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FARM DEPARTMENT.

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INVESTIGATIONS OF THE ROOT DEVELOPMENT OF
SOME FORAGE PLANTS.

During the many centuries preceding the present time, nearly all investigators of plants have limited their work to the study of the parts which grow above the ground. A few German botanists have studied the branching of the stems of plants so thoroughly that some claim that each genus, and even each species has a characteristic way of branching, and that all forms which belong to one species may be shown to be but variations from the typical form of that species.

The aerial part of plants as can readily be seen, although differing widely in form when all members of the vegetable kingdom are considered, do not vary materially in a certain variety. Winesap apples trees are known by their methods of branching. This regularity of branching is not materially interfered with because there are few obstacles met by the growing tops to cause the tender parts to change their directions of development. It is only in locations where the winds act upon the tender grow-

ing parts of plants that they are caused to grow into forms which depart somewhat from the type of the variety to which they belong.

The German botanist, Sachs, and others working in the same line, have learned that the roots of plants also develop according to distinct types. But, these typical root systems are seen only when proper conditions are provided. The roots, while developing, must be grown in a medium of equal fertility which offers no resistance to the progress of a root, no matter how delicate the growing point may be.

The German investigators whose reports I have read investigated the root systems of seedlings under perfect conditions and determined the forms which were typical of many species of plants.

The development of roots in the field was studied at Geneva, New York by Dr. Sturtevant and Prof. Gaff during the years 1882-87. Dr. Sturtevant says: "The relation between the surface-feeding roots and those that grow deeper than four inches was found to be as 1000 to 1." Lawes and Gilbert, of Rothamstead, England, have done some work in this line also. Prof. Hays, of Minnesota, has pursued the work in Iowa and also in Minnesota. Prof. King, of Wisconsin, has done much in this line in connection with his work in Soil Physics. Prof. Hilgard, of California, has studied the development of roots in connection with his soil investigations for many years.

The various results obtained by investigators whose reports we have read induced us to lay aside all preconceived notions concerning the development of roots and decide that the only way to inform one's self concerning the root system of any plant is to dig and examine both soil and roots.

Prof Goff, who investigated this subject at Geneva, New York, says:

"Botanists tell us that a certain degree of warmth, moisture and oxygen is indispensable to the development of roots, and when these are present, the rapidity of growth and number of branches are dependent upon the amount of available plant food. In the stratum of soil in which the balance of these four conditions is, on the whole, most favorable to root growth, the roots develop fastest. And this is doubtless one law that governs their distribution. "

Sachs tells us that the only part of the root system which

absorbs food is the root hair. These are never found far from the growing points of the roots. They are short-lived—an individual root hair being active only a few days. So, if from any cause, the roots stop growing for any considerable time the plant must suffer materially.

We found a case of this kind while examining the roots of oats near Junction City, Kansas, in May 1895. A severe drought had checked the growth of the oat plants. This was followed by heavy rains, and the oats had begun growing again when we made the examination. Upon digging the plants, all the first root systems were found to be dead, and new secondary roots had been thrown out from the crown of the plants just beneath the surface of the soil. The old systems were regularly developed, and had penetrated the soil to a depth of from 18 to 24 inches. The soil upon which these plants grew was a sandy loam about three inches deep underlaid by a subsoil of jointed yellow clay. In an adjoining field, oats were found to be growing vigorously. Their first rootsystems were alive and healthy. These grew upon a black sandy loam 15 inches deep underlaid by clay, samples of which have been used as moulding clay in a kindergarten school. Roots were traced 30 inches deep.

The primary or seminal roots of corn (the roots which originate at the lower end of the germ) seem to have two uses. 1st, to hold the plant in place, 2nd, to gather food for the use of the plant while the secondary or true feeding roots, are developing. We noticed that these roots seemed to be dead when the secondary roots (those which originate in the stem above the seed) were still vigorous. German investigators have learned that the seminal roots of all monocotyledonous plants die early in the lives of the plants.

Wishing to note whether planting corn at different depths influenced the position of the first whorl of nodal, or secondary, roots with reference to their distance beneath the surface of the soil, corn was planted in pots 1/2, 1, 2, 3, 4, 5, 6 and 7 inches below the surface. After the plants had grown 30 days, all were taken from the pots and examined. It was found that the first whorl of nodal roots originated approximately at the same distance beneath the surface of the soil in all cases.

In April, 1895, several varieties of wheat were examined. All the roots which had grown in the fall were dead. New roots had started from the crowns of some of the plants. Some of the

young roots were 15 inches long. Many of the dead roots had penetrated two feet, and some had spread as far horizontally.

OATS.

May 15th, 1895, I dug beside some oat plants which were growing upon land which had been heavily manured recently. The roots branched very much in the top soil, and when a piece of well rotted manure was entered, it was filled with fibrous roots. In the clay subsoil and unrotted manure, but few branches were formed.

On April 9th, 1896, oat roots were examined. The oats examined had been planted at different times beginning March 1st. The plants grown from the 1st, 8th and 15th of March seedings were equally developed. The soil upon which these oats grew is a thin sandy loam underlaid by a stiff clay subsoil. In some places, the top soil had all blown off leaving the plants growing in clay. The top soil was usually from one to four inches thick, but the clay had been loosened so that there was from six to eight inches of comparatively loose soil for the use of the plants. It was found that the grains that were planted shallow threw out more primary roots than did those planted deeper. It was also noted that all kinds of oat roots grew more nearly straight down in the loose ground than in the compact ground. It was observed that plants from very deeply planted seeds were weak when they appeared.

At a later period when some oat plants were dug up it was found that the part of the plant which is below the surface of the ground and between the seed and the crown of the growing plant was dead and brittle. The same was observed in wheat plants during the fall of 1894.

GRASSES.

In March, 1895 the roots of little blue stem (*Andropogon scoparius*) were traced a depth of eight feet in one place and six feet in another. These plants grew close to a deep ditch. Their position may have enabled the roots to penetrate deeper than they could in a field away from a bank.

Buffalo grass (*Buchloe dactyloides*) was examined where it was found growing on a "hard-pan" spot. There was about a half inch of soil and beneath this, the clay was so hard that a pick-

axe was used to loosen it. At three feet blue shale, or soapstone, was found. There were a few pockets in the shale where the clay extended three inches deeper. The roots of the buffalo grass went to the shale in every case.

TAME GRASSES.

During the latter part of April and first part of May, 1895, a number of tame grasses were examined. The tops were all green by this time, but none were growing rapidly.

Reed canary grass (*Phalaris arundinaceae*) roots formed a dense mat to a depth of two feet. From there they grew thinner until only a few were found at a depth of five feet. Some were traced three feet horizontally.

Tall meadow oat grass (*Festuca elatior*) roots were found mainly in the upper foot of soil. Some were traced four feet and six inches deep. Some roots extended two and a half feet horizontally.

English blue grass (meadow fescue) was found to form a dense mat of roots to a depth of one foot. A few were traced three feet and six inches deep. This grass grew in a meadow with a mixture of grasses, so the horizontal development could not be learned.

The soil upon which these three grasses grew is a moist sandy loam underlaid by a friable clay. Water was found five feet beneath the surface.

Red clover (*Trifolium pratense*) which was one year old was found to have roots penetrating four and one-half feet, and extending one and one-half feet horizontally. It grew on a sandy loam eight inches deep underlaid by a stiff clay subsoil.

A plant of flat pea (*Lathyrus Sylvestris Wagnerii*) was examined July 2nd, 1895. It was planted in the spring of 1894. The soil upon which it grew is like the soil described under red clover. The main root was one inch thick at the surface. It grew straight down, throwing off several branches as it went until it reached a depth of four feet. The longest branch left the main root at twenty inches below the surface and grew aside twelve inches. It then turned straight down and came to an end five and one-half feet below the surface.

ALFALFA.

Alfalfa growing upon a "hard-pan" spot was dug up. The gritty "hard-pan" soil was found at a depth of 16 inches. The

top roots usually threw out many fibrous roots in the upper 12 inches of soil, and branched much after the "hard-pan" was reached. A few were followed 28 inches deep where they were about the size of knitting needles at the place they were abandoned on account of shell rock. In the "hard-pan," the roots were pitted all over by sand grains.

In a moist spot in the same field, a root 5 feet long was taken out whole. Nitrogen gathering root tubercles were found on its fibrous roots at a depth of 5 feet. In another place in the field where the alfalfa was thick, a root was traced 6 feet deep. The soil in which the alfalfa grew best, and where the roots were traced the deepest is a sandy loam 12 inches thick underlaid with a friable clay subsoil.

In both the deep pits, many cylindrical holes were found in the subsoil. At first, they were called worm holes; but later, H. R. Hilton, of Topeka, Kansas, has shown us that air trapped between water in the soil and water sinking into the ground causes such holes as the ones described.

This alfalfa was one year old when examined.

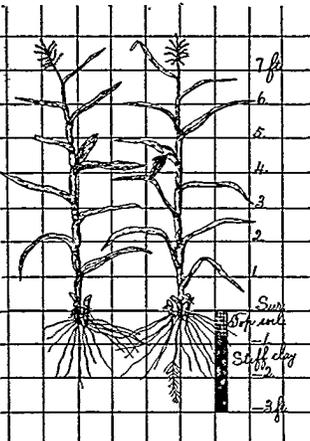
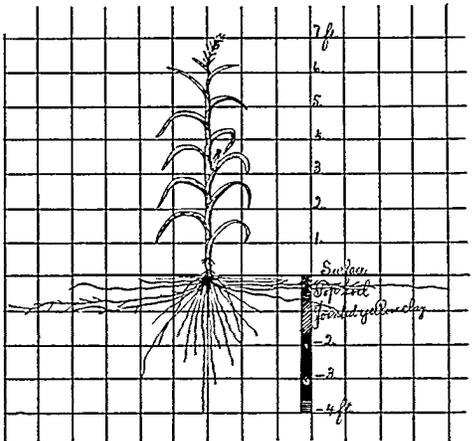
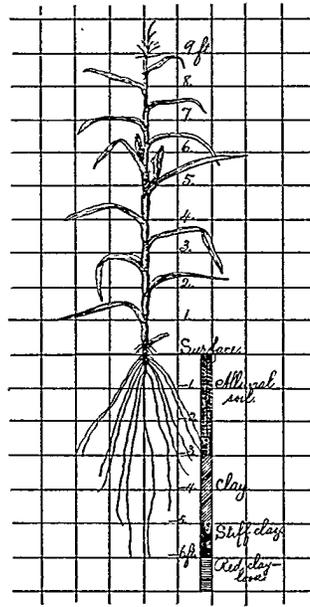
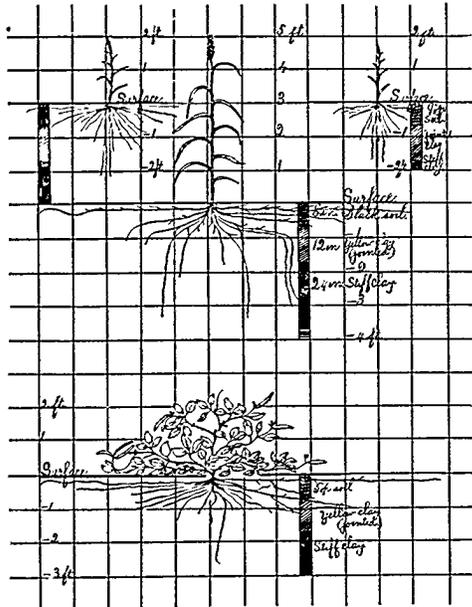
RUSSIAN SUNFLOWER.

June 15th, 1895, several Russian sun-flower plants were dug up. They were growing upon a sandy loam soil about four inches thick which was underlaid by stiff clay. Some roots penetrated two feet deep, but they were few and small at the depth. Some were traced three and one-half feet horizontally. The great mass of feeding roots were found within one foot of the plant, and also in the upper twelve inches of soil. That much they occupied completely—almost filled it. There were no signs of moisture at a depth of 15 inches. Many cracks were found in the subsoil, and the roots were found following them.

SPECIAL PLATS.

As the roots of plants mingle so much in common field culture that it is difficult, if not impossible to follow a long root to its end, a plat of ground was set apart for the culture of a few plants for the purpose of studying their root systems under natural conditions of growth. Small plants were planted in rows five feet apart, and the larger ones were planted in hills eight feet apart each way. The plat was kept clear of weeds and other plants not

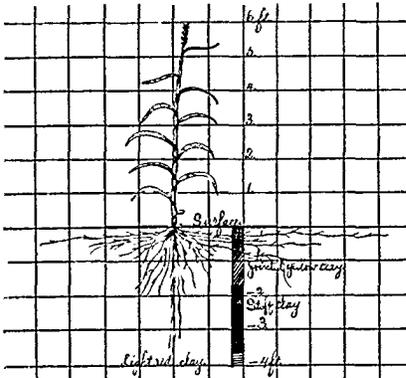
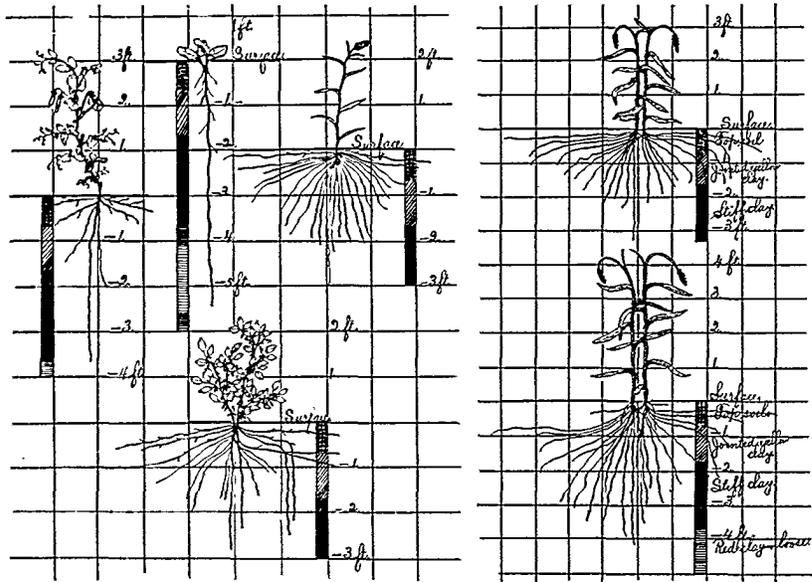
Historical Document
 Kansas Agricultural Experiment Station



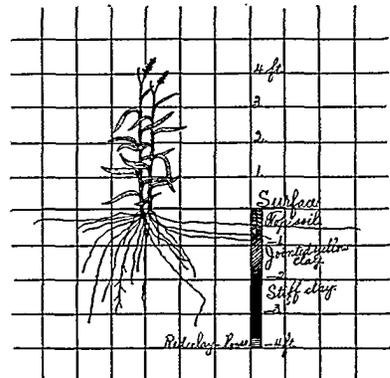
No. 1 Common Millet, African Millet, Hungarian Millet and Black-eyed Cowpea.
 No. 3 Pride of the North.

No. 2
 No. 4

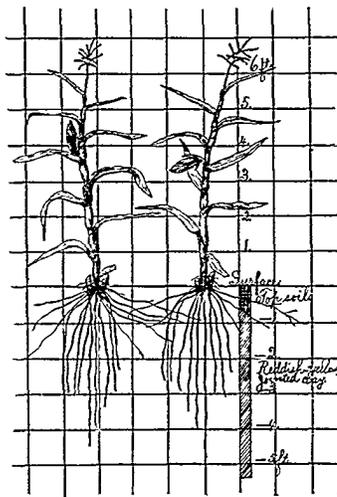
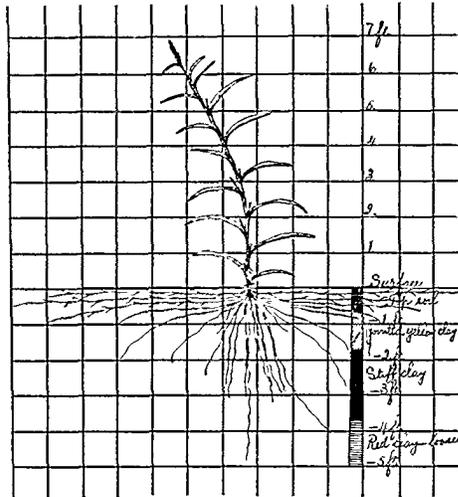
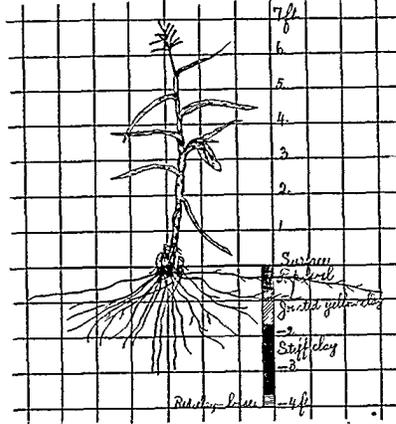
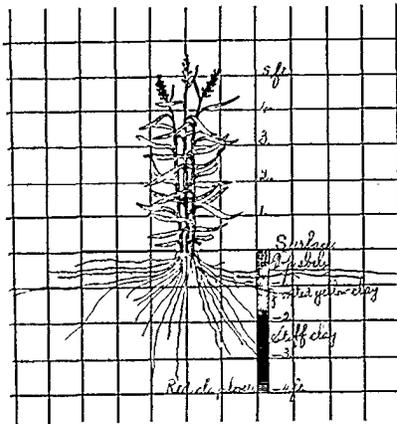
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No. 5 German Millet, *Physalis Lanciolata*, Canada
 Field Pea and Soy Bean.
 No. 7 Sorghum, Kansas Orange.

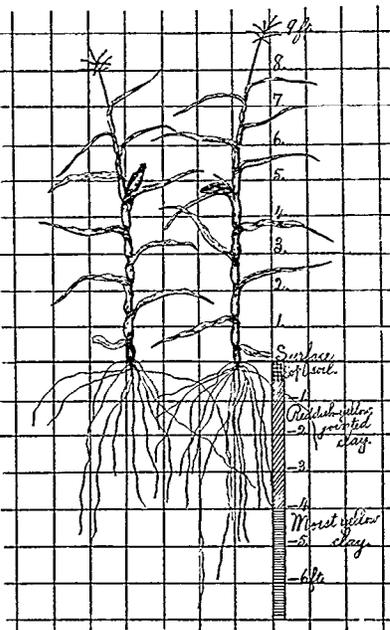
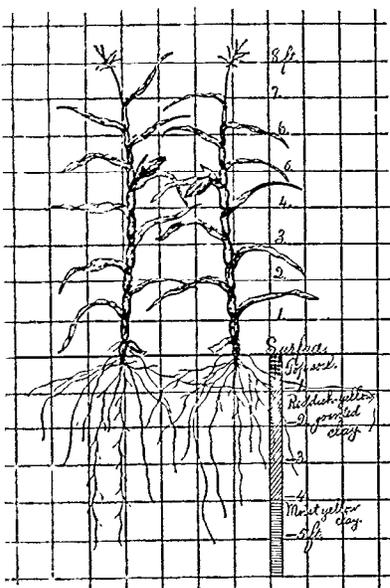
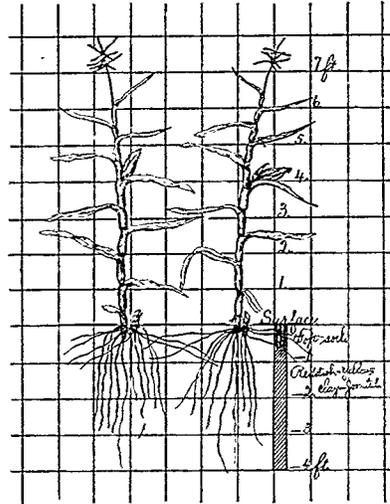
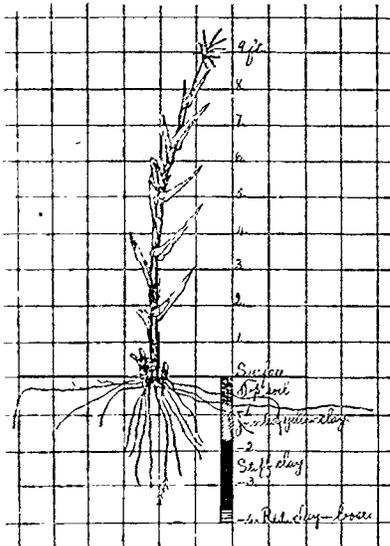


No. 6 Jerusalem Corn and Brown Durra.
 No. 8



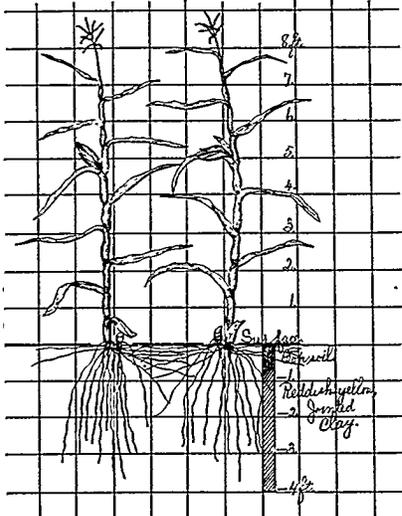
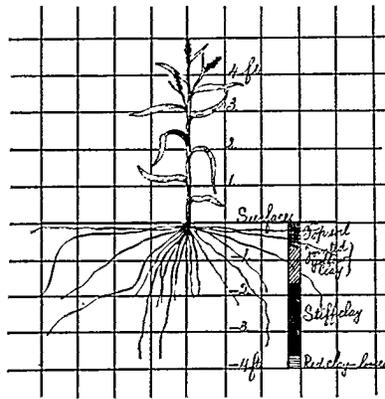
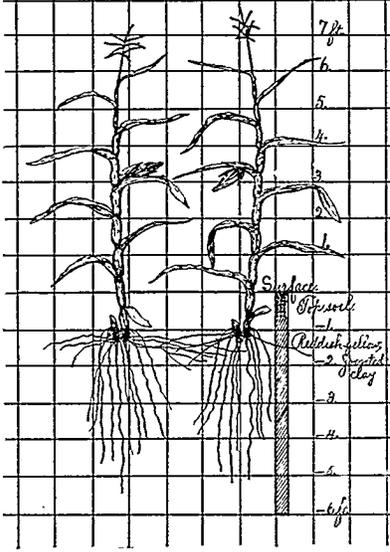
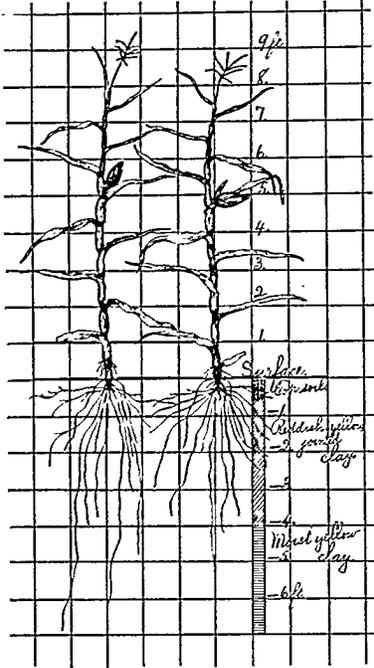
No. 9 Yellow Milo Maize.
 No. 11 Pearl Millet.

No. 10
 No. 12 Listed deep culture.



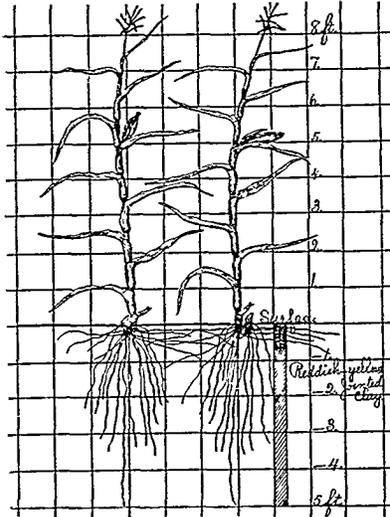
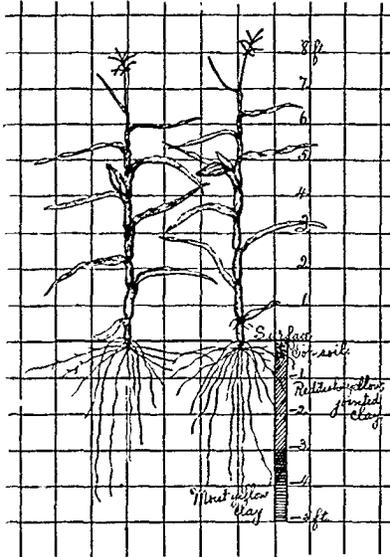
No. 13
 No. 15 Subsoiled '95.

No. 14 Listed, shallow culture.
 No. 16 Planted ordinary way.



No. 17 Subsoiled '94.
 No. 19

No. 18
 No. 20 Surface planted, surface culture.



to be investigated, and was carefully cultivated by hand during the growing season.

Only the horizontal spread and perpendicular penetration of the roots was considered in this work, as it was planned as preliminary to more thorough work. The plants were not dug up until they reached maturity, or were in a condition suitable for fodder.

When a plant was sufficiently developed, a hole was dug about four inches from it. In all cases where the plants were in rows, a foot or more of the row was washed out by a stream of water from a hydrant. A spraying nozzle was used to prevent the breaking of delicate roots. But with the greatest care possible, many roots were broken.

While digging and washing, the positions of the roots washed out were noted. And, when a sufficient number of plants had been washed out, a drawing was made showing the longest lateral roots and also the ones which penetrated deepest, together with such others as were necessary. Do make a cross-section showing the average root system of those washed out in addition to the roots of extreme length

Where the plants were in hills, holes were dug near the hills, and dirt was washed from the roots, as in the other cases. The long horizontal roots were all close to the surface, and were readily washed out by a stream of water. Long roots were followed by washing and digging until the end was found or the root lost. After the washing and digging was completed, drawings were made from what could be seen, and from notes taken during the progress of the work. These drawings represent the longest roots found and also those found in a cross-section from four to six inches thick.

August 8th a row of navy beans were washed out and examined. Some of the roots were traced 34 inches deep, and some lateral roots were traced 36 inches from the plants. Many roots were traced two feet from the row. Nearly all the roots were found in the upper eight inches of soil.

Several peanut plants were examined September 2nd. The deepest root penetrated 30 inches, while the lateral roots were found to be in the upper foot of soil, and from 12 to 20 inches long.

While digging out the peanut plants I found a root of "ground cherry" (Fig. 5) (*Physalis lanceolata*.) It had few fibrous roots, and no branches. It penetrated the soil five and one-half feet.

ILLUSTRATIONS.

In the accompanying cuts the squares represent square feet. The surface of the ground is marked by a line somewhat heavier than the others. The kind of soil upon which the plant grew is represented by sections marked to show the thickness and nature of the various strata.

The root system of the black-eyed cow pea (Fig. 1) grew 7 feet to one side and two feet and ten inches into the soil. The top covered a circle 6 feet in diameter, and was two feet high.

The soy bean (Fig. 5) was 2½ feet high. Its roots penetrated 2 feet and 10 inches, and spread nearly three feet to one side.

The green Canada field pea (Fig. 5) grew 3 feet high. Its top root penetrated 3½ feet, while its horizontal roots were mainly in the upper foot of soil and spread not more than 1½ feet from the plant.

Common millet (Fig. 1) grew 20 inches high, and was quite slender. Its roots penetrated about 20 inches and spread to each side about the same distance.

Hungarian millet (Fig. 1) grew 2 feet high. Its roots spread 28 inches each way and penetrated to about the same depth.

German millet (Fig. 5.) grew 30 inches high. Its roots spread about 34 inches to each side and penetrated to a depth of 36 inches.

African millet, or black-hulled white Kaffir corn, (Fig. 1) grew five feet high, quite strong and unbranched. Its roots penetrated to a depth of 40 inches, and spread about 70 inches horizontally.

Kansas Orange sorghum (Fig. 7) grew 6 feet high. Its roots spread 6 feet horizontally, and grew 3½ feet deep.

Pearl millet, (*Penicillaria spicata*.) (Fig. 11) grew from five to eight feet high in a thick row. Its roots grew 58 inches deep, and 6 feet laterally. All the roots were fine and thread-like. These plants were characterized by bearing abortive ears at nearly every joint on the stem. Brace roots and abortive brace roots were found at remarkable distances from the ground.

Jerusalem corn (Fig. 6) grew 3 feet high. Its roots grew 40 inches deep and a little farther horizontally.

White Milo maize (Fig. 8) grew 4½ feet high and suckered badly. The leaves were still green September 27th. Its roots grew 39 inches deep and the longest side root was 6 feet.

Yellow Milo maize (Fig. 9) was 5½ feet high. Its roots were traced 4 feet deep and 6 feet laterally.

Red Kaffir corn (Fig. 23), grew 5½ feet high. Its roots were traced 4 feet deep and 5 feet laterally.

Brown Durra corn (Fig. 6), grew 4½ feet high, the upper joint forming a "goose-neck." Its roots were traced 4 feet deep and 4 feet laterally.

White Kaffir corn (Fig. 19), grew 5 feet high. Nearly all the stalks branched forming two or more heads. Its roots were traced 4 feet deep and 4 feet to each side of the hill.

The sorghums in the plats had very few brace roots which originated above the ground. The upper whorl of secondary roots usually originated at the surface of the ground.

CORN.

Pride of the North corn (Fig. 3), planted July 7th, spread to one side 7 feet and grew 3½ feet deep. The same variety planted May 16th, developed a root system which penetrated 3 feet deep, and its lateral roots spread only 4 feet on each side. The two hills grew about two rods apart, and were treated alike except as to time of planting. Both bore good ears, and the stalks were about the same height.

A stalk of corn growing in a draw which had been filled in by washing (Fig. 2), grew 10 feet high and bore two good ears. Its roots were traced 6 feet deep. They grew only a short distance laterally.

Mosby's Prolific corn (Fig. 4), grown in a field where stiff clay was found at a depth of 10 inches. This corn was planted with a corn planter, and cultivated deep with a common cultivator. Its deepest roots ended at 2½ feet below the surface. The lateral development of roots could not be traced on account of other roots.

Mosby's Prolific corn grown in a special plat (Fig. 10), developed roots which grew 3 feet deep and 6 feet laterally.

Solomon Valley Mammoth corn (Fig. 13), grew in a special plat. The stalks were 7, 8 and 9 feet high respectively. The ears were medium size. This is a large late variety. Roots were traced 3 feet 8 inches deep and 5½ feet laterally.

Effect of Deep and Shallow Culture on the Position and Development of Roots in Upper Soil.

To investigate this, six plats were examined. The depth to which the roots penetrated was learned by digging holes at the ends of the plats. The distance below the surface at which the roots were found, was discovered by examining the upper soil between the rows in many places in each plat. The stalks on the different plats were much alike, all being tall and slender. The yield of corn was light. In this field, many of the roots grew deeply into the subsoil. The subsoil in which these roots grew allows water to pass through it very readily. All the plats examined were planted to the same variety of corn. The plats which were listed and cultivated deep gave the largest yield. There was but little difference in the depth to which the roots under different treatment penetrated, nearly all the plants examined for depth of root growth sent roots down four feet or more.

In corn which was listed and cultivated deep, (Fig. 12), the roots were nearly eight inches below the surface in the middle between rows. In the plat listed and cultivated shallow, (Fig. 14), the roots were found four inches from the surface in the middles. In corn surface planted and given deep culture, (Fig. 24), the roots were four inches from the surface in the middles. In the plat, which was surface planted and cultivated shallow, (Fig. 22), the roots were found three inches below the surface in the middles. In the plat, which was surface planted and cultivated deep and shallow, (Fig. 18), the roots were five inches below the surface in the middles. In the plat which was surface planted and given surface culture, (Fig. 20), roots were found one inch below the surface in the middles, and in one place fibrous roots mingled with the surface crust.

Effect of Subsoiling upon Root Penetration.

In this investigation, the roots of corn growing upon four plats were examined. One of the plats had been subsoiled in the spring of 1894, and another was subsoiled in the spring of 1895. The other plats were lying next to the subsoiled plats and were merely plowed. They were used as check plats to determine the effect of subsoiling. The soil is a sandy loam underlaid by a jointed clay subsoil.

The corn growing on a plowed plat, (Fig. 18), showed a root penetration of nearly five feet. On a plat which was subsoiled in 1894, the roots, (Fig. 17), were traced 6 feet and 9 inches deep. The longest one struck a hole at a depth of 5 feet and followed it the remainder of the distance. The roots of corn on a plowed plat, (Fig. 16), were traced 6 feet and 9 inches deep. They followed no hole. The roots of corn on the plat which was subsoiled in 1895, (Fig. 15), were traced 5 feet 3 inches deep.

The corn grew 9 to 10 feet high on all three plats. The difference in the yields of subsoiled and plowed plats was slightly in favor of the subsoiled plats.

CONCLUSION.

With all the work done, and also that of other workers in the same line before us, we do not feel justified in drawing any general conclusions; but will content ourselves with making a record of the facts given and reporting progress. We feel that a record of the rainfall, soil temperatures at different depths, sunshine and all meteorological conditions which effect crops should be appended to the foregoing to make it truly valuable to the scientific investigator.

However it is hoped that the work done may serve to induce many to investigate the root development of plants in the soil of their own farms. It is not absolutely necessary to use water in tracing roots. After the hole is dug beside the plant, a sharp pick may be used in the rough work and when following fine roots the point of a pen knife used carefully will answer the purpose. Delicacy of touch will soon be acquired so that very satisfactory work may be done with the simple tools which are in every farmer's hands. Work of this kind greatly adds to one's knowledge of the soils with which he works, and it seems to us that such work will pay the farmer well.