 5. ……Comparative dosages of various insecticides to S. oryzae Linné and T. ferrugineum Fab.

Species of Insects	Dosages of Insecticides per 400gm. of Paddy Rice	Weighted mortality	X Difference			
S. oryzae Linné	25mg.	86.9	68.81			
	50mg.	91.8	73.35	5.54*		
	100mg.	95.5	77.76	8.95**	4.41	
	250mg.	94.8	76.79	7.98**	3.44	0.95
T. ferrugineum Fab.	25mg.	63.80	52.98			
	50mg.	84.10	66.52	13.54**		
	100mg.	79.70	63.25	10.27**	3.27	
	250mg.	85.60	67.74	14.76**	1.22	3.49

Conclusion. …… The gammer isomer of BHC requires shorter time to kill S. oryzae Linné and T. ferrugineum Fab., DDT and rotenoid require longer. The order of effectiveness is gamma-BHC>DDT roteroid. The later shows less insecticidal value as comparared with the former two. 50mg. of insecticide incorporated in 400 gm. of paddy rice is enough to kill 91.8% of S. oryzae Linné and 84.1% of T. ferrugineum Fab.

* The writer has been assisted by Messrs. M. Y. Tang, F. L. Yu and P. P. Li, to whom his thanks are due for the cordial help always afforded him. Most cordial acknowledgment is due to Prof. S. T. Yie for his kind advice and encouragement.

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臺灣積谷害蟲及其防除之初步研究

李　景　星

本文乃調査本省米谷貯藏之現狀，並作三種殺蟲藥劑對于米象 (Sitophilus oryzae Linn.) 及擬谷盜 (Tribolium ferrugineum Feb.) 之毒力初步試驗。

作者曾調査臺北、臺中、臺南及高雄四縣之倉庫及碾米廠等，所採得害蟲標本，學名已鑑定者，計有十二種，其中以米象，擬谷盜及谷蠹(Rhizopertha dominica Fab.)爲害最烈。

所用三種殺蟲藥劑爲5% DDT 粉劑，5% gamma-BHC 粉劑及1.5% rotenoid 粉劑，每種粉劑 25. 50. 100及250毫克與稻谷 400 克分別混藏，結果以 gamma-BHC 殺死米象及擬谷盜所需時間最短而 DDT 及 rotenoid 則較長。毒力則 gamma-BHC 最大，DDT 次之，rotenoid 又次之，故 rotenoid 粉劑實無應用之價値。至藥劑之用量：稻谷 400 克與上述之粉劑50毫克混藏，已可殺死米象 91.8% 及擬谷盜 84.1%

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SOME DESCRIPTIVE AND TAXONOMIC CHARACTERS OF CITRUS FRUITS GROWN AT RIVERSIDE, CALIFORNIA, AND SZECHUAN, CHINA *

Chang-chih Hu

(May, 1951)

CONTENTS

INTRODUCTION

The citrus fruit is economically important. Citrus includes many species and varieties. Citrus is an evergreen and widely distributed in the temperate, subtropical and tropical zones. It is grown on different soils and in varying topographical regions. In the different citrus growing areas there are different cultural practices, methods of propagation, orchard management and problems of disease and insect control. This study is applied to several species and varieties of citrus fruit. It will point out some of the characters of citrus fruits by morphological and physioloigal methods. This variety study is valuable to plant breeding and horticulture. During the last century the knowledge of variety improvement, rootstock study, methods of orchard management and disease and insect control has greatly progressed. Following these new investigations, the description and classification of citrus varieties needs revision. The author is interested in systematic pomology and during the past 24 years has studied citrus varieties in China (1928-1950), in Japan (1924-1928), and in the United States of America (1950-1951). This paper describes the taxonomic characters of some citrus fruits with special reference to a comparison of chemical and physical composition of different species and varieties from Riverside, California, and Szechuan, China.

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* This paper presents one phase of the studies conducted by the author at the Citrus Experiment Station, University of California, Riverside, California, U.S.A. in 1950-1951 under the direction of Dr. E. R. Paker, Dr. W. P. Bitters, and Dr. J. W. Cameron. The material presented here is compiled from the observations which the author made on plant material growing at that station, from his previous observations in China, and from the litrature.

METHOD

The description of each variety was recorded on a citrus variety description blank, planned by the author. The form is divided into following parts:

Ⅰ. Sample records. Date of picking, number, species, variety, location, rootstock, date of tree planting, fruit number and weight.

Ⅱ. Description of fruit.

A. External characters.

1. Description of the form and appearance at base and apex of fruit.
2. Measurement of the fruit weight in grams, length and width in centimeters (in each sample 30 to 100 fruits were measured and the average taken).
3. Stem and calyx-description of the charaeteristics and measurements.
4. Rind-color classification, according to the Ridgeway color standard; description of the oil glands using the terms conspicuous or inconspicuous; size designated as large, medium or small; characters described as despressed, even or raised on surface.

B. Internal characters. (Description and measurement of the different parts in longitudinal and cross sections of fruit.)

1. Longitudinal section of fruit.
   (a) Peel thickness in m.m. on fruit apex, median and base.
   (b) Thickness of flavedo and albedo on fruit median, and idenfication of color.
   (c) Determination of the adherence of the peel and segment.
   (d) Observation of whether core axis is hollow or solid, straight or curved, and measurement of width of median of axis in m.m.
   (e) Shape of segment.
2. Cross section of fruit.
   (a) Number of segments.
   (b) Shape of segment, uniform or variable.
   (c) Easy or difficult to separate segments.
   (d) Septa thin or thick, color or lack of color, and tough or tender.
   (e) Core width and description (hollow or solid).
3. Flesh.- Description of color according to the Ridgeway color standard; as texture fine, coarse, tender, firm; size and shape of vesicles; pulp granulation-light or heavy-and position of-apical or basal.
4. Seed.- Determination of whether variety is seedless or seedy. If seedy, the number of seeds are counted and a description is made of the shape, surface appearance, and color of cotyledon, and the number of embryos.
5. Juice.- Ten fruits were used for juice study. The fruits were first weighed and then squeezed by an electric reamer. The juice was then weighed in gm. The peel and pulp were weighed separately. It was then possible to

calculate by weight the percentage of juice and the percentage of peel and pulp of the fruit in each sample. The soluble solids and citric acid of the juice were analyzed. The percentage of soluble solids in the juice was measured by a hydrometer (0°-15° Brix degree) and corrected for temperature differences. The percentage of citric acid in the juice of each sample was determined by placing 5 or 10 cc of juice from a metric pipette into a clean 250 cc Erlenmeyer flask and adding enough distilled water to make 100 cc volume. Two drops of phenolphthalene were added and then the solution was titrated by 0.1562N NaOH (1 cc of 0.1562N, NaOH=0.01 citric acid) and the citric acid percentage in the juice calculated from the titrations as follows:

$$\% \text{ of citric acid in juice} = \frac{\text{Titrater cc} \times 0.01}{\text{Specific gravity of juice} \times \text{sample juice cc}} \times 100$$

The juice color was examined by placing the juice in a test tube and illuminating it under an electric fluorescent light. The color was judged according to th Ridgeway color standard. The flavor and aroma of the juice were judged by tasting and distinguishing the quality grade as inferior, fair, good, or best.

II. Ripening Season.

The number of days from the date of flowering to fruit maturity aids in distinguishing varieties. The Washington Navel orange growing at Riverside, California, flowers in the middle of April. The fruit ripens from January to April. The Valencia blooms at about the same time, but the fruit ripens later from May to September of the following year. The Valencia is a late variety of the sweet orange. The Satsuma orange ripens early in November to December. Orange varieties mostly ripen in December to January. The harvesting season differs and varies. It also may be modified by the climate; especially temperature and sunlight, which affects the fruit ripening season greatly. Citrus fruits growing in mild temperatures and good sunlight, such as at Riverside, California, are harvested over a much longer period than in other citrus growing areas.

The so-called fruit ripening season depends upon fruit quality. When the soluble solids and acid content reached a standard for each variety, the fruit was considered to be ready for harvest. (Lemons and limes are picked according to size and color.) The standard ratio of soluble solids to acid in the juice is 8:1 for the sweet orange, 6:1 for grapefruit.

COMPARISON OF FRUIT CHARACTERS

I. Comparison of Fruit Characters.

A. Weight and size.

The pummelo and grapefruit the largest of the citrus fruits; oranges, lemons and mandarins are medium; and the lime and kumquat are the smallest. The fruit weight and size aids in distinguishing species and varieties, but these characters are flexible. They can be modified by environmental factors, fertilizers, irriga-tions, disease, pest control, rootstocks, tree age, and alternate bearing. The fruit weight and size may be affected by a combination of these factors. The fruit weight and size of some different species and varieties of citrus from Riverside, California, and Sazechuan, China, were examined by the author and the data presented in Table 1 to 5.

TABLE 1.—Comparison[1] of Fruit Characters of Different Citrus Varieties. (Riverside, California, November-December, 1950).

Variety & Stock[2]	Weight gms	Length cm	Width cm	Juice % by wt.	Peel and Pulp %	Soluble Slids %	Citric Acid %	Peel Thick-ness mm	Flavedo Thick-ness mm	Segm-ents	Core Width mm	No. Seeds
ACID LIME, MEXICAN GROUP												
Thornless Mexican (sw)	14	3.1	2.6	39	58	10.85	7.5	2.2	0.5	10	3.8	1.8
Weet Indian (R.L.)	19	3.5	3.1	43	52	11.00	7.1	1.8	0.5	10	3.5	5.2
ACID LIME, LARGE FRUIT, TAHITI, TAHITI GROUP												
Bearss (sw) (seedless)	81	5.8	5.2	43	54	9.2	4.8	2.7	1.0	10	5.1	0
Pond (sw) (seedless)	78	5.8	5.1	42	53	8.9	5.2	2.8	1.0	10	4.0	0
Pond (R.L.) (Seedless)	89	6.0	5.0	45	52	8.8	4.9	3.1	1.0	10	3.4	0
ACCID LIME, MANDARIN-LIME GROUP												
Kusaie (R.L.)	35	3.8	4.1	47	47	8.9	5.1	2.4	1.5	9	7.0	7.1
Rangpur (R.L.)	65	5.1	5.0	47	47	8.8	4.6	2.5	1.0	9	6.6	5.7
SWEET LIME GROUP												
Otaheite (R.L.) (Werricke lime)	54	4.7	4.8	42	52	7.7	0.3	3.1	1.5	8	5.2	0
Palestine (sw)	122	6.3	6.1	49	49	8.0	0.1	2.5	1.0	11	7.4	4.1
HYBRID-LIMEQUAT, *Fortunella* sp. x *Citrus aurantifolia*												
Limequat (R.L.)	8	2.8	2.4	34	59	9.3	5.8	1.4	1.0	8	2.6	1.0

1 Each sample consisted of 100 fruits for weight, length, width measurements, and 10 fruits for juice and other measurements.

2 (sw) sweet orange; (R.L.) Rough lemon.

TABLE 2.—Comparison[1] of Fruit Characters of Different Citrus Varieties. (Riverside, California. December, 1950)

Variety & Stock[2]	Weight gms	Length cm	Width cm	Juice % by wt.	Peel and Pulp %	Soluble Solids %	Citric Acid %	Peel Thick-ness mm	Flavedo Thick-ness mm	Segm-ents	Core Width mm	No. Seeds
ACID LEMON, EUREKA GROUP												
Eureka (R.L.)	126	7.7	5.9	36	58	8.3	4.6	5.7	1.0	9	5	5
Genoa (R.L.)	99	6.9	5.4	38	57	8.5	4.4	4.9	1.3	9	4.8	7
Villafranca(R.L.)	101	6.8	5.6	39	57	8.8	3.5	5.5	1.0	9	5.3	6
Villafranca (sw)	131	6.7	5.5	41	54	9.7	4.5	5.1	2.0	10	5.1	9

ACID LEMON, LISBON GROUP												
Lisbon (s)	124	7.8	5.9	42	54	10.4	5.3	4.9	1.5	10	5.0	5
Messer (cutting)	88	6.9	5.3	42	53	10 1	4.7	3.8	1.5	10	5.0	4
Perrine lemon (cutting)	51	5.4	4.4	47	47	10.0	6.5	2.1	1.0	12	4.2	9
SWEET LEMON GROUP												
Dorshapo (R.L.)	130	8.7	5.9	36	61	7.5	1.5	6.0	1.0	9	4.4	1

[1] Each sample consists of 30 fruits for weight, length, width measurements, and 10 fruits for juice and other measurements.

[2] (s) sour orange, (sw) sweet orange (R.L.) Rough lemon.

TABLE 3.—Comparison[1] of Fruit Characters of Different Citrus Varieties. (Riverside, California. August-September, 1950)

Variety & Stock[2]	Weight gms	Length cm	Width cm	Juice % by wt.	Peel and Pulp %	Soluble Solids %	Citric Acid %	Peel Thickness mm	Flavedo Thickness mm	Segments	Core With mm	No. Seeds
GRAPEFRUIT, PALLID PULP GROUP, SEEDY												
Clayson (s)	357	9.1	9.1	35	61	10.1	1.2	10.1	3	13	11.2	56
Foster, whits (s)	275	8.8	8.3	31	61	13.5	1.8	9.3	3	13	10.5	60
Hall, silver (s)	346	9.3	9.0	34	61	12.5	1.7	10.8	4	14	10.4	45
Imperial (s)	289	8.8	8.3	34	61	13.5	1.4	9.0	1	11	11.6	35
McCarty (s)	312	8.8	8.8	39	57	12.7	1.7	9.2	3	13	10.7	50
Triumph (s)	499	11.3	10.1	39	58	10.0	1.0	11.4	3	11	15.3	22
Windsor (s)	353	9.1	9.1	38	57	11.9	1.6	9.9	3	12	10.2	58
GRAPEFRUIT, PALLID PULP GROUP, SEEDLESS												
Cecily (s)	208	7.7	7.6	38	61	13.4	1.9	8.5	4	13	9.4	6
Healton (s)	335	9.0	9.1	39	60	9.2	1.8	10.2	3	13	16.0	3
Howells (R.L.)	248	8.3	8.2	38	62	10.8	1.4	9.8	3	13	11.0	3.4
Marsh (s)	224	7.8	7.7	40	59	14.5	1.2	8.1	2	13	9.6	3.7
GRAPEFRUIT, PINK PULP GROUP, SEEDLESS												
Pink Marsh (seedling)	389	10.2	10.1	42	57	9.1	1.0	9.8	3	12	17.0	1.9
Red Blush (s)	335	9.4	9.4	42	57	8.6	1.3	10.4	3	13	15.0	3.5

[1] Each sample consists of 30 fruits for weight, length, width measurements, and 10 fruits for juice and other measurements.

[2] (s) sour orange, (R.L.) Roagh lemon.

TABLE 4.—Comparison[1] of Fruit Characters of Different Citrus Varieties. (Riverside, California. January, 1951)

Variety & Stock[2]	Weight gms	Length cm	Width cm	Juice %	Peel and Pulp %	Soluble solids %	Citric acid %	Peel Thickness mm	Flavedo Thickness mm	Segments	Core Width mm	No. of seeds
SWEET ORANGE, NAVEL FRUIT GROUP												
Golden Buckeye (s)	143	6.9	6.4	52	47	12.9	1.18	3.3	0.5	10	8.0	0
Golden Nugget (s)	208	7.8	7.2	51	45	13.9	1.4	4.2	1.5	11	6.6	0

Navelencia (S)	158	7.1	6.7	45	53	13.8	1.2	5.0	1.5	10	7.7	0
Surprise (S)	200	8.0	7.2	42	57	12.0	1.1	6.1	1.0	10	9.3	0.1
Thomson (S)	168	7.4	6.9	40	55	13.0	1.1	5.7	1.5	10	11.0	0.7
Washington(SW)	220	8.3	7.6	39	58	11.4	1.1	6.8	1.5	11	12.7	0
Washington (T)	260	8.5	7.8	46	53	11.57	1.1	6.6	1.5	10	10.5	0.3
Washington (R.L.)	199	7.8	7.2	45	53	10.47	1.0	6.6	1.5	11	11.0	0.3
SWEET ORANGE, VALENCIA LINES (AUGUST, 1950)												
Azusa (SW)	163	7.2	6.4	51	48	12.43	0.84	5.7	3	10	5.6	5
Campbell, O L.[3] (SW)	127	7.5	7.0	41	57	11.87	0.91	6.1	2	10	10.6	3.1
Campbell, Y.L.[4] (SW)	266	8.0	6.5	42	66	11.94	0.92	7.5	3	10	15.8	2.4
Cutter, O.L.(SW)	169	7.4	6.9	41	47	11.71	0.87	7.3	2	10	13	5
Cutter, Y.L.(SW)	300	8.8	8.4	40	57	11.91	0.88	8.4	2	10	24	0.2
Frost, O.L. SW)	180	7.5	6.9	45	54	11.25	1.00	6.8	2	10	8.2	3
Frost, Y.L. SW)	201	7.7	7.1	46	52	11.41	0.8	7.1	3	9	11.2	4
Olinda (SW)	722	8.3	7.2	50	45	12.85	0.8	6.5	3.5	9	6.2	3.4
SWEET ORANGE, NORMAL FRUIT GROUP												
Early oblong(S)	111	6.4	6.1	39	58	10.47	1.9	6.5	3.0	10	6.7	10.3
Paperrind (S)	109	6.0	5.9	51	42	11.81	1.2	3.6	1.2	10	7.3	15
Parson Brown P)	112	6.1	6.1	44	53	12.03	1.4	5.5	1.0	10	8.2	4.5
Pineapple (S)	96	5.7	5.8	34	58	10.03	1.3	5.8	1.5	10	8.3	15.7
Selecta (S)	140	6.7	6.4	49	48	10.01	1.6	5.2	1.5	10	7.1	8.8

1 Each sample consisted of 30 fruits for weight, length, and width measurements, and 10 fruits for juice and other measurements.

2 (S) sour orange, (SW) sweet orange. (T) trifoliate orange, (R.L.) Rough lemon, (P) pummelo.

3 Old line.

4 Young line.

TABLE 5.—Comparison[1] of Fruit Characters of Different Varieties. (Szechuan, China.)

Variety & Stock[2]	Weight gms	Length cm	Width cm	Juice by wt. %	Peel and Pulp %	Soluble solids %	Citric acid %	Peel Thickness mm	Flavedo Thickness mm	Segments	Core width mm	No. of seeds
ACID LEMON, JANUARY 5, 1939												
Eureka (P)	165	7.6	5.5	51	46.5	8.2	6.3	6	1	10	6	7
Peking Lemon (Mayer) (P)	108	6.6	6.0	56	27	7.0	4.2	3	1	10	7	10
PUMMELO, NOVEMBER 22, 1938												
Lain Shan Yu (P)	1229	12.1	18.0	48	44.6	8.1	0.3	15	2	30	14	150
Bon Chi Yu Layering	1779	14.5	17.6	34	55.5	10	0.9	22	2	15	6	125
SOUR ORANGE, JANUARY 23, 1939												
Tai Tsu-Kou seedling	80	7.0	8.7	37	57.8	8.2	1.5	10	2	10	13	30

SWEET ORANGE, DECEMBER 5-13. 1938												
Hwang Kuo Kin-Tan, 25 seedling trees averaged	184	6.9	7.1	53.	44.7	10	0.9	4.7	1.5	10	9.5	17
Kwang Kuo Kiang-Tsing, 25 seedling trees averaged	162	6.1	6.8	41	51	10	1.3	4.2	1.5	10	9.0	17
Kwang Kuo Yunnan, 1 seedling	220	7.2	7.7	50	49	6.8	0.8	4.5	1	10	17	17
TANGERINE OR MANDARIN, NOVEMBER-DECEMBER, 1938												
Hongchieh, seedling	136	5.0	7.5	54	44	11	0.3	2.0	1	10	27	15
SATSUMA ORANGE, OCTOBER, 1941												
Wenchou (T)	117	5.5	8.4	49	51	11	1.6	2.6	1	12	13	4

[1] Acid lemon, pummelo, sour orange. Each sample consisted of 10 fruits for measurements: Hwang Kuo (Szechuan sweet orange), each sample consisted of 30 fruits for weight, length, width measurements, and 10 fruits for juice and other measurements.

[2] (P) pummelo.

B. Shape.

In citrus fruit the outline or shape can be divided into globose, oblate, ovoid, obovoid, pyriform and spindle. The appearance of the stylar end and stem end also shows special characters. The stylar end shape can be distinguished as round, depressed, naveled, papillose and some appear furrowed, ribbed, or areolate. The stem end shape can be distinguished as round, depressed, acute necked, and sometimes, ridged, or areolate.

The Fruit Shape Classification of Some Citrus Species and Varieties.

Species & Variety	Outline	Stylar end	Stem end
Lime- Thornless Mexico	Oblong	Nippled	Round
Bearss	Obovoid	Nippled	Round
Lemon- Eureka	Oblong	Nippled	Necked
Lisbon	Oblong	Areolate	Round
Villafranca	Oblong to Globose	Nippled	Round
Grapefruit- Marsh	Globose to Oblate	Round	Round
Pummelo- Lian Shan yu	Oblate	Round	Round
Bong Chi yu	Obovoid	Round	Round to necked
Sweet- Washington Navel	Oblong	Navel	Depressed, round
orenge- Thomson	Globose to ovoid	Navel	Depressed, round
Valencia: Olinda	Oblong	Round	Depressed, round
Parson Brown	Globose	Round	Round
Hwang Kuo	Globose to Oblate	Round	Round
Mandarin- Hong chieh	Oblate	Depressed	Depressed
Satsuma	Oblate	Depressed	Round to necked

The shapes of citrus species and varieties is different. In the sweet orange seedy variety fruit shapes are mostly oblate.

C. Rind (Peel).

The characters of the rind of citrus fruit include differences in color, size and number of oil glands, aroma and thickness of rind. The color of the rind varies (and correlates with the color of the pulp and juice) in different species and varieties of citrus fruits as shown in the following chart:

Color[1] of Peel, Pulp and Juice in Different Citrus Species and Varieties

Species and Variety	Color of		
	Peel	Pulp	Juice
Lime			
Thornless Mexican	Chalcedony yellow	Chalcedony yellow	Chalcedony yellow
Bearss	Lemon yellow	Pale green yellow	Straw yellow
Lemon			
Eureka	Viridine yellow	Empire yellow	Martine yellow
Lisbon	Viridine yellow	Baryta yellow	Buff yellow
Villafranca	Viridine yellow	Pingard yellow	Martine yellow
Grapefruit			
Marsh	Baryta yellow	Buff yellow	Maize yellow
Pink Marsh	Flesh ocher	Light salmon	Light Buff
Pummelo			
Lian Shan yu	Lemon yellow	Greenish lemon	Greenish lemon
Kao Panne	Lemon yellow	Light yellow	Light yellow
Moanalua	Pale orange yellow	Shrimp pink	Pinkish yellow
Sweet orange			
Washington Navel	Orange chrome	Deep orange	Cadmium yellow
Thomson	Mikado orange	Light orange	Light cadmium
Valencia, Olinda	Capucine yellow	Orange	Cadmium yellow
Mandarin and Tangerine oranges			
Hong chieh	Flame scarlet	Salmon orange	Capucine orange
Satsuma	Orange	Orange yellow	Orange yellow

[1] The colors were examined under an electric fluorescent light and the Ridgeway Color Standard and color nomenclature followed.

D. Oil glands.

The number per square centimeter and size of oil glands in peel of mature fruit differ between species and varieties of citrus fruit. The oil glands may be distinguished according to primary (diam. 1.0-1.7mm), secondary (diam. 0.5-0.7mm), and tertiary (diam. 0.2-0.3mm). The three types depend upon size. Under a microscope (9x) the author found that lime peel contains a high number of secondary oil glands; lemon peel contains a high percentage of primary oil glands; Marsh grapefruit peel contains a high percentage of primary and secondary oil glands; sweet orange contains a high percentage of primary and secondary oil glands; the Washington navel oranges contained more primary oil glands than other navel varieties examined. Clementine tangerine and Owari Satsuma orange contain a high percentage of both secondary and tertiary oil glands. The oil glands can be distinguished as depressed, even, or raised. The data on oil glands of different species and varieties is shown in Table 6.

TABLE 6. Average Number per Square Centimeter and Size of Oil Glands in Peel of Mature Fruit of Some Citrus Species and Varieties. Observation made Midway between Stem and Stylar Ends of Fruit (Feb. 1951)

Fruit Species and Varieties	No. of fruit examined (a)	Type of Oil Gland: Primary No.	Primary diam. mm.	Secondary No.	Secondary diam. mm.	Tertiary No.	Tertiary diam. mm.	Total No.	Peel Color
C. aurantifolia									
Thornless Mexican Lime.	20	166	0.5[(b)]	—	—	—	—	166	Calcedony yellow
C. Limon									
Eureka Lemon	20	70	0.9[(c)]	—	—	—	—	70	Light viridine yellow
Fortunella margarita									
Nagami Kumquat	10	40	1.0	36	0.5	—	—	76	Cadmium orange
C. grandis									
Siam Pummelo	10	44	1.7	8	0.7	—	—	52	Lemon yellow
C. paradisi									
Marsh Grapefruit	10	60	1.6	44	0.7	—	—	104	Pinard yellow
C. sinensis (Sweet orange)									
Washington Navel	10	60	1.4	48	0.7	16	0.2	124	Orange crome
Thomson Navel	10	44	1.0	60	0.7	8	0.3	112	Mikado orange
Golden Buckeye Navel	10	28	1.25	56	0.7	68	0.2	152	Buff orange
Average	30	44	1.22	55	0.7	37	0.2	129	
C. reticulata									
Tangerine Clementine	20	32	0.9	54	0.6	80	0.2	166	Flame scarlet
Satuma orange owari	10	28	0.8	36	0.6	58	0.25	120	Orange chrome
Average	30	30	0.8	45	0.6	63	0.22	143	

(a) Each fruit measured at four locations midway between stem and stylar ends.
(b) Impossible to distinguish primary, secondary and tertiary oil glands, range in size was 0.28–0.7mm.
(c) Impossible to distinguish primary, secondary and tertiary oil glands, range in size was 0.55–1.4mm.

E. Flavedo and Albedo.

The flavedó is the oil gland layer. The albedo is the mesocarp. Both were measured in mm. The peel thickness in limes and mandarins is thinnest (2-2.5 mm) lemon and sweet orange medium (3-9 mm), and grapefruit and pummelo thickest (10-25 mm).

Only the mandarin segments do not adhere to the peel. In the other species the peel always adheres to the segment. The comparison of thickness of peel, flavedo, albedo, and peel percentage in weight of citrus species and varieties is shown in Tables 1-5. The firmness, aroma, oil, and taste (flavor) also are important characters of citrus peel.

The Washington Navel, sweet orange, and Valencia peel are firm and good for handling. The lime, lemon, kumquat peel are high in aroma and oil content, and are good for peel products. The thickness of the outer epidermis is important, because it influences the apperance of peel characters and determines the amount of handling the fruit will withstand.

F. Calyx.

The size or diameter, shape and thickness of the sepals can differ from one another in the various species or varieties. For instance, the sepals on pummelo and grapefruit are larger, on lime and mandarin smaller, and on lemon and sweet orange medium.

G. Cross section.

First the number of segments and their shape and uniformity were compared. The number of segments and varieties of citrus fruits were studied. The data is shown in Tables 1-5, The segments number 15-20 in a pummelo, 11-14 in grapefruit, 9-11 in sweet orange, 10-12 in mandarin, 8-11 in lime, 9-10 in lemon. The number and shape of segments of fruits can be varied by pollination, or flower bud differentiation.

H. Septa (Enveloping Membrane).

Septa characters differ between citrus species and varieties. It can be distinguished according to the thickness, toughness, and color. The pummelo and grapefruit septa are thicker, the sweet orange is medium, and the mandarin is thinner. The pummelo septa is tough, but the mandarin and sweet orange septa are tender. It is important to pay attention to the character of the septa in the selection of a citrus variety. Some varieties contain color in the septa, such as the pink color of the septa in the pinkfleshed grapefruit and pummelo. Some sweet orange varieties contain a yellow color in the septa.

I. Longitudinal Section.

The following measurements can be taken. Peel thickness in mm at the median, apex and base, especially for thicker peel varieties. Next, the width of the core is noted and whether it is hollow or solid, the axis straight or curved. The width of the core and its hollow or solid characters differ with species and varieties. The data obtained from the citrus varieties which were examined is shown in tables 1 through 5. The width of the core in the mandarin is greatest, being 27 mm; the grapefruit core varies from 9 to 17 mm; the sweet orange is 5 to 10 mm; the lemon is 4 to 5 mm; and the lime core is the smallest, being 3.5 to 5 mm. The core of the mandarin is usually hollow.

In the grapefruit, and the sweet orange. the hollowness of the core depends upon the variety and degree of fruit maturity.

J. Flesh.

The flesh or pulp of citrus fruit consists of juice sacs or vesicles. The color of the pulp and the size and shape of the vesicles are described. The pulp color of some citrus species and varieties is described in the table on page 112 of this manuscript. Pulp color is an important character of citrus species and varieties. The size of the vesicle is largest in the pummelo and grapefruit; medium in the sweet orange and lemon; smallest in the lime. In the mandarin it is short and plump. The flesh of citrus fruit has a character of granulation which makes a part of the pulp stiff. The granulation impairs the fruit quality. Attention should be paid to granulation in the pulp. The author found granulation of the Valencia orange to be most common in August and September. Granulation develops late in the season in over-matured furit in Riverside, California.

K. Juice.

The percentage of juice in fruit by weight and the color of the juice, the percentage of soluble solids and citric acid in the juice, the bitterness aroma, and flavor of the juice were tested and described in each sample. The percentage of juice of citrus fruit differs in species and varieties and is affected by the maturity of the fruits, the climate, and the kind of rootstocks used. The juice per cent by weight in fruit is 40-50 per cent for citrus fruits (refer to tables 1-5).

1. Color of juice.

The color of the juice depends upon the variety, the rootstock and the period of fruit maturity. Limes, lemons, grapefruits and pummelos have yellow juice; the sweet orange and mandarin have orange juice. A comparison of the juice color of mature fruit of citrus varieties is shown in the table on page 112 of this manuscript, as are the colors of the peel and pulp.

2. Percentage of solids and citric acid in juice.

This is a flexible character in citrus fruits. It can be modified by climate, period of fruit maturity, rootstocks, and methods of orchard management. Therefore, to determine the quality of citrus fruit, it is necessary to consider the genetical characters and the enviromental factors, The Valencia orange picking season in California lasts for seven months, from April to October. In Florida it is from February to March or April. The California Valencia has a long harvesting season and is especially good during the summer season. The excellent production is obtained through proper methods of orchard management and the favorable climate and soil conditions for the Valencia variety.

The percentage of soluble solids and citric acid in the juice of citrus groups and varieties was examined by the author in samples from July, 1950 to February, 1951, in California, and from October to December, 1938, in Szechuan, China. The lime, lemon are high in acid content. The Marsh grapefruit, pummelo, Siam, sweet orange, Washington Navel and Valencia, and Hong chieh and Owari mandarins have a well balanced ratio of solids and citric acid content.

3. Bitterness of juice.

The commercial citrus all have a non-bitter taste, except the grapefruit.

4. Aroma.

This is an impoatant character in citrus fruits. The lime, lemon, grapefruit, pummelo, sweet orange, and mandarin are high in aroma. The aroma is formed by the citrus oils. The citrus oil is produced from the oil glands. Therefore, the amount of aroma depends on the development of the oil glands and their function. In 1951 the auther studied the avrage number of oil glands per squre centimeter and the size of the oil glands in the peel of mature fruit of different citrus species and varieties. These studies showed a high number of primary oil glands in Eureka lemon (70), Nagami Kumquat (40), Siam pummelo (44), Washington Navel (66), Thomson Navel (44), Campbell Valencia (76). A low number of primary oil glands was found in Golden Buckeye Navel (28), Clementine tangerine (32), Owari satsuma orange (28). In the Thornless Mexican lime the number of secondary oil glands (diameter 0.5 mm) is 166 per square centimeter. The question arises as to whether the high number of primary or secondary oil glands per squre centimeter in the peel of mature fruit is correlated with the degree of aroma. The evidence suggests that citrus varieties which have a high aroma contain a high number of primary oil glands. The data is shown in the table 6. The aroma is due to an ester contained in the citrus oil. The aroma of citrus fruits in California, in the author's opinion, is higher than in fruits grown in China. The author believes that the aroma may be modified by climate, rootstock, and methods of orchard management.

5. Flavor.

The flavor of citrus fruit is dependent upon soluble solids, citric acid aroma being well blended. If these are out of balance, the fruit will have an undesirable quality.

L. Seed.

Seed characters differ in citrus species and variety. Seedless varieties are preferred. In California the seedless varieties of citrus fruit are chiefly grown. In China seedless or seedy varieties are grown. Varieties of sweet orange, mandarin and pnmmelo are grown in Szechuan, China. The juice quality of fruit is good if the seed content is high. Hwang kuo (sweet orange) contains 17 seeds; Hong chieh tangerine contains 15 seeds. Even the seedless satsuma orange growing in Szechuan would produce seeds because it is planted beside the groves of seedy varieties. In South China mostly seedless citrus fruit of Tankan, Ponkan and Tienchen (sweet orange) are grown. The seedy citrus fruit is adapted for growing in the lower temperature regions such as Szechuan. The seedless varieties of limes are the Thornless Mexican, Bearss, Pond, Sweet lime, and Werricke lime. The Eureka and Lisbon lemon group contain 4 to 9 seeds. The nearly seedless varieties of grapefruit are the Cecily, Healton, Howells, Marsh, Pink Marsh and Red Blush. The commercial seedless varieties (less than 10 seeds per fruit) of sweet orange are the Thomson Navel, Washington Navel, and all lines of Valencia. In the sweet orange normal fruit group, most varieties are seedy. In the pummelo the Kao Panne originated in Siam as a seedless variety. Some seedy citrus varieties can be used for rootstock purposes, especially the polyembryonic. It is important that varieties used for rootstock purposes are uniform and true to type so the results they will give can be reasonably predicted. Therefore, the use of sweet orange, sour orange, and mandarin for citrus rootstocks was encouraged. If a seedy variety, the seed shape, size, color of cotyledons, number of embryos, color of seed coat and chalazal spot descriptions are needed.

II. Description of Commercial Viarieties of Citrus Fruits.

In the description of fruit of commercial citrus species and varieties (according to taxonomic characters) a key was devised. The description of commercial species and varieties the name, origin, distribution, fruit characters, and uses. The fruits were examined at the Citrus Experiment Station, University of California, Riverside, California, in 1950-1951, and at the University of Nanking, which moved into Chengtu, Szechuan, China, during 1937-1944 in the Second World War. This key follows on the next:

KEY TO COMMERCIAL SPECIES OF CITRUS FRUIT

A. Fruit pulp very acid (above 5% acid in juice).

- B. Fruit small, 3-6 cm in length, 2.5-5.0 cm in width, oval; apex nippled; oil glands flush with surface, numerous; oil abundant.⋯*Citrus aurantifolia* **Lime**
- BB. Fruit medium, 7-8 cm in length, 5-6 cm in width, oblong; apex nippled, rind thick, 4-6 mm, yellow; oil glands large, up to 0.9 mm diameter, flush or depressed; lemon aroma distinctive.⋯⋯⋯*Citrus Limon* **Lemon**

AA. Fruit pulp sweet, sugars and acid blended (soluble solids to acid ratio, 8:1).

- C. Rind adherent.
  - D. Pulp pale or pink; rind yellow or pink.
    - E. Fruit medium to large, up to 8-12 cm in diameter, oblate, globose,

obovoid··*Citrus paradisi* **Grapefruit**

EE. Fruit larger, up to 18-20 cm in diameter; oblate, obovoid, or pyriform··*Citrus grandis* **Pummelo**

DD. Pulp and rind orange color; fruit medium, diamster 6-8 cm globose, oblong, oval or oblate··························*Citus sinensis* **Sweet orange**

CC. Rind loose; color red to orange; fruit diameter 5-9cm; oblate, globose, oblong, obovoid; apex depressed··············*Citrus reticulata* **Mandarin** *or* **Tangerine**

A. Limes (*Citrus aurantifolia* **Swingle.**).

The lime is indigenous in the East Indian Archipelago, and was brought to the attention of Europeans in the Thirteenth Century. The lime was brought to the Americas by the Spanish and Portuguese explorers in the early part of the Sixteenth Century. It escaped from cultivation in the West Indies and in southern Florida. The peoples of Mexico, the West Indies, and other tropical countries like limes and use them extensively. The mandarin lime, Rangpur type, was introduced in China before the Twelveth Century from India. We called it the "Canton lemon" which grows wild extesively in Canton, Garhwal and Kumaun of India; there it is called Jambhiri.

I. Acid lime.

A. Mexican Group.

The limes are divided into three groups, the acid limes, the mandarin limes, and the sweet limes. The acid lime is important commercially. The fruit is high in percentage of acid and oil, and is oblong to oval, apex papilled, peel chalcedony yellow, and may be large or small depending upon the variety. The small-fruited limes are called the tıue limes or Mexican group. The large-fruited limes are called the Tahiti group. The Thornless Mexican and West Indian are the leading varieties in the Mexican group.

(a). Thornless Mexican. This variety originated in the West Indies. It was reported there in 1892 on the Shawford Estate, Dominica, when a lime tree was noticed without the usual formidable spines. This variety was introduced by the United States Department of Agriculture in 1910, then distributed to Florida, Texas and California.

The variety is characterized the same as the Mexican (West Indian) lime but the branch is thornless.

Fruit character.-Fruit maturing more or less throughout the year. The harvest season is mostly in the fall to spring. Fruit borne on the tree evenly, form oblong; size small, diam. 3.1 cm. in length, 2.6 cm. in width; base rounded and smooth, apex nippled and ringed; rind smoth and leathery, very thin, 2.2 mm. in thickness; oil glands small (diam. 0.5 mm.) and numerous (166 per sq. cm. on maturefruit rind surface); surface even; oil abundant, highly aromatic; segments 10, uniform, separation difficult, membranes thin, core slender (width

3.8 mm.): flesh color chalcedony yellow; texture fine and firm; juice color light chalcedony yellow, juice percentage in fruit 40, very acid (contains 7.5 % cf citric acid in juice), highly aromatic; seeds few, average 1.8, small, ovate, surface smooth; cotyledons light green, embryos 1-2.

B. Tahiti Group.

This is a group of large fruited acid limes. The commercial varieties are Bearss and Ponds. The fruit is larger. and the flavor and aroma not so pronounced as with the Mexican Group.

(a) Bearss (Bearss Seedless).

The Bearss lime originated about 1895 on the place of T. J. Bearss, a Southern Pacific station agent who was both experimenter and nurseryman, at Porterville, California. It is probable that the Bearss was from a selected seedling grown from Tahiti seed. The Bearss is well known in California. It is also grown to some extent in Arizona and in Hawaii.

Fruit characters. Fruit ripens in winter to late spring, maturing more or less throughont the year, bearing in clusters, evenly distributed on the inside and outside of the tree. Fruit obovate, base slightly necked, apex slightly nippled. 5.8 cm. in length, 5.2 cm. in width; fruit stem slendar; calyx raised, 7.5 mm. in diam.; sepals obtuse; rind adherent. lemon yellow in color, tender and aroma medium, in 2.7 mm thickness; segments 10, uniform, separation difficult, septa thickness medium; flesh pale green yellow, texture fine; juice 43%, straw yellow color, aroma weak, flavor acid; seedless.

(b) Pond (Ponds Seedless).

The Pond lime was first propagated in California from buds obtained from the Moanalua Gardens in Honolulu, Hawaii, by H. J. Webber of the California Citrus Experiment Station at Riverside, in 1914. It belongs to the Tahiti type; the fruit is seedless and the juice quality is poorer than the Thornless Mexican.

II. Mandarin type limes.

(a) Kusaie and Rangpur Limes.-

These limes belong to the Mandarin lime group. They are an acid lime; fruit pulp is high in acid content; no aroma; fruit shape globose. These two varieties are cultivated for ornamental purposes. The Rangupur is used as a rootstock for sweet orange in India.

III. Sweet limes.-Sweetlime varieties are Otaheite (Werricke lime) and Palestine. Fruits contain very low percentage of acid; are only grown for ornamental purposes.

IV. Limequat.-This is a hybrid of kumquat and lime. It contains 5.8 percent acid in the juice.

B. Acid Lemon, *Citrus Limom* Burmann.

The lemon grows wild in Garhwal and Almora, Himalaya, India, There it is called **Nimbu** or **Limbu** for lemon. The lemon is rarely grown in India and China. It was grown early in the Thirteenth Century in China. The old name of lemon in China was "Shangmon" or "Shang tao (Fragrant Peach). In the early part of the Twentieth Century lemon varieties were reintroduced. The Eureka, Lisbon and Villafranca were brought from Europe and the United States of America, as well as Japan, to Kwantung, Formosa and Szechuan. There are a few commercial lemon acreages in production in China now.

The history of lemon culture in the United States of America is that it was first brought here when Columbus discovered America in 1492; then the Spanish settlers continued bringing lemons and others citrus fruits to the United States of American in the Sixteen Century. The lemen industry was first established in Flodida. By 1880 it had been generally established in California.

1. Eureka Group.

The fruit pulp is very acid, color light lemon yellow; shape elliptical and more or less drawn out at each end; nippled and necked; tree open, spreading; branches and twigs few, coarse and rigid; foliage open; leaves dark green, round at apex or short-pointed.

(a) Eureka.

The Eureka lemon originated as a superior seedling among a bunch of seedlings grown from seed that had been obtained from imported Sicilian lemons and planted by a Dr. Halsey, of Los Angeles, California, in 1858. In 1860 Andrew Boyle purchased several hundred of these seedlings; when they fruited three or four smong them were found to produce smooth, thin-skinned fruits. In 1877, C. R. Workman, son-in-law of Boyle, gave buds from one of these, good seelings to Thomas A. Garey, a nurseryman of Los Angeles, who propagated trees and found them to produce a superior fruit. Garey introduced the variety under the name Garey's Eureka. This variety was introduced to Chengtu, Szechuan, China, in 1924 by Dickison.

Fruit characters.-The Eureka lemon harvesting period in California in the interior valleys is from December to May, in the coastal sections the peak of production is in March with minor peaks in June and August. The Eureka is a heavy yielder, and young trees begin bearing early.

Fruit color lemon yellow; surface slightly rugose, pitted, usually with more or less marked longitudinal ridges; shape obovate to elliptical or oblong; size medium, diam. 6.0 cm.; length 7.7 cm., average weight 126 gm.; base gradually rounded, frequently necked or slight collared, usually more or less lobed; calyx medium in size, diam., 8 mm., even or somewhat sunken; apex rather abruptly rounded or shouldered; areole indistinct, or a slight circular furrow at base of nipple; areolar area protruded into a usually short but sometimes long and pointed nipple; rind medium thin, 5.7 mm. in median oil glands large, globose to obovoid; primary oil gland, diam. 0.9 mm., 70 per sq. cm. of peel on mature fruit; flavedo one-third to one-foerth thickness of rind; albedo white; axis small, diam. 5.0 mm., solid; segments averaged 9, regular; pulp tender, fine-grained, Empire yellow to pale green yellow; vesicles spindle shaped, slender; juice abundant, clear, very acid; quality and flavor excellent; seed few, none to 8 per fruit. The soluble solids and acid percent content in juice varied with rootstocks (table 2), climate and methods of orchard management.

(b) Genoa.

The Genoa has tree and fruit characters of the Eureka type and is only slightly distinct from that variety. It was introduced into California from Genoa by Jose Rubio, of Los Angeles, about 1875, and taken thence to Florida by A. I. Bidwell in 1881. The fruit is small, and the variety is not commonly propagated now.

(c) Villafranca.

The variety belongs to the Eureka type. It is a larger, more vigorous-growing tree. The Villafranca was introduced into Florida from Europe about 1875 by General Sanford, of Sanford, Florida. When this variety was introduced into California is unknown. It is not commonly grown in California. Fruit characters are the same as Eureka.

2. Lisbon Group.

Lisbon lemon fruit is distinguished from that of the Eureka by its apex which is abruptly nippled, the rind smoother to grained, and less markedly ribbed. The Lisbon was first introduced into California from Australia in 1874. Elwood Cooper of Santa Barbara, California, in 1872 conceived the idea of importing budded trees of Lisbon lemon from Australia. The first shipment was a failure, but a second shipment arrived in good condition in 1874. Some of these trees were sent to Thomas A. Garly, of Los Angeles, who propagated and distributed the variety.

Fruit characters.-Lisbon in general is a heavier yielding tree than the Eureka but it tends to ripen a somewhat larger proportion of its fruit in the winter. The peak of production of the Lisbon lemon in the interior section (Corona, California) is in February, with a secondary peak in May. In the coastal section (Santa Paula, California) the peak of production is in March, with a very minor peak in June. The fruit is lemon yellow in color; surface smooth and even or inconspicuously ribbled, shape ellipsoid to oblong; size medium, diam. 6.0 cm., length 7.8 cm.; base gradually tapering into a short but usually inconspicuous neck which is smooth or slightly lobed or fluted; calyx medium in size, diam. 9 mm., even or slightly depressed; apex gradually round in a usually rather large and prominent nipple; areole an irregular furrow at base of nipple, frequently deeper on one side than the other, forming a characteristic side wrinkle; rind finely pitted, slightly rugose, thin, 4.5 mm. in thickness; oil glands large, globose to obovoid; primary glands necked, surface depressed; flavedo one-third thickness of rind; albedo white; axis small, diam. 5 mm., solid; segments averaged 10 of 10 fruits; pulp tender, fine grained, baryta yellow, vesicles spindle shaped, long, slender; juice abundant, clear, very acid; quality excellent; seeds medium in size, shape ovate, few-none to 10 or more; embryos 1-2; cotyledons white.

C. Grapefruit, *Citrus pasadisi* Macf.

Grapefruit is a species quite closely related to pummelo or shaddock (*Citrus grandis*) The only distinct characters are the fruit, flower, leaf (wing leaf), and the trees are smaller than the pummelo. It originated in the West Indies and may be a hybrid pummelo with sweet orange because a self-pollinated grapefruit seedling grows into an orange-like or a pummelo-like form. Grapefruit is mostly grown in the United States and Puerto Rico. The varieties of grapefruit are classed in two groups-those with a pallid colored pulp, and those with a pink colored pulp.

1. Pallid pulp group, .seedless.

(a) Marsh (seedless).-

The history of the Marsh is somewhat obscure, but the variety apparently originated from a seedling grapefruit grown on the farm of William Hancock at Socrum, near Lakeland, Florida. Hancock purchased the place in 1862 from a Mrs. Rushing, who is credited with having planted the seedling which later became the parent of the Marsh variety. The name "Budded Seedless Grapefruit" was used until C. M. Marsh propagated and distributed the variety under the name **"Marsh's Seedless"** in the catalogue of Lakeland Nurseries in 1894-1895. The Marsh is recognized today as one of the best of the grapefruit varieties. It is widely grown in Florida, Texas, California and Arizona, and also in South Africa, Palestine, Australia, and South America. It was introduced in Formosa and Japan in 1925, along with the Pink Marsh variety; now these two varieties are extensively planted in Formosa.

Fruit characters.-Fruit color Baryta yellow to apricot yellow; surface very smooth and even; shape oblate to globose, symmetrical; size medium to large, diam. 7.7 cm. and length 7.8 cm.; base evenly rounded or slightly collared; basal, usually slightly depressed, sometimes nearly even; calyx medium small, diam. 10 mm., even or slightly depressed; apex rounded or slightly flattened; areole an indistinct circular furrow; areolar area smooth, mainly even; stylar scar medium in size, even or depressed in a small apical pit; rind medium thin, 8 mm., flavedo thickness 2 mm.; oil glands medium in size, primary 1.6 mm. and secondary 0.7 mm. in diameter, obovoid to ellipsoid, necked, surface mainly even, somewhat depressed; albedo light yellowish-white; axis small to medium, diam. 9.6 mm., mainly solid; segments averaged 13; membranes tender; pulp colonial buff, tender, malting; vesicle fusiform, medium in size; juice abundant, highly flavored; seed few, 3 to 8 per fruit, size medium, irregular wedgeshaped to obovoid; inner seed coat cinnamon to orange-cinnamon; chalazal spot snuff brown; harvesting season November to September in California, March to August in Florida, November to February in Formosa.

2. Pink pulp group, seedless.

Pink pulp grapefruit is a sport from the pallid pulp grapefruit. The pink Marsh (Thompson), Red blush (Webb), Ruby and Foster are the varieties. The Thompson is th best in jucie quality.

(a) Thompson Seedling (Pink Marsh).-

The Thompson originated as a bud sport from a tree of typical Marsh growing in the grove of W. B. Thompson, at oneco, Florida. The limb bearing the pink fruits was discovered by S. A. Collins, of Oneco, in 1913 at which time it formed one of the three large main branches of the tree. The variety was named and introduced by Reasoner Brother, of the Royal Palm Nurseries, Oneco, Florida (catalogue for 1924). Another very similar pink-fleshed bud variation of the Marsh was described by A. D. Shamel (1926) as occurring at Riverside, California.

Fruit characters.-Season early to medium, fruit color light yellow to flesh ocher; surface smooth; shape oblate to spherical, symmetrical; size medium, diam. 10 cm., length 10.2 cm.; base evenly rounded or slightly collared; basal area nearly even or slightly depressed, smooth or with slight radiating ribs; calyx medium in size, diam. 13 mm., slightly sunken; apex rounded or somewhat flattened; areole indistinct; aeolar area mainly even, smooth: stylar scar small, slightly depressed; rind medium thin 9.8 mm.; oil glands conspicuous, large, even, depressed in fruit base; flavedo thin 3 mm., not oil soaked; albedo white; core small, width 17 mm., maily solid; segments average 12, pulp tender, color light ochraceous salmon; juice abundant, 42% by fruit weight (pink pulp variety is richer in juice than pallid pulp variety), light buff color, flavor typical grapefruit, quality good to best; seeds average 1.9, inner seed coat cinnamon color.

D. Pummelo or shaddock, *Citrus grandis* **Osbeck.**

The pnmmelo orignated in India and Malaya. Their name for it was Batabi lemboo. It was grown in China from ancient times, around 1100 B. C. The pummelo is very common in Kwangsi, Kwangtung, Formosa, Fukien, Chekiang, Hunan, Szechuan, and produces a superior quality fruit. The best varieties are the Mato-Pei-yu, Wentanyu, Sha tien-yu, and Kao phanne.

1. Lian shan yu (梁山柚) is a variety produced from Wentanyu and grows in Changchow, Fukien. It commonly grows in Lianshan, Szeechuan. It is mostly propagated by grafting and the pummelo is used for stock.

Fruit characters.-Fruit color lemon yellow, oblate, large, diam 18 cm., length

12 cm.; base round, apex slightly depressed, calyx large, surface smooth, oil glands numerous, convex on surface, rind thickness 15 mm., albedo white, segments 20, septa medium thick, core large, loose; pulp greenish yellow, juice greenish lemon yellow, juice sweet, aromatic, slightly bitter; quality good, seeds numerous-contains 150 per fruit; size large, seed shape cuneate, cotyledon white, mono-embryo; harvesting season from November to April in Szechuan, China.

2. **Bon chi yu** (蓬溪柚) is grown in Ho chia pa, Bon chi, Szechuan, China. It is propagated there by using a layering method.

Fruit characters.- Fruit color lemon yellow; obovoid; base round ridged; apex even or slightly depressed; oil gland spherical; rind thickness 2 cm.; albedo white, segments 15; core large 6 cm., hollow; pulp pale reddish; lots of juice, good quality; 120 seeds per fruit, large wedge-shaped seeds, seed coat yellowish white, cotyledons white. Picking season from November to January in Szechuan, China.

E. Sweet orange, *Citrus sinensis* Osbeck.

The sweet orange is native in the Sikkim Mountains in India. There it is called Nagarunga or Nagrunga. The sweet orange was introduced in China in the earliest days of the Chinese Han Dynasty (one century). In Chinese the name for sweet orange is "Cheng", or "Hwangku" and recently the translation for sweet orange is "Tien-cheng" (甜橙).

Cheng (橙) name for sweet orange or sour orange appeard in Shon lin Fu (上林賦), edited by Suma Shong Zu (司馬相如) (179-117 B.C.).

Hwang-kan (黃柑) is a name for sweet orange commonly used in Western China. This name has appeared "Kwang chih (廣志)" edited by Kuo I-Kung (郭義恭) (502-551 A.D.).

Hwang Kuo (黃果) is the colloquial term applied to the sweet orange in Szechuan, Kweichow and Yunnan.

Tien-cheng (甜橙) is a proper translation for sweet orange and Suan cheng (酸橙) for sour orange. It appeared in "Chih-wu Ming shi Tu Kao" (植物名實圖考) (Illustrated Manual of Chinese Plants) by Wu Chi-tsing (吳其濬) 1848 A.D.

The sweet orange culture in China has a long history and the sweet orange is extensively grown at the present time in southern and western China. In was introduced in the Mediterranean regions probably in the second half of the Fifteenth Century through the Genoese trader, as Gallisio (1811, pp. 307-325) asserted, or about 1500 A.D. by the Portuguese navigators returning from India by the newly discovered route around the Cape of Good Hope, as believed by Killer Mann (1916). It is highly probable that the superior varieties of the sweet orange, such as the world now cultivates, were first brought from Southern China by the Portuguese about 1520, shortly after they occupied Macao, near Canton, where very choice varieties of sweet oranges are grown. The sweet orange was widely grown in the early part of the Sixteenth Century. The citrus fruit was introduced by Columbus in 1493 in the Americas from the East Indies. The cultivation of citrus began in Florida about 1565 and in Caifornia about 1769. The oranges mentioned in California literature of 1798 were the beginning of the prosperous industry which has grown until now California leads the world in citrus production.

Sweet orange varieties, according to H. J. Webber (1949) are divided into three groups, the normal fruit group, the navel fruit group, and the blood fruit group.

1. **Normal fruit group.**–The **Jaffa** in Palestine, and the Valencia in California, Florida; South Africa, and Australia, are the commercial varieties belonging to nomal sweet orange group. The Hwangkuo (name of sweet orange in Szechuan), Sekkan (雪柑), Tien chen, Shang sui chen and Cheokan (Tankan in Fukien) are commonly grown in China. The fruit ripening season of the normal sweet orange varieties is quite distinct. They should be divided into early-maturing, Midseason-maturing, and late-maturing varieties.

(a) **Valencia (Valencia Late; Harts Late; Hart's Tardiff).**–

The Valencia orange was first introduced into Califoria by A. B. Chapman and George H. Smith, who in 1876 received an unlabeled package of orange trees from the Thomas Rivers Nursery, Sawbridgeworth, England. Chapman planted and grew these trees on his ranch at San Gabriel. The only variety that prove to be of value was one which Chapman at first called the Rivers Late. A citrus grower from Valencia, Spain identified the variety as one grown in Spain under the name "Naranja tarde de Valencia". Chapman then adopted the name "Valencia Late" by which the variety has come to be generally known, The Valencia was introduced in China in 1908, and is now growing in southern China and Formosa. The author studied Valencia nucellar lines at the Citrus Experiment Station, Rverside, Calfornia, during 1950-51, and found the Olinda, Cutter, Campbell, and Frost young lines to be good nucellar seedling lines in the Valencia.

(1) **Fruit characters.**–The fruit characters of the Valencia are very similar to those of the Sekkan, which is commonly grown in southern China. It is possible the Valencia was derived from the sweet orange of southern China, because the Sekkan ripens in June and is a late variety of the sweet orange. The Valencia is a late variety, ripening from April to October in Carifornia, and from April to June in Frorida and southern China. The fruit color is cadium to capucine yellow, the surface is smooth to pebbled and rough; shape mainly oblong, varying spherically; size of Oinda medium large, diam. 7.2 cm., length 7.2 cm; fruit weight average 222 gm.; base evenly rounded, sometimes with low, inconspicuous collar; collar area mainly almost even, sometimes slightly depressed; rugose or with short radiating furrows; calyx medium in size, diam. 10 mm., mainly even, even, somewhat depressed; sepal obtuse; apex evenly rounded; areole indistinct or a slight circular furrow, stylar scar small, even or slightly depressed; rind; of Olinda line medium thick, average 5.4 mm., oil glands medium to large, nemerous, conspicuous, raised, even and depressed, oil abundant; flavedo one fourth thickness of rind; albedo light

yellowish white; core medium in size, Olinda average 6.2 mm., solid; segments usually 9-10; membrane tender; rag little; pulp orange colored; texture fine, tender; vesicles fusiform, medium in size; juice abundant, 49-54 % of fruit by weight, flavor excellent; waste little; seeds few, average 3.4, medium in size, obovoid to broadly ovate, cotyledons white, polymbryonic, average 4 embryos.

(b) Hwang Kuo (name of sweet organe in Szechuan, China).- This is an old, seedy variety of sweet orange widely grown in Szechuan, China. The author studied this variety in Szechuan during 1938-1942. These trees are mostly seedlings. The general fruit characters of Hwang kuo (the average of twenty-five tree samples, each sample consisting of 30 fruits for weight, length and width measurements, and 10 fruits, for juice and other measurments) are as follows:

(1) Fruits characters.- This variety ripens from December to January in Szechuan, China; it has a fair keeping quality if placed in storage immediately after harvest (will keep from 4 to 5 months); fruit color brilliant orange yellow; fruit shape oblate, average diam. 6.8 cm., length 6.1 cm., weight 192 gm. of Kiang-Tsing samples, and average diam. 7.1 cm., length 6.9 cm.. weight 184 gm. of Kin-Tan samples; apex round, stylar scar distinct, base round and slightly depressed; stem thick; calyx size medium; oil glands on fruit surface numerous, fine, mostly convex, few concave; rind tight, 4-4.5 mm. in thickness; oil gland shape rounded and uniform, yellow in color and fragrant; albedo yellowish-white and soft; segments average 10, uniforn, medium sized, slightly reniform; septa medium thick, tough and colorless; core diam. 9.0-9.5 mm., coarse and hollow; pulp orange yellow; vesicles spindle-shaped, long and plump; quality good to very good, but contains a high number of seeds, average 21 per fruit. The chemical composition of the fruit immediately after harvest is as follows: juice content 49% by weight; citric acid 1.0% per cent; soluble solids 9%; suger 7%; seed oval or cuneate, yellowish-white: cotyledon white, chalaza purple; polyembryonic embryos 2-9 per seed.

2. Navel fruit group.-This group consists of fruits the normally develop navels. The Washington is a leading variety in this group.

(a) Washington (Washington Navel; Riverside Navel; Bahia).-The Washington Navel orange, which was first imported from Brazil in 1870 by the U. S. Department of Agriculture, was sent out from Washington under the name Bahia. It first fruited and first attracted attention at Riverside, California. The Washington apparently originated near Bahia, Brazil, in the early part of the Nineteenth Century. According to the studies of Dorsett, Shamel, and Popenoe, the variety is believed to have been first propagated sometime between 1810 and 1820 by a Portuguese who lived at Cabulla, a suburb of Bahia. Although the mode of its origin is not definitely known, the studies of these authors indicate that it most likely arose from a bud variation of the Brazilian variety known as the **Selecta orange (Laranja selecta)** which has a fruit much resembling the **Washington** and which "frequently shows a marked tendency to produce navel fruits, even though normally without any vestige of a navel." The excellence of the fruit was recognizeed early, about the time that it was introduced in the United States.

Although the Washington Navel had been introduced in the United States several times, it wasn't until William Saunders introduced trees of it in 1870 that this variety was propagated for distribution. In 1873 two budded trees were sent to Mrs. Luther C. Tibbets of Riverside, California, who grew them in her home yerd. It is from these two trees, one of which is still living, that the navel orange industry of California and mainly of the world has developed. The Washington Navel was introduced in Florida in the early part of 1835, and from the United States to Japan in 1880, and from Japan to China in 1920. It is now widely grown in Wakayama, Shiznoka of Japan and Szechuan, Chekiang in China. The Washington navel is especially adapted to growing in szechuan, China.

(1) **Fruit characters.**-Harvesting season January to April in Riverside, December to January in Szechuan, China, and middle citrus region in Japan. Fruit color orange chrome; surface finely rugose, rather coarsely pitted; shape oblong, ovoid, or ellipsoid; size large, diam. 7.8 cm. length 8.5 cm., weight 260 gm.; base evenly rounded to slightly collared; collar area medium depressed, rugose, radially furrowed and lobed; furrow short, commonly extending only through the collar, or slightly beyond; calyx size medium, diam. 15 mm.; apex sometimes evenly rounded, but mainly slightly protruded and broadly nippled; navel medium to large in size, enclosed to broadly open (55% closed), sometimes protruding; areole a furrow at base of protruding nipple or indistinct; areolar area smooth or indistinctly furrowed or lobed radially, commonly raised more or less by enclosed navel; stylar scar usualy disrupted by navel growth, sometimes intact, medium large; rind medium thick, 6.6 mm.; oil glands numerous; rather conspicuous, primary glands (diam. 1.6 mm.) 60 per sq. cm., secondary glands (diam. 0.7 mm.) 44 per sq. cm. on fruit surface, depressed, even or convex; oil quantity moderate to abundant, odor very attractive; flavedo medium thin, one-fourth thickness of rind; albedo light yellowish-white; core medium, diam. 11 mm., solid; segments usually 10-11; septa tender; pulp deep orange colored; texture fine, firm; considerable rag; vesicles medium in size, fusiform; juice medium abundant, very rich and highly flavored; seedless.

(b) **Thomson (Thomson Navel).**-The Thomson is a strain of the Washington and originated as a bud variant from that variety. It was discovered by A. C. Thomson. of Duarte, California, and was named and introduced by him about 1891. The fruit differs markedly from the Washington in having a smoother, lighter-colored rind; in showing fewer and smaller oil glands, with the surface over the secondary and tertiary glands depressed or even, instead of even or convex; and in maturing earlier, For a short period after its introduction it was extensively planted in California. The fruit quality proved to be poor, however. The variety has been grown and tested in Arizona and Florida and in various foreign countries, but it has never been grown commercially except in California. This variety was introduced in Japan in 1902.

(1) **Fruit characters.**–Picking time is from December to March in Riverside. It is earlier than the Washington. Color mikado orange; surface smooth, finely pitted: shape globose to ovoid or ellipsoid; size large, diam. 6.9 cm., length 7.4 cm., average weight 168 gm.; base evenly rounded to a low, usually inconspicuous, but sometimes very pronounced collar; collar area slightly to medium depressed, rugose and radially furrowed, usually with several deep furrows extending through collar to one-fourth or one-third the height of the fruit; calyx medium in size; apex sometimes evenly rounded, but mainly slightly to markedly protruded, nippled or with large open navel; navel medium to large in size, mainly open (70%), sometimes protruding; areole mainly indistinct, sometimes a light circular furrow; areolar area with smooth, glossy rind, less primary but more secondary oil gland (Tables 4), commonly raised more or less into a flat, broad nipple by the enclose navel, sometimes with slight irregular radiating ribs or lobes; stylar scar mainly disrupted by navel growth, even or depressed in a small shallow pit; rind medium to thin, thickness 5.7mm., flavedo thin, one-fourth to one-third thickness of rind; albedo light yellowish-white; core medium in size, diam. 11 mm., solid or semi-hollow; segments average 10, regular; membranes medium tender; pulp light cadmium; texture firm; rag considerable; vesicles fusiform, medium in size, slender; juice medium abundant, cadmium yellow, quality and flavor good; usualy seedless; chemical composition of juice-soluble solids 13%, citric acid 1.1% (sample from Riverside, analyzed in January, 1951; at the same time Washington Navel juice was analyzed and found to contain 11.4% soluble solids, and 1.1% citric acid). Thomson Navel shows earlier maturity.

3. **Blood orange.**–The blood orange is extensively grown is Sicily, but is not important in the United States, Japen or China. The blood orange belongs to the sweet orange group and its special character is the scarlet red juice sacs mixed with pulp.

F. Mandarin and tangerine oranges. (*Citrus reticulata* Blanco)

There are many varieties of loose skinned oranges. They are thin peeled, have small seeds with green cotyledons, embryo, and small solitary flower; the leaf is small, narrow, lanceolate, apex acuminate, wing inconspicuous. H. J. Webber grouped them in a species called *Citrus reticulata*. He divided the varieties into the following: King, Satsuma, Mandarin, Tangerine, Mandarin-lime, and Mitis (six groups). The King, Satsuma, Mandarin and Tangerine are important groups growing in China. King is a common variety in Siam and Cochin China. The Mandarin varieties Ponkan and Suhwikan are delicious oranges growing in southern China. The others, Hwang chieh, Tsao chieh, Mie-chieh, are smaller fruit and commonly grown in Kiangsi and Chekiang provinces in China. Tangerine is a scarlet, loose-peeled orange, very commonly grown in Fukien, Szechuan, and Hunan. There are several varieties of Tangerine. The color of the Tangerine is very attractive.

1. Satsuma.- The Satsuma orange is a chance seedling from Tsaochieh, originating in Wen chow and Hwanggai of Chekiang, China. It was introduced to Japan in the earliest days of the Tang Dynasty (Eighth Centrury) by Japanese monks who studied Buddhism in Tien Tan Mountains near Hwanggai, Chekiang, China. The Wen-chow (溫州) and Hwang-gai (黃岩) are famous citrus growing regions in Chekiang, China. Satsuma orange is the English name for Unshow mikan as it is called in Japan. In this variety the trees are vigorous, heavy-bearing and early-maturing. The fruit is medium sized, seedless.

2. Mandarin-lime, Mitis.-The mandarin-lime and the mitis are not broadly grown in China. The mandarin-lime is called "Canton lemon" and the mitis is called "Su-ki chieh" (ever-bearing mandarin).

3. Tangerine group.-A very superior quality of tangerine is growing in Scechuan and Fukien provinces of China. In Szechuan the tangerine is called "Hong chieh". The author studied the variety selection of tangerine in Szechuan during the years 1938-1942. The following description is obtained from the Hong-chieh in Szechuan.

Fruit characters.-The picking season is from December to January in Szechuan; the color is flame scarlet; shape oblate, uniform; size medium, diam. 7.5 cm., length 5.0 cm., weight 136 gm; apex depressed, stylar scar medium; base slightly depressed, ribed; stem medium thick, calyx small, color green; lobes 5, obtuse; oil glands numerous, fine, flush with surface, somewhat concaved; peel loose, tender, fragrant, thin 2 mm.; flavedo one half thickness of rind; albedo yellowish-white; segments 10, uniform; core loose, diam. 2.7 mm., large; pulp salmon orange, coarse grained, oval, short; juice abundant, 54 per cent in fruit by wt.; color capucine orange, sweet, aromatic, quality best; seeds number 15, small, shape oval with beak, cotyledons green, polyembryonic; juice composition soluble solids 11%, citric acid 0.3%, very sweet. (Samples from Naikiang, Szechuan, China, analyzed in December.)

4. Wenchou (Owari, Owari Satsuma orange).-The Owari Satsuma orange was introduced in 1920 to Chengtu, China. It is very well adapted for growing there. In recent years there is considerable production in Wenchow, Changsha, citrus region in China.

Fruit character.-The fruit from Chengtu, Szechuan, China, matured in early November to December in Chengtu, Szechuan. The color is orange; shape oblate, size diam. 8.4 cm., length 5.5 cm.; base rounded, tapering and ridged; calyx medium to small, green; apex slightly depressed, scarred, somewhat navel marked; oil glands, 120 per sq. cm. on fruit median surface of Satsuma orange, 166 in Tangerine, the latter being higher; peel loose, 2.6 mm. thick; flavedo one-third thickness of rind; albedo yellowish-white, tender; segments 12, uniform; septa thick and tougher than

Hong chieh (Tangerine); core diam. 13 mm., large, loose; pulp orange-yellow, vesicles coarse, spindle-shaped; juice abundant, 49% by wt., orange yellow color, sweet and taste sprightly, quality best; practically seedless, but if tree is growing near a seedy citrus tree, it is influenced by pollination and sometimes produces seeds; 4-5 seeds, in Szechuan-produced fruit, seed small, oval, cotyledons green, polyembryonic; juice composition-soluble Solids 1 %. citric acid 1.6%. There are quite a number of new lines of Satsuma orange being produced from nucellar seedlings and bud sports in the United States and in Japan.

DISCUSSION AND SUMMARY

Many botanists and horticulturalists have classified and described the citrus fruits of the world since earliest times. The literature concerned with citrus taxonomy is classified as before and after Carolus Linnaeus 1707-1778 A. D.

Citrus literature written before Linnaeus:

Theophrastus 370-286 B.C. **Historia plantarum.** In this book are described the citron and lemon. He named citrus fruits "Hesperides" which means fruit of paradise.

Johnnls javianus 1538 A.D. **Jardan Hesperides.** Two volumes.

Manardus 1561 A. D. **De citrus. Aurantus ac Limonus.**

Ferrarius 1584-1633 A.D. **Hesperides** (1646 A.D.)

Volckamer 1708 A.D. **Hesperides.**

Volckamer 1714 A.D. **Hesperides** (continuation).

Citrus literature written after Linnaeus:

G. Gallesio 1772-1839. **Traite du Citrus** 1811 A.D.

The Italian literature described varieties of citron, lemon, sour orange, and sweet orange, and the propagation and history of varieties.

A. Risso 1777-1845 A.D. **Essei sur Historic Historic Natureile des Orangers.** published in 1838.

M. Tenore 1847 A.D. **Sull Aranzio Mandarino.**

O. Penzig 1850-1929. **Studi botanici sugji agrumie sulle affini** (1887).

E. Bonayia 1826-1908 A.D. **Cultivated oranges and lemons of India and Ceylon** (1889 A.D.)

The botanists, C. Linnaeus, P. Osbeck, N. L. Burmann, L. Loureiro, A. von Bunge. B. Hayata, classified and named citrus species and varieties. Recently scientists W. T. Swingle, H. J. Webber, H. B. Frost and A. D. Shamel in the United States and T. Tanaka, Y. Tanaka and the author in Japan and China have done more work of classification and description of citrus and its relatives. The horticulturists paid more attention to fruit quality in citrus varieties.

Authors assert the taxonomic study of citrus fruit is needed in order to put into print a foundation for the study of the relation of fruit variety characters to genetical, physiological and ecological factors and horticultural aspects.

Summary-The author conducted this experiment with material from Riverside, California, and Szechuan, China. The climate and soil condition and topography are quite different. The trees described are for the most part twenty years old. The following conclusions were obtained.

1. **Ripening season.**-The ripening season of citrus fruit differs in different species and varieties and is modified by climate, especially as influenced by sunlight and temperature. The climate of California is favorable to citrus fruit growing and is conducive to a long season. This is a merit point for citrus production, because temperatures are not too high in summer or too low in winter. In Riverside one can pick citrus fruit from the tree the whole year around. The citrus fruit picking season in Szechuan is from November to January, only three months. In southern China the season is from October to May, eight months. The temperatures at which injury to citrus fruits occurs are below-1°C. (30°F.) and above 49°C. (110°F.).

2. **Longevity and yield.**-Longevity and yield are affected by heritage, rootstocks, climate, soils, and methods of orchard management. The author found the annual yield per tree of sweet orange at Riverside to be higher than Szechuan or southern China. The ratio is 2 or 3: 1 for the same tree age. This is caused by different methods of orchard management and climate and the distance between trees in an orchard. The longevity of citrus fruit also differs with genetical, physiological, ecological and pathological aspects. Lots of diseases and insects shorten the life of the citrus tree. The quick decline virus in California and the tree borer (**Melanustra** spp.) in Szechuan are the two most serious problems of citriculture in these two regions.

3. **Yield.**-Yield is influenced by fertilizers (see literature by E. R. parker and W. W. Jones, 1951). E. R. Parker and W. W. Jones carried on long-term fertilizer projects with orange fruits. The yield is affected by various sources of nitrogen-whether or not a cover crop is grown, whether or not a nitrogenous fertilizer is applied; whether or not a phosphate or potash is used; kind and amount of manure used.

4. **Shape and size.**-The shape and size of citrus fruits are affected by heredity, pollination, fertilizers, irrigation and climate.

5. **Weight.**-Weight is affected by fruit pollination, amount of fertilizer used, and method of irrigation.

6. **Rind.**-Rind thickness may be increased by using a high amount of potassium, or being grafted on Rough lemon stock. The color is a genetical character and differs for species and varieties (see author's key to citrus species).

7. **Segments.**-The number of segments is a comparatively stable character, but it can be modified by bud differentiation and the effect of pollination.

8. **Pulp.**-Pulp color and texture are stable characters.

9. **Juice.**-Juice color is a stable character, but juice composition and odor can be

modified by climate, fertilizers and rootstocks.

10. Seeds.-Seedlessness and seedyness are inherited characters. They can be ovule development and pollination effects. Citrus seed formation is influenced to yield, size quality and season of maturity. The author found the seedy sweet orange distributed in the far North, Chen Ku (城固) Shensi Province, latitude 32.40°N., Kin-Tan (金堂) of Szechuan, latitude 31°N. in China, but seedless sweet oranges are produced in southern China in latitude 20°-25° N. The latitude of Riverside is 34° N. and the climate is warm in the winter. In China at a latitude above 30° N. it is cold in the winter because of the influence of the cold Siberian winter wind. The seedy citrus fruit ripens earlier and the tree is hardy. Therefore, a seedy variety is best grown in a low temperature citrus region. The sweet oranges are harvested from December to January, and after picking the fruit is stored, in Szechuan. In California the citrus fruit hang on the tree during the long season and one is able to pick the fruit during four to six months of the year. Therefore, it is not necessary to keep the fruit in storage. The orange, fruit quality is higher in California than the Hwang Kuo growing in Szechuan (table 4). It is caused by the difference in variety climate, kinds of fertilizer, and other methods of orchard management. The long season of sunshiny days and the excellent methods of orchard management are the reasons for California oranges being the best in the world.

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中 文 摘 要

中國四川美國加州柑橘品種性狀之記載與分類 (1)

胡 昌 熾 民國四十年（1951）五月

SOME DESCRIPTIVE AND TAXONOMIC CHARACTERS OF CITRUS FRUITS GROWN AT RIVERSIDE, CARIFORNIA, AND SZECHUAN, CHINA

Chang-chih Hu

May, 1951

(1) 本文係在美國加州大學研究論文之一

研討與結論

多數植物學者與園藝學者曾於甚早時代研究柑橘類之分類與記載，其文獻可分別爲林奈氏（Carolus Linnaeus (Carl von Linné)1707—1778 A.D.）時代之前與後兩部分。

柑橘文獻在林奈氏以前者

Theophrastus 370—286 B. C. Historia plantarum

西氏：(370—286 B.C.) 植物史，記有枸櫞，檸檬稱柑橘爲果實之王。

Johnnls javianus 1538 A.D. jardan Hesperides Two volumes

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Ferrarius 1584—1633 A.D. Hesperides (1646 A.D.)

弗氏：柑橘 (1646 A.D.)

Volckamer 1708 A.D. **Hesperides**

福氏：柑橘 (1708 A.D.)

Volckamer 1714 A.D. **Hesperides** (Contimation)

福氏：柑橘 (續篇) (1714 A.D.)

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朴氏：印度，錫蘭栽培柑橘誌（1889 A.D.）

植物學者林奈氏（C. Linnaeus），歐氏（P. Osbeck），潘氏（N.L. Burmann），洛氏（L. Loureiro），彭氏（A. von Bunge），早田氏（B. Hayata）曾作柑橘之分類與訂名，近代科學者史氏（W. T. Swingle），韋氏（H. J. Webber），佛氏（H. B. Frost）與夏氏（Shamel）在美國與日本田中長三郎氏（T. Tanaka），田中諭一郎（Y. Tanaka）與其他中日學者作柑橘及其同類之分類與記載，園藝學者對於柑橘品種果實之品質尤爲注意。

著者等均認爲柑橘果樹分類之研究實的探討品種果實性狀與遺傳，生理及生態等因子之關係以及園藝性狀之基礎。

結論：著者整理在中國四川及美國加州實驗之材料，兩地方之氣候，土壤，地勢十分不同。記載之材料均以二十年生者爲多。得下列各結論。

1. **熟期**：柑橘之熟期由種類、品種而不同，由氣候而變異，以日照與氣溫之影響爲最有關係。柑橘生產以冬季不冷，夏季不太熱爲重要因素。在美國加州河邊鄉能全年採收柑橘，在中國四川採柑橘主在十月至十二月，可貯藏至五月有八個月之期間。對柑橘果實有害之溫度爲攝氏零度以下（$-1C° = 30°F$）與攝氏49°C（110°F）以上。

2. **樹齡與生產量**：樹齡與生產量受遺傳，根砧，氣候，土壤及果園管理方法等影響而不同。著者實驗測定發現甜橙同樹齡每株每年生產量在加州河邊鄉高於中國之四川及南部，其比例爲 2：1 或 3：1。實因氣候，果園管理方法（繁殖，肥料，病蟲害防治）與栽植距離（加州 $30Ft^2$，四川$20Ft^2$）等之不同所致。柑橘之樹齡亦受遺傳，生理，生態及病害等因素之影響而不同，多種之病害及蟲害均可縮短柑橘之樹齡，柑橘早衰症（毒素病）在加州，天牛在四川是兩種限制樹齡延長的因子。

3. **生產量**：生產量是受肥料之影響，特別爲氮素，（參閱 Parker, E.R. and Joner, W. W. Effects of Fertilizers Upon the Yields, Size and Quality of Orange Fruits. Bull. 722, Calif. Agri. Exp. Sta. 1951）柏氏與龔氏作過橙類久年肥料試驗，其結果用各種氮肥與有或無覆蓋作物，氮肥之有或無，磷肥，鉀肥之用與否及有機肥料種類與不同用量等比較試驗，證明產量是受氮肥給源的影響。

4. **果形與大小**：柑橘果形與大小是受遺傳，授粉，肥料，灌溉及氣候等影響而不

同。

5. 果重：果重受果實之授粉與否，施肥量及灌溉方法等影響而不同。

6. 果皮：果皮厚度因用過量鉀肥或粗皮檸檬為根砧而增厚，果皮色是遺傳性，因種類及品種而不同（參閱著者柑橘種類檢索表 P13）。

7. 瓤囊：瓤囊數是比較固定的形質，但可由花芽分化與授粉影響而變異。

8. 果肉：果肉色與肉質是固定形質。

9. 果汁：果汁色是固定形質，但果汁成分與香氣可因氣候，肥料及根砧種類而不同。

10. 種子：無種子與多種子是遺傳形質，可由胚珠生成與授粉影響而不同。柑橘種子之生成可影響其產量，大小，品質及成熟期。著者發現多種子甜橙分佈於中國較北部陝西城固，緯度為北緯 32.4°N，四川金堂，北緯 31°N。但無種子甜橙產於中國南部北緯 20—25°N 度之間之各地。美國加州河邊鄉緯度為 34°N，冬季是溫暖，在中國北緯 30°N 是寒冷，因受西伯利亞寒流影響。多種子柑橘成熟早而樹性耐寒，因此多種子品種適於生長低溫柑橘區域。甜橙在四川十二月至一月採收，而貯藏果實至五月，在美國加州柑橘在樹上存留季節甚長，一品種可採收四至六個月之久，因此無貯藏柑橘之需要。甜橙品質在加州產者比四川黃果為優良（參閱表4），此實因品種，氣候，肥料種類，果園管理方法等之不同所致。而加州日照季節長與果園管理方法之周全，是加州甜橙優於世界產品的重要理由。

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