第 13 卷 第 2 期 土 壤 学 报 Vol. 13, No. 2
1965 年 6 月 ACTA PEDOLOGICA SINICA June, 1965

草甸棕壤区耕作土壤的层次发育及其肥力特征*

陈恩鳳 周礼愷 武冠云 王淑芳
（中国科学院林业土壤研究所）

自然土壤經人类耕作活动后的变化如何？在土壤剖面上有何反映？对于土壤分类与土壤肥力的影响如何？这些都是土壤研究中十分重要的課題。在土壤分类方面，自然土壤若受人为活动的影响及其所导致的土壤性質的变异大，便应将这类土壤在分类中作較高級的划分；否則，則应作較低級的归类。在土壤肥力方面，不同的耕作方法常引起不同的肥力变化，浅耕主要影响表土，往往形成犁底层；深耕可能影响到心土，甚至底土，能够破除犁底层。它們对作物生育有着很不相同的影响。

本項工作的目的，在于系統地探討深、浅翻情况下土壤的性質变异以及肥力变化，为土壤分类及土壤肥力的研究提供一些基本資料。因为土壤的性質变异以及肥力变化必然会綜合地反映在剖面的层次发育上，所以本項工作是从土壤的层次发育着手的。

就自然土壤及浅耕情况下的耕作土壤而言，其剖面层次可从形态变化的程度来划分，一般在浅耕情况下的耕作土壤除保留原有自然土壤的表土、心土及底土外，往往还具有一分布位置較高的犁底层；而适宜深耕后的土壤，其表土、心土、有时甚至底土常被翻动和混合，再想从形态变化划分剖面层次就感到困难了。这便使我們产生可否根据土壤肥力的动态变化，即土壤营养物質和其他肥力因素的分配、轉化規模及其对于作物的供应情况，来进行层次划分的想法。我們設想，土壤上下层次所受地表生物气候的影响必然有所不同，其中营养物質的轉化規模及速度也迥异，从而对于作物生长有着不同的作用。例如，上部土层受地表生物气候的影响較大，物質轉化較快，比較活动，其肥力水平密切地影响着作物的前期发育；下部土层受地表生物气候的影响較小，物質轉化較慢，比較稳定，其供肥能力对作物的后期发育影响較大。

当然，所述肥力动态变化均存在于所有的土壤中，但在适宜深耕后的土壤里很可能表現得更为突出，因而可以作为耕作土壤层次划分的主要标准。

1960—1962 年，曾在辽宁的沈阳、辽阳及熊岳等地同一土类（草甸棕壤）的浅翻地（处理 1）及深翻地（处理 2）上布置了生物試驗，并对各处理不同土层（0—10、10—20、20—40 及 40—60 厘米）的化学、生物化学及物理学的特性进行了相当大量的研究，所获結果显示了类似的規律性。現将主要部分綜述如下。

（一）土壤中速效磷的变化（見图 1）

土壤中磷的分布，由于移动性較小，显示了甚为清晰的层次分化：0—20 厘米处較高

---

* 参加本工作的，还有党连超同志。

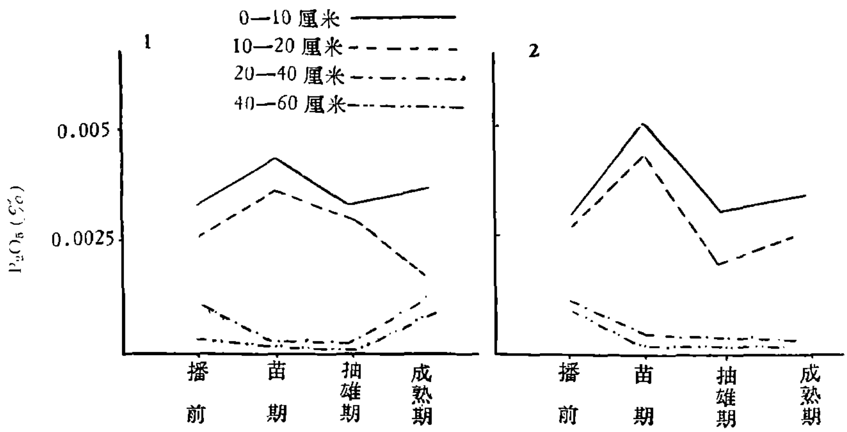


图 1　土壤中速效磷含量的变化 (1962，沈阳，供試作物：玉米)

(其中尤以 0—10 厘米为最高)，20—40 厘米較低，40—60 厘米更低。上层磷量于作物生育盛期有所減少。在未破除犁底层的土壤中，上部土层含磷量的变化曲綫比較平緩。而經适宜深耕后，不仅上部土层的磷量起伏較大，而且下部土层的磷量在作物生育后期因新根較多，吸收較强，而有显著的減少。

(二) 土壤中生物学活性的变化 (見图 2—4)

在所有供試土样中，土壤呼吸強度、轉化酶及脲酶活性均随土层深度而減小，显示了明显的层次分布特征。与未破除犁底层的土壤相比，經适宜深耕后的土壤下部土层均有着較高的生物学活性，且以 20—40 厘米土层增高得最多。

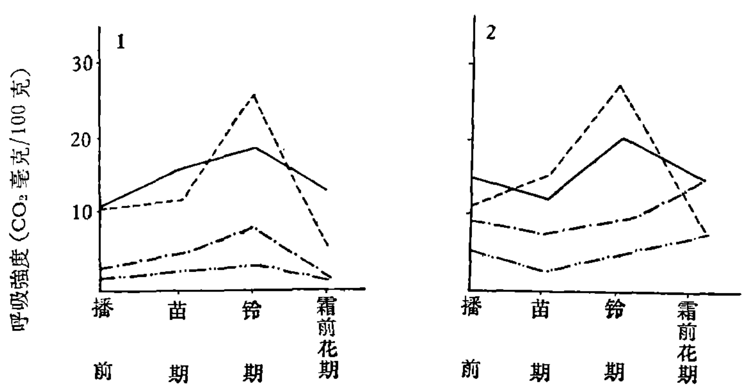


图 2　土壤的呼吸強度 (1962，辽阳，供試作物：棉花)

就土壤生物学活性的变化进程而言，呼吸強度及轉化酶活性系随作物生长而增強，至生育盛期(营养生长与生殖生长盛期)达最大値，而后則趋于減弱。这与栽培作物及有关微生物区系的生命活动情况相符合。

脲酶活性的变化情况与作物的氮素营养規律及土壤氮素的轉化进程間存在着一定的相关性，在作物大量需肥期間，脲酶活性显著增強，而土壤氮素亦減低得最多。在深翻区，下部土层中的脲酶活性于作物生育后期显著增強，土壤氮素的轉化进程有了加速，从而改善了作物的氮素营养。

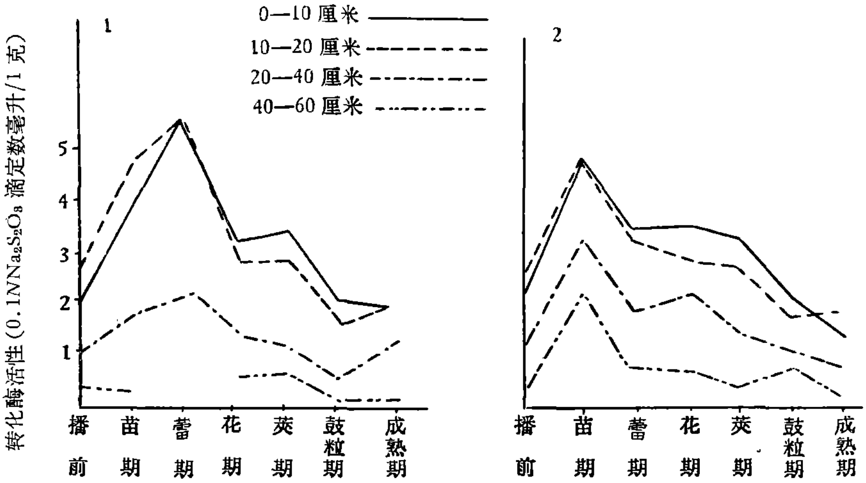


图 3　土壤的转化酶活性（1960，沈阳，供试作物：大豆）

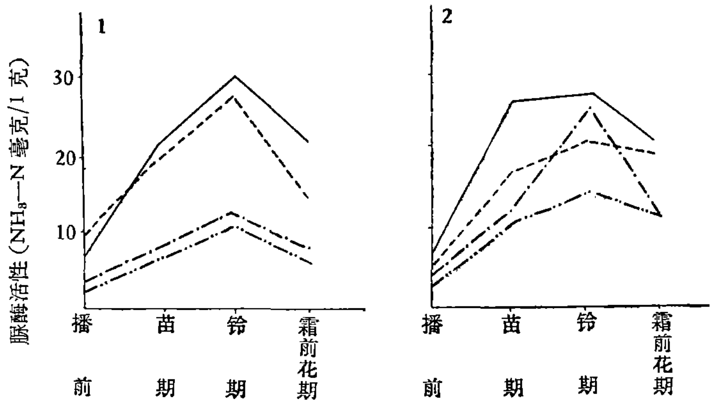


图 4　土壤的脲酶活性（1962，辽阳，供试作物：棉花）

（三）土壤中腐殖质組分的变化

土壤胡敏酸与富啡酸的含量变化見图 5。

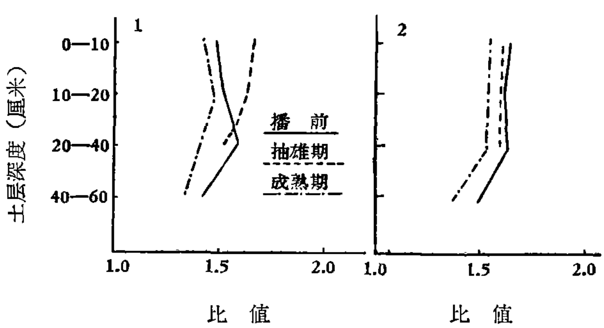


图 5　土壤胡敏酸与富啡酸的比値变化（1962，沈阳，供试作物：玉米）

土壤胡敏酸与富啡酸的比値在浅翻区以 0—20 厘米土层較高，在深翻区則以 20—40 厘米处为最高。至于在各处理的 40—60 厘米土层中，該項数値均較上部土层的为小。深

翻区比浅翻区有着較大的胡敏酸/富啡酸比值。从該比值的变化情况看来，深翻区的表土下部或心土层比較稳定，而浅翻区則变化較大。

（四）作物的生育情况与产量

对大豆生育情况的测定結果（表 1）表明，在适宜深耕的情况下，大豆苗期的根部生

表 1　大豆的生育情况（1960，沈阳）

处理	1					2				
项目 / 生育期	地上部分重/地下部分重	株高/根深	株幅/根幅	根深(主轟,厘米)	根幅(主轟,厘米)	地上部分重/地下部分重	株高/根深	株幅/根幅	根深(主轟,厘米)	根幅(主轟,厘米)
苗期	6.50	0.43	0.36	7.0	6.0	4.90	0.23	0.28	16.0	7.0
蕾期	10.30	0.47	0.50	16.0	12.0	10.70	0.71	0.73	16.5	8.5
花期	1.58	1.19	1.47	32.0	20.0	6.40	1.23	2.37	26.0	18.0
荚期	4.50	1.32	0.67	34.0	32.0	5.30	1.07	0.84	28.0	27.0
产量(公斤/1,000平方米)	197.3±10					220.0±7				

长良好，分布較深較广，而此时地上部分株高及株幅只是适当发育，地上部分与地下部分的重量比例較之浅翻区还低，为后期的发育打下了良好的基础。因而到了蕾期，无論是株高与根深、株幅与根幅，或是地上部分与地下部分重量的比例都迅速提高，超过浅翻区，地上部分生长轉入盛期；而浅翻区的植株可能由于根系在生长中期仍續向縱深发展，直至花期地上部分生长始轉入盛期。

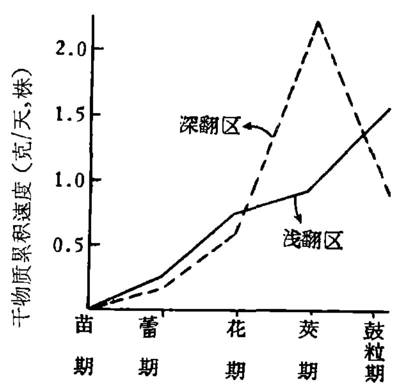


图 6　大豆植株的干物质累积速度（1960，沈阳）

不同耕作方法对于植物生长的影响亦可由植物干物質的累积进程（图 6）得到說明。在深翻区，自花期后有着較大的累积速度，到荚期达到頂峯；而浅翻区的增长速度則較小，直至荚期后仍在継續增长，但为时已嫌过晚，以致影响了最終产量（見表 1）。

所有上述研究結果表明，在不同耕翻深度的影响下，土壤的性質及肥力的变化很不相同。

連年浅耕的土壤常在其剖面上形成了分布位置較高的犁底层，減緩了較深土层中营养物質的轉化进程，降低了該层的生物学活性，从而使得土壤中各种肥力因素的轉化規模及其进程較少适应于作物生育的需要。

經适宜深耕后的土壤則不同，由于上下土层的翻动和混合，在其剖面上形成了一种新的特有层次組合。后者既不同于自然土壤发生发育的 A、B、C 层，也不同于在浅耕条件下形成的耕作土壤的剖面发育层次。按照肥力的动态变化，它可能包括下述的层次：

（1）活动层（0—20 厘米左右）：活动层 a（0—10 厘米左右），受地表气候及农事活动的影响甚大，营养物質的轉化进程較少与作物的需要相适应。活动层 b（10—20 厘米左右），受地表气候及作物根系与有关微生物区系的影响較大，营养物質的轉化較快，对作物

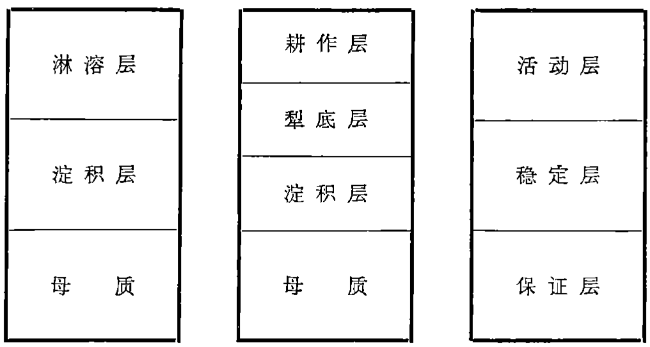
生育前期的水分和养分供应較好，比較活动而欠稳定。

（2）稳定层[1]（20—40 厘米左右）：受地表气候及生物的影响較小，物質轉化較慢，对作物生育后期影响較大，比較稳定而欠活动。

（3）保証层（40 厘米以下）：物質轉化最慢，对所有上部土层的肥力状况具有补足的作用，在通常情况下不需特別处理。

上述层次組合比較适合作物生育的需要，且在适宜深耕后的相当长时期內（在本試驗中如第三年）仍能保持。

綜括上述，我們可用下述图式来表明自然土壤与耕作土壤的不同层次发育特征。



自然土壤　　浅耕情况下的耕作土壤　　经适宜深耕后的耕作土壤

参 考 文 献

[1] 中国科学院西北生物土壤研究所土壤组：关中小麦地深耕调查。土壤通报，6期，6—21 页，1959 年。

[2] Strelkow, I. G. und Andrejewa, N. M.: Die Vertiefung der Acker Krume leichter Böden in Zusammenhang mit deren Kultivierung, Probleme der Fruchbarkeit leichter Böden VEB Deutscher Landwirtschaftsverlag 1961.

[3] Hofman, E.: Die Enzyme im Boden und ihre Bedeutung für seine Biologie und Fruchtbarkeit, Z. Acker- u. Pflanzen-Bau, 100:31—35, 1955.

[4] Дробник, Я.: Изучение биологических превращений органических веществ в почве. Почвоведение, № 12, 62—71, 1957.

[5] Маштаков, С. М., Кулаковская, Т. Н. и Гольдина, С. М.: Активность ферментов и интенсивность дыхания как показатель биологической активности почвы. Докл. АН СССР 98: № 1, 141—144, 1954.

1) 我们称此层为“稳定层”，除因该层的物质转化的进程较为稳定外，还由于它能密切配合表土，保证获得比较稳定的产量。这也说明适宜深耕的必要。

THE HORIZON DEVELOPMENT AND ITS CHARACTERISTICS OF CULTIVATED SOILS IN MEADOW BROWN EARTH REGION

CHEN EN-FANG, CHOW LEE-KAI, WU GUAN-YUIN AND WANG SHU-FANG

(Institute of Forestry and Pedology, Academia Sinica)

SUMMARY

So far as the natural soil and cultivated soil formed under conditions of shallow plowing are concerned, we can distinguish their profile horizons morphologically to a certain extent. But in case the soil is subject to a proper deep plowing, its surface soil, subsoil and sometimes substratum are generally overturned and mixed up, and there will be little possibility for one to distinguish morphologically the profile horizons. This induces us to think whether it would be possible to distinguish the horizons chiefly on the basis of dynamic variations of soil fertility. We are convinced to believe that the influences of bioclimate to the upper and lower layers are certainly diverse, and the transformation progression and rate of nutrient materials in these layers are also widely different, and hence these various layers have their different specific functions for plant growth. Owing to these, the dynamic variations of fertility may be considered to be the prime criterion for the horizon division of the cultivated soils.

In the period of 1960—1962, a number of experiments were conducted on the shallow plowed plot (treatment 1) and deep ploughed plot (treatment 2) of the same soil group (brown meadow soil) in Shengyang, Liaoyang and Shonyue of Liaoning Province, and various kinds of investigations were made relating to the chemical, biochemical and physical properties of various layers (0—10, 10—20, 20—40 and 40—60 cm). The results obtained showed similar characteristic features, and the prime parts described synethetically are as follows:

1. Variations of available phosphorus in soils

The quantitative variations of available phosphorus in soils are shown in Figure 1.*

The distribution of phosphorus in soils, on account of its less mobility, showed very distinct horizon differentiation: its amount was higher in 0—20 cm soil layer (and the highest in 0—10 cm), that in 20—40 cm was lower, and lowest was in 40—60 cm. In soils whose plowsoles were not broken down, it was noted that the quantitative variation curve of phosphorus in upper soil layers was comparatively smooth. But, after a proper deep plowing, it was found that not only the amount of phosphorus in upper layers fluctuated appreciably but also in lower layers due to vigarous growth of new roots and their stronger absorbing ability in the later stage of crop development, the phosphorus content was found to decrease noticeably.

2. Variations of biological activities in soils

The variations of biological activities in soils are shown in Figures 2—4.

In all the soils investigated, respiration intensity and activities of invertase and

* Fig. and tab. see Chinese text.

urease were found to decrease with the depth of soil layer, showing a remarkable characteristics of horizon distribution. Comparing with those soils whose plowsoles were not broken down, it was found that any soil subject to proper deep plowing showed a higher biological activity in the lower layers, where the most vigorous increase was found in 20—40 soil layer.

So far as the variation progression of soil biological activities is concerned, respiration intensity and activity of invertase were found to increase with the growth of crops, up to a maximum at the stage of vigorous growth, and then diminished gradually.

3. Variation of humus components in soils

Quantitative variations of humic and fulvic acid in soils are shown in Figure 5.

Specific value of humic vs. fulvic acid in soils was higher in 0—20 cm layer of the shallow ploughed plots; but in the deep ploughed plots, the highest value was found in 20—40 cm layer. As far the 40—60 cm layer of all plots, this value was lower than that of the upper layers. The deep ploughed plots had a greater specific value of humic vs. fulvic acid and a smaller variation of it than the shallow ploughed plots.

4. Developmental features of crops and their yields

The results of the determination of developmental features of soybean as shown in Table 1 showed that under conditions of proper deep plowing, the growth of roots was normal at the seedling stage, they were found to distribute deeper and broader. But at this time, the hight and width of the plant of the aerial part were found to develop only appreciably. The weight ratio of the aerial vs. underground part was even lower than that in the shallow ploughed plots. All of these established a sound basis for the later growth of plants. Thus, at flower bud stage, the ratio of plant height vs. root depth, width of aerial part vs. that of root area as well as aerial vs. underground part all increased rapidly, exceeding those in the shallow ploughed plots, and the growth of aerial part came to the vigorous stage. As for the plants in the shallow ploughed plots, their roots were still at the middle stage of growth extending continuously into deeper layers. The growth of aerial part did not become vigorous till flowering state.

All the results of the foregoing investigations indicate that, under the influences of various plowing depths, variations of soil property and fertility are widely diverse.

When soil is subject to successive shallow plowing, a plowsole of higher position in always formed in its profile. The presence of the latter slows down the transformation process of nutrient materials in the deeper soil layers and diminishes the biological activities in those places. All these tend to make the transformation scales and their progressions of fertility factors in soils less adaptable to the needs of plant growth.

Different features may be found in case of the soil which has undergone a proper deep plowing. On account of the overturn and mixture of the upper and lower soil layers, a new characteristics horizon combination is formed on its profile. This combination is different both from the genetic horizons A, B and C of the cultivated soils formed under conditions of shallow plowing. According to the dynamic variation of soil fertility, it may consist of the following horizons (scheme see Chinese text):

(1) Active horizon (0—20 ± cm)

Active horizon 1 (0—10 ± cm) is so much influenced by the atmospheric factors and agricultural activities that the transformation progression of the nutrient materials corresponds very little to the needs of crops.

Active horizon 2 (10—20 ± cm) is influenced relatively apparently by the atmospheric factors, crop roots and related micropopulation; the transformation rate of nutrient materials is comparatively fast; it has a better supply of water and nutrient materials for early growth of crops; it is more active but less stable.

(2) Stable horizon (20—40± cm)

Stable horizon is influenced less apprecially by the atmospheric factors and organisms. Living on the surface soils, the transformation rate of materials is relatively slow, it has, however, a more striking influence on the later growth of crops, it is more stable but less active.

(3) Reserve horizon (beneath 40 cm)

Reserve horizon has the slowest transformation rate and the ability to make good and to assure the fertility situations of all upper soil horizons. Under general conditions, it is not necessary to make any treatment.

The horizon combination related above can meet well the requirements of plant growth and last a comparatively long time after proper deep plowing (in our experiment, the third year).