

**MINISTRY OF AGRICULTURAL POLICY
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Poltava State Agrarian Academy

Department of Selection,
Seed Studies and Genetics

**BASICS OF SCIENTIFIC
RESEARCH IN AGRONOMY**

lecture notes of the
students of the Agronomy Faculty of education and qualification
level - "Bachelor"

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INTRODUCTION. BASIC CONCEPTS. FIELD EXPERIMENT AND ITS PECULIARITIES

1. The history of research in agronomy

The history of agronomy and research are inseparable. Agronomic study is probably the most ancient, since the very observation of plants and the conditions for their development laid the foundation for scientific agronomy. But the inception of the agronomic research as such can be referred to the second half of the XVIII century and is associated with the name of one of the agronomy founders A.M. Bolotov.

The first research facility on the territory of the Russian Empire was the experimental field in Horkey (Belarus) which lasted for almost a quarter-century. It was managed by the famous chemist D.I. Mendeleev along with his associate, a well-known scientist-physiologist, K.A. Timiryazev.

The oldest field of research in Ukraine is Poltava which was arranged for work in 1885. The names of such famous scientists as M.I. Vavilov and V.I. Vernadsky are associated with Poltava region. The nature and possibilities of Ukrainian black soil were explored by V.V. Dokuchayev, the founder of genetic soil science as an independent study. A big boost in the experimental case came up back in the days of the Soviet Union. The formation of big RDCs (Research and Development Centres) is related to that particular epoch. In the USSR as long ago as the 80-ies of the previous century there were 225 research institutes, 322 plant-breeding stations, 88 complex stations, 260 substations and experimental fields. In our country during this period there was formed an extremely powerful network of research institutions, among which it stands to mention such establishments as the Institute of Horticulture named after V.Ya.Yuriev, Institute of grain farming, Odessa Institute of selection and genetics, Institute of arable farming and many other specialised scientific institutions. To this end, research structures as well as the work of educational institutions of agricultural profile should be added.

2. Structure and tasks of OSR (Office of Scientific Research)

Scientific laboratory is an elementary structural part of scientific institutions. It can be an integral part of the department, chair, at the production unit, academy of sciences. This type includes fundamental, sectoral, basic research laboratories, and so on.

Substation may comprise scientific laboratories and is a subdivision of the research station, research institute. Depending on the task of this structural unit, it can be permanent or temporary. At the substations they run check-up of the technologies worked out by the research stations in the conditions of agricultural production, provide methodological assistance and determine the economic efficiency of the implementation of new technologies.

Experimental fields are there for stationary field studies on the efficiency of the introduction of new shift of crops, use of fertilisers, means for land erosion control, plant protection products. The experimental fields contribute to the implementation of new cultivating technologies in a specific region.

Scientific departments are an integral part of such institutions as research stations and institutes. In the agronomical field of specialisation they are divided into departments of breeding, plant protection, biotechnology, etc. They also include scientific laboratories.

At *research stations* the results of scientific studies are implemented for the conditions of a specific region.

The prerogative and task of the Research Institute is to solve a complex of problems existing in agriculture, particularly in agronomy. The institutes are responsible for the level of research work, implementation of recommendations in the process of production, test of the economic efficiency of new technologies.

The scientific work of the Research Institute is conducted by UAAS (Ukrainian Academy of Agricultural Sciences).

The main tasks of agronomic science are the following:

- development of the theory and practice for the increase and reproduction of soil fertility;

- development of rational structures of cropland acres and shift of crops;
- creation of new high-yielding varieties and plant hybrids;
- ecological safety of new technologies;
- development of the theory and practice of crop programming;
- development of new methods and techniques of research and increase of their objectiveness.

3. Methods of scientific agronomy

The main methods of agronomic research include laboratory, vegetative, lysimetric and field. The most important thing is the experiment in the field. The field study is the final stage of the research that evaluates the agrotechnical and economic benefit of introducing a new cultivation technology.

Scientific research in agronomy can be theoretical and experimental. In most cases, the exact theoretical solution of a problem in agronomy is impossible, they need to be experimentally substantiated.

The source of theoretical studies is the observation and their generalisation, but as a rule, the experiment is the only reliable way to solve the assigned task, and it confirms the accuracy of the theoretical conclusions.

Observation is the registration of the phenomenon or its quantitative and qualitative aspects, state, characteristics or properties. Agrometeorological, phenological observations, the observation of the state of weed infestation of crops, presence of nutrients in the soil, behaviour of varieties and others are carried out in agronomic practice. In most cases, the systematisation of research and the establishment of interrelationships between phenomena and the object of research allow us to determine a broad picture of the interaction of plants with the environment. But active observation or experiment is much more effective.

The term *study* means the investigation of an object where they artificially create phenomena or change the life conditions of plants up to extreme for better insight into the subject matter of the phenomenon, its origin and cause. The most important feature and peculiarity of the exact experiment is its reproducibility. In

other words, the experimenter can independently reproduce the process, that interests them, regardless of nature. But at the same time research requires a lot of efforts, it has to be carefully planned, contain nothing in excess, and the experiment should completely fit in the imagination of the researcher.

One of the main tasks of the experiment is the quantitative assessment of its variants; in agronomic practice the variant may be variety, fertiliser, plant protection product, agrotechnical method, etc. The variant, which is compared with other variants, is called control or standard. A full set of experimental and control variants draws up a circuit of the experiment. The variants are divided into quantitative and qualitative. The first ones include those variants whose factor gradation is measured in quantitative units, for example, doses of irrigation, depth of soil cultivation, dose of pesticide, and so on. Qualitative variants include exploration of the varieties of plants, methods of irrigation or soil cultivation.

Mainly four types of experiments are used in agronomic practice: laboratory, lysimetric, vegetative and field.

Laboratory experiment is carried out in room conditions or thermostats, boxes, climatic chambers, where it is possible to accurately install temperature and moisture regimes, lighting and other factors. Laboratory methods allow solving many problems, particularly in seeding, they set the energy of germination and the similarity of seeds.

Vegetative experiment is run in vegetative houses, greenhouses, growing rooms, phytotrons. The essential condition of the vegetative experiment is the presence of a plant. Vegetative experiments are conducted in order to establish a quantitative evaluation of the factors and their interaction with plants. Depending on the substrate, they distinguish soil, sand, gravel, sterile cultures.

Lysimetric experiment is carried out in the field in lysimeters where the soil is insulated all round from the surrounding soil. The main constructional condition of the lysimeter is a device which makes it possible to determine the water percolation. Lysimetric experiments are used in agriculture, land-clearing,

agrometeorology, physiology to figure out the water balance, transpiration coefficient, etc.

Field experiment is conducted directly in the field and it is the most valuable and most objective in terms of agronomy.

4. Requirements for the field experiment.

Field experiment is the most difficult in terms of a large number of factors affecting plants. The value of the field experiment depends on certain methodological requirements:

- 1) typical nature of the experiment (representativeness) – the compliance of the conditions of its conduct with the natural and agronomic conditions of a region;
- 2) observance of the principle of a single difference;
- 3) conduct of the experiment on a specially selected area;
- 4) harvest record keeping and reliability of the experiment.

When designing field experiments, it is necessary to follow the unity of all the conditions, except for that one which is being studied.

Field research must be carried out on an area which is history-aware. Otherwise, its results may turn out to be false and contain incorrect data.

Harvest record keeping and its qualities are the final stage of any experiment. At this stage, it is especially important to follow the established methods of harvest record keeping in order to maintain the reliability of the experiment. In the contrary case, it will lose its credibility despite the compliance with the three preceding principles.

While conducting the research one can face three types of errors:

- 1) random errors – those that arise under the influence of many factors that are not kept in the experiment and whose operation can often not be established separately;
- 2) systematic errors – caused by systematic variations in the soil fertility, the direction of the slope, etc., the characteristic feature of these errors is

they either overestimate or underestimate the results of the experiment. On the contrary from random errors, such errors are not mutually repaid and bend the general picture of the experiment;

3) gross errors – caused by negligence of the researcher and should not be allowed during the experiment.

It is important to note that the presence of errors in the experiment cannot be restrained by any methods of mathematical processing or modeling.

SPECIAL FEATURES OF THE FIELD RESEARCH PRACTICE

1. Peculiarities of the field experimental conditions

One of the most important features of the field experiment is a strong dissimilarity and variation of the surrounding factors: year-wise meteorological conditions, heterogeneity of soil fertility.

The great dependence of crops and effects of the variants on meteorological factors requires special attention while evaluating the results of the experiment. Therefore, it is often necessary to use the results of one-year observations. In this case, the final conclusions should be formulated being based on the results of at least three-year data.

The peculiarities of variations in soil fertility are studied by methods of *reconnaissance crops*. It is a close-growing crop of a culture that precedes the layout of the experiment. Crop record keeping is held by fractional method. Empirical practice means that fractional areas differ in yield.

The general feature of the variability of soil fertility is that random and systematic variations are present on the experimental site. The random variation always fluctuates around a certain average number, so it is statistically insignificant. The regular variation, by contrast, has a strong impact on the results of the experiment. The natural variability of soil fertility depends on the relief of the experimental field, culture, plot area. The regular variation reaches 70% of the total variation. It is not limited by an increase of the plot area, and therefore the

size of the plot cannot be reduced. In order to avoid the influence of the natural variation of soil fertility, they use the method of randomisation.

2. Requirements for the land plot and its preparation for the experiment

The first requirement for the test plot is its typical or representative nature, i.e. its properties, relief and soil fertility should respond to the zone or region where it is planned to implement the research results. The second requirement is the homogeneity of the soil covering which ensures high accuracy of the results. To choose a test plot it is necessary to study its history, the relief and micro-relief, typical vegetation and a number of other accidental factors.

The history of the test plot plays an extremely important role. Three to four years before the layout of the experiment, one should grow the same crop at the test plot, use a single fertiliser scheme, soil cultivation, etc. The treatment of chalking, introduction of organic matter, deepening of the arable layer, etc. must also be the same. This requirement is especially important for industrial research. It is desirable for the researcher to independently conduct the analysis of history of the test plot.

When choosing a test plot, random factors should be taken into consideration. In particular, one should not place the experiments closer than 50-100 m from residential buildings or solid wood; not less than 30 m from separate trees and 20 m from solid fences and roads.

Traces of excavation works, old roads, places for storage of organic matter, remain of buildings or livestock units are not allowed on the test plot because they have a long-term impact.

After studying the history of the test plot, they investigate its soil covering in order to establish its typical nature. For this purpose, they use a soil map or conduct a soil study. Sometimes they run reconnaissance crops.

The relief of the test plot should also be typical of the given area as well as of the culture. An equal area or one with an angle of not more than 1-2 m per 100

m is preferred. If the test plot has a large slope angle, then the number of variations should be small, and the repetition of the experiment should be placed at different levels of the slope on the plots stretched along the slope. The micro-relief is especially important to take into account while setting up irrigation experiments and, if necessary, one should level the surface.

3. Preparation and study of the test plot

For a more detailed study of soil fertility, reconnaissance crops are used. Test sowing is used in the production conditions. This is a close-growing crop of any culture that is produced on the entire plot area for greater leveling of soil fertility. It differs from the usual crops by agrotechnical measures being held at the highest level. With the help of leveling crops, they achieve for several years a decrease in the variability of fertility that arose as a result of the application of various agrotechnical techniques on the parts of the test plot.

Given the low quality of agrotechnical works, the effect of leveling crops is not significant.

The leveling crop cannot dampen the impact of such agronomic measures as chalking, introduction of the organic matter, phosphate fertilisers and deepening of the arable layer. That is why the main task of such crops is to reduce the variability caused by minor factors and the weed management.

A simple estimation of plant leveling in the test sowing is the most important indicator of the suitability of the plot for the experiment.

In the case of designing the experiments with perennial cultures, fractional crop yields are used. The data from previous studies of multi-year cultures are used to plan the optimal structure of the experiment and statistically equalise the factors not studied in this procedure.

CLASSIFICATION AND USE OF AGRONOMIC RESEARCH

1. Types of field experiments

There are two main groups of field experiments: ones on the study of agrotechnical practices, and others on variety testing. The first group of experiments investigates various agrotechnical techniques: means of soil cultivation, norms and methods of irrigation, fertilisation and other operations, both individually and as a whole. On the basis of experiments on variety testing, the zonation of heavy yielder high-quality products of varieties and plant hybrids is carried out.

Depending on the number of factors being studied, experiments are divided into one-factor and multi-factor. Depending on the scale of soil and climatic conditions, experiments are divided into single and mass (geographic). Experiments are also divided into short-term, multi-year and long-term standing upon the duration of their conduct, and on those built-in on the experimental fields or production conditions depending on the location.

2. Experiments according to their location

Experiments in scientific institutions are divided into:

- small-plot research (conducted on experimental fields with an area of 10 m²);
- laboratory-field research (area 11-50 m²)
- field research (area 50-200 m² and more);

Experiments in production are divided into:

- experimental tests (at the productive crops there are allocated strips with the width of the aggregate capture, the length of the experimental area is 5-10 times bigger than its width);
- exact comparative experiments (the area width is a multiple width of aggregates with the total area of the plot 500-2000 m);
- research on the effectiveness of new agromeasures such as control strips whose width corresponds to that of the harvesting unit, and the length goes along with that of the rages having the total area up to three hectares.
- demonstration research, area 200-400 m²;
- production research held on the whole area of the shift of crops.

3. Experiments according to the geographical scope of scientific institutions

Geographic (mass) experiments are conducted in different soil and climatic zones according to a single methodology developed by the scientific center. Scientific centers coordinate the research, generalise their results and give recommendations for implementation.

Individual experiments are also run in different soil and climatic zones but without a single methodology and scheme.

4. Division of field experiments according to their duration

- Reconnaissance (temporary) experiments are conducted within 1-2 years in order to detect the impact of agro-measures or varieties.
- Short-term experiments (lasting for 3 years) are held for writing a thesis or candidate's dissertation. Such a period is sufficient to establish the influence of any agronomic reception.
- Multi-year experiments, lasting for 11-50 years, are run in-person at the scientific research institutions or educational establishments. The main task of these experiments is to study the effects, interaction and aftereffects of agrotechnical methods, being systematically carried out, on soil fertility and product quality.
- Long-term experiments are conducted in separate research establishments of certain soil and climatic zones. They are indispensable in the study of processes taking place in agrocoenosis, calculations of losses of the fertiliser elements, scales of environmental pollution. The results of these experiments often have a contradictory character, but they notably point to new directions of the scientific research.

These experiments are also essential for solving fundamental issues and complex study as well as for demonstration purposes. In Ukraine the oldest long-term research is the rye monocrop which was built-in on Poltava research station in 1885.

5. Use of experiments to solve specific problems

Small-plot experiments are used to study areas of nutrition, seed rates, new agents, fertiliser doses, growth stimulants. As a rule, it is more appropriate to test such experiments being new, yet to be common deficient products. In such experiments the side ratio of areas should be: 1×2 , 1×4 , 2×2 , 2×4 , 2×5 m. The smaller the area of the test plot is, the bigger the replication of the experiment must be, but not more than 8.

The results of small-plot experiments are verified in the *laboratory-field* practice. In addition to field research, they conduct analyses of plants, soil for the establishment of plant interactions and the environment. The replication of experiments is 5-6-fold.

Experimental trials are used in production to improve the technology of growing field crops. The best variants of these experiments are verified in exact comparative experiments. The field mechanisation must be provided in such experiments best of all, where the number of variants is 3-4 with the same replication.

Experiments to record the economic efficiency of new technologies are used to check the recommendations of research institutions. Another purpose of these experiments is to improve the recommendations in specific production conditions. In the field, where the experiment is taking place, 3-4 strips are allocated in different places. They are a control where the field fertility is being investigated, and new technology is not applied to them. By each control strip they allocate a research one. A new technology is applied to them and the rest of the field. The dimensions of the control and test strips as well as their number must be the same. Harvesting from the field starts first of all on the control strips, then on the experimental lanes and finally on the field. The effectiveness of the practice is determined by comparing labour charges and the cost of additional products.

Demonstration experiments are used in promulgation of new technologies. The scheme of the experiment differs by certain organisational moments, namely, a detailed description of the variants and their content, aesthetically designed stands

and labels, roads made for the movement of large groups of people. Farms, conducting demonstration experiments, hold seminars with specialists from other institutions and research workers.

Production experiments differ from the previous ones by their complexity. Technology systems are estimated in them in production conditions. Such experiments are carried out on the work team terrain or entire farms.

6. Experiments on variety testing.

There are two types of variety testing: the station one and state variety tests. The station test is run by research institutions, its purpose is to identify the best variants and prepare them for the state variety testing. State variety tests are carried out on strain test plots. Its goal is to objectively evaluate the material transmitted.

Variety test stages are the following:

- advanced test is carried out in collection crops under the reduced program. Its task is to discover the best varieties and referrals to the primary variety test;
- initial variety test whose program is the same as at the strain test plots. In this case, the best forms are selected for competitive trial;
- competitive variety test is carried out by virtue of the expanded program for 2-3 years. The material in it is investigated according to the whole complex of economically valuable factors: yield, resistance to the conditions of cultivation, quality of the harvest;
- industrial variety test is carried out to estimate the suitability of new varieties and hybrids to mass crops.

State variety tests are carried out according to a single method approved by the State Commission for Variety Testing and Protection of Varieties.

BASIC ELEMENTS OF THE FIELD STUDY METHODS

1. Variants of field experiment and their number

Any factor being a subject of study can be a variant of the field experiment. The number of variants is determined by the tasks of the experiment and its content, it does not affect the typical nature of the experiment, but can significantly affect the error. With the number of variants increasing (more than 12-16) the experiment's error increases as well, its area grows and organisational difficulties arise. Thus, the number of variants in the experiment should not exceed the above figure. If the number of variants is too small, then the experiment's error will also increase, and to avoid this, one needs to augment the replication.

2. Replication and repetition of the experiment

Replication of the experiment in the territory is the number of cognominal plots of each variant, replication in time is the number of years of observation. Territorial replication captures better the variations of the experiment of all the variability of the test plot, which allows to improve the accuracy of the experiment. Replication in time makes it possible to study the influence of factors irrespective of age conditions. Quite often, both time replication and replication in the experiment are used simultaneously. Particularly, the experiment's error decreases with 4-6-fold replication.

Repetition means a part of the test plot which has a full set of variations. It is particularly effective to implement the repetition, given that full repetitions are located on variegated fertility fields, but within the repetition the soil fertility is more or less homogeneous.

6-8-fold replication is more appropriate to use in experiments with small plots. A higher replication is used while studying microfertilisers, growth stimulants, and the like. Multi-factor experiments are best carried out in 2-3-fold replication.

Experiments can be arranged by the method of organised repetitions (a full set of variants placed densely) and by the method of unorganised repetitions or full randomisation. The last method is used when there is no need to control the logical variation of experimental conditions in small experiments on well-leveled areas.

There are two ways of placing repetitions: solid and scattered. If the area where it would be possible to locate the whole experiment (for example, on the slopes) is absent, the second method is used. This method is also used in the study of soil erosion.

3. Influence of the area, direction and shape of the plot on the accuracy of the experiment

The plot area can significantly affect the accuracy of the experiment. It is experimentally confirmed that the accuracy of the experiment increases to an area of about 100 m², but then it decreases. Together with the area of the test plot, the total area of the experiment increases, which makes it difficult to fit on a plot with homogeneous soil fertility. The size of the plot for different types of the field experiment depends on its objective, culture, variegated soil fertility and agricultural technology. Thereby, one should take into account the possibility of maximum mechanisation of the field work.

When determining the size of the plot, one must take into consideration the peculiarities of culture, width of spacings, etc. The more plants are sown on a square meter, the smaller the area of the test plot can be. In small-seeded crops, the plot area can be found in the range of 20 ... 25 m², cereals – 40 ... 60 m², in arable crops – 50 ... 100m².

But the increase in the size of the plot on the variegated fertility soil leads to the decrease in the accuracy of the experiment. Therefore, in such cases, it is appropriate to increase the replication of the experiment. Experimental practice has set the size of the plot – 50 ... 100 m², but it is clear that in experiments with fruit crops it can significantly differ from 100 m².

The plot of the experimental area is divided into general and accounting. The total area, in addition to the accounting one, includes borders. They exist to reduce the impact of neighbouring variants, especially in experiments with fertilisers, herbicides. The width of the side strips varies from 0.5-1.5 m to 2-3 m. Borders are not pledged in breeding crops.

The direction of the plot plays an important role in the objectivity of the experiment. The longer side of the plot should coincide with the direction of variation of the soil fertility. When there is a wood line, the area is placed straight across it.

The shape of the plot can be:

- square (with 1:1 aspect ratio); such plots are used in experiments with harsh chemicals when the wind can carry them to the neighbouring areas;
- rectangular (with 1:10 aspect ratio); they are used most often.
- elongated (1: 11 and more).

The effect of elongation is the highest with 1:10-1:15 aspect ratio. Lengthened areas are more rational to use on the slopes. They are oriented along the slope to capture the variegated soil more fully. But the essential disadvantage of these plots is their large perimeter.

The width of the plot should be planned with a multiple width of the capture of the machines' tools and installations.

PLANNING FIELD EXPERIENCE AS WELL AS OBSERVATIONS AND RECORDS

1. Planning the field experiment

The experiment was first planned by R. Fischer, the author of the method of dispersion analysis. Planning involves several steps:

- the choice of the topic, formulation of the task and definition of the object of research;
- analysis of the state of covering the issue;
- formulation of the working hypothesis;
- development of the scheme and methodology of the experiment.

Factor gradation is its dose.

The step of an experiment is called the difference between two gradations. Both the gradation and step of the experiment need to be selected very carefully. If

the experimental step is too large, then there is a risk of losing the maximum point. If the step is too small, it will lead to a significant increase in the area of the experiment, which can significantly affect its accuracy.

The parameter of the experiment is the reaction of an object to a factor or factors. Parameters may be yield or any other economically valuable features. The main requirements for the parameters are their measurability and physical content. Requirements for the factor are the following:

- must be regulated (doses of the preparation, irrigation rules, depth of sowing, etc.);
- the factor must be measured with a fairly high accuracy;
- a combination of several factors;
- factors must not depend on each other.

The experiment should be modeled mathematically, so that a particular method of statistical analysis could be used to process its results.

2. One-factor and multi-factor field experiments.

One-factor experiments. The variants of this experiment may differ quantitatively if the norms and doses of preparations or depth of the soil cultivation are studied, and qualitatively when the varieties or methods of irrigation, soil cultivation are compared. A typical cultivation technology is taken as a control, or the last can be absolute (only natural background).

When planning multi-factor experiments, they arrange full factorial designs and incomplete factorial designs. FFE (full factorial experiment) includes all the combinations of factors and gradations. The number of variants of the experiment is determined by the formula M^n , where M stands for the number of gradations and n means the number of factors.

FFE has advantages over the one-factor experiment:

- 1) the data of the experiment will show the influence of each factor under the conditions of another;
- 2) practical recommendations will be more reliable;

3) if the factors do not interact, each of them is evaluated separately.

Even a three-factor experiment is difficult to locate geographically since, as can be seen from the formula, at least three gradations will already have 9 variants, but if one applies even a 3-fold replication, then the number of plots will equal 27. Therefore, incomplete factorial schemes are arranged.

3. Multi-factor stationary experiments

At the first stage of planning such experiments they develop its complete scheme, and on the second one the method of deployment in space and time is worked out. Such experiments are used when working with perennial crops or while estimating shift of crops, fertiliser systems or soil cultivation.

4. Planning the experiment technique

Depending on the purpose of the experiment it is necessary to consider the form, size, direction of placement of the plot, replication, system of location of repetitions. It must be considered that all work, and especially harvesting and output yield records, should be carried out in short time. When placing the experiment, one should follow the rule: the areas with a long side should be located in the direction in which the soil fertility changes. The exception is only provided by experiments on the study of soil erosion.

5. Planning observations and records

When planning a research, it is necessary to consider the following points:

- 1) which observations, records and analyses are included in the program; there is no need to include all observations in the program; the focus is the main requirement;
- 2) to set the terms of observation which depend on the purpose of research and technical possibilities;
- 3) to establish the optimal volume of samples;
- 4) to ensure the representativeness of samples.

PLACEMENT OF VARIANTS IN THE FIELD EXPERIMENT

1. Classification of methods of the variants' placement

There are three main groups of methods of the variants' placement in the experiment: standard, systematic and randomised. The standard method is characterised by more frequent control placement. If a standard is placed through a single plot, then this method is called the iambic method, if through the two plots – the dactyl method. The standard methods are based on the fact that the fertility of the test plot is changing gradually and there is a correlation dependence between the crops of the nearest plots. Each variant is compared to its control. Standard methods of placement have significant disadvantages:

- 1) there is not always a significant correlation dependence between the crops of neighbouring plots;
- 2) it is difficult to compare variants far removed from each other;
- 3) are very bulky and do not rationally use land.

In the systematic placement the order of the following variants in each repetition is determined by a certain scheme (sequential or checkrow). The easiest scheme is the sequential placement of plots in one row. The advantage of the systematic method is its simplicity, and the disadvantage is often unpredictable distortion of effects by variants. Therefore, it is more appropriate to use these methods in previous research, demonstration experiments and in studies with optional statistical data processing.

2. The effectiveness of systematic and randomised placement of the experimental variants.

Randomised placement of the variants was proposed by R. A. Fischer. It contributes to a better inclusion by each variant of all the variability of soil fertility. The effectiveness of the systematic placement of variants is about 50%, while that of the randomised one is about 96%.

3. Randomised methods of the variants' placement

The easiest randomisation is blind draw that is made for each individual repetition.

The method of unorganised repetitions (full randomisation) is effective at a small number of variants (2-4) when they do not control the local variation of soil fertility, while working with perennial fruit crops when the test plot is small in area. But with an increase in the number of variants, it is necessary to use the method of organised repetitions; by this method, in each repetition, variants are placed randomly in plots. It is important to have the same soil fertility within each repetition. The plots of each repetition are placed in one or two layers. Sometimes repetitions can have an irregular stepped form.

Most researchers believe that with this type of placement one should not have more than 15-20 variants. If the number of variants is more than 8-10, it is more appropriate to introduce one more control area for each repetition.

Latin square and latin rectangle. The latin square method lets eliminate the systematic change in soil fertility in two perpendicular directions. The plot is divided into horisontal and vertical direction on as many rows and columns as many variants are there in the experiment. Both each row and each column have a full set of variants. The shape of the plot should be close to a square, the number of variants should be equal to the number of repetitions. Variants in columns and rows should be placed randomly on a random number table. The disadvantage of the latin square is the equality of the number of repetitions and variants. So, with a large number of variants the experiment takes too much place. In such cases, they use the latin rectangle method. The number of variants should be a multiple of the number of repetitions. The variants by plots are placed in the same way as in the latin square.

The method of split plots is used for laying out multi-factor experiments. The method is used when it is necessary to obtain precise information in relation to a factor, and the other factors do not require high accuracy. This method is also used in cases where it is possible to combine entire groups of factors. In the split

plot method, the area of one experiment is used as blocks of another. It means they split into areas of the second order, and those, in their turn, split into the third order, etc. The variants are placed by the method of randomisation. The areas of the first order are randomised in each repetition, and areas of smaller orders take their place in the areas of larger orders.

Blending. The method of split plots has one serious disadvantage: in multivariate experiments, the interaction of higher orders is evaluated more precisely than the interaction of the lower ones. The blending method allows to avoid it.

ESTABLISHMENT AND OPERATION OF THE FIELD EXPERIMENT

- 1. The test plot layout.**
- 2. Field work on the test plot.**
- 3. Crops record keeping.**
- 4. Primary processing of the results of the experiment.**

The most important condition for obtaining exact experimental data is compliance with all the technical rules, as technical errors that may occur at any stage cannot be corrected by any statistical processing.

Before laying out the test, the experimental plot should be thoroughly investigated and studied. After that, a schematic image of the experiment is worked out specifying the exact size of the whole experiment, the number of repetitions, etc., it is extremely important for the area of repetitions and plots to strictly correspond to the established size, all the plots should be of the same length and width, have a rectangular shape.

1. Before going out into the field, one should prepare the alidade, tape-measure, cord, range-poles, reference marks.

The plot layout begins with the application of the overall contour of the experiment and repetitions. The experiment should be placed so that it is surrounded by borders at least 5 m wide on all sides. One should have such

accuracy of the placement that the inconsistency for every 100 m is no more than 5-10 cm.

The contour detection of the experiment is as follows. On the longer side they lay off the line, retreat 5-10 m from the field boundary and hammer a fid. Then they measure the desired distance following the line and they put the second fid. They put perpendiculars in deferred points and measure the width of the test plot. If the straight corners were put over correctly, then the opposite sides will be equal. If they are not equal, then the work must be repeated. After they lay out the total area into repetitions and plots using a tape-measure and fids. On the fids they indicate the numbers of plots.

It is obligatory to provide a border of at least 5 m for the whole test plot, 1-1,5 m next to each plot, 2-3 m between adjacent plots. For short-term experiments on the study of planting terms and methods, the width of the border can be 0.5 - 0.75 m.

The borders around the plots are not allocated in the experiments on variety testing, although this is wrong, as the strong-grown varieties can impede the weak-grown ones.

2. The most important rule is the simultaneity of work. This is the strongest requirement. Even a time break of 6-8 hours leads to the distortion of the results of the experiment. If this violation is regular, then the reliability of the experiment is completely lost. Consequently, simultaneity, the same quality of completion and short-term fieldwork are the most important condition of this aspect. The agrotechnical background at the test plot should be optimal for the manifestation of the factor being studied. It is inadmissible to study nitrogen fertilisers in the area where organic fertiliser, rich in nitrogen, was introduced as the main fertiliser if its effect is not studied in the experiment.

The main requirement for the introduction of fertilisers is uniformity. Organic fertilisers are obligatory introduced on the plots on a sampling basis, they must be uniform in their composition, origin, moisture, and the like. It is

unacceptable to leave organic fertilisers in heaps for more than 1 day on the test plots.

Mineral fertilisers should also be sifted and ground. Mechanised fertiliser application is only possible on plots of elongated shape with the area of at least 500 square meters. If one adds a mixture of fertilisers, then it should be well blended and homogeneous. When having manual dissemination, fertilisers are brought in packages or boxes and are equally distributed on all plots, then they check the correctness of the layout. They are dispersed so that there is a residue that can always be equally distributed, and if the fertiliser is lacking on any part of the plot, then it is considered to be spoilt. It is desirable to introduce mineral fertilisers in calm weather.

Soil cultivation should also be uniform, qualitative and simultaneous as it is not itself an investigated factor. Plowing and other techniques should be carried out through all the plots perpendicular to their longer side. Ribs and crowns are inadmissible and should be placed on borders. Quite often these works are carried out in one direction with a free running backward.

When sowing, serious attention should be paid to the quality of the sowing material, the technique of sowing or planting. It is necessary to be held in one day. The seed rate is set by the number of similar seeds. The difference in sowing of 4-6 hours sometimes leads to the difference of 1-2 centners / ha. Therefore, in the case of solid sowing, it can be carried out perpendicularly to the placement of the plot. Sowing aggregates are activated at the distance of 1.5 m before the start of the plot and are switched off once the plot is left. Shutdowns are unacceptable. Arable crops should be placed with an entire number of rows and an equal number of plants.

Crop tending is not different from that of production, and the requirements for it are the same as for the previous work. Special works include weeding of tracks, field end trimming. They trace the record and protective parts of the plot. At the end of the plot, they make borders of 2-5 m, despite the border

being around the whole experiment. The width of the tracks should be 20-30 cm in the cultures of solid planting, sometimes it is made by blanking off one coulter.

In the experiments on variety testing, where the influence of variants on each other is not significant, they do not allocate side borders but replace them with paths. Extremely wide tracks can remarkably affect the result of the experiment, in addition, they overgrow with weeds.

3. The plots are seen over a few days before picking up, exclusion is made if needed. The harvest from the borders is collected earlier. The reasons for the exclusion are: damage to crops caused by nature, cattle, rodents, errors in the layout and operation of the experiment. If more than half of the area is damaged, then it is excluded completely. But in any case, exclusions and defects are not desirable since they distort the results of the experiment. The working mode of the harvesting unit is very important, its downtime between the collecting of adjacent plots.

The crop is necessarily converted to standard moisture and 100% purity, for which a medium sample of at least 1 kg is selected.

$$X = \frac{Y(100 - B)(100 - C)}{(100 - B_1) \times 100} \quad \text{where:}$$

X – grain yield at 14% moisture, Y – yield without moisture adjustment, B – grain moisture during weighing, B¹ – standard moisture, C – content of impurities.

If they are hand-picked, then wooden labels are attached to each bundle, which indicate the experiment, variety, variant, plot numbers and repetition, the number of bundles from the plot. Once the bundles are dried, they are immediately threshed out.

The corn crop is converted by the formula:

$$X = UP \times (100 - V): 8600 \quad \text{where:}$$

X – grain yield at 14% moisture, U – yield of cabbage in full maturity and wax ripeness, P – grain yield from the cabbage harvest (%), V – actual grain moisture,

8600 – coefficient of conversion of the cabbage harvest to grain yield at 14% moisture.

They keep record of the crop yield by a continuous method, weighing directly in the field. If there is a big content of impurities, then it is necessary to take samples of 10-15 kg to determine the amount of adherent soil. These same samples can also be used for qualitative evaluation of the crop.

After threshing the baskets of the sunflower, they take its samples of 300 g in separate bags to determine the moisture and content of impurities. The crop yield is rendered up to 12% purity and 100% moisture according to the same formula as for cereals.

The harvest of perennial grasses is carried out by a continuous method. They weigh either green mass or hay. The crop yield is rendered up to 16% moisture:

$$X = Y (100-B): 84$$

While corn is being estimated on silage, it is weighed immediately. To specify the percent of leaves, stems, corncobs, they take 10-20 plants and decompose them on these components.

It was established that in the potato and sugar beet crops, the loss of sporadic plants long before harvesting increases the productivity of the neighbouring ones by 20-50%. Therefore, different methods of correction are used. The corrections are not carried out at 4% loss, they take place at 4-20% loss and the whole plot is rejected at more than 20% loss. The most reliable method of correction is to calculate empty places and remove adjacent plants. The marginal plants are not removed near empty places if they appeared before harvesting. The actual area is calculated by the formula:

$$S = (R-N) P,$$

where R – the estimated number of plants per plot, N – number of missing plants, P – the feeding area of one plant.

Along with homogeneous loss, it is supposed that half the area of empty places is used by neighbouring plants and compensated by their higher yields. Therefore, part of the fallen plants is also included in the calculation:

$$y = \frac{AR}{R - 0,5N},$$

where A – the actual harvest from the plot, R – the estimated number of plants per plot, N – the number of absent plants.

Another way is the following:

$$Y = (A + Rx) / 2;$$

Where x – the average actual weight of one plant.

5. Components of data processing:

- agronomic analysis of data processing;
- primary digital processing;
- statistical evaluation of the experiment data.

The agronomic analysis involves the comparison of the actual method of holding experiments to the one, defined by the requirements, a critical review of the data on yield, the release of data from various inaccuracies. Experiments with a major violation of methods and errors are not of value and cannot serve to present the results of the experiment. Therefore, they are rejected.

Primary digital processing of the field experiment data includes:

- records from the plot for the harvest of 1 ha;
- reduction to standard moisture;
- the yield table compiling – the determination of the yields of variants, repetitions, total amount, the definition of average yield.

When compiling this table, they use a principle that the great bulk of numbers should be three-digit. If any of the plots falls out of the records, then the most likely yield is calculated.

If it is necessary to compare cultures different in commercial yield (fibre, grain, root crops), then they are transformed into price reference, feed units, and the like. For example, one can evaluate the shift of crops in this way.

In each number it is necessary to take so many significant digits to make the last sign doubtful.

Rules for rounding digits: if the figure being dropped is less than 5, then the last saved figure does not change; if before rounding, the significant figure is followed by 5, then the last figure is increased by 1 if it is unmatched, and stays the same if it is equal to 0 or matched.

Statistical processing should be conducted adequately to the operated experiment, and despite the PC being there, it should be deeply understood by the researcher.

DOCUMENTATION AND REPORTING IN SCIENTIFIC AND RESEARCH WORK

Primary documentation: a diary of the experiment and a journal. It also includes work-books, laboratory journals, records, recorder tapes.

A diary is a copybook that should be portable: it must have a dense cover and small sizes. However, its volume should enclose all information during the research. In the case of multi-year research, it is necessary to keep several diaries – one for each year. To avoid losses in the diary, the researcher's contact information is indicated in it. The data of the observations, works, records and analyses carried out are diarised in chronological order. At the same time they indicate the equipment and quality of work. Extreme factors as episodes and pests are compulsory to be fixed. Sketches and photos can also be used in the diary. It is necessary to photograph determining the variants and scale. Records encoding is allowed in the diary, but there should be the access to information for other users.

Diary form:

General information about the experiment

Topic

Name, purpose and tasks of the experiment

Year of the layout and location

Project coordinator and responsible performer

Scheme of the experiment

The program and methodology of basic research – observation, records, analyses

Approving authority, methodology and experimental scheme

The plan of the experimental layout in kind

The area of the test plot

The area of the record plot

Replication

The total number of plots in the experiment

The area of the experiment

History of the test plot

Soil, relief and micro-relief, slope direction.

Estimation of the test plot: the method of keeping records, the coefficients of variation, the experimental error.

Agrochemical characteristics of the soil before the experimental layout

Notes are taken with a simple pencil or a ball pen. If one makes corrections, the last must specify a person, time and reason of application.

The journal of the experiment is filled in on the basis of the diary with a presentation of data for each run analysis or vegetation period. The journal

contains the working hypothesis, topic and section of the research, year of the layout and operation of the experiment, approving authority of the experiment methodology, the research program, the scheme and plan of the experiment. The size of the experiment, repetitions, plots, borders, the placement of vegetation pots in the field experiment as well as orientation in space are indicated on the plan.

For the field experiments they indicate the history of the plot and soil characteristics: type, subtype, depth of the arable layer, soil profile, mechanical composition, agrochemical properties of the soil, forecrop, fertiliser system.

General information gives a description of the seed grain or planting material, time limits and quality of sowing or planting. The journal also reveals preliminary results, experimental conditions and agrotechnical operations.

Be sure to specify:

- a list of works on the layout and operation of the experiment from picking up the forecrop to harvesting;
- results of all the analyses, observations and experiments;
- results of the harvest records;
- results of statistical processing of the experimental outcomes;
- preliminary conclusions.

Each experiment has its own journal prepared. There are also several journals in the long-term experiments. Corrections in journals are not allowed. If it is needed to correct the inaccuracies so far, then they are crossed out and the rights are written down. Corrections should be grounded and signed by the performer and project coordinator. The same thing goes for additions.

Important documentation. The final step is to write a report or scientific paper in the form of an article or dissertation. This document provides production recommendations. The report is prepared according to the requirements of the state standard which determines the structure and rules of execution.

Report requirements:

- clarity and logic of the material presentation;
- vigour of the argumentation;

- shortness and accuracy of the wording;
- justification of the recommendations.

The research report should include:

- cover sheet;
- list of performers;
- summary;
- content;
- a list of basic terms, symbols, units of measurement;
- introduction;
- the experimental part;
- conclusions;
- a list of sources;
- appendix.

In the introduction they indicate the state of covering the problem and the argumentation of research, initial data, relevance, novelty, topic relation to other research works. The purpose of the experiment is also indicated in it.

One should compare the received information with similar results of other works, estimate the completeness of the problem solution and reliability of the results.

FIELD RESEARCH ON SOIL DEFENSE

The complexity of the problem of studying erosion lies in the degree and nature of the flow of erosion processes that vary greatly by the volume and intensity of water runoff, wind speed, meteorological conditions. Therefore, the study should be conducted within 6-8 years. Another problem is the placement of experiments on large areas. This allows to get objective information about the process, avoiding the influence of border effects and adjacent variants.

1. Experiments on soil protection against water erosion. The most accurate indicators of the intensity of erosion processes are the loss of water and soil in the runoff and outwash. To determine them, they create runoff plots equipped with special measuring devices. This is a small catchment – a slope, isolated by metal or wooden sides. The most common are runoff plots with ground ridges 25-30 cm high, 50-60 cm wide below and 20-25 cm wide above. Such ridges do not interfere with the carrying out of agrotechnical measures and after work they are renewed. At the bottom of the runoff plot they install a metal catch water tray. It can also be made of wood or other material. From the tray, the water flow enters through the pipe into the measuring tank. The runoff plots are equipped in autumn on the experimental variants. The size and number of runoff plots depends on the purpose of the experiment, extent of the slope, technical capabilities. Sometimes they are placed in several rows to establish the differentiation of the washout on different sections of the slope.

Equipment, observation, records of the washed material require significant material and labour costs, therefore their quantity is limited to 12-16, and they are located in contrast variants in two replications. A two-fold replication of the observation of liquid and solid material allows to use various methods of statistic analysis: dispersion and correlation. The dimensions of runoff plots are 100-150m × 10-20m. The long side is oriented along the slope towards the main slope lines. The minimum area of runoff plots should be at least 1000 square meters. A compulsory requirement is soil processing across the slope with the turn of aggregates on the borders 8-10 m wide. It is also necessary to make 4-5 meter side borders. Thus, to run studies on water erosion, the area of the plot should be about 2000 square meters. Therefore, it is extremely important to properly plan the experiment and technically equip it.

The plot is selected on one-way slope. Depending on the purpose of the experiment, the plot can be located along the whole length of the slope or on its most characteristic part. The total area of the experiment should correspond to the

experimental capabilities of the experimenter, since it is necessary to ensure the high quality of agrotechnical measures. The optimal size is 4-6 hectares.

Repetitions are placed in a solid or scattered way (if there are areas with deep draws or steep slopes). The optimal number of variants is 4-5 with a randomised repetition. In order to give the correct recommendations for production, the research should be conducted with such differentiation which would allow to fully estimate the action and interaction of antierosion measures. Therefore, the experiment establishment is carried out using the split plot method with the randomised placement of variants.

The replication of the experiments should be 3-4-fold. If the number of variants is big, then the repetition can be dual. If, in addition to the study of erosion processes, there are studies run on the effects of fertilisers or other factors, then two-factor experiment is carried out. The background variants are put in 2-3-fold replication, and variants of the second order are laid in 4-6-fold one.

An important aspect is the study of storm runoffs. They are either experimenting with natural shower rains or simulating them using rainwater systems that can form droplets with a diameter of 3-4 mm and a drop height of 3-4 m. When artificially sprinkled, the size of the plots is usually 0.5-50 m.

The action of rain drops is determined using Ellison's cups. These are metal cylinders with a diameter of 77 mm and a height of 50 mm with a metal lath attached to their bottom. On the runoff plots the weight of the washed-out soil is determined by the formula:

$$M = \frac{O \cdot M_1}{O_1},$$

where O – the volume of soil and water in the vessel, M^1 – the mass of dry soil in the vessel, O^1 – the volume of the sample taken for filtration

The intensity of soil loss is measured with the help of studs, where the millimeter divisions are marked off.

2. Experiments on soil protection from wind erosion. In the study of wind erosion, the characteristic features of experiments are the following:

- stationary and duration (6-8 years and more);
- bigger area of plots;
- orientation of experiments along, and sowing across the prevailing winds.

The area and shape of the plots should prevent border effects. In practice, the area of experiments ranges from 500 square meters to 1 hectare, and in production it equals 0,5-2ha. The shape of the plot is rectangular with a ratio of 1: 4 or square. The width of the plot is not less than 30 m. If there is a wood line, then the plot is oriented perpendicularly to it, or at a distance not less than 20 times the height of plantations. One-factor experiments are laid in 5-6-fold replication in a randomised way, and for the previous and exploratory crops, the replication should be 2-3-fold. One-factor experiments as well as 2-3 factor ones are placed by the method of randomised repetitions. Multi-factor experiments are laid by split plot method in 3-4-fold replication. In order to minimise the influence of other factors, the plots are placed by methods of the latin square and latin rectangle.

Harvest records are carried out on a universal basis, the selective method is inadmissible.

It is necessary to take into account the short terms of carrying out agrotechnical measures, so if there is no need, one should not increase the area of the plot.

3. Experiments on fields protected by wood lines. The peculiarity of space between strips is zoning of the action of wood lines on the wind strength and speed:

1. The windward zone is 10 times the height of the wood line and occupies the space from the edge of the strip to the edge of the snow plume.
2. Central zone has 10-15-fold height.
3. The windward zone does not exceed 5 times the height of the strip.

4. The control area occupies the space between the central and windward areas. It is allocated in fields where the distance between wood lines is 30-35 height.

Along with the zoning of the space between strips, they have the wind speed, moisture, air and soil temperature correlated. Therefore, it is necessary to evaluate the crop differentiated for each zone. The area and shape of the plot are set according to the methodology, taking into account the characteristics of the variation of the soil fertility, the purpose and the task of the experiment. Replication is 4-6-fold. The method of randomised repetitions: each plot that covers all the zones is divided into subplots. All the observations and records are conducted in each zone. One should take into consideration that the tith of the soil and the ripeness of harvest are also differentiated zonally.

The width of borders is 8-10 m.

The simplest design of a collecting gutter is a long drawer which is dug in so that its edges are located at the surface level of the soil. Its long side is orientated across the prevailing winds. The amount of blowland is determined by the formula:

$$X = 10A / P,$$

where A – the mass of soil in the collecting gutter, P – the cross-sectional area of the collecting gutter.

The easiest method is rod-shaped when the wire rods are applied to the ground with the help of markers.

EXPERIMENTS ON FERTILISER USE

1. Schemes of experiments. The efficiency of the fertilisers utilisation can be investigated in several directions: the action of individual elements of mineral nutrition in different ratios for crop, fertiliser systems, the timing and methods of fertiliser distribution. A recommended fertiliser rate in a certain zone is taken as being a control. The general scheme of the experiment may take the following form:

1. recommended norm
2. $\frac{1}{2}$ recommended norm
3. $\frac{3}{4}$
4. $\frac{5}{4}$
5. $\frac{6}{4}$
6. $\frac{7}{4}$
7. double recommended dose

When applying a certain type of fertiliser, other fertilisers may serve as the background, for example, phosphoric-potassium for nitrogen ones, etc. If it is planned to investigate the effect of fertilisers in the shift of crops, then a two-factor experiment must be laid, where the very crops are the second factor. If one studies the methods and timing of fertiliser application, then the scheme may be as follows:

- 1) all the nutrient elements are applied for the primary tillage;
- 2) for the secondary tillage;
- 3) PP (phosphorus potassium) – for the primary soil tillage, nitrogen – for the secondary tillage;
- 4) PP (phosphorus potassium) for the primary tillage, and nitrogen – while sowing and 1-3 times during the period of vegetation.

If one plans to determine the effectiveness of organic fertilisers or organo-mineral fertiliser system, then one sets up stationary experiments. The type of the study scheme can be as follows:

- 1) the recommended dose for a simple reproduction of humus;
- 2) half of this dose, and the rest is by mineral fertilisers;
- 3) mineral fertilisers are introduced instead of organic ones;
- 4) the recommended dose for the expanded reproduction of humus;
- 5) variant 2 + variant 4;
- 6) variant 3 + variant 4.

If the effect of different forms of organic fertilisers is studied, then the scheme of the experiment can be the following:

- 1) semi-decomposed manure (k);
- 2) farm slurry;
- 3) poultry manure;
- 4) peat;
- 5) earth-peat compost;
- 6) straw;
- 7) green manures;
- 8) sapropel.

Experiments are also carried out with mineral fertilisers on the impact of their forms on yields of individual crops. If one studies minor elements, then the simplest scheme of the experiment will be, for example, the following:

- 1) boron;
- 2) manganese;
- 3) zinc;
- 4) cobalt etc.

Experiments on the study of bacterial preparations are run in a similar way.

2. Planning research. It is compulsory to study the conditions of the plant nutrition in the main periods of their growth and development. In this case, the plants level of nitrogen, moving forms of phosphorus and potassium are determined. Balance settlement of nutrients is also carried out. In the experiments with mineral fertilisers, one should determine the soil acidity, since most of them increase it. The same survey is also carried out in the study of organic fertilisers as they are used to normalise the soil acidity.

It is also obligatory to determine the intensity of microorganisms (evaluated by the rate of decomposition of fibre, nitrification capacity); changes in the humus content of the root layer; displacement of niters; depthwise distribution of the main nutrients; the content of heavy metals in the soil.

Depending on the culture the state of overwinter, resistance of plants to storing, weed estimation, quality indicators of products are also taken into account in addition to biometric indicators.

EXPERIMENTS USING DIFFERENT WAYS OF SOIL CULTIVATION

1. Schemes of experiments. The directions of the experiment are worked out depending on the kind of cultures planned for cultivation. Whether it is the primary or secondary tillage, one can divide them into three subgroups by the terms, depth, ways of cultivation. Schemes of experiments depend on forecrops and the research area.

For example:

- 1) moldboard plowing at the depth of 24-25 cm (k);
- 2) boardless plowing of soil;
- 3) disk harrow plowing at the depth of 10-12 cm;
- 4) plowing at the depth of 14-16 cm.

When studying the terms of cultivation, the following scheme may be proposed:

- 1) cultivation straight after harvesting the forecrop;
- 2) in 2 days;
- 3) in 4 days;
- 4) in 6 days.

The following scheme can serve as an example of studying the depth of cultivation for sugar beet:

- 1) plowing to the depth of 12-14 cm;
- 2) 16-18 cm;
- 3) 20-22 cm;
- 4) 24-26 cm;
- 5) 28-30 cm (k);
- 6) 32-34 cm

Observation and records:

- soil texture at the maximum depth of cultivation, volume of moisture and air, ratio of the soil interstices and its solid phase;
- the dynamics of soil density during the vegetation in a 30-cm layer;
- aggregate composition of the arable layer;
- washing out texture resistance;
- soil permeability;
- moisture of the root layer.