Assoc. Prof. ANGEL TRIFONOV, phD,
mechanical engineer

MACHINES FOR PLANT PROTECTION

A textbook for the students from master course "PLANT MEDECINE"
Agricultural University – Plovdiv

Academic publishing of Agricultural University
Plovdiv, 2018

THE PURPOSE OF THE COURSE

EDUCATIONAL GOALS

The module **“Machines for plant protection"** has a pretentions to give appropriate knowledge about the doses and volumes of pest distribution, types of pest formulations, spray coverage, types of sprayers and their elements, sprayer inspection before use, sprayer calibration for work and equipment for pest control in the field and in greenhouses.

The students are introduced to the assemblies and components of machines with ways to regulate and adjust for proper condition providing quality work in compliance with all the requirements for environmental protection.

A big part of the course is dedicated to the plant protection techniques, including different hand sprayers and knapsack motor sprayers.

Special attention is paid to tractor mounted and trailed sprayers for different crops. In this course are also studied self-propelled sprayers, aircraft sprayers, machines for dusting with chemical powders and machines for mechanical weed control using soil tillage techniques.

ACQUIRABLE SKILLS

At the end of the course the students should be able:

- to calculate the doses and volumes of pest distribution,
- to measure spray coverage,
- to know the elements of the sprayers and principles of their work,
- to make the right choice of the elements of calibration (types and volume of nozzles, tractor speed, working pressure, way of moving on the field, output and area per load).

Introduction

1. The concept of mechanization of agriculture

The mechanization of production in every sphere of human labor (including in agriculture) leads to the replacement of manual labor with machines and mechanisms using different types of energy.

The main objectives of the mechanization of production are to increase labor productivity and relieve people of heavy manual and time-consuming practices.

The mechanization of production contributes to a rational and economical use of raw materials and energy, reducing costs and improving the quality of manufactured products. Along with the improvement and modernization of technical equipment, the mechanization of production is inextricably linked to higher levels of worker skills and improved organization of work.

The technical means of mechanization in agriculture include:

- **working machines -** with them the technological operations are directly carried out (for example, in agriculture, these are plows for plowing, seed drills, sprayers for plant protection practices, etc.);
- **power machines** – with them the working machines are driven (for example in agriculture these are tractors, electric motors and internal combustion engines when carrying out stationary work on a site, etc.);
- **supporting machines and mechanisms** – they are not directly involved in the operations but are necessary for the production process (e.g. fan and pump aggregates, etc.).

The introduction of mechanization in agriculture is one of the main ways to improve the efficiency of production and working conditions.

Productivity in agriculture is determined by selection, chemistry and irrigation, but also the degree of mechanization plays a major role in production processes.

In some agricultural practices, such as soil cultivation, sowing, planting, fertilizing, chemical spraying, grain harvesting, silage harvesting, etc., a high degree of mechanization has been achieved and manual labor has been reduced to a minimum. Agricultural farms are equipped with powerful tractors, high-performance combine harvesters, combined machines performing multiple operations, high-performance machines and more.

2. Classification of agricultural machinery

Agricultural machinery is classified by the type of function and by the type of aggregating with the power machine (linkage with the tractor).

By the type of function, machines are divided into six groups depending on the work processes they carry out.

They are: for ploughing, for surface soil cultivation, for sowing (or planting), for growing crops, for harvesting and for post-harvest processing of products.

By the type of aggregating (connecting to the power machine), agricultural machines are divided into mobile and stationary. Both types are aggregated.

To do so, they need to join a relevant energy source - a tractor, a truck, a self-propelled chassis, an internal combustion engine, an electric motor. Depending on the way of this connection, the mobile machines are trailed, mounted, semi-mounted and self-propelled.

3. Classification of machine organs

They are two types - working and supporting.

Working organs are those, which are in direct contact with the processable material, performing the work process. The workable material can be soil, seeds, seedlings, fertilizers, water, plants, etc.

Supporting organs are all other bodies, which not involved in the work process. They only create normal conditions for the work organs. Such are the frame, the drawbar, the chassis, the transmission, lifting, adjusting and other mechanisms.

Chapter I. MACHINES FOR CHEMICAL APPLICATION

Introduction

The purpose of applying agricultural chemicals is to provide nutrients for plant growth and to control weeds, insects and other crop pests, and plant diseases. Proper application of agricultural chemicals is crucial in successful modern agriculture. Agricultural chemicals, over the years, have become more sophisticated but also more expensive, so good methods avoid over-application.

The major classifications of agricultural chemicals are fertilizers, pesticides (including insecticides, which kill insects), herbicides (which kill plants), fungicides (which kill fungi), growth regulatory hormones, and pheromones for biological control of insects. These chemicals may be either dry or liquid. The chemicals may be applied before planting during seedbed preparation, during planting, and/or after germination during the active growth period.

In this chapter, we will discuss the chemical application methods and related equipment, their functional components and operating principles, equipment calibration, testing, and other related topics.

THEME 1. MACHINES FOR APPLICATION OF DRY CHEMICALS (powders and granules)

Dry chemicals in agricultural use are primarily fertilizers, herbicides, and insecticides. Technically many of these are powders; however, powders that are large in particle size and flow easily - as is the case with these agricultural chemicals - are referred to a granular material. That is the term used in this book.

There are some agricultural chemicals that are non-granular powders of small sizes, such as insecticide powders applied by dusters. Because of drift and poor coverage these are of limited use in commercial farming. Better choices include liquid pesticides or granular pesticides that are liquid chemicals impregnated on inert granular carriers such as clay, sand, or corncobs. Application of dry granules has certain advantages. It eliminates the need to haul water and the mixing required with liquid chemicals.

Chemical drift, i.e., droplets that do not land on the intended target, is generally not as great a problem as it can be with liquids. The application equipment is less expensive and more trouble-free since no mixing, pumping, and agitation is involved. While practicing conservation tillage, better control is possible with granules than sprays since granules filter through the foliage onto the soil. Also, granules are generally safer to use than liquid formulations.

However, granular material is generally more expensive than the liquid chemicals. The granular material has poor metering characteristics and the uniform distribution is a problem. The use of granules is limited to soil applications as they require moisture to become activated. Granular pesticides must be kept in a dry place and they are more bulky to store and transport.

Traditional granular pesticide rates have been 12 to 24 kg/ha with 5 % to 15 % active ingredient. With the availability of granular pesticides that are 20 % to 50 % active ingredient there is a trend toward lower rates of application. Some new formulations have 75 % to 90 % active ingredient with a recommended application rate as low as 1,2 kg/ha. With increases in the concentration of active ingredients, there has been a shift toward smaller granular particles. Smaller particles tend to give better coverage by increasing the number of particles per unit area, but they are more prone to drift.

1. Methods for application of granular chemicals

Granular fertilizer may be spread uniformly over the entire field, in a broadcast application, or it may be applied in narrow rows, which is called a banded application. It may be applied before planting, during planting, or in established crops. Pre-planting applications include applying the material either on the soil surface or placing it below the surface using an appropriate tillage attachment. Material applied on the surface may be incorporated into the soil using an appropriate tillage tool (generally a field cultivator or a disk harrow) as part of normal seedbed preparation.

Fertilizers may be placed deep into the soil with a chisel type cultivator. A fertilizer distributor may be used as an attachment to a plow that places it in the furrows below the surface at plowing depth. Application during planting is commonly done by fertilizer drills. Hoppers, tubes, and furrow openers are built in the drills to place the fertilizer below and to the side of the seed rows. Similarly, row-crop planters have attachments to place fertilizers in a narrow band on either side of the seed row. The furrow openers for fertilizer are separate from the seed furrow openers and they can be adjusted independently in the vertical and horizontal directions.

Application in established crops puts chemicals either on the surface or below the surface of the soil. The method of application depends upon the crop and the planting type. In solid-planted crops, fertilizers may be surface applied using either a drop-type or a rotary spreader. In row crops, granular chemicals may be banded between the rows or applied on either side of the rows as a side dressing.

2. Equipment for application of granular chemicals

The equipment for applying granular material includes drop-type (gravity), rotary (centrifugal), and pneumatic (air) spreaders. Equipment may be drawn behind tractors or mounted on trucks or aircraft. Drop-type spreaders may be either for a broadcast application or for a banded application.

A drop-type applicator for banded application is shown in Figure 1. This applicator utilizes several small hoppers as compared to one long one. The material is metered and dropped through a tube and is spread in a wide band by a diffuser. Some fertilizer distributors have furrow openers to place the material below the surface. This type of spreader is most commonly used as an attachment to planting equipment.

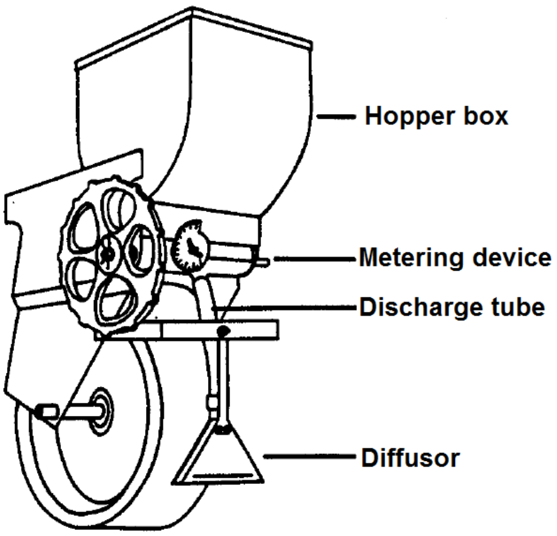


Figure 1. A drop-type applicator for banded application

Tractor-drawn units have 2,5 to 3,5 m long hoppers with narrowly spaced openings in the bottom. The openings are generally 150 mm apart. A ground-wheel-driven shaft located inside the hopper near the bottom carries agitators to help flow the material (Fig. 76). A slide gate is used to control the openings and to shut off flow during the turnaround.

Rotary spreaders are used for a broadcast application. These spreaders have one or two rotating disks with multiple vanes to impart energy to the granules. The material is metered onto the disks and is thrown wide due to the centrifugal force (Fig. 2). Rotary spreaders are generally tractor mounted, but some of the larger commercial units are truck mounted with twin spinners.

In order to realize the technological process of spreading, each machine is equipped with the following work units: a hopper 4, agitator, metering device 5 and a spreading device 6. The purpose of the metering device is to deliver a certain amount of fertilizer to the spreading device, thereby regulating the chemical or fertilizer rate.

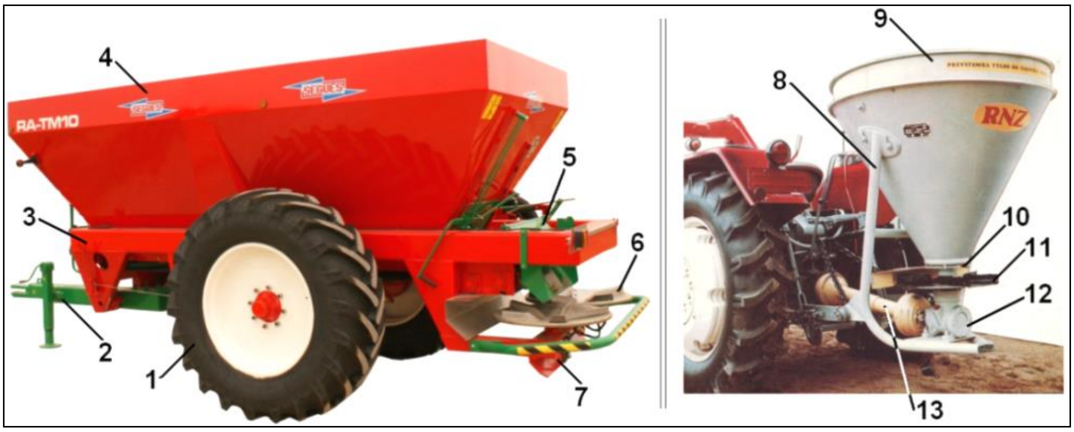


Figure 2. A tractor-drawn and tractor-mounted rotary applicator (rotary spreader):
1 – supporting wheels; 2 - drawbar; 3 - frame; 4 - fertilizer hopper; 5 - metering device; 6 - spreading discs; 7 - gearboxes; 8 - frame with hitching device; 9 - fertilizer hopper; 10 - metering device; 11 - spreading disk; 12 – gear reducer; 13 - cardan shaft

Centrifugal spreader - purpose and device. It is designed for dispersing dry chemicals, lime and gypsum matherials for control of pH of the soil (meliorating substances) and mineral fertilizers in granular, crystalline and powdery form. It consists of a hopper 5 (Figure 3), a metering unit 6, spraying disks 8 and drive mechanisms 7.

Technological process. When the machine moving forward the conveyor 2 (Figure 3) moves along the bottom of the hopper 5 and moves the matherial to the outlet. A metering device 6 is provided at this outlet which leaks out a chemical layer of a certain thickness. Metered matherial is directed through a chute to the rotating discs 8.

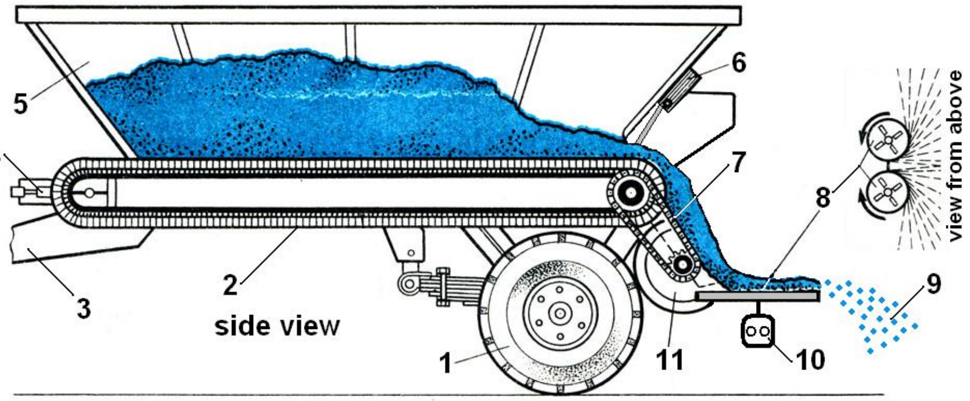


Fig. 3. Scheme of centrifugal spreader: 1 – supporting wheel; 2 - wire-belt conveyor; 3 - drawbar frame; 4 - tensioning station; 5 - fertilizer hopper;6 – metering device; 7 – chain drive; 8 - spreading discs; 9 - fertilizer particles; 10 – hydraulic motor; 11 - friction wheel

The centrifugal forces are transmitted to the dry particles through the disc blades and they are spread over the field in a strip of a certain width which depends on the diameter of the disc, its rotation speed and the height at which the disc is located. The drive is provided by a hydraulic motor 10 (Figure 3). In some constructions, this is done through a gearbox connected to the tractor PTO with cardan shaft.

Pneumatic applicators can be used for either broadcast or banded application. They have a centrally located hopper from which granules are metered, delivered by air through tubes across the width of the machine, and spread by impinging onto deflector plates. Pneumatic applicators allow central tank filling, easier installation on tillage implements, improved distribution, and easier transporting of trailer mounted applicators. A pneumatic applicator is shown in Figure 4.

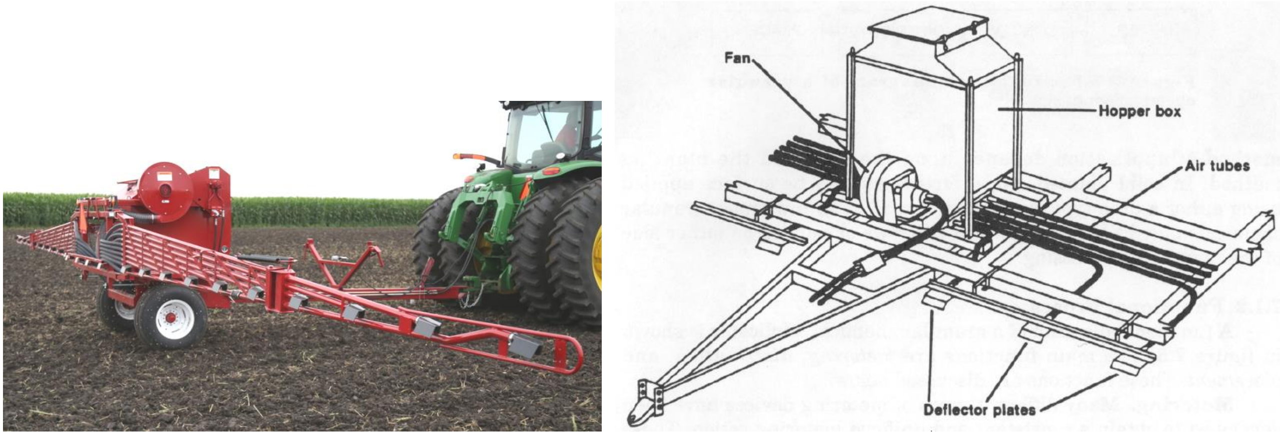


Figure 4. A pneumatic applicator for broadcast application

The technological process is as follows. When the machine moving forward, the matherial from the hopper 6 (Figure 5) passes through the dosing device and falls into the air tube 4 where it is lifted by the airflow created by the fan 1.

The formed granules-air mixture passes through the diffuser system to equalize the concentration across the flow section. The distributor 5 separate the total flow into portions that go along the tubes 7 to the spreaders 8 arranged on the frame 3. If the distribution is broadcast, the spreaders are arranged on the bar so that the formed jets of chemical overlap. The pneumatic spreader can also be used for band application. The agitators in the hopper prevent the formation of vaults when the chemical leaks from the hopper to the dispenser.

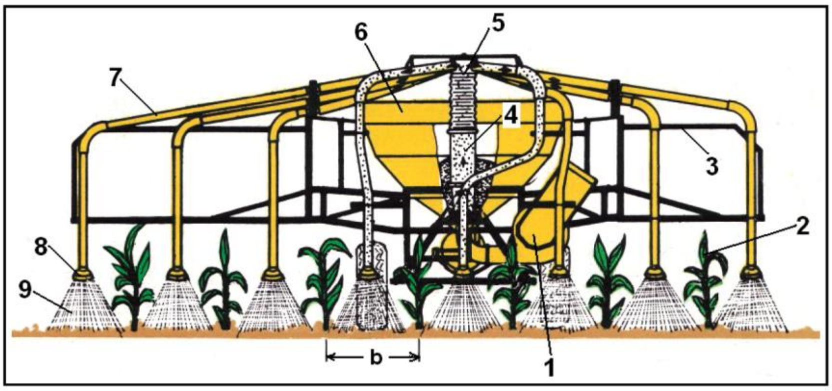


Figure 5. A pneumatic applicator for banded application: 1 - fan; 2 - plant; 3 - frame; 4 - pneumatic product tube; 5 - distributor; 6 - hopper; 7 - tubes; 8 - spreader; 9 - scattered chemical

Functional processes of granular chemical applications

A functional diagram of a granular chemical applicator is shown in Figure 6. The main functions are *metering, conveying, distribution*, and *placement*. These functions are discussed below.

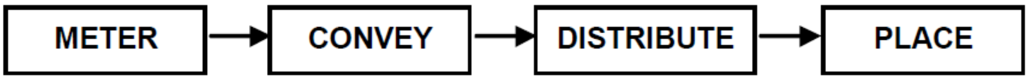


Figure 6. The functional diagram of a granular chemical applicator

3. Metering

Many different types of devices have been developed to obtain a consistent and uniform metering of granular chemicals. These devices are generally driven by a ground wheel that stops metering when the implement is stopped or lifted off the ground. Metering devices may be divided into a *positive flow* and *gravity flow*.

Positive flow metering devices provide for more accurate metering because a cavity is used to meter a certain volume of fertilizer (or other material). The rate of movement of the cavity determines the metering rate. Gravity flow devices rely on the orifice size to meter the flow rate. These differences are discussed in the following sections.

The *star-wheel feed* metering device is used on some grain drills and a few row crop side-dressing attachments. Dry chemical, carried between the teeth of the feed wheel, falls into the delivery tube by gravity while material carried on top of the wheel is scraped off into the delivery opening. The discharge rate is controlled by raising or lowering a gate above the wheel.

Metering devices for some row-crop attachments have horizontal *rotating bottom plates* that fit up against the stationary bottom ring of the hopper base (Figure 7). The discharge rate is controlled by an adjustable gate over a side outlet. Sometimes there are two outlets permitting two bands from one hopper.

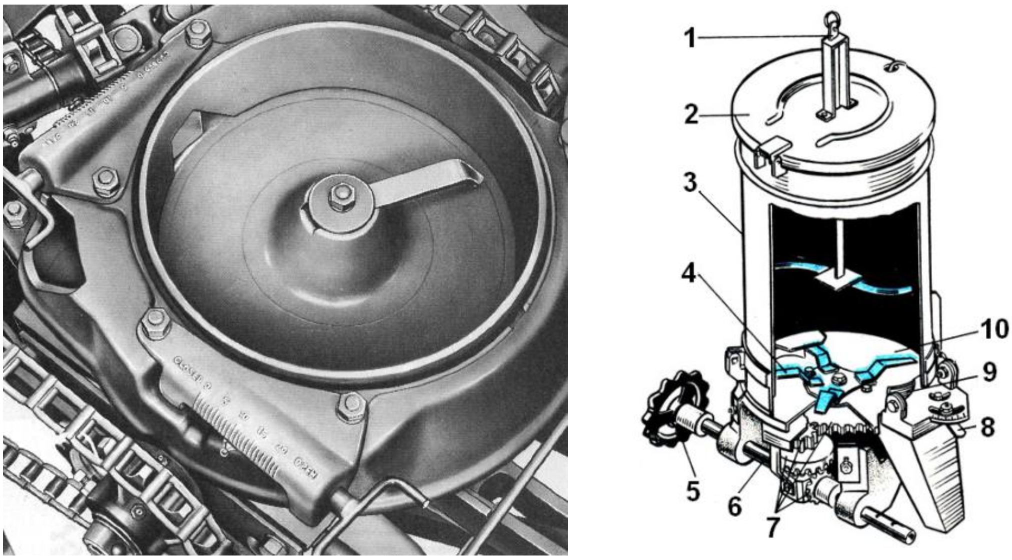


Figure 7. A rotating bottom metering device

Belt-type metering devices are sometimes employed where relatively large application rates are required, as on rotary broadcasters with large hoppers. Some units have a flat wire belt (usually stainless steel) that drags the material along the hopper bottom (Figure 8) and others employ rubberized fabric belts. The discharge rate is controlled by an adjustable gate above the belt. The discharge can be split into two or more streams if desired.

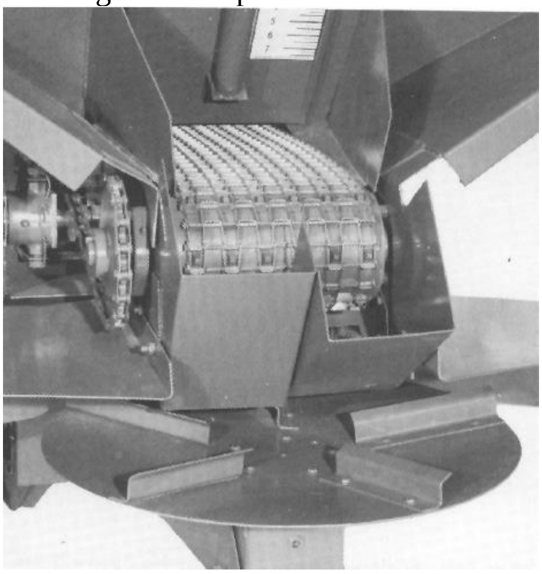


Figure 8. A wire-belt metering device on a centrifugal broadcaster

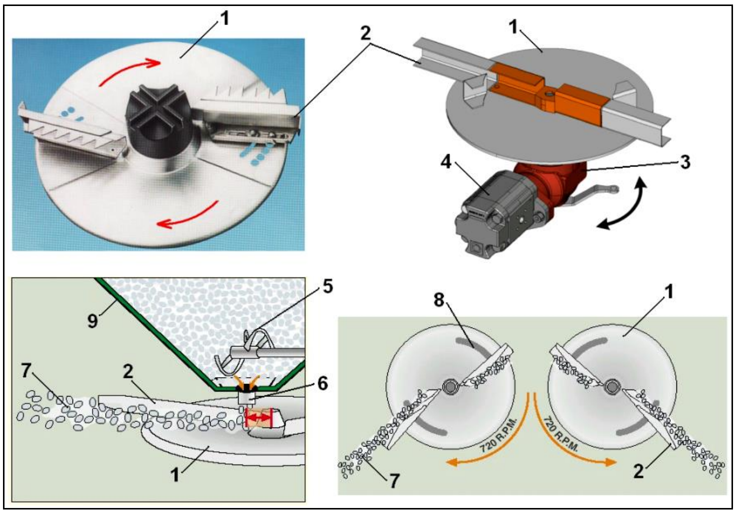


Fig. 9. Working bodies of centrifugal spreader: 1 - disc; 2 - blades; 3 – gear reducer; 4 – hydraulic motor; 5 - agitator; 6 - dosing device; 7 - fertilizer particles; 8 - adjusting holes; 9 - fertilizer hopper

4. Distribution

Devices to distribute dry chemicals are of three main types: rotary, gravity, and ram-air spreaders. *Rotary spreaders* usually consist of a single or a double counter-rotating horizontal spinner. The direction of rotation is such that the adjacent sides in the counter-rotating spinners move the material rearward. The spinners have blades that may be radial, forward pitched, or rearward pitched with respect to the radius (Fig. 9). The blades may be either straight or curved. Forward-pitched blades give greater carrying distances for free-flowing materials, while rearward-pitched blades unload sticky material (e.g., moist lime) more readily. Rotary spreaders are used with broadcast types of applicators. A stream of granular material is dropped on the spinner and is thrown out by the action of centrifugal force. For a double spinner, the stream is usually split in two by an inverted V-shaped splitter.

To improve the uniformity of the spread of fertilizer in the field, straight or curved blades with different cross-section are mounted on the working surface of the disc (Fig. 9). The disc diameter for different machines is varied from 35 to 75 cm. The disc is positioned at a height of 45-65 cm, depending on the design of the gear unit and the required ground clearance. Its rotation speed is in the range of 540 to 1000 rpm.

Uniformity of coverage is one of the most important performance criteria (Fig. 10). The horizontal distance through which the particles are thrown is affected by the particle size, density, and shape in addition to the spinner speed and geometric configuration. The components of a dry blend tend to separate as the larger particles of the same density travel farther. Wind also affects the carrying distance, and hence, the distribution pattern.

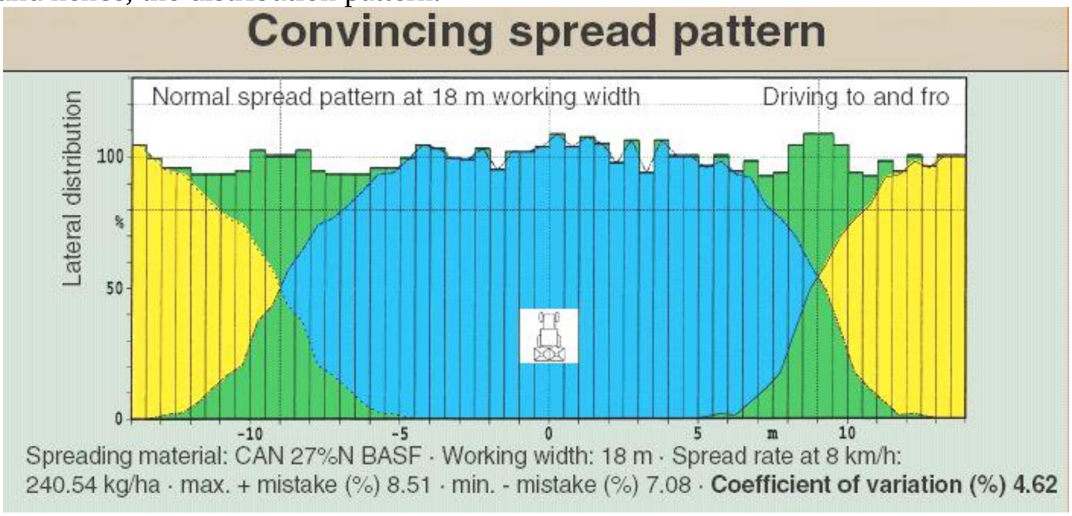


Fig. 10. Uniformity of coverage of centrifugal spreader at 18 m working width

5. Placement

Placement devices may apply the chemical on the surface or below the surface. Surface applications are often incorporated into the soil by a tillage tool if done before planting. On growing crops, especially solid-planted crops, a chemical is nearly always applied as a top dressing and not incorporated into the soil. Fertilizer (or other chemical) may be placed below the surface by a planter or a cultivator, or placed deep in the soil using chisel plows, or drilled into established pastures and other sods with special equipment.

Banded placement during row-crop planting is accomplished with applicators that are independent of the seed furrow opener. Double-disk, single-disk, and runner-type openers, similar to seed furrow openers, are often used. Fertilizer grain drills often deliver the fertilizer (or other chemical) through the seed tube, placing it in direct contact with the seeds in furrow. Separate disk openers are sometimes provided in front of the seed openers so that the seed row is not disturbed.

6. Fertilizing apparatus

The most common types are disc, screw, turbine, centrifugal, oscillating and pneumatic. The first three types of machines are used for the fertilizer application (or other chemical) of seed drills, planting machines and cultivators for plant nutrition. The other three types are used in the fertilizer spreaders for distributing upon the field.

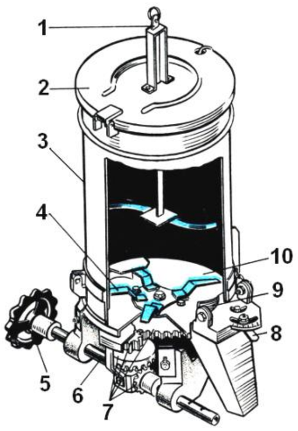


Fig. 11. Scheme of disc apparatus: 1 - level indicator; 2 - lid; 3 - fertilizer box; 4 - agitator; 5 - chain wheel; 6 - shaft; 7 - gear reducers; 8 - regulator; 9 - diverter; 10 - rotating bottom (disk)

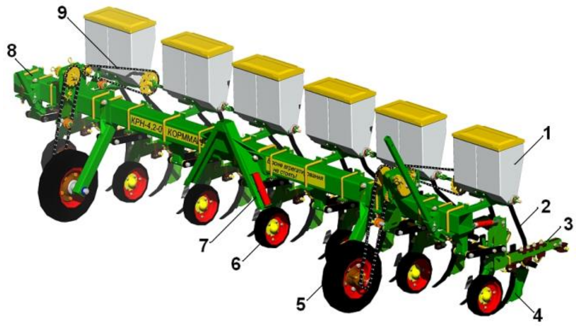


Fig. 12. Scheme of cultivator for plant nutrition with screw mechanism: 1 - fertilizer apparatus; 2 – fertilizer tube; 3 - working section; 4 - blade for mineral fertilizing; 5 – cultivator wheel; 6 - section wheel; 7 - hitching device; 8 - frame; 9 - chain drive

The disk fertilizer apparatus (Figure 11) consists of a cylindrical fertilizer box 3. The rotating bottom 10 is a metal disk. On both sides of the bottom of the box have openings with a rectangular shape. Under the openings are attached the grooves to which the fertilizer tubes are connected. The width of the exit holes is covered by the fertilizer diverters 9.

The stirring of the fertilizer in the box is affected by the agitator 4. When the disc 10 is rotated, the fertilizer is directed by the diverters 9 to the outlet openings from where it flows into the tubes. Level indicator 1 shows the amount of fertilizer in the box. The amount of discharged fertilizer is changed by the regulators 8 connected to the diverters 9.

THEME 2. MACHINES FOR APPLICATION OF LIQUID CHEMICALS

Due to the advancement of agricultural science, most fields remain covered under crops for a longer duration of time due to multiple cropping, intensive farming and better irrigation facilities. Due to this, there is an increase in plant pests and diseases also. So it has now become necessary to use pesticide and fungicide for controlling pests and diseases. Sprayers and dusters are used for this.

Because dusts have much greater drift hazard and lower deposition efficiency than sprays, most pesticides application other than granular soil treatments are now in the form of sprays, usually water emulsions, solutions or suspensions of wettable powders.

Liquid chemicals include fertilizers, herbicides, pesticides, and growth-regulating hormones. Liquid pesticides may be either *contact* or *systemic* type. Contact pesticides kill insects, fungi, etc., by coming in contact. To be effective, full coverage of the target, normally achieved by smaller droplets, is necessary. Systemic pesticides are taken in by the plant and they translocate within the plant. Full coverage of the plant is not required and larger droplets that are less prone to drift are acceptable.

Methods for application of liquid chemicals

Liquid chemical application methods vary depending on whether they are applied pre-planting**,** during planting, or post-planting. Pre-planting applications generally are fertilizers and herbicides and may include subsurface or surface application. Liquid chemicals applied during planting generally include fertilizers and herbicides. Post-planting chemical applications may include fertilizers and all types of pesticides.

Liquid chemical application methods may be further divided based on the area covered. This may be *broadcast*, *banded*, and *directed spray*. In a broadcast application the chemical is applied uniformly on the ground or on the crop. In the banded application the chemical is applied in narrow bands or strips. Several nozzles are used in directed spray for row-crop applications for a more complete coverage of the plants. Figure 13 shows the three methods of application.

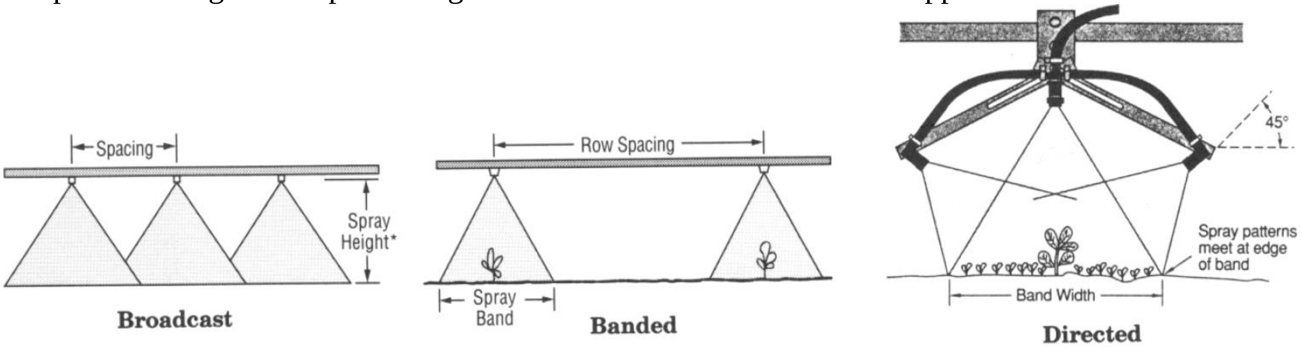


Fig. 13. Methods of application of liquid chemicals

Equipment for application of liquid chemicals

Types of equipment for this practice are:

a) Boom-type field sprayers

b) High-pressure orchard and general purpose sprayers

c) Air-blast sprayers which utilize an air stream as a carrier for sprays

d) Air-craft sprayers

e) Aerosol generators, which atomize liquids by thermal or mechanical means and are widely used for control of mosquitoes and some plant diseases.

Sprayers are used for various purposes:

1. Application of insecticides to control insects on plants
2. Application of fungicides to control plant diseases
3. Application of herbicides to kill weeds, either indiscriminately or selectively
4. Application of pre-harvest sprayers to defoliate or condition crops for mechanical harvesting
5. Application of hormone (growth regulating) sprays to increase fruit set or prevents early dropping of fruit
6. Application of sprays to thin fruit blossoms
7. Application of plant nutrients (sprays) directly to the plant foliage
8. Application of biological materials such as viruses and bacteria, in spray to control pests

The main function of sprayers are:

1) To break the liquid into droplets of an effective size

2) To distribute them uniformly over the plants

3) To regular the amount of liquid to avoid excessive application

A desirable quality of sprayer work:

1) The sprayer should produce a steady stream of spray materials in the desired size of droplets so that plants to be treated may be covered uniformly.

2) They should deliver the liquid at sufficient pressure so that it reaches all the foliage and spreads entirely over the sprayed surface.

3) It should be light yet sufficiently strong, easily workable and repairable.

Low-pressure sprayers

Low-pressure sprayers are used to apply pre- and post- emergent chemicals to control weeds, insects, and diseases. Boom-type sprayers are used on tractors, trucks, or trailers; a tractor-mounted boom-type of field sprayer is shown in Figure 14 and 15. Low-pressure units usually operate in 0,15 to

0,35 MPa range and apply 50 to 200 L/ha. However, in some ultra low volume (ULV) applications, the rates may be as low as 10 L/ha to a few mL/ha.

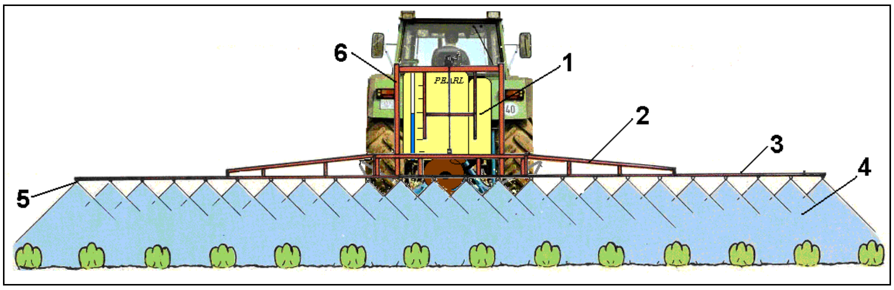


Figure 14. Boom-type field sprayer: 1 – reservoir (tank); 2 – boom (bar); 3 - pipeline; 4 - streams of spray solution; 5 – sprinkler (spray nozzle); 6 - frame

Figure 15. Boom-type field sprayer: 1 - frame; 2 – spay nozzle; 3 – boom (bar); 4 - pipeline; 5 – reservoir (tank); 6 - pump; 7 – control of spraying

The boom sprayer consists of a frame 1 with a hitching device (Figure 15), a tank 5, boom 3 with a piping system 4 on which the spray nozzles 2 are spaced apart from each other. It is equipped with a pump 6, filters and controls 7. The name "boom" comes from the support structure of the spray system, which is a metal bar. It must be both lightweight and robust in order to be able to withstand the high vibrational load in the field while simultaneously carrying the solution pipelines and nozzles.

Tank-on-tractor mounted sprayers hold from 300 to 1000 L. For application in the standing row crop, high-clearance sprayers have been developed. They have a frame high enough to clear corn, cotton, and other tall crops. The spray boom may be raised or lowered depending upon the crop height. The sprayer may be mounted on a trailer or wheels and pulled through the field by a tractor. Tank capacity may be as high as 4000 L. The boom width may vary from 8 to 30 m.

Skid-mounted sprayers may be placed on a pickup truck or a flatbed truck. The tank size may be up to 10000 L and the boom width up to 18 m. The trucks are fitted with flotation tires so they can operate in wet conditions.

Aircraft-mounted low-pressure sprayers have the advantage of rapid coverage and applying chemicals when conditions are otherwise unsuitable for ground rigs. Because of the limited weight carrying capacities, aircraft-mounted sprayers are most suited for low application rates of less than 50 L/ha. The aircraft speed varies between 50 to 125 km/h for helicopters and 175 to 250 km/h for airplanes as they fly about 2 to 8 m above the crop height.

High-pressure sprayers

High-pressure sprayers are similar to low-pressure sprayers except they operate under much higher pressure, up to 4 MPa, and generally do not have a boom with multiple nozzles. High-pressure sprayers are used in orchards where it is necessary to spray to the top of the trees and to penetrate the thick tree canopy. High-pressure sprayers are more expensive because the parts are made to withstand higher pressures.

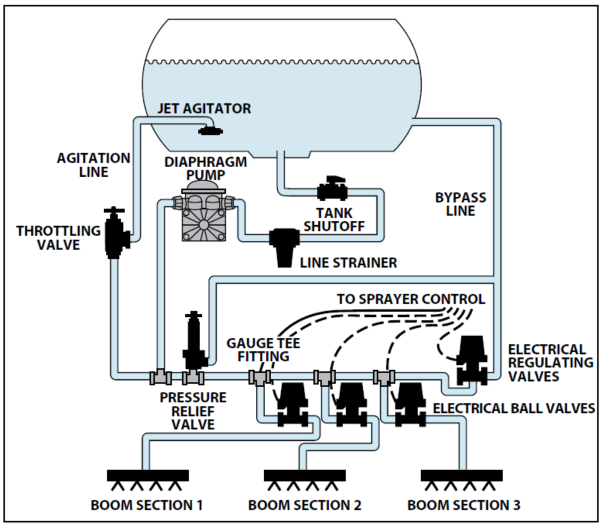
Air-carrier sprayers

Air-carrier sprayers are sometimes called *air-blast sprayers* or *mist blowers* (Fig. 16). The liquid is atomized either by pressure nozzles or rotary atomizers in a high-velocity air stream. The atomized liquid is then carried to the target by the air stream. The sprayers are capable of generating air flow rates in the range of 2.5 to 30 m^3/s with air speeds ranging from 125 to 240 km/h. Since air is used to carry the pesticide to the target, concentrated pesticides can be used resulting in substantial savings in the amount of water needed and the time required for refilling.

Figure 16. An air-blast sprayer

Functional processes of applying liquid chemicals

Figure 17 shows a typical arrangement for a hydraulic sprayer. A hydraulic sprayer consists of a tank to hold the liquid chemical, an agitation system to keep the chemical well mixed and uniform, a pump to create flow, a pressure regulator valve to control rate of flow, a series of nozzles to atomize the liquid, and miscellaneous components such as boom, shut-off valves, fittings and strainers. The main functional processes—pumping, agitation, and atomization—are discussed below.



Two-Way Plumbing Diagram (Positive Displacement)

Figure 17. Schematic diagrams of a low-pressure hydraulic sprayer with diaphragm pump

Working process. The prepared working solution in the tank 1 (Figure 18) is fed through the filter 3 to the pump 4. The pressure of the solution increases. The liquid directs to the central shut-off valve 8, redirected to the section valves 6, then to pipeline 9 or if it is desired to temporarily stop the spraying - to the regulator 7 and the overflow 12. A portion of the solution after the pump is fed to the hydraulic agitator 2 by means of a pipe. The pressure regulation is via the regulator 7, the excess solution returned to the tank by the overflow pipeline 12.

Filtration of the solution takes place through the coarse filter 13 placed on the hole of the tank under the lid 14, the fine filter 3 placed before the pump and the fine filters 10 placed after each of the sectional valves 6. The bodies of each of the nozzles 11 also have a fine filter - as a final barrier to the small opening of the nozzle 11. The requirement is that the mesh openings of the latter of the filters are about 15-20 % smaller than the size of the nozzle orifice. For example, when working with nozzles of 1 mm mesh size, the filter mesh should have a hole size of up to 0,8 mm.

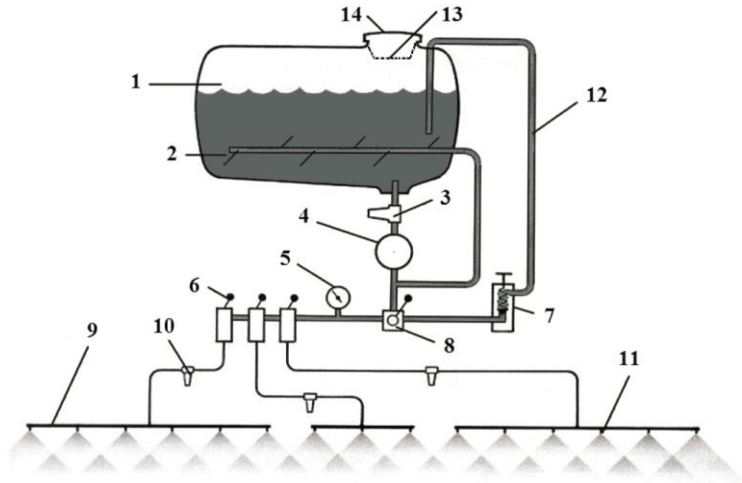


Fig. 18. Technological sheme of a boom sprayer: 1 - tank; 2 – hydraulic agitator; 3 - fine filter; 4 - pump; 5 - pressure gauge; 6 - sectional valves; 7 - pressure regulator; 8 - central shut-off valve; 9 - pipeline; 10 - fine filter; 11 - nozzle; 12 - overflow, 13 - coarse filter; 14 - lid

6. Tractor fan sprayers

The device of these sprayers includes a tank (Figure 19) which is mounted on the frame. The working fluid pressure is increased by a pump and then fed to nozzles which are located at the outlet of the fan. After the working fluid is dispersed from the nozzles, the droplets are taken by the air flow created by the fan, and are transported to the plants. The control system controls the pressure of the solution, the agitator, the central shut-off valve, the sectional valves, etc.

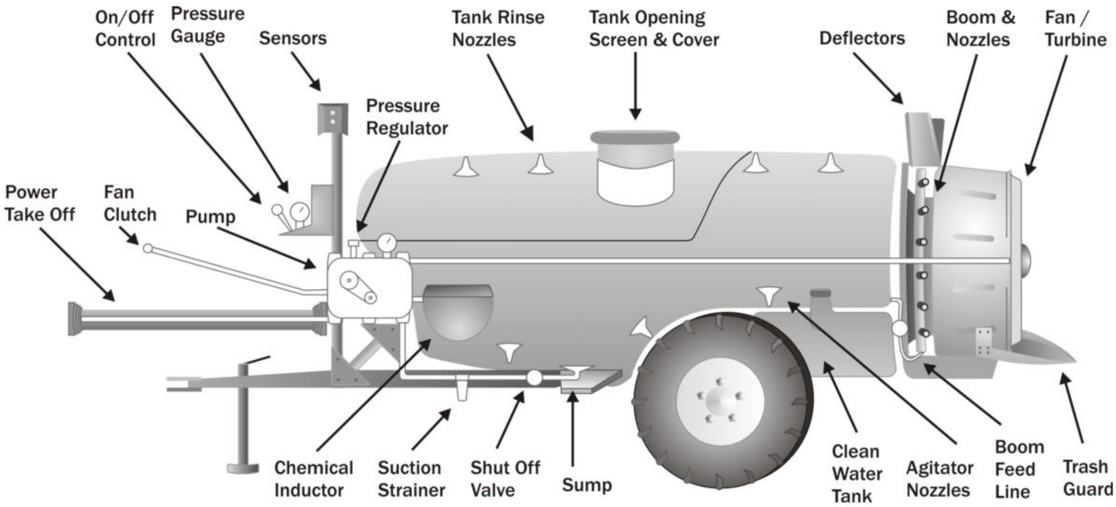


Fig. 19. Scheme of a tractor fan sprayer

Different attachments for fan sprayer

The attachments are three types - standard type, column type and octopus type (Figure 20). This allows them to be used in various cases to improve spraying quality.

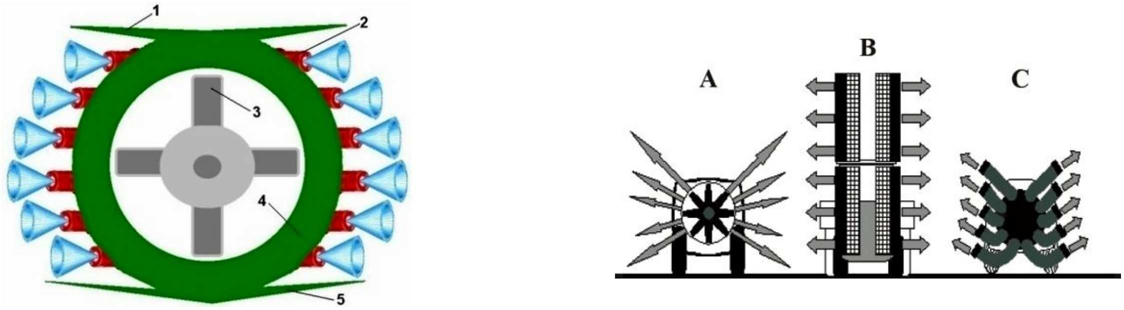


Fig. 20. Sprayer system of a fan sprayer: A - standard type; B - column type; C - octopus type. Markings: 1 - upper air spoiler; 2 - nozzle; 3-axis fan; 4 - fan diffuser; 5 - lower air spoiler

The nozzles 2 (Figure 20) of fan sprayers are usually centrifugal. They are arranged in an arc or straight tubes in the fan diffuser 4. The direction of the air flow is regulated by the fan spoilers (Figures 20, 1 and 5).

These sprayers are usually fitted with piston or diaphragm high-pressure pumps (values up to 20-30 bar corresponding to 2-3 MPa).

7. Tractor pneumatic sprayers

In these sprayers, the spraying and transfer of the drops of the working fluid are carried out with an air flow at a speed of 80-100 m/s. High dispersion is achieved, with the average droplet diameter being 50-100 μm. The flow is created with a centrifugal fan and is distinguished by its high speed passing through diffuser tubes. The nozzles during operation should be at a small distance from the plants - from 0,5 to 2 m.

Pneumatic sprayers are few types - for vineyards, for orchards with low trees and for field crops.

Pneumatic sprayers for vineyards and orchards. They are distinguished from those for field crops on their broadcasting system. It consists of diffuser nozzles 5 and 9 (Figure 21). The airflow is created with one or two centrifugal fans 6 and through pipes 10 or a common distribution chamber is directed to the diffusers of the spray nozzles.

Fig. 21. Tractor pneumatic sprayer:
1 - reservoir; 2 - hitching system; 3 - filter; 4 - frame; 5 - diffusers with nozzles; 6 – centrifugal fan; 7 - solution distributor; 8 - hoses; 9 - diffusers with nozzles; 10 - central air duct; 11 - cover and coarse filter

The liquid is fed with a centrifugal pump and hoses or tubes with a small cross section to the distribution devices 7 which take it to the hydraulic nozzles in the diffusers. Pneumatic sprayers create a high-quality coating with a low operating fluid consumption.

8. Self-propelled sprayers

These types of sprayers are used for spraying large areas. They are mainly produced as boom sprayers with a large working width (from 20 m to 35 m, Figure 22), but there are also variants such as fan sprayers. They apply to a great extent the electronization and automation of the spraying process.

These types of sprayers are equipped with an on-board computer, speed sensors (radar systems), pressure and flow sensors, electronic tank level control systems, wind speed measurement systems, hydraulic lift systems, and pivoting frame, hydraulic systems for extending and folding the boom, for lifting and lowering the boom, tracking and correcting systems for aligning the boom and relieving the oscillations, and hydraulic drive of the wheel system.

Fig. 22. Self-propelled bar sprayer

The sprayer connects to an agrarian navigation system (GPS principle) that can automatically operate the sectional stop valves to avoid overlapping already sprayed areas and strips. This system can also drive the sprayer automatically in a straight line, to determine exactly where the next workflow is to be performed (therefore no markers are required). The automation maintains the application rate of spray solution, keeping it constant despite the change in the working speed.

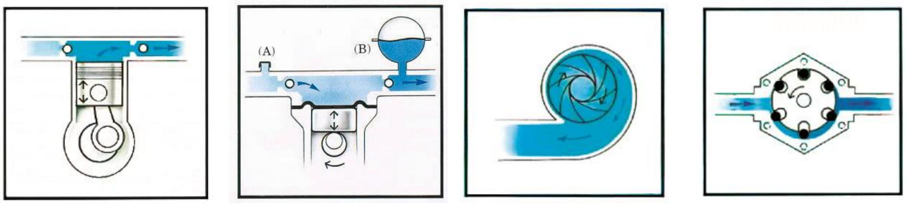
Very good working conditions for the farmer are created - a comfortable, well-protected cabin with air conditioning and other extras, good visibility in all directions, ease of machine control and full control of the working process, electronic displays and surveillance cameras, the sprayed area and the spent working solution, etc.

Pumping

Positive-displacement pumps. With *positive-displacement pumps*, the output is not affected by the output pressure and the flow is created by positively displacing a volume by a mechanical means such as a piston or plunger. In contrast, with a *centrifugal pump*, flow is created by the action of centrifugal force. The output drops as the output pressure is increased. Positive-displacement pumps found on sprayers include a piston (plunger), rotary, and diaphragm types. These are self-priming, and they all require automatic (springloaded) bypass valves to control the pressure and to protect the equipment against mechanical damage if the flow is shut off.

Piston (plunger) pumps (Fig. 23,a) are a kind of positive-displacement pump that is well suited for high-pressure applications such as high-pressure orchard sprayers and multipurpose sprayers designed for both high- and low- pressure spraying. They are more expensive than other types, occupy more space, and are heavy, but they are durable and can be constructed so they will handle abrasive materials without excessive wear.

Crank speeds on the smaller piston sprayer pumps (38 L/min and less) are mostly 400 to 600 rev/min. High-pressure piston sprayer pumps (4.1 to 5.5 MPa) are usually operated at 125 to 300 rev/min have capacities of 75 to 225 L/min.



a) b) c) d)

Fig. 23. Pump types: a) piston; (b) diaphragm (membrane); (c) centrifugal; d) roller

Diaphragm pumps (Fig. 23,b) are another type of positive-displacement pump. They are becoming more widely used and are available with flow rates up to 20 to 160 L/min and pressures up to 3 MPa. Since the valves and the diaphragm are the only moving parts in contact with the spray material, these pumps can readily handle abrasive materials.

Centrifugal pumps (Figure 23,c) do not create flow by mechanically displacing a volume, as do positive-displacement pumps. Instead, they depend upon a centrifugal force for their pumping action. They are essentially high-speed (3000 to 4000 rev/min), high-volume devices not suitable for high-pressure applications because the pump output drops off rapidly when the outlet pressure is above 0,2 to 0,3 MPa. The pressure or head developed by a given centrifugal pump at a particular speed is a function of the discharge rate.

Centrifugal pumps are popular for certain types and sizes of sprayers because of their simplicity and their ability to handle abrasive materials satisfactorily. They are well suited to equipment such as air-blast sprayers and aircraft sprayers, for which high flow rates are needed and the required pressures are relatively low, and are used on many low-pressure field sprayers. The high capacities are advantageous for hydraulic agitation and for tank-filling arrangements.

Speeds in these applications are generally in the range between 1000 and 4000 rev/min, depending upon the pressure required and the diameter of the impeller. Since centrifugal pumps do not have positive displacement, they are not self-priming and do not require pressure relief valves for mechanical protection.

Rotary pumps, another type of positive-displacement pump, are popular for low-pressure sprayers, the most common types being *roller pumps* (Figure 23,d). Roller pumps have a slotted rotor that rotates in an eccentric housing. Rollers in each slot seal the space between the rotor and the wall of the case. The rollers are held against the case by centrifugal force during pump operation.

As the rollers go past the inlet, the space expands creating low pressure and causing the liquid to be drawn in toward the housing. The liquid trapped between the rollers is moved towards the outlet as the rotor turns. Now the cavity between the rollers contracts, expelling the liquid out through the outlet port. Pump output is determined by the length and diameter of the housing, its eccentricity, and the speed of rotation.

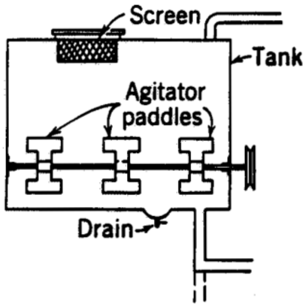
Teflon is a common material for the rollers, although rubber, steel, and carbon are also used. Rotary pumps of are compact and relatively inexpensive, and can be operated at speeds suitable for direct connection to the tractor PTO. Although they are classed as positive-displacement pumps, leakage past the rollers causes a moderate decrease in flow as the pressure is increased.

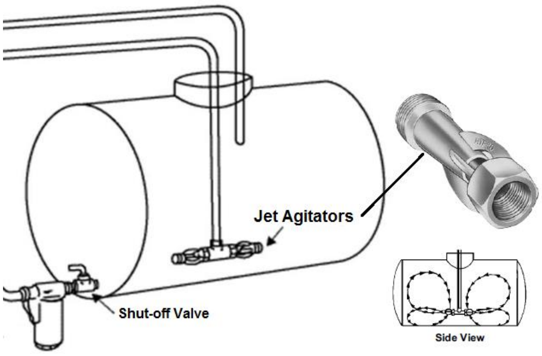
The normal output of roller pumps ranges from 20 to 110 L/min and maximum pressures range from 0,3 to 1 MPa. Roller pumps wear rather rapidly under abrasive conditions, but the rollers can be replaced economically.

Agitation

Many spray materials are suspensions of insoluble powders or are emulsions. Consequently, most sprayers are equipped with agitating systems, either mechanical or hydraulic.

Mechanical agitation is commonly accomplished by flat blades or propellers on a shaft running lengthwise in the tank near the bottom and rotating at a speed of 100 to 200 rev/min (Figure 24). The following relations apply to round-bottom tanks with flat, I-shaped paddles sweeping close to the bottom of the tank.





(a) (b)

Figure 24. Mechanical agitation (a) and hydraulic agitation (b)

For *hydraulic agitation*, a portion of the pump's output is discharged into the spray tank through a series of jet nozzles or orifices located in a pipe along the bottom of the tank. The energy and turbulence from the jets provide the mixing action. Figure 24,b shows hydraulic agitator nozzles.

The principal advantage of hydraulic agitation is its simplicity as compared with the mechanism and drive required for mechanical agitation. With hydraulic agitation, however, the spray pump must have additional capacity and the power requirements will be considerably greater than that for mechanical agitation, especially at high pressures. For high-pressure sprayers, mechanical agitation is definitely the more economical system.

Atomization

The main objective of atomization is to increase the surface area of the liquid by breaking it into many small droplets for effective coverage of plant and soil surfaces. During atomization, energy is imparted to the liquid to break it into small droplets by overcoming surface tension, viscosity, and inertia.

Types of atomizers. Based on the form of energy applied to produce atomization, the atomizers may be categorized as *pressure, rotary,* or *pneumatic* atomizers. Pressure atomizers are the most common type used in agriculture. In *pressure atomizers*, pressure energy is used to break up a liquid jet. Pressure atomizers (but not rotary atomizers), often referred to as *nozzles* (Figure 25), produce several different spray patterns (Figure 26), described below.

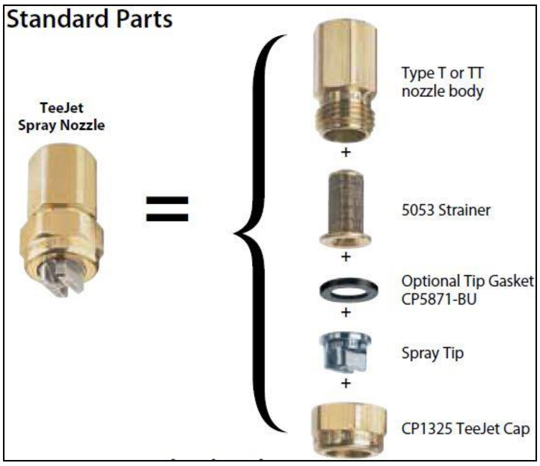


Figure 25. A typical spray nozzle assembly

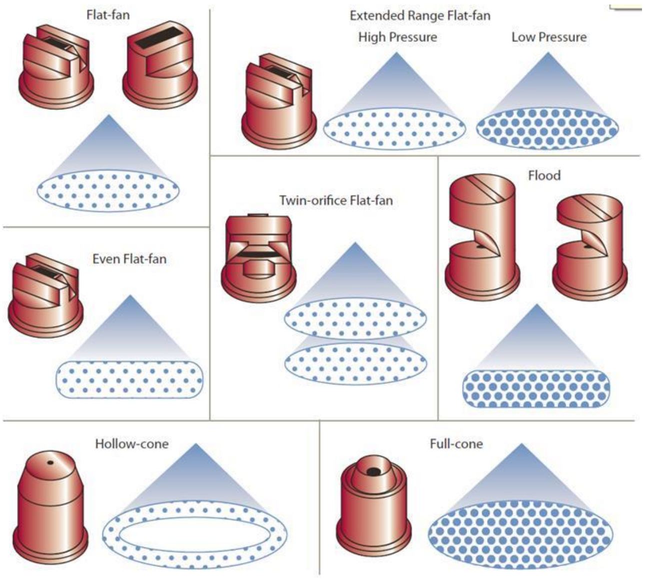


Figure 26. Various types of spray nozzles and spray patterns

Regular flat-fan nozzles (Fig. 27) are used for most applications of herbicides and for certain pesticides when it is not necessary to penetrate foliage. These nozzles produce a flat-fan spray that requires overlapping of pattern to obtain uniform coverage. The spray angle varies from 65° to 110° with 80° being the most common. Nozzle spacing is generally 50 cm on the boom. The boom height varies with spray angle and the amount of overlap desired. A minimum of 30 % overlap is needed for uniform coverage.

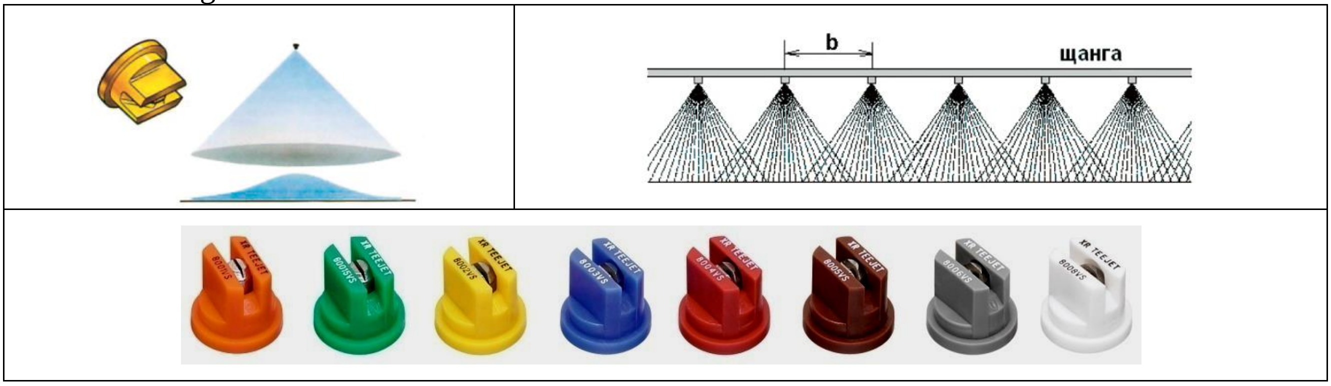


Figure 27. Regular flat-fan nozzles

The operating pressure is generally 0,1 to 0,3 MPa when applying herbicides to produce medium to coarse droplets that are not susceptible to drift. Finer droplets are produced as the pressure is increased. Some herbicides are applied at a pressure of 0,3 to 0,4 MPa to generate finer droplets for maximum coverage. The LP or “low pressure” flat-fan nozzle develops normal pattern at pressures of 0,07 to 0,18 MPa. Operating at lower pressures results in larger drops and less drift.

Even flat-fan spray nozzles (Fig. 28) provide a spray density that is more even across the width of the spray, as compared to the standard flat-fan spray with its tapered spray distribution. Since overlapping would produce a very uneven spray pattern, these nozzles are only for band application over or between rows. The band width is determined by adjusting the boom height. The common spray angles are 80° and 95° and the operating pressures range from 0,1 to 0,3 MPa.

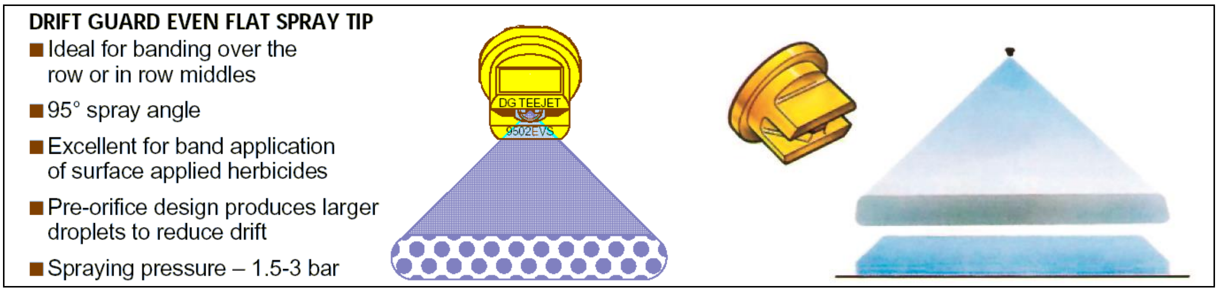


Figure 28. Even flat-fan spray nozzles

Flooding flat-fan nozzles produce a wider spray pattern than the other flat-fan nozzles (Fig. 29). They are most suited for broadcast applications where the uniform surface application is critical. Uniform spray application is obtained by 100 % overlap of individual spray patterns. These nozzles produce large droplets and reduce drift when operated at 0,1 to 0,2 MPa pressure. Pressure changes affect the uniformity of spray pattern more with flooding flat-fan nozzles than with regular flat-fan nozzles.

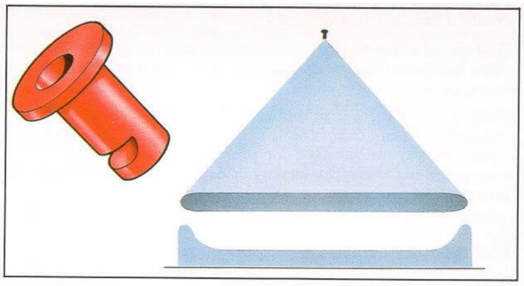


Figure 29. Flooding flat-fan nozzles

Hollow-cone spray nozzles (both disk and core types) utilize a two-piece, disk-core, hollow-cone spray tip (Figure 30). The core gives the fluid a swirling action before it is metered through the orifice disk, resulting in a circular, hollow-cone, spray pattern. These nozzles are most suited for directed spray in row-crop applications when drift is not a concern, as these nozzles are operated at 0,5 to 2 MPa pressures. Since the droplets are small, these nozzles are most suited for contact herbicides, insecticides, and fungicides where full coverage of plant foliage is essential.

Figure 30. Hollow-cone spray nozzles

Whirl-chamber hollow-cone nozzles (Fig. 31,a) have a whirl-chamber above a conical outlet that produces a hollow-cone pattern of cone angles up to 130°. These nozzles are best suited for broadcast surface applications of herbicides. For best results, the nozzle is tilted towards the rear at a 45° angle. Since the droplets tend to be larger, these nozzles are most suited for systemic herbicides and where drift may be a problem. The operating pressure ranges from 0,1 to 0,4 MPa.

a) b) c)

Figure 31. Whirl-chamber hollow-cone nozzle (a); rotary atomizer (b, c)

In *rotary atomizers* (Fig. 31,b,c), as opposed to the various pressure nozzles listed above, the energy to produce droplets comes from a rotating wheel, disk, or cup. As the speed increases, smaller droplets are produced. Rotary atomizers are not as common in agricultural applications as are pressure nozzles. Rotary atomizers are also called *controlled droplet atomizers* (CDA) for their ability to produce droplets that are more uniform in size compared to other atomizers.

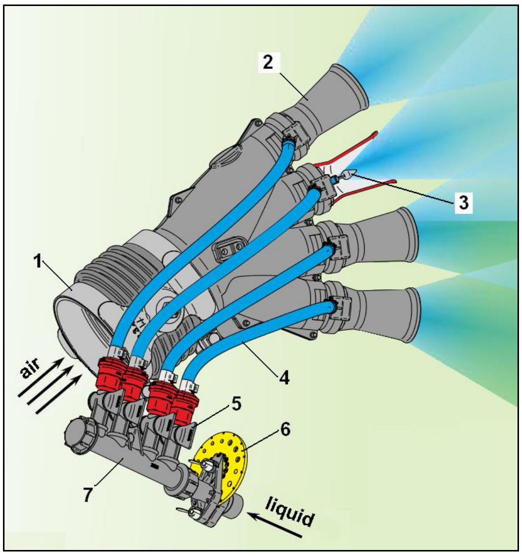


Fig. 32. Pneumatic diffuser nozzle assembly: 1 - air duct; 2 - diffuser; nozzle; 4 - tube; 5 - crane; 6 - dosing plate; 7 - distributor

Pneumatic nozzles. In this type of nozzles, the spraying energy is obtained from the flow of 80-100 m/s of air flow. With these, high dispersion spreading is achieved. Pneumatic spraying is accomplished by the pulsation of air velocity and the turbulence of the flow or its direct impact on the liquid. The diffuser nozzle (Figure 32) consists of a diffuser 2 into which a small tube 3 is inserted for supplying a working fluid. Spraying is mainly due to airflow pulsations. The working fluid is not supplied with high pressure. The flow rate is controlled by a dosing plate 6 with different sized holes.

Droplet size and size distribution. When liquid is atomized, droplets of various sizes are formed. The spray droplets are classified by their diameters, typically measured in microns (µ). The performance and effectiveness of an atomizer depend upon the droplet size and size distribution. Table on Figure 33 shows some of the characteristics of various size droplets. The area covered and the volume of liquid in individual droplets is important in achieving effective and efficient application.

Spray droplet size and its effect on coverage for a 10 L/ha application rate

Droplet diameter, µ	Type of droplet	Area relative to a 10 µ droplet	Volume relative to a 10 µ droplet	No. of droplets per cm^2	Coverage relative to 1000 µ droplet
5	Dry fog	0.25	0.125	1,524,647	200
10	Dry fog	1	1	190,581	100
20	Wet fog	4	8	23,822	50
50	Wet fog	25	125	1,525	20
100	Misty rain	100	1000	191	10
150	Misty rain	225	3375	56	6.7
200	Light rain	400	8000	24	5
500	Light rain	2500	125,000	1.5	2
1000	Heavy rain	10,000	1,000,000	0.2	1

[1] Microns are also called micrometers and may be abbreviated µm. One micron is one millionth of a meter. A person with normal eyesight can see 100 µmwithout any magnification.

Fig.33. Table for spray droplet size and its effect on coverage for a 10 L/ha application rate

Smaller droplets of the same volume provide more coverage. For example, one 200 µ droplet when broken into 64 droplets of 50 µ diameter will cover four times more area than the 200 µ droplet (Fig.34). The droplet distribution is also important from the point of view of spray drift. The smaller the droplet size the longer it takes for it to settle and the higher the probability of drift.

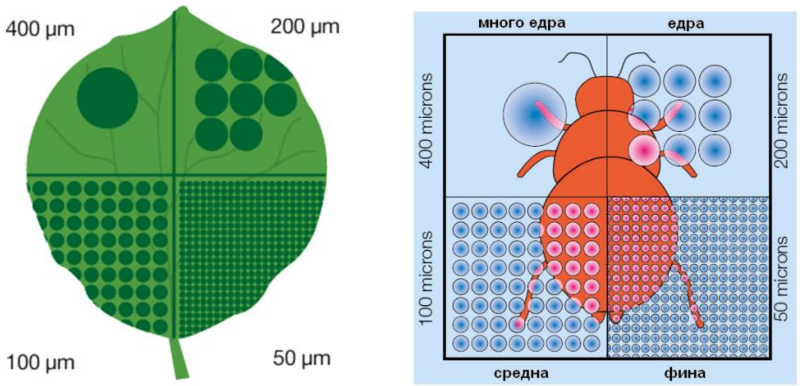
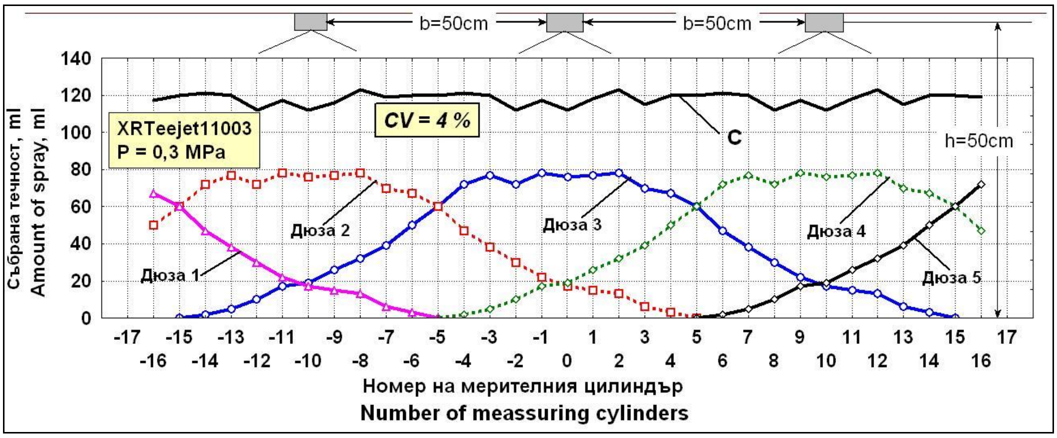


Fig. 34. Examples for the diameter of drops and the increasing the number of drops

Sprayer performance is evaluated by the uniformity of coverage and spray patterns, droplet size and size distribution, and target deposition and drift.

Uniformity of coverage. The uniformity of coverage is determined by:
(a) the type of nozzle,
(b) the nozzle spacing,
(c) the boom height,
(d) the angle of the spray nozzle.

As shown in Figure 35, the most uniform coverage is produced with a flat-fan nozzle with a wide angle, with the boom height set at the minimum recommended height. Raising or lowering the boom results in over- application or under-application. The figure also shows the effect of spray angle on the uniformity of the spray pattern. For narrow spray angle nozzles, the spray pattern is much more sensitive to changes in boom height.



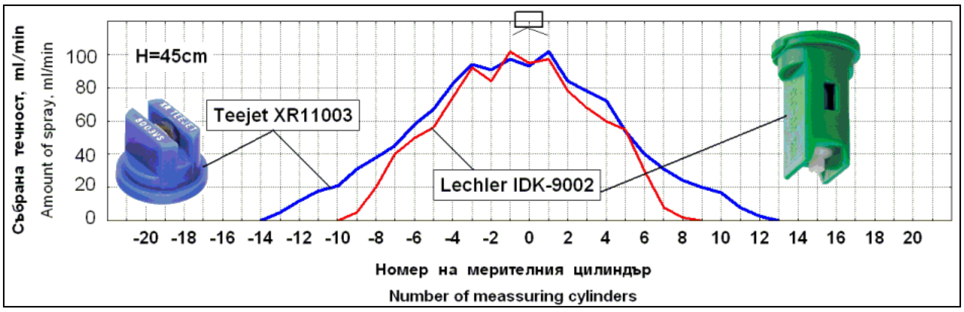


Figure 35. Uniformity of coverage of flat-fan nozzles

It is generally recommended that for flat-fan spray nozzles a 60 % overlap should be obtained by adjusting the boom height. (The overlap is defined as the width covered by two adjacent nozzles divided by the width covered by a single nozzle, expressed in percent.) The boom height can be calculated for a given amount of overlap and nozzle spacing.

However, manufacturers' recommended minimum boom height should be used because the actual spray width is somewhat less than the theoretical value as calculated by the spray angle and the boom height. The recommended amount of overlap for flooding flat-fan nozzles and some wide-angle hollow-cone nozzles is 100 %.

Droplet Size. Droplet size is affected by nozzle type, spray angle, flow rate, and operating pressure. Generally, the hollow-cone nozzles produce the finest droplets, flat-spray nozzles the next-finest, while the full-cone nozzles produce the coarsest spray. The droplets become finer as the width of spray increases, due to spreading of the liquid sheet to a greater angle, which produces more fines at the edges. For a given type of nozzle, the smallest capacity nozzle produces smaller droplets and vice versa.

As the operating pressure increases the droplet size decreases. It is, therefore, important to realize that while increasing the application rate by increasing pressure, the droplet size would decrease and may result in higher drift. Liquid viscosity and density have a very little effect on droplet size in the range commonly found in the agricultural application.

Drift and coverage. Spray drift poses a significant hazard to the environment, as most pesticides, herbicides, and fertilizers are toxic or have other undesirable effects on unintended targets. Smaller droplets tend to drift more than larger ones, because smaller droplets take longer to settle. Note that as the droplet size decreases settling time increases in a logarithmic manner. Droplets that take longer to settle are very prone to drift (Fig. 36). Every nozzle produces droplets of different sizes, but if the size distribution is very wide, a lot of droplets will be undersized and be prone to drift.

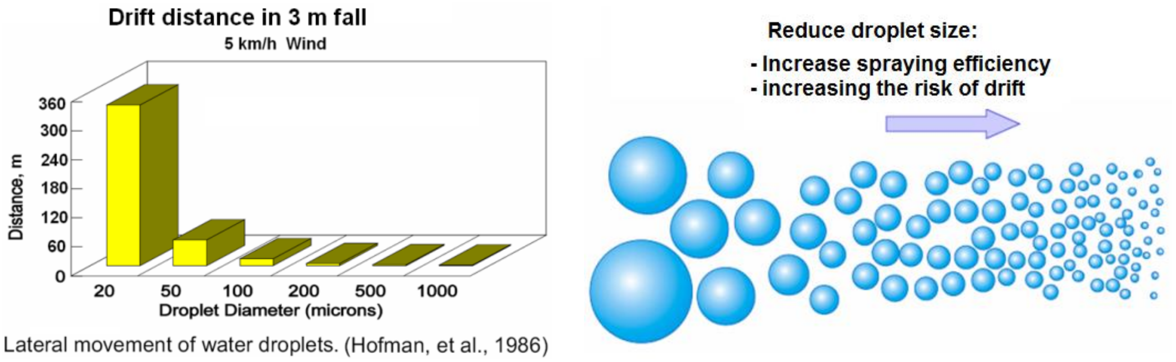


Fig. 36. Dependence between droplet size, spraying efficiency and the risk of drift

It is, therefore, best to produce a narrow distribution of droplet sizes near the desired size. Generally, a balance has to be struck between the large droplets and the small droplets. Large droplets give greater penetration of the plant canopy while smaller droplets give greater coverage. The table in Figure 110 shows the effects of droplet size on coverage. As the droplets become smaller the coverage increases for the same application rate.

For systemic herbicides, larger droplets would be acceptable, but for contact herbicides or fungicides, full coverage made possible by smaller droplets is more desirable. In addition, although smaller droplets give better coverage they evaporate at a faster rate adding to the drift.

Research is underway to improve sprayer efficiency and reduce drift. Electrostatic charging and air-curtain sprayers are two results of the efforts in this direction. Droplets are electrostatically charged to improve their tendency to adhere to the plants thereby increasing the efficiency of coverage and reducing drift. In air-curtain sprayers, the droplets are introduced in a fast moving air stream to increase penetration into the plant canopy.

Nozzle wear

Spray nozzles are made of various materials such as ceramic, plastic, brass, stainless steel, alloy steels and more. The solution passes through their high-pressure openings and the abrasive particles it carries wear out the surface of the hole. Wearing is not only the abrasive but also the chemical action on the material from which the nozzle is made. So every nozzle has a certain life and he has finished (i.e. deteriorating his features) should be scrapped and replaced with a new one - the nozzles are not subject to repair.

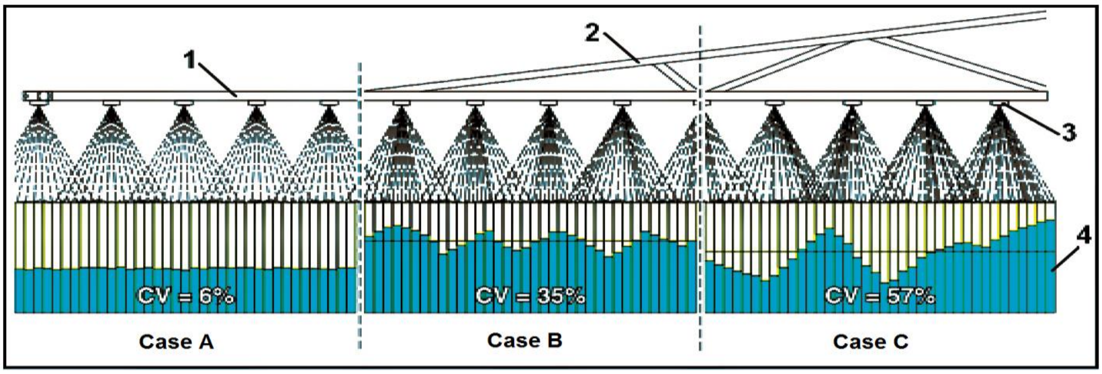


Fig. 37. Graph of the solution distribution under the boom: Case A - new nozzles; Case B - worn nozzles; Case C - destroyed nozzles. Markings: 1 - pipeline; 2 - boom; 3 - nozzle; 4 - accumulated liquid in the measuring cylinders

There have been found that ceramic nozzles have the highest wear-resistance. For example, after 60 hours of operation at a pressure of 4 bar (0,4 MPa), their working orifice increased by only 3,8 %, while under the same operating conditions the increase in steel was 8 % and in the plastics – 20 %. Nozzles made of softer metals such as brass, bronze, aluminum, etc. under these operating conditions, increase their orifice by an average of 25 % to 32 %, which is why they are more quickly damaged and often replaced with new ones.

The nozzles made of alloy steels and stainless steel, high accuracy is achieved in making orifices using laser technology to produce them. Their disadvantage is their relatively high price. The uniformity of spraying is strongly influenced by the degree of wear or destroying of the nozzle (Figure 37).

Operation of the boom sprayer in cases B and C of Figure 37 should not be allowed due to the risk of poor spraying quality and poor distribution of the working fluid over the area. For example, at a required Q = 300 l/ ha rate, some strips will be sprayed with 200 l/ha, and others with 400 l/ha, which is absolutely unacceptable especially when working with herbicides. The easiest thing to do is worn sprayers to be scrapped and replaced with new ones – otherwise, there is a risk of destroying much of the crop and losing too much.

Clogging of spray nozzles

Clogging of the nozzles is an extremely unpleasant fact, resulting in a very poor spraying quality. In order to prevent this, it is necessary the sprayer have a minimum of three-stage filtration.

Cleaning of the nozzle should not be done with metal objects (needle, nail, wire, etc.) as the shape of the hole changes and the nozzle starts to work poorly - it is advisable to use a special hard-plastic brush (Figure 38). Also, cleaning should not be done by mouth due to the risk of poisoning. A powerful air jet from a compressor can be used. In all cases, rubber gloves should also be used.

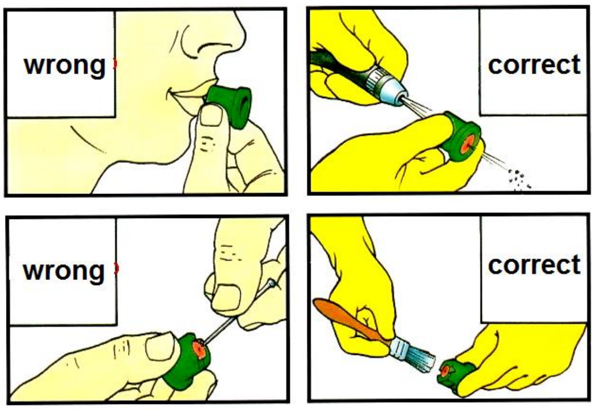


Fig. 38. Correct and incorrect ways to clean clogged nozzle holes

When clogging the nozzles, some strips of the field may remain untreated with working fluid or remain partially treated (Figure 39).

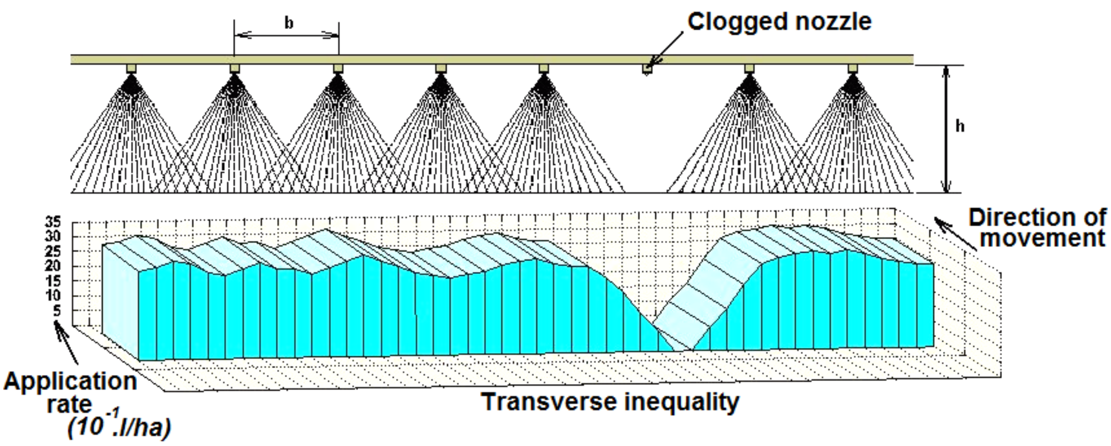


Fig. 39. Distribution of working fluid under the bar when clogging a nozzle

12. Elements for controlling and regulating the sprayers

The control elements are usually mounted in one block (Figure 40) and it is secured in a convenient place for the tractor driver - to easily manipulate it. The main shut-off valve 2, the pressure regulator 3, the pressure gauge 5, the section valves 6 and the filter 8 are assembled. With the main shut-off valve we stop the working fluid to the nozzles in maneuvers at the end of the field. When the main valve is closed, all the solution is redirected back to the tank using hose 4.

The pressure regulator separates the excess solution and returns it back to the tank also via the hose 4. The remaining amount of solution is passed through the filter 8 to the sectional valves and from there to the nozzles. If desired, the farmer may exclude any of the sections, provided they are not needed (for example at the end of the block when spraying the last strip, over roads, etc.).

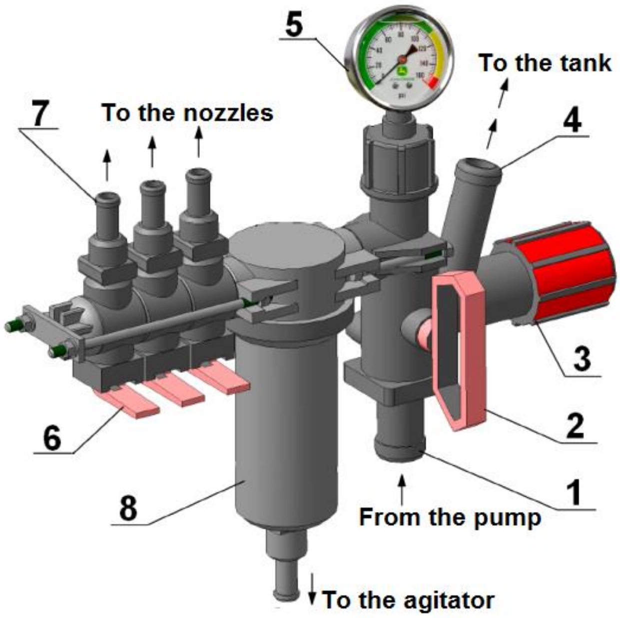


Fig. 40. A set of elements for controlling and adjusting the sprayer: 1 - a hose coming from the pump; 2 - main shut-off valve; 3 - pressure regulator; 4 - the excess solution hose; 5 - pressure gauge; 6 - sectional valves; 7 - hoses going to the spraying system; 8 - filter

13.Filters

For the normal operation of the sprayer, at least three-stage filtration of the solution must be ensured, the last and the finest filter being in the nozzle body.

Otherwise, the nozzles are clogged by the larger particles that carry the working fluid (rust particles, sands, undiluted powder balls, etc.).

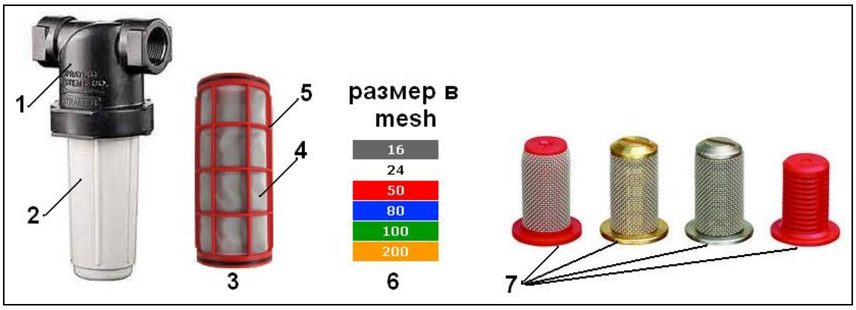


Fig. 41. Filters for sprayer: 1 - body; 2 - cup; 3 – insert body; 4 – filter meshes; 5 - armature; 6 - standard mesh sizes; 7 - filters for nozzle bodies

In order to filter the working fluid, coarse filters are applied to the tank hole, fine filters (Fig. 41, position 1, 2 and 3) before the pump and after the pump, and fine filters in the nozzle bodies (Fig. 41, position 7) as the final stop of the larger particles in the solution along their way to the nozzle opening.

14. Electronic control and signaling elements. Automatic sprayer control systems

When operating the sprayer in the field, the tractor driver must strive to maintain a constant speed, as it directly affects the preset operating fluid flow rate. For example, we set an application rate of Q = 300 l/ha and a working speed of 7 km/h at which the sprayer mode is calculated. If we allow increasing the working speed to 9 km/h, then the application rate immediately drops to 230 l/ha. If the working speed drops to 5 km/h, the cost rate increases drastically to 420 l/ha.

This defines the so-called longitudinal unevenness of spraying. From this example, you can see how important it is and why it is necessary to strictly observe the predetermined working speed of the tractor.

For these reasons, computerized systems are already placed in modern sprayers to maintain a constant application rate regardless of working speed fluctuations (Figure 42). Flow, pressure and velocity sensors are installed on the sprayer to send their signals to an onboard controller (computer). It produces a control signal to influence the sprayer elements so as to maintain the persistence of the application rate over time.

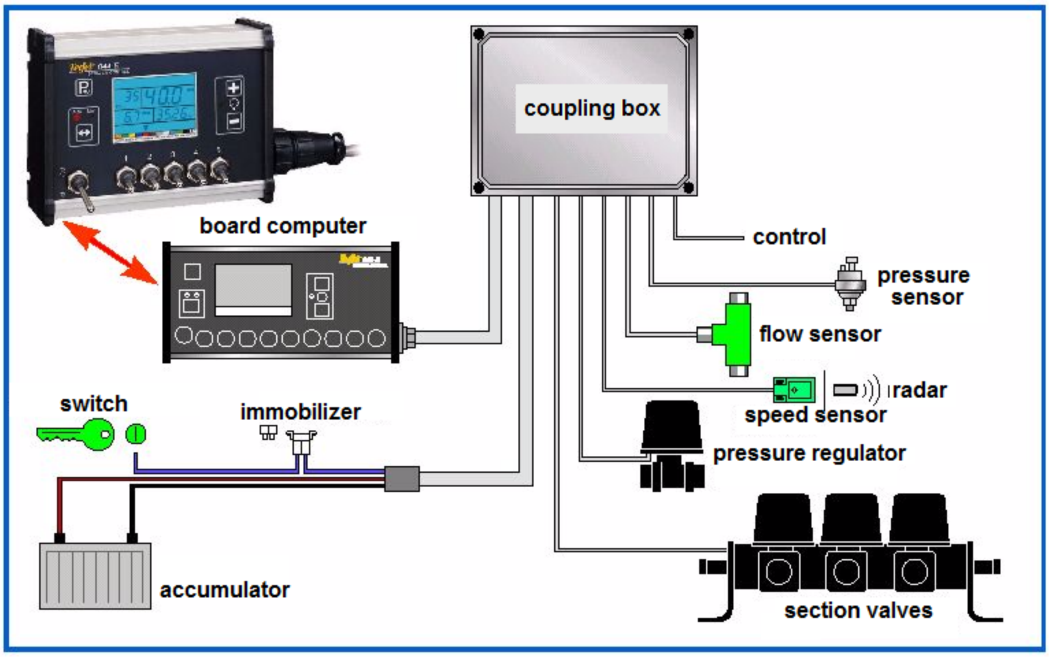


Fig. 42. Control system and automatic control of a sprayer with an on-board controller (computer) and various types of sensors

The controller monitor (Figure 43) shows: the working fluid pressure, the system flow rate, the speed of movement, the moment value of the solution flow rate, the area sprayed so far, etc. The control panel can be manually operated by means of electric switches: the pressure of the solution, the launching and stopping of the nozzles throughout the boom, the start and stop of only a certain section of the boom, and others.

Fig. 43. On-board controller panels with monitors and control buttons

When GPS navigation is available, on the monitor has forward direction option and for automatic control of the sectional valves so there is no overlap of the treatment zones.

All these electronic systems to the sprayer contribute to better coating uniformity, higher spray quality, ease work of the tractor driver, give him the confidence that at any moment he fully controls the situation and can intervene if the system comes out of balance.

Quality control of the operation

The number of droplets per unit area can be determined on control sheets of water-sensitive paper (Figure 44), which are located at different places in the plantation (usually the paper is yellow and when the drops fall on it, the footprint becomes blue, allowing accurate counting of droplets).

For systemic plant protection products, it is sufficient for 1 cm^2 area to reach 30-40 pcs. of droplets, and in contact plant protection products - 80-100 pcs/cm^2.

The normal droplet distribution is shown in Fig. 44,a, and Fig. 44,b. Lowering the sprayer speed and spraying with larger droplets will result in the droplets being merged. In this case, the spraying quality is getting worse and the danger of "pouring" and running the solution is high (Figure 44, c, d).

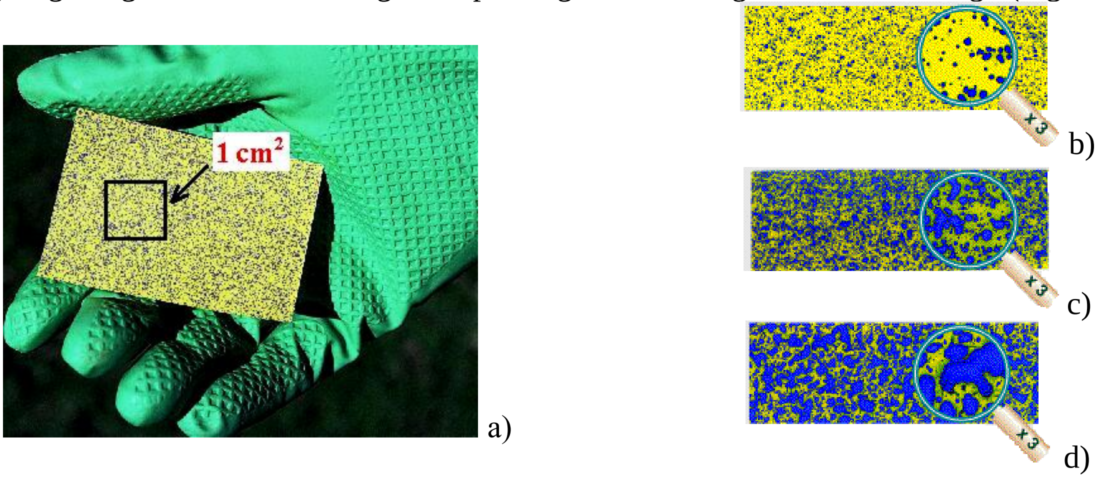


Fig. 44. Controlling the number of drops per unit treated area

In conclusion, some more important rules are given in aspect of the uniformity and quality of spraying:

- Observe the height of the boom over the field (usually h = 50 ÷ 60 cm) and the distance between the nozzles (usually b = 50 cm);
- if possible new sprayers should be used and all be the same type and size;
- to check the wear of the nozzles (checked at least once a year); worn and broken nozzles are scrapped and replaced with new ones;
- frequently to do monitoring of the clogging of the nozzles during work; to apply three-stage filtration of the solution;
- to ensure boom stability during operation; to install compensators that reduce the oscillations of the boom;
- to ensure a constant speed of the tractor; the permissible deviation from the speed shall not be more than 0,5 km/h.
- to ensure the technical condition of manometers, regulating devices, valves, pipelines, and of all filters and nozzles;
- In order to protect the filters and nozzles from clogging during operation, attention must be paid to the preparation of the working fluids; for this purpose sources of pure water are used and the preparations (especially the powders) must be thoroughly diluted in advance;
- The fan and spraying system must be kept clean of dust, leaves, etc., which may interfere with a normal operation;
- the filters must be cleaned after each or at least several spraying tanks, and the filtering elements must always be kept in good condition and, if necessary, replaced with new ones;
- after the operation, if there is any working fluid in the tank, it must be poured into a designated area. All parts of the sprayer are cleaned and daily maintenance is carried out and, if necessary, repaired.

16. Adjusting the sprayers for operation. Sprayer calibration

Adjustment the sprayer for plant protection is an integral part of the spraying operation. This is done to ensure that the manufacturer's requirements are met for accurately dosing of the chemical over the treated area or plants. Care must be taken to adjust sprayer to work, as any overdose or inadequacy of the preparation can lead to major economic losses due to crop damage, soil and environmental pollution, a high cost of plant protection products, fuel, lubrication, labor and others.

General principles for adjustment of boom sprayer:

1. Select the appropriate application rate of the working solution Q in l/ha.
2. Select the appropriate working speed v of the tractor/sprayer unit in km/h.
3. Calculation of sprayer working width B_p in m.

$$B_p = n.b,$$

where: n is the number of nozzles;
b - the distance between nozzle bodies, m.

4. Calculation of the required minute flow rate q of a nozzle in l/min

$$q = \frac{Q.v.b}{600}, \text{ l/min}$$

5. Determination by a table (or graph) the size of the sprays and the working pressure of the solution.
6. Preparation of the working solution (percentage solution or solution with a dose of the preparation per hectare).
7. Assemble the nozzles, adjusting the height of the spray boom, starting the sprayer, adjusting the pressure.
8. Control the speed of sprayer and the quality of the drip coating.

General principles for adjustment of an air-blast sprayer (fan sprayer):

1. Select the appropriate application rate of the working solution Q in l/ha.
2. Select the appropriate working speed v of the tractor/sprayer unit in km/h.
3. Select the way of moving the sprayer in the plantation (Figure 45).
4. Calculation of sprayer working width B_p in m

$$B_p = m.b,$$

where: m is the number of spray rows per one working move;
b – between row spacing, m.

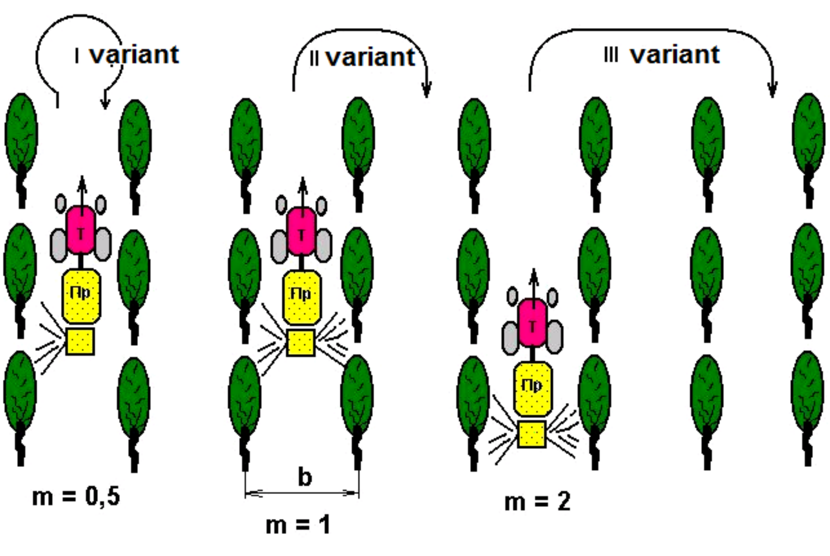


Fig. 45. Variants of motion of the sprayer in the plantation:
twice in one row (m = 0.5); one time in a row (m = 1); over one row (m = 2)

5. Calculation of the required minute flow rate q of a nozzle in l/min:

$$q = \frac{Q.v.B_p}{600.n}, \text{ l/min}$$

6. Determination by a table (or graph) the size of the nozzles and the working pressure of the solution.

7. Preparation of the working solution (percentage solution or solution with a dose of the preparation per hectare).

8. Assemble the nozzles, adjusting their direction angle, starting the sprayer, adjusting the pressure.

9. Adjusting the fan speed and airflow direction.

10. Control the speed of sprayer and the quality of the drip coating.

THEME 3. MACHINES FOR SEED TREATMENT WITH CHEMICALS (DECONTAMINATION)

The term "treated" means "to give an application of a pesticide on seed to a process designed to reduce, control or repel disease organisms, insects, or other pests which attack the seed or seedlings."

Decontamination is a process in which seeds are treated with a chemical preparation before sowing. Thus, the treated seed, when sown in the soil, is protected from pathogenic organisms and pests.

There are three ways of chemical decontamination - wet, dry and semi-dry. In the wet decontamination the seeds are treated with a solution, in the dry – with powder formulation, and in the semi-dry - wetted seeds are mixed with a powder preparation.

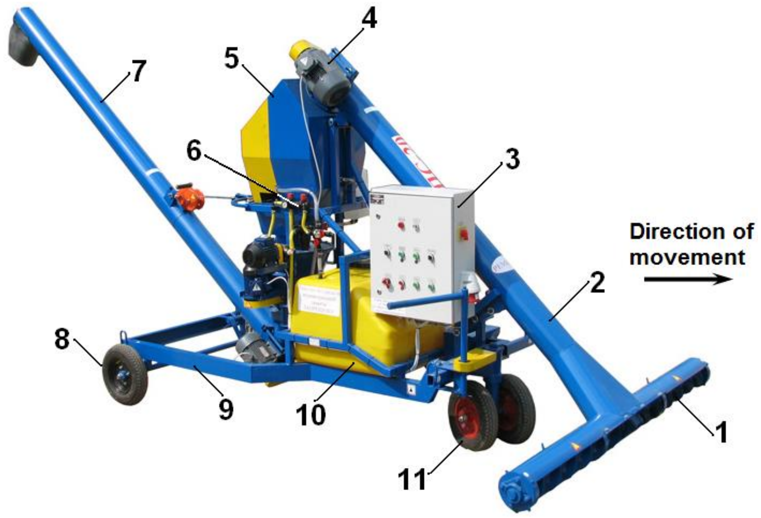


Fig. 46. Self-propelled seed decontaminator: 1 - auger conveyor collector; 2 - loading auger conveyor; 3 - control panel; 4 - electric motor; 5 - bunker; 6 - dosing system; 7 - unloading auger conveyor; 8 – supporting wheels; 9 - frame; 10 – tank for the solution; 11 - steering wheels

Device

Seed threaters must be able to carry out the three ways of decontamination. Therefore, they consist of three systems: grain feeder, solution (or water) feeder and powder feeder. These three dosed components are fed into a mixer.

The grain feed system is compiled with an auger collector 1 (Figure 46), loading auger conveyor 2 with an electric motor 4, a bunker 5 and dosing bodies at the bottom of the bunker. The liquid supply system consists of a tank 10, a pump and dosing system 6. The machine is mounted on wheels and moves on the workplace by an electric motor. There are two speeds - slow working speed and fast transport speed. The operation mode is set by the electric panel 3.

Chemical Seed Treater CT 25

The **Chemical Seed Treater CT 25** is used for continuous, wet chemical treating of seed such as grain, corn etc.

Construction:

The chemical seed treater consists of the product inlet 1 (Fig. 47), the chemical seed treating chamber with the distribution and spraying disc 5, the dosing unit with a pump and the secondary mixing unit 6. The drives are operated with a gear motor. The chemical seed treater is controlled by a control cabinet with a touch panel and is lined with wear plates.

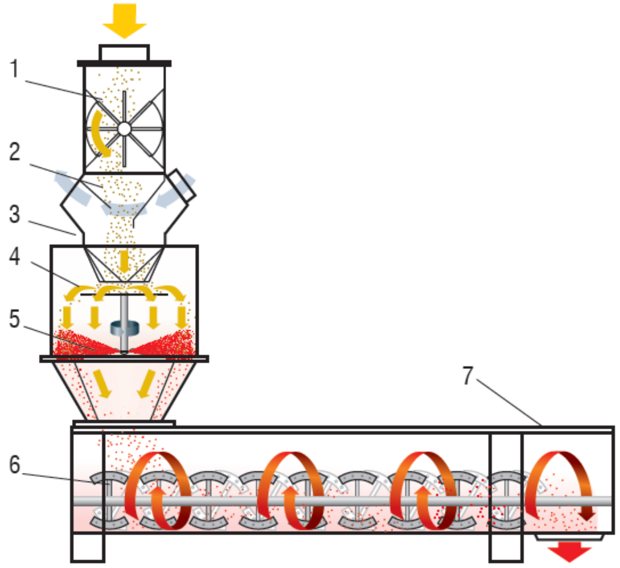


Fig. 47. Scheme of chemical seed treater type CT-25: 1 - inlet with rotary seed valve; 2 - aspiration system; 3 - inlet hopper; 4 - seed distribution disc; 5 - spraying disc; 6 - secondary mixing unit with a discharge outlet of the seed; 7 - aspiration connection

Description:

The seed is transported to the chemical seed treating chamber over the inlet. There, the product is distributed in an even product veil by a rotating distribution disc.

The seed dressing is dosed by a metering pump on a spraying disc and evenly sprayed on the seed, creating a fine mist, and then brought in contact with the product veil.

After applying the seed dressing, the product is transported to the secondary mixing unit where an even and uniform distribution of the seeds is ensured.

Technical Data		CT 25
Capacity (based on wheat)	t/h	5 to 25
Electrical drives		
Distribution disc	kW	0.75
Secondary mixing unit	kW	1.5
Rotary seed valve	kW	0.37
Dosing of chemical liquid	ml/100kg	200 - 800

Fig. 48. Technical data of chemical seed treater type CT-25

Basic settings of the decontaminator:

- adjusting the amount of incoming grain to the decontamination chamber;
- adjust the amount of powder;
- adjust the amount of working solution;
- decontamination mode is set on the control panel.

Chapter II. MACHINES FOR SOIL TILLAGE

Machines for soil tillage have to prepare the soil for the degree of suitability for further working processes such as sowing, planting, fertilizing, etc. Soil cultivating is the oldest operation in agriculture and machines for this operation have the longest path of development and the greatest variety of species and types.

THEME 4. TYPES OF MECHANICAL TILLING THE SOIL. GENERAL CLASSIFICATION OF TILLAGE MACHINES.

1. Importance and agrotechnical requirements for soil tillage

The main task of soil tillage is to improve the physical properties of the soil layer in order to create good conditions for the sowing, emergence and development of the crop plants.

Soil tillage means the application of mechanical force to the workable layer by different kinds of agriculture machine tools (plows, cultivators, harrows, rotary tillers, rollers, disk harrows, etc.).

The main importance of soil tillage is that it significantly preserves and improves its soil fertility. Qualitative soil tilling not only allows regulating the aggregate of soil processes, but also ensures high efficiency of the other agrotechnical measures - fertilization, control of diseases and pests, weed destruction, quality sowing, etc.

Tillage may be defined as the mechanical manipulation of soil. In agriculture, the objectives of soil tillage are:

- To develop a desirable soil structure for a seedbed or a root bed. A granular structure is desirable to allow rapid infiltration and good retention of rainfall, to provide adequate air capacity and exchange within the soil, and to minimize resistance to root penetration. Compared to a root bed, a good seedbed has finer particles and greater firmness in the vicinity of the seeds, to enhance moisture absorption by the seeds needed for germination.
- To control weeds or remove unwanted crop plants.
- To manage plant residues. Thorough mixing of residue is desirable from the tilth and decomposition standpoints, whereas retention of residue on the soil surface or in the top layers reduces erosion.
- To minimize soil erosion by following such practices as contour tillage, listing, and proper placement of plant residue.
- To establish specific surface configurations for planting, irrigating, drainage, or harvesting operations.
- To incorporate and mix fertilizers, manure, pesticides, or soil correctives into the soil.
- To realize segregation. This may involve moving soil from one layer to another, removal of rocks and other foreign objects, or root harvesting.

Different types of soil cultivation are subject to appropriate agrotechnical requirements. The main ones are: observing the set depth of tilling, burial of plant residues, crushing large soil lumps and flattening the surface of the field.

Deviation of the mean factual depth from the set maximum of 5% is allowed.

In the plowing operation (reversing of the soil layer), high uplands and deep furrows are not allowed. The burial of plant residues should not be less than 90-95%. The crushing of the soil should be such that lumps of up to 10 cm in size are not less than 80%, measured by the weighing method.

In the pre-sowing tillage of the soil, the main requirements for the different types of tilling are the shredding of the soil layer, the even mixing of the spread fertilizers and the shredded plant residues and the leveling of the field surface.

In the inter-row tilling the requirements are: to be completely destroyed the weeds; the irrigated furrows to have a properly shaped profile so as not to be covered with soil or plant residues.

In order to create good conditions for the emergence, growth and development of agricultural crops, it is necessary to carry out such a system of soil tillage, which helps to solve the following tasks:

- establishing a fixed ratio between the solid, liquid and gaseous phases in the soil;
- optimal regulation of the water, air, heat and nutrition of the soil;
- weed control in crop cultivation;
- burial of plant debris, fertilizers and herbicides at the required depth;
- sowing seeds from cultivated crops at optimal depth;
- development of plant roots in the soil layer and their penetration at a greater depth;
- accumulation and preservation of moisture in the soil around the roots of the plants;
- decomposition of the organic matter into the soil layer;
- providing the necessary microrelief on the soil surface;
- soil protection against erosion (non-admission transferring the soil from water and wind).

2. Types of mechanical tillage of the soil and machinery for carrying out this practice.

Tillage methods and equipment. A tillage tool is defined in this textbook as an individual soil-engaging element, such as a plow bottom or a disk blade. A tillage implements consists of a single tool or a group of tools, together with the associated frame, wheels, hitch, control and protection devices, and any power transmission components. For tillage implements, the processing system consists of the tillage tools, while the other components form the support systems.

At all the world the farmers choose from a variety of implements for soil tillage. The set of implements that an individual farmer chooses depends on local customs, crop type, soil moisture level, soil type, and the amount of plant residue from the previous crop. Tillage implement selection is also affected by the availability of implements, power units, labor, and finances.

The three hitching configurations available for these implements are: *integral* (mounted), *semi-integral* (semi-mounted), and *drawn* (pull-type, trailed). Integral and semi-integral implements are attached to the three-point hitch of a tractor, but a drawn implement is attached to the drawbar.

An *integral* plow, in the transport position, is fully supported by the tractor. The rear furrow wheel of an integral implement provides vertical and lateral support along with the hitch when the implement is in its operating position. Plowing depth for an integral plow is usually controlled by changing the vertical position of the tractor's hitch.

A *semi-integral* plow is supported at the front by the tractor's hitch and at the rear of the plow's furrow transport wheel in both the transport and operating positions. The front of the plow is raised and lowered by the tractor's hitch while the rear of the plow is raised and lowered by a remote hydraulic cylinder. A *drawn plow* (or implement) is fully supported by its own transport wheels and is raised and lowered by a remote hydraulic cylinder.

Depending on the thickness of the cultivated soil layer (the depth of treatment) the soil tillage is divided into the following three groups – basic (*primary tillage*), surface (*secondary tillage*) and special. Although the distinction is not always clear-cut.

A primary tillage operation is the initial, major soil-working operation after harvest of the previous crop; it is normally designed to reduce soil compaction, cover plant materials, and rearrange soil aggregates.

Secondary tillage operations are intended to create refined soil conditions following primary tillage. The final tillage operation prior to planting a crop is usually secondary tillage, but farmers may use more than one secondary tillage operation. In some situations, a tillage operation may fit the definition of both secondary and primary tillage. For example, a farmer may prepare a field for planting winter wheat with a single disking operation after harvesting soybeans. This single disking operation is both the initial tillage operation after harvest and the final tillage operation before planting.

Erosion of soil by wind or moving water is a problem that plagues agriculture in many parts of the world. The erosion process removes nutrients and other chemicals from land as well as soil. Some farmers use conservation tillage, a practice which leaves plant residue on the soil surface to reduce erosion. Practicing *conservation tillage* can reduce the time and energy required for tillage, although this practice frequently requires better management than *conventional tillage*.

Basic soil tillage (primary tillage). Implements used for primary tillage are moldboard plows, disk plows, chisel plows and subsoilers.This practice applies for plowing at a depth of 18 cm to 35 cm. There is shallow plowing (18-21 cm), medium plowing (22-27 cm) and deep plowing (28-35 cm). Tillage machines for this practice are called plows (Figure 49, a).

a)

b)

Fig. 49. Machines for basic soil tillage: (a) a plow; (b) subsoiler

Basic soil tillage includes and another operation, called subsoiling (very deep tillage). It is carried out at a depth of 50-100 cm and it is suitable for soils with a shallow humus. It also applies to seasonally-soaked and secondary-compacted soils, as well as to soils subject to erosion.

To perform this operation, machines called subsoilers are used (Fig.49, b). Subsoiler is a kind of plow with no moldboard, used to loosen the soil at a big depth below the surface without turning it over.

When repeatedly plowing at the same depth, the soil layer is compacting and it is formed so-called "plowing heel" (over compacted soil layer) that prevents the penetration of moisture into the root system of the plants in the lower soil horizons, and vice versa.

In addition to a positive effect on soil fertility, deep tilling (subsoiling) ensures a better economic result, higher productivity and lower fuel consumption per unit of surface area.

The soil is aerated and drained better, which creates favorable conditions for the development of the root system of the plants and thus increases the yield per unit area. Most farmers use only one primary tillage operation after harvesting a crop. An exception is when a farmer uses a subsoiler in the fall shortly after harvest followed by another primary tillage in the spring.

a)

b)

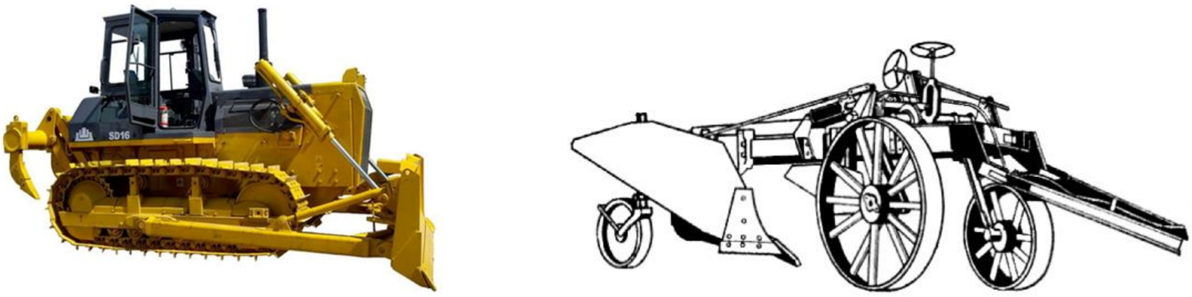
c)

d)

Fig. 50. Machines for surface tilling: (a) cultivator; (b) disc harrow; (c) rotary tiller; (d) rotary hoe

Surface tillage (secondary tillage). Includes pre-sowing soil tillage at depth of up to 15 cm, soil tillage in spaces between rows in vegetable cultures and perennial plantations at depth of up to 12 cm, shallow loosening up to 16 cm, etc. The machines used for surface tillage (Figure 50) are cultivators, disc harrows, rotary tillers, ordinary tooth harrows, rotary hoes, spring tillers, rollers, etc.

Special soil tillage. This group includes the machines for tillage of long time uncultivated lands, for development of marsh and rocky soils, and the preparation of crops for planting vineyards, orchards and rice crops (removing stones, tree and shrub cleaning, leveling, draining, ultra-deep plowing, etc). The machines for these practices are (Figure 51) bulldozers, land leveling machines, big plows, etc.



a) b)

Fig. 51. Special tillage machines: (a) bulldozer; b) big plow for ultra-deep plowing

3. Effects of machine organs on soil

Depending on the objectives to improve the soil quality and to create conditions for the development of the plants, the soil layer is subjected to the following treatments: reversing, translocation of layers (mixing), soil loosening, compacting, hoeing, furrowing, drainage and more.

The reversing of the layer consists in shifting the positions of its upper and lower layers. In this case, the layer may turn over completely in 180^0 or partially - up to 135^0.

When **translocate the layers and loosening**, soil volume density is reduced, resulting in improved water and air permeability and increased biological activity.

Compaction is an anti-loosening treatment. The bulk density and the capillary capacity of the soil are increased. The contact area with seeds and plant roots increases. The degree of loosening or compaction is estimated by the thickness of the treated soil layer before and after treatment.

Mixing is applied to leveling the soil structure or evenly distributing fertilizers and other substances (for example: soil herbicides) throughout the volume of the tilled layer.

Hoeing is a type of treatment to kill weed vegetation by pruning the root system.

Furrowing is done to create a suitable surface for planting some crops, gravity watering, etc.

Cutting the soil with a wedge. Cutting is one of the most common working processes and is the basis of the work of almost all soil working bodies. There are two types: cutting without sliding and sliding cutting. For sliding cutting, less force than non-slip cutting is required. Therefore, it is desirable to design all working bodies of the machines to cut with sliding.

4. General classification of soil tillage machines

Separation of soil cultivation machines by species is done on two indications - technological and energetic. According to the technological operation (the type of processing), these machines are subdivided into share plows and disc plows, subsoilers, cultivators, rotary tillers, harrows, rollers and combined machines.

According to the way of transferring the energy from the tractor to the working bodies, the machines are:

- with passive working bodies;
- with active working bodies;
- with combined working bodies.

Machines with passive working bodies are pulled by the tractor hitch and carried out the operation for which they are intended without additional energy supply.

Machines with active working bodies are pulled by the tractor, but additional power is supplied to them by:

- drive shafts connected to the power take-off shaft (PTO shaft) of the tractor;
- hydraulic motors connected to the tractor's hydro system;
- electric motors connected to the tractor's electrical system.

Machinery having both passive and active working bodies or working bodies of different uses are called combined.

THEME 5. MACHINES FOR BASIC SOIL TILLAGE

They are also called machines for deep soil tillage. These include plows, subsoilers and big plows for ultra-deep plowing. Most commonly farmers used plows.

The tasks of the plowing operation are:

• reversing, loosening and partially mixing the soil;
• destruction of the emerging weed vegetation by pruning roots;
• moving the surface weed seeds and the plant residues deep into the soil;
• improving the physical, water and air properties of the soil;
• plowing of difficult moved fertilizers (phosphorus and potassium) to the depth of their use.

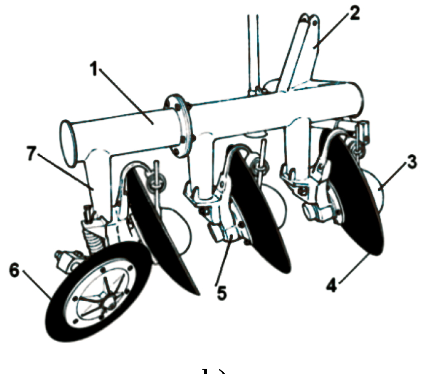
1. Plows - purpose and species

From the point of view of the principle of operation, they are moldboard plows (fig.52, a) and disk plows (fig.52, b).

Disk plows

The common *disk plow* consists of a series of disk blades 4 mounted individually on a frame as shown in Figure 52,b. The disk blades are set at an angle, called the *disk angle,* from the forward line of travel, and also at a *tilt angle* from the vertical. Standard disk plows usually have three to six blades, spaced to cut 18 to 30 cm per disk. The disk angles vary from 42° to 45° and the tilt angles vary from 15° to 25°. The disk diameters are commonly between 60 and 70 cm.

a)



b)

Fig. 52. Types of plows: a) moldboard plow; b) disk plow: 1 - frame; 2 - a hitching device; 3 - scraper; 4 - disk blade; 5 - bearing body; 6 - a furrow stabilizer wheel; 7 - stand

Disk plows are used for primary tillage and are available in integral, semi-integral, and drawn hitching configurations. They are most suitable for conditions under which moldboard plows do not work satisfactorily, such as in hard, dry soils, and in sticky soils where a moldboard plow will not scour. Scrapers, furnished as standard equipment on most disk plows, assist in covering plant residue and inverting the soil and prevent soil buildup in sticky soils.

Under most conditions, and particularly in hard, dry soils, any disk tool must be forced into the ground by its weight rather than depending upon suction as does a moldboard plow. Consequently, disk plows are built with heavy frames and wheels (total masses of 180 to 540 kg per disk blade), and even then additional mass must sometimes be added to obtain the desired depth. The soil penetration ability of a disk plow depends upon disk diameter, tilt angle, and disk angle.

A standard disk plow does not have special attachments to protect its disk blades from damage due to impact with rocks buried in the soil. Usually, the disk plow is able to withstand impact forces because of its heavy frame and its lower operating speed.

Moldboard plows

Moldboard plows are the most common implement used for primary tillage, but they are never used for secondary tillage. They are usually equipped with adjustments to ensure that the plow is level in the longitudinal and lateral directions and that the plow bottom is oriented with the landside parallel to the direction of travel.

All moldboard plows are equipped with one or more tillage tools called *plow bottoms* (Figure 53). Each plow bottom is a three-sided wedge with the landside and the horizontal plane of the share's cutting edge acting as flat sides and the top of the share and the moldboard together acting as a curved side. The primary functions of the plow bottom are to cut the furrow slice, shatter the soil, and invert the furrow slice to cover plant residue. Most moldboard plows are also equipped with tillage tools called *rolling coulters* (Figure 53) to help cut the furrow slice and to cut through plant residue which might otherwise collect on the shin or plow frame and cause clogging.

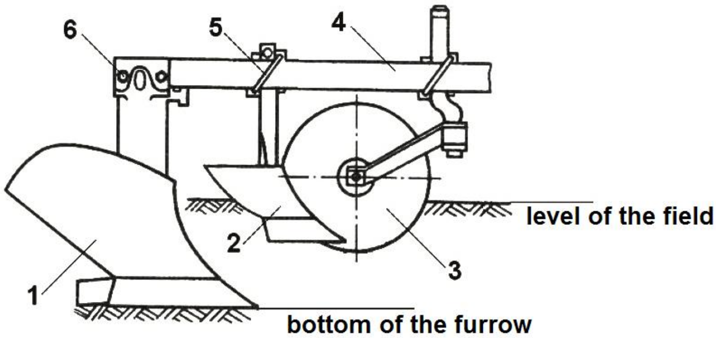


Fig. 53. Scheme of moldboard plow with disc blade: 1 – plow bottom; 2 – small plow bottom; 3 – disc blade (rolling coulter); 4 – frame; 5 – bracket; 6 – fastening bolts

Integral moldboard plows have the lowest purchase price and the best maneuverability for small and irregular fields. However, they are limited in size due to tractor stability and the lift capacity of the hitch. The furrow transport wheel of a semi-integral plow is automatically steered to provide more maneuverability than for a drawn plow. Both integral and semi-integral plows improve a tractor's traction by applying a downward force on the hitch. Drawn plows provide the most uniform plowing depth, but have the highest purchase price.

Moldboard plows are frequently equipped with automatic reset mechanisms that allow a plow bottom to move rearward and upward to pass over an obstacle, such as a rock, without damage. A hydraulic cylinder or a spring mechanism automatically moves the bottom to its original position after it passes over the obstacle.

Subsoilers

Subsoilers are used to break through and shatter compacted or otherwise impermeable soil layers and to improve rainfall penetration (Figure 54). They have heavy standards that can be operated at depths of 45 to 75 cm or more. Subsoilers do very little soil mixing and no soil inversion. They are most effective under dry and firm soil conditions.

A subsoiling operation is usually followed by another primary tillage operation before secondary tillage is begun. Most subsoilers use the integral hitching configuration, but a few are available with the drawn hitching configuration.

Subsoilers frequently rely on the heavy design of the frame and standards for protection during impact with buried rocks. Figure 54 shows a mounted type V-frame subsoiler.

Figure 54. A mounted-type V-frame subsoiler

Types of moldboard plows

Most often they are divided into two groups: plows for general purpose and plows for a special purpose.

Moldboard plows for general purpose are used in the field of cereal cultivation, grain legumes, technical crops and other crops. They carry out basic tillage of the soil at a depth of 25-35 cm and pre-sowing tillage at a depth of 15-20 cm. They are for plowing of stripes and for smooth plowing.

Moldboard plows for a special purpose are for ultra-deep plowing, for vineyards and fruit trees, for rocky soils and others.

With big plows for ultra-deep plowing (Figure 51, b) is carried out tillage of the soil at a relatively large depth (60-100 cm) on areas where perennials (vineyards, orchards, raspberries, etc.) are to be planted. They usually have only one plow body and one coulter, as their force for traction is very large.

The plows for vineyards and the fruits make the shallow plowing of the soil in the areas between the rows.

Plows for stony soils are used for plowing soils, which also contain relatively large stones. The plow bodies of these plows are equipped with automatic protectors. They pull out for a moment from the soil every working body encountered a stone and immediately after it passes it back to its original position.

2. Working bodies of the moldboard plows

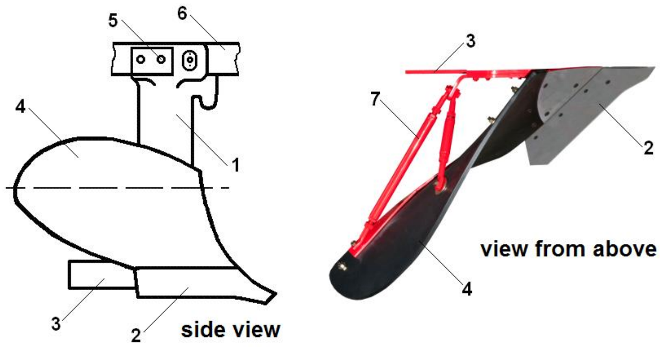


Fig. 55. Scheme of plow bottom: 1 – support; 2 – plowshare; 3 – landside stabilizer; 4 – moldboard; 5 – fastening bolts; 6 – frame; 7 – stabilizing arms

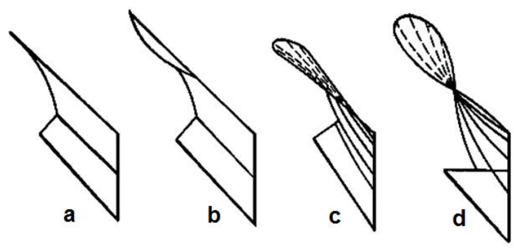


Fig. 56. Different types of moldboards for plows: a) cylindrical, b) ordinary, c) semi-screw, d)screw.

The working bodies of the moldboard plow are (Figure 53): *plow bottom, small plow bottom, disc blade (rolling coulter)*. They are fastened to the plow frame by bolts 6 and clamps. When the plow is moved forward, each plow bottom cut the soil layer, lift it and turn it into a furrow made by the front plow bottom. With this effect, the soil layer is crushed and the soil aggregates are partially mixed. The *disc blade (rolling coulter)* cuts the vertical wall of the last furrow to make it smooth and free of fallen soil lumps in it.

In this way, the plant residues and fertilizers are covered with soil. The plow bottom consists of a *plowshare* 2 (Figure 55), a *moldboard* 4, a *landside stabilizer* 3 and a *support* 1.

Various types of plows are used in different moldboards (Figure 56): cylindrical, ordinary, semi-screw and screw.

The cylindrical type of moldboard crushes the soil heavily because it raises it intensely but does not turn it well. The screw type, on the contrary, turns very well but slightly crushes the soil layer. The ordinary type and semi-screw type are intermediate. The cylindrical type is designed for the tillage of light soils, the ordinary type - for connected, swamps, and the screw type - for heavy meadow and clay soils.

Disc blade (rolling coulter). It cuts a soil layer on the furrow wall in order to obtain a smooth wall and a clean bottom of the furrow on which two of the wheels of the trailed plows move, as well as the right wheels on some tractors. When the bottom is clean, the running resistance is less, and the depth of work is kept constant.

3. Positioning of plow bodies

The plow bodies are located on the plow frame at a sufficient distance so that the soil layer and plant residuals can freely pass between them. The arrangement for positioning the plow bodies on the frame is as shown in Fig. 57.

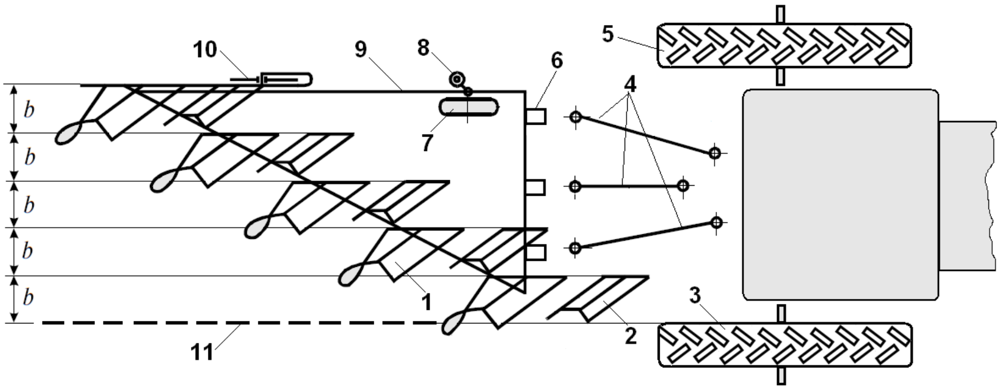


Fig. 57. Scheme for the positioning of the plow bodies of the frame - top view:1 - a plow body; 2 – small plow body (coulter); 3 - right-hand wheel of the tractor, 4 - the arms of the hitching system of the tractor; 5 - left-hand wheel on the tractor; 6 - a plow hitching device; 7 - wheel of the plow; 8 - screw mechanism; 9 - the longitudinal beam of the frame; 10 - disk knife; 11 – a line of the furrow from previous work run

The *small plow body (coulter)* (Figure 58) is placed on the plow frame so that its front point is 25-30 cm in front of the top of the next plow body. If the distance is too small, the small plow body will prevent normal soil reversal from the next plow body. If the distance is large, the front plow body will interfere with the work of *small plow body.*

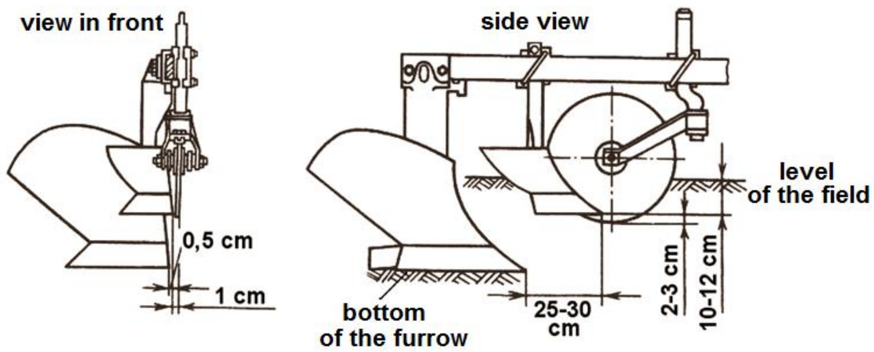


Fig. 58. Scheme for the placement of the working bodies of a plow

7. Methods of plowing. Advantages of plowing.

Plowing patterns

An optimal tillage pattern reduces the time spent in non-productive work. One of the most important objectives of a tillage pattern is to minimize the number of turns and maximize the length of the tillage runs. There are several patterns that can be used when tilling a field. These are:

A. circuitous pattern (обиколен)

B. headland pattern

A.Circuitous pattern

Plowing begins at the edge of the field and works toward the center of the field always throwing the soil towards the outside of the field. It is the most commonly used system for plowing in Asia. It is commonly used with moldboards and offset disc harrows.

B. Headland pattern

There are 3 different headland patterns of plowing:

1. Gathering
2. Casting
3. One-way pattern

Casting pattern

This system is similar to the gathering pattern but requires plowing to begin at the edges. Furrow slices are turned to the edges of the field. This system can also be used with all types of plows.

Plowing with gathering and casting patterns has significant disadvantages. Regardless of whether the plowing starts from the middle or the ends of the field, dead furrows and back furrows are always formed that change the microrelief negatively. In the places where furrows form, conditions for water erosion are created. Additional soil treatments are required to level the surface, especially irrigation areas.

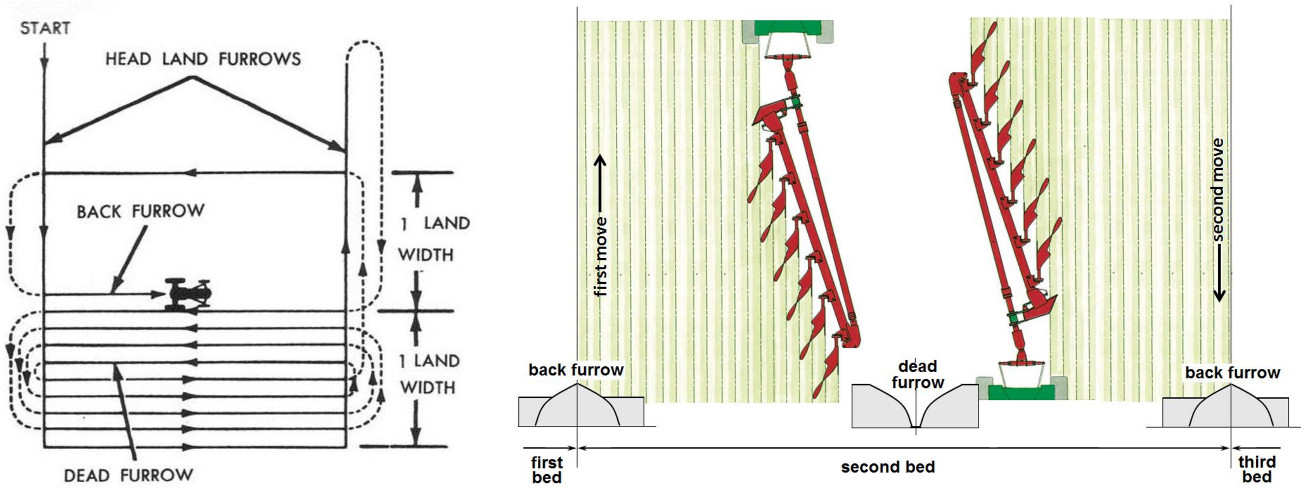


Fig. 59. Scheme of casting pattern of a plowing

One-way pattern (one-way plowing)

Most moldboard plows are designed to turn the furrow slices only to the right. Two-way plows (reversible plows), however, have two sets of opposed bottoms that can be used selectively. With this arrangement, all the furrows can be turned toward the same side of the field by using the right-hand bottoms for one direction of travel and the left-hand bottom on the return trip.

The two sets of bottoms (1 and 2) are mounted on a common frame 3 that is rotated by angle 180° about a longitudinal axis to change from one set to the other as shown in Figure 60. In most cases, the rotation is accomplished with a hydraulic cylinder 4 that is part of the plow. A two-way plow eliminates the back furrows and dead furrows, leaving the field more nearly level for irrigation or drainage. Two-way plows are also advantageous for terraced fields or contour plowing and for small fields of irregular shape.

From an agronomic point of view, a flat surface plowing is provided but the plow has a smaller working width, it is heavier and more complicated by structure - there are additional hydraulic elements 4 for turning the frame (Fig. 60), an axis 5 around which it rotates the frame, two wheels for controlling the depth of work (one for the upper and the lower row of plow bodies), etc.

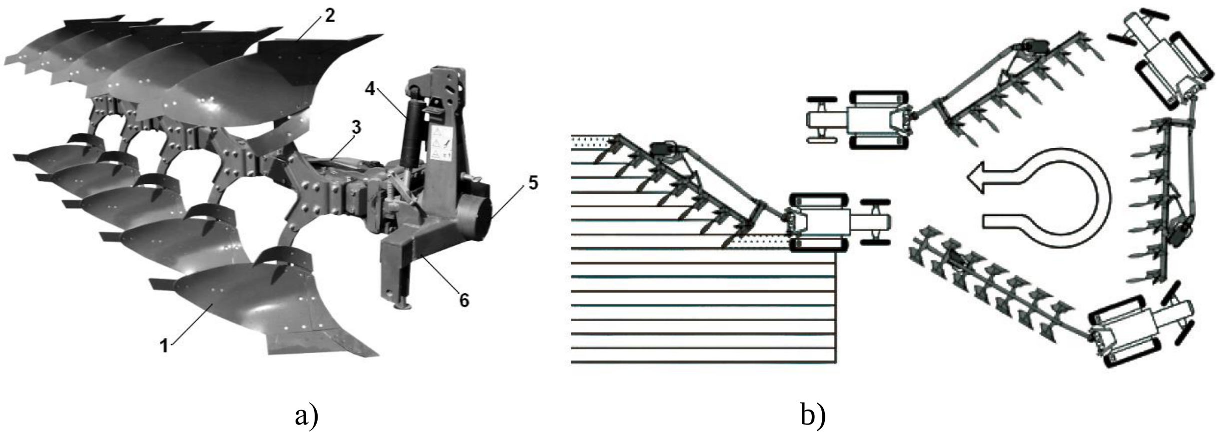


Fig. 60. **A rear-mounted two-way reversible plow:** ***(a) and plowing with two-way plow (b).***
Positions: 1 – bottom row plow bodies; 2 – top row plow bodies; 3 – frame; 4 – hydraulic power cylinder; 5 – axis of rotation of the frame; 6 – hitching mechanism

Advantages of plowing

The traditional soil cultivation system, which is based on autumn deep plowing, is a practice that is a major for crop plants due to many advantages.

After deep plowing conditions are created to improve the water regime of the soil.

The non-cultivated soil is covered with weeds that evaporate a lot of water and reduce moisture stores. Non-cultivated soil cracks and evaporation of moisture increases. The deep-plowed soil has better water penetration and better absorbs water from precipitation.

The nutrition regime of the plowed soil improves due to better aeration, which provides active microbiological activity and mobilization of nutrients from the deeper layers of the soil. The structure of the soil is improved, and in some cases also the mechanical composition of the soil layer. This process also destroys perennial weeds, growing vegetatively, cutting them deeper.

THEME 6. MACHINES FOR SURFACE TILLAGE OF THE SOIL

Surface soil tillage includes pre-sowing soil preparation up to a depth of 15 cm, soil tillage in cultivated crops (row crops) and perennial crops (vineyards and orchards) at depths of up to 12 cm, shallow loosening up to 16 cm, furrowing, rolling, etc.

Typically, this is done after the soil has made basic tillage, so surface tillage can be considered as additional.

The machines used for surface tillage are cultivators, disc harrows, rotary tillers, ordinary tooth harrows, rotary hoes, spring tillers, rollers, etc.

Secondary tillage in conventional tillage systems

Any tillage operations performed after the primary tillage are called secondary tillage. Generally, several secondary tillage operations are performed before the field is ready for planting. The main objective of secondary tillage is to break down large clods and to prepare an ideal seedbed for planting. An ideal seedbed is the one that allows for good seed-to-soil contact, conserves moisture needed for germination, and allows for vigorous and uninhibited root and shoot growth.

The equipment used for secondary tillage are generally called *harrows*. The most common harrow is the disk harrow. Spring-tine harrows, spike tooth harrows, cultivators, and rotary hoes are other types. In dry climates, cultipackers are often used for the final tillage operation before planting. The purpose of a cultipacker is to increase the density of the top few centimeters of the soil depth. This tends to break the capillaries in this soil zone and prevent moisture from escaping.

Disk harrows

Disk harrows differ from disk plows in that there is no tilt angle and several blades are mounted on a common axis called the gang. They are lighter and have smaller wheels than disk tillers. In disk harrows, the gang may be arranged in different configurations as shown in Figure 61. The arrangements may be single-action, offset, or tandem. It should be noted that the gangs are always in pairs with opposite disk orientation to balance the side draft produced by each disk.

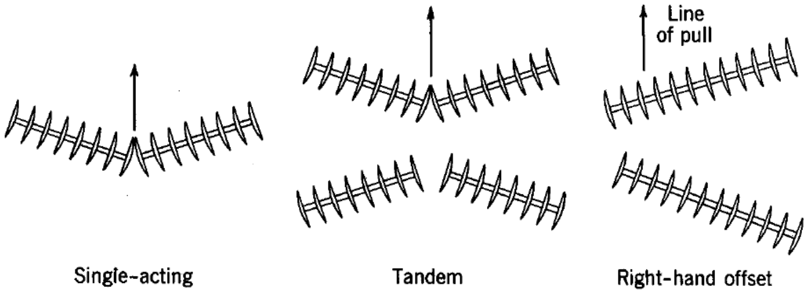


Fig. 61. Gang arrangements for three general types of disk harrows

Disk harrows may be either mounted or pull type. Smaller units tend to be mounted while larger units tend to be pull type with wheels for transportation. Remote hydraulic cylinders are used to raise or lower the implement from the driver's seat. Some very large units are designed to fold over for transportation. Pull type units with wheels allow for better depth control.

The size, weight, spacing, depth, and angles of the disks are selected based on the field conditions and the purpose of disking. Disk diameters range from 40 to 80 cm, and weights range from 20 to 200 kg/disk. Disking with larger disks should be followed by lighter disks for final seedbed preparation. Disk spacing increases with disk diameter.

Narrow disk spacing of about 18 cm is used for final seedbed preparation when the ground is not hard with little surface residue. Disk spacing of about 23 cm is used for mixing of chemicals or cutting of surface trash. A spacing of about 28 cm and higher is needed for harder soils or when the heavy surface residue is present. The operating depth is determined by the soil conditions and the weight per unit disk of the plow.

The gang angle varies from 15° to 35° as measured from a line perpendicular to the line of travel. Gang angles may be changed to meet the field conditions. Increasing the gang angle makes the disks more aggressive, increasing their depth and power requirement.

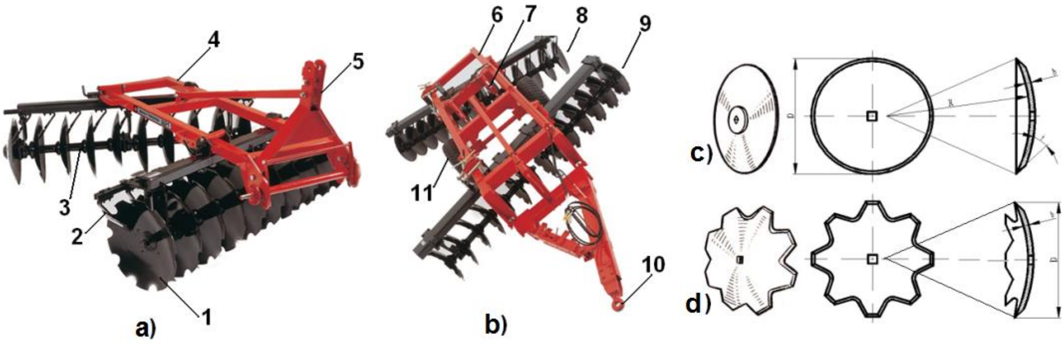


Fig. 62. Disc harrows and working bodies: (a) mounted disc harrow; (b) trailed disc harrow; (c) plain discs; (d) cut discs. Markings: 1 - working disk; 2 - scraper; 3 - axis; 4 - frame; 5 - hitching device; 6-frame; 7 - hydraulic power cylinder; 8 - rear battery; 9 - front battery; 10 - drawbar; 11 - supporting wheels

Working bodies of disc harrows

The operating organs are spherical discs and are smooth (Figure 62, c) and cut out (Figure 62, d). As a geometric body, they are a segment of a hollow sphere and are characterized by a disk diameter D, a radius r and a thickness δ. On the outside, the disk is sharpened. In the middle of the discs, holes are made to be mounted on an axis.

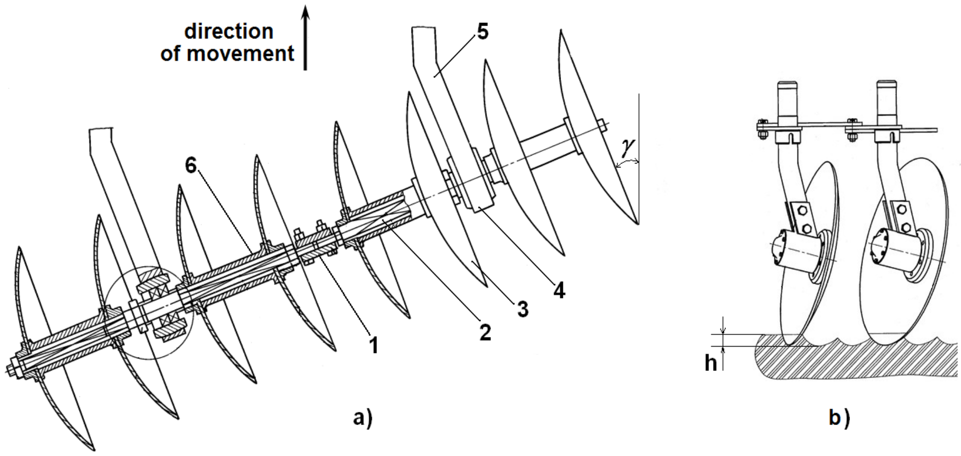


Fig. 63. Scheme of disc battery a) and height of the roughness b).
Markings: 1 - bushing bracket; 2 - axis; 3 - working disk; 4 - bearing body; 5 - beam; 6 - spacer sleeve;
γ - angle of attack; h - height of the roughness at the bottom of the furrow

Disc battery. The spherical discs are arranged like the plow bodies. The special feature here is that they are mounted on an axle (Figure 63). The axis is placed that so the plane of the cutting edges of the discs engages an angle γ, called the angle of attack in the direction of movement. The disks (up to 12 pieces) spaced on the axis form a disc battery. When the disk drive moves forward, the spherical discs contact the soil at the lower end, rotate with the axis, and carry out the workflow. Thanks to their rotation, they are easier to clean from clinging soil and plant debris. That's why these machines have advantages over the plows in more hard working conditions.

Single-acting disc harrows are mainly used for soil tillage after harvesting.

The goal is to loosen the soil to a depth of 8 cm, to maintain soil moisture and to destroy the emerging weeds.

As opposed to the normal disc harrows, the single-acting harrows are one-way machines (they have only one row of batteries and turn the soil in one direction only).

Their batteries have between 8 and 10 disks that can be adjusted for angle of attack $\gamma = 20–35^0$. Their working width is 3 to 10 m.

Adjustment of the disc harrows is limited to: connecting the machine to the tractor hitching system; horizontal alignment of the machine frame in transverse and longitudinal directions; adjusting the depth of work of the working organs by lifting the support wheels with the screw mechanisms; angle adjustment of the attack γ; check the functionality of the disc harrow as a whole.

Cultivators

The cultivators perform cutting and loosening the soil at the depth of 8 to 14 cm. With the loosening of the soil the air-gas regime improves, the microbiological life is activated, the moisture is stored in it. Conditions for better penetration of humidity from atmospheric air and precipitation are created. They also carry out the destruction of weeds without reversing the soil layer. With cultivators is performed pre-sowing soil tillage for the depth of seed sowing, doing the furrows and bedding formation for vegetable crops.

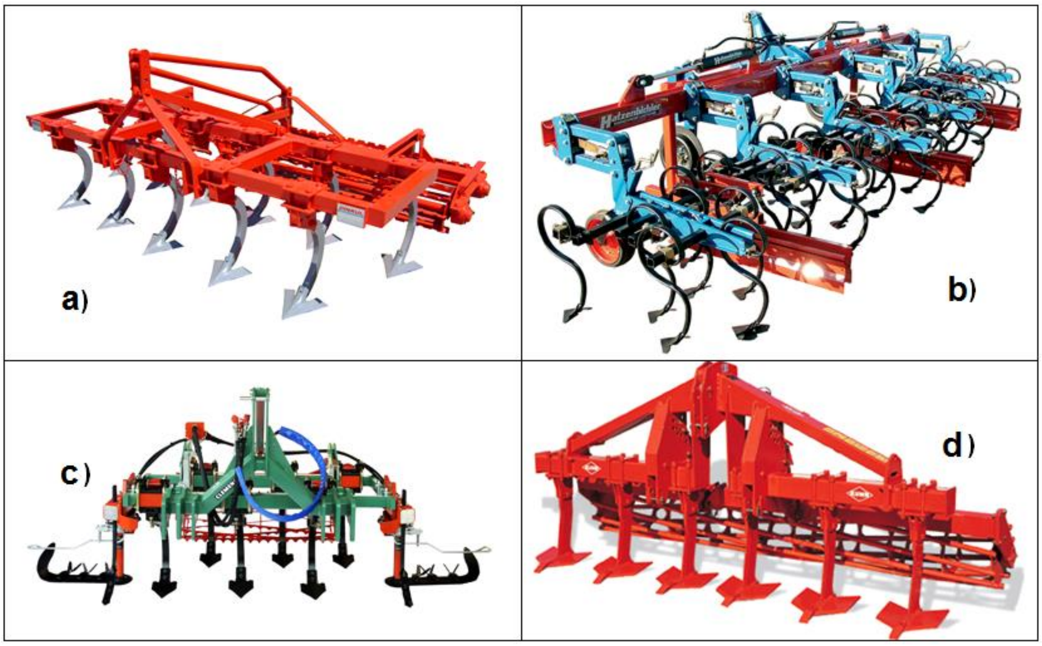


Fig. 64. Types of cultivators: a) field cultivator, b) row crop cultivator, c) cultivator for vineyards and orchards, d) anti-erosion cultivator

The basic types of cultivators are (Fig. 64): *field cultivators, row crop cultivators, cultivators for vineyards and orchards, anti-erosion cultivators, rotary cultivators.* Field cultivators are often used as secondary tillage tools for seedbed preparation. They are similar to chisel plows in appearance but they operate at much shallower depths.

Figure 65 shows the different types of tools that can be attached to a cultivator shank for different applications. Field cultivators may be either mounted or pull type with wheels for depth control. Some very large units are designed to be folded while transporting.

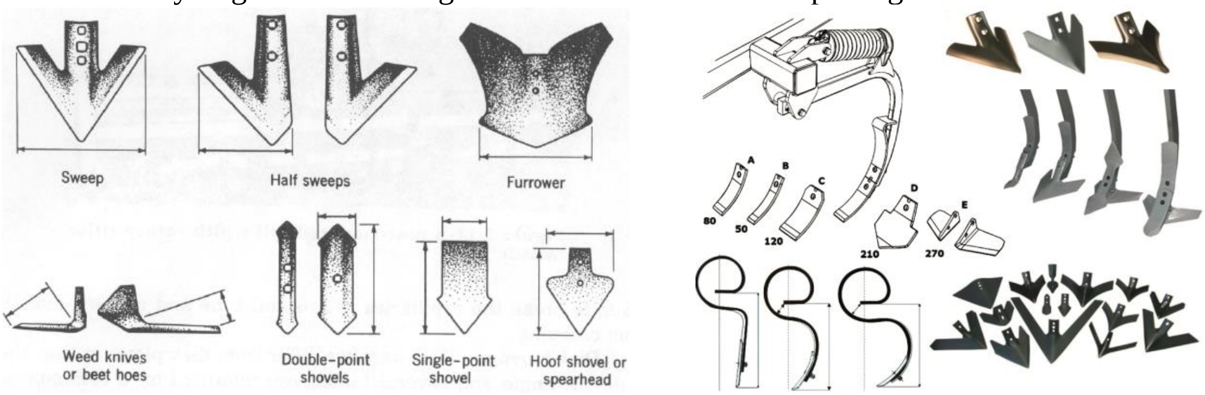


Fig. 65. Different types cultivator tools

The lateral tine spacing may vary from 15 to 30 cm. Usually, two or three rows of tines are used with fore and aft spacing ranging from 50 to 80 cm. Row crop cultivators have the tines spaced to go between the crop rows. They are used for cultivation and weed control operations during the active growth period of crops planted in rows.

Structure of field cultivators. Types of working organs. Emplacement of work bodies.

Field cultivators consist of working bodies 1 (Fig.66), frame 2, hitching device 4, wheels 3. The operating organs are arranged in two or three rows, so that the whole soil surface is processed. The wheels are provided with screw mechanisms 5, which adjust the working bodies to the required depth of work.

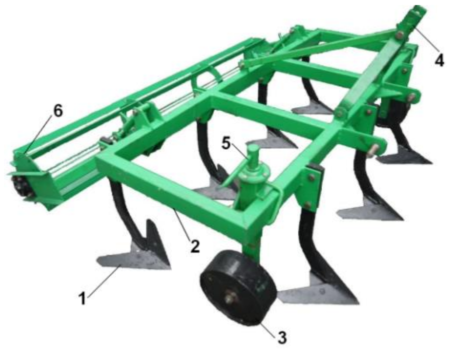


Fig. 66. Structure of the field cultivator:
1 - working body; 2 - frame; 3 - wheel; 4 - hitching device; 5 - screw mechanism; 6 - additional working body (lump cutter)

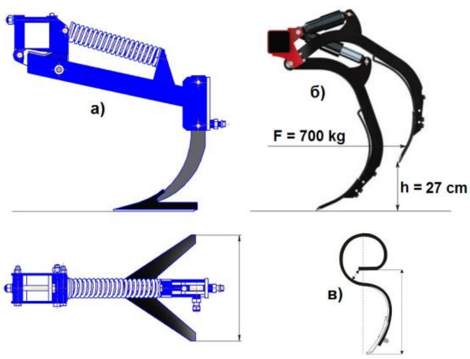


Fig. 67. Types of protectors of the working organs for field cultivator:(a) springs;(b) hydraulic; (c) spring steel stands

Various types of protectors are used to protect the working organs from fracture during operation: springs (Fig. 67, a), hydraulic cylinders (Figure 67, b) or spring steel stands (Figure 67, c).

When exercising a force F on the working body, which is greater than normal, a temporary lifting of the body occurs. Once the obstacle has been overcome (stone, solid lump of soil, etc.), they are lowered again into the working position.

The positioning of the working organs in a two-row scheme is in chess principle, and in a three or more row it is in a complex way (Figure 68).

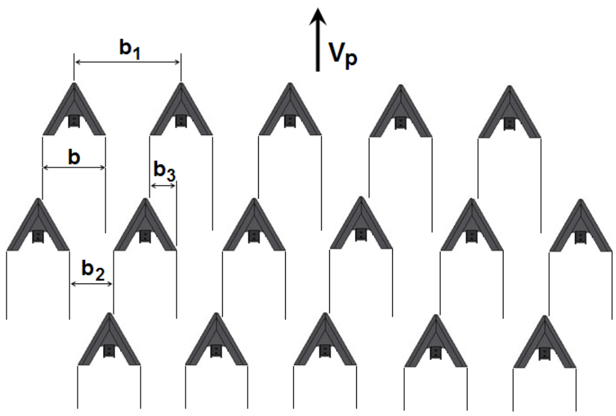


Fig. 68. The positioning of the working bodies of the field cultivators: b - working width of one organ; b_1 – a distance between organs in the order; b_2 – non-tilled zone between organs of the row; b_3 – overlapping of the tillage area by the previous working body; V_p – the direction of movement and operating speed of the unit

Cultivators for row crop cultivation

These types of cultivators are used for tillage the soil and for killing the weeds between the rows of the crops. The unprocessed area on the left and right of the row is called the protection zone (designation “c” in Fig. 69). Tillage between the rows of crops (row cultivation) is carried out at a depth of 4 to 10 cm depending on the type of cultivator, type of soil, number of weeds per unit area and others.

The work bodies are located in the sections in such a way as to provide a suitable "c" protection zone (Figure 69). It must be wide enough to preserve the stems, leaves and roots of the crop plants. It is usually from 8 cm to 20 cm depending on the crop and the degree of plant growth.

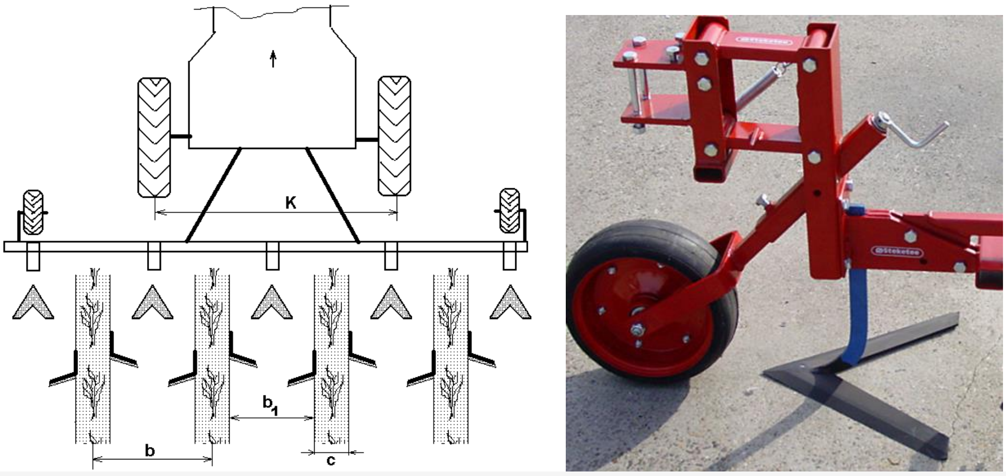


Fig. 69. Scheme of the cultivator for row cultivation and working section: c - protection zone; b – spacing between the rows; b_1 – processed area; k – the distance between the wheels of the tractor.

When working at high speeds or in low-growing crops, these cultivators are provided with protective devices in the form of shields, discs or other. The aim is not to put soil over the crop plants. In this type of cultivators, the ways of reducing the protection zone are as follows: use of cultivators with a steering wheel and an auxiliary worker seat; use of front linkage cultivators; use of cultivators on self-propelled chassis tractors; use of cultivators with electronic sensors and video cameras.

Fig. 70. Cultivator for hoeing with rotating teeth bodies with passive action.

Combined cultivators for inter-row and intra-row soil tilling. Several companies, which produce agricultural machinery, offer additional work organs to traditional row crop cultivators. These organs enter into the protection zone and tilling the soil around crop plants without damaging them.

An example of this is the developed cultivator with rotation fingers and passive action. The fingers are made of flexible material (plastic or rubber), placed on a metal disc (Fig. 70). The disc is attached to the axle with bearings. On the disc are also mounted metal fingers, bent to the soil, which ensures the rotation of the working organ and the loosening of the soil near the crop plants.

Device and types of working bodies of cultivators for row crop cultivation

In this cultivator, the frame 3 (Figure 71) is a square sectional beam. On it is mounted the hitching mechanism by which the cultivator is aggregated to the tractor. The wheels 4 is also mounted on the frame, which serves as a support for the cultivator during operation and for driving the fertilizers dosing mechanisms. The working organs 5 of this cultivator by their stands are fastened to separate sections (usually an odd number - e.g., 5, 7, 9, etc.) that can be moved on the frame and fixed by staples. In this way, they are adjusted for a different distance between rows of the crop. The work organs shall be located in the sections in such a way as to provide a suitable protection zone *c*.

It must be wide enough to keep both the ground and underground parts of the crop plants undamaged. It is usually 8 cm to 20 cm depending on the crop and the degree of plant growth. The tillage zone b_1 is the difference between the distance of rows of the crop *b* and the protective zone *c*:

$$b_1 = b - c$$

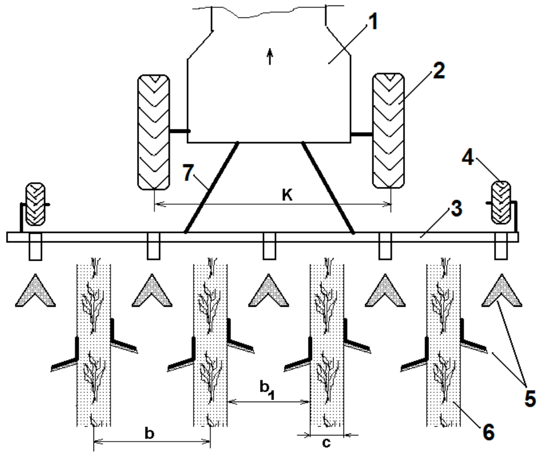


Fig. 71. "Tractor and cultivator" aggregate:
1 - energy tool (tractor); 2 - wheel of the tractor;
3 - the frame of the cultivator; 4 - supporting wheel;
5 - working bodies of the section; 6 - crop plants and a protection zone around them; 7 – hitching mechanism

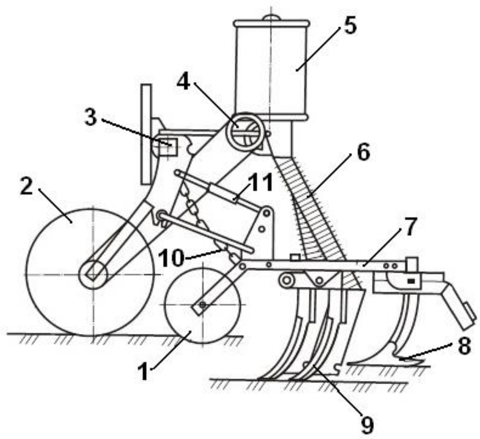


Fig. 72. Device of a cultivator section:
1 - a supporting wheel of the section; 2 - cultivator support wheel; 3-frame; 4 - chain drive; 5 – hopper for mineral fertilizers; 6 - tube; 7 - beam of the section; 8 – double-sided cultivator sweeps;
9 - fertilizing organs; 10 - chain;11 - parallelogram device

The working section of the hoeing cultivator consists of a beam 7 (Figure 72) whereby the working organs 8 and 9 are located by clamps. Each section has a support wheel 1 which copies the terrain and maintains a constant depth of tillage of the working organs. In order to be independent of the vertical oscillations of the cultivator frame 3, the work section is connected to it by a parallelogram device 11. The chain 10 serves to lift the section into a transport position. Cultivator chassis also houses mineral fertilizer hoppers 5 which, through a metering mechanism and tubes 6, deliver fertilizer to the furrows made by the working organs. The drive mechanism is actuated by a chain drive 4 which is connected to the axis of the drive wheel 2 of the cultivator.

Working organs of the cultivators. Cultivator sections are assembled with easy-to-change cultivation organs. Depending on their purpose, the organs are sweep blades, weed knives, organs for mineral fertilizing, blades for soil loosening, bodies for furrowing etc. (Figure 73).

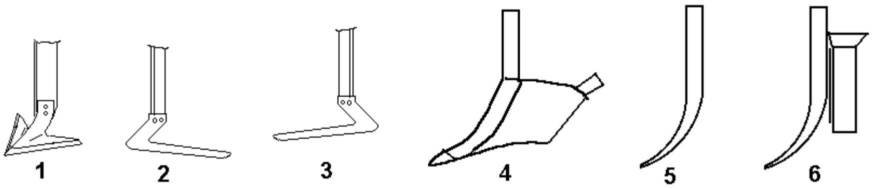


Fig. 73. Types of working organs of a cultivator for row crop cultivation: 1 - two-sided sweep blade; 2 - one-sided right weed knife; 3 - one-sided left weed knife; 4 - furrower; 5 - blade for soil loosening; 6 – blade for mineral fertilizing

Different combinations are made with the working organs, which allow the following operations to be carried out (Figure 74): hoeing, hoeing with fertilizing, loosening, hilling, making irrigation furrows, etc.

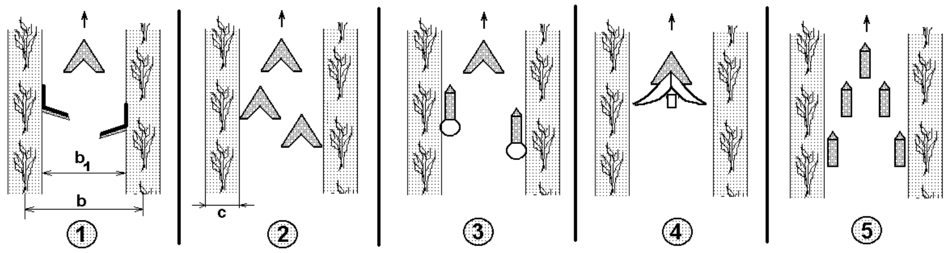


Fig. 74. Types of operations for row crop cultivation: 1 - hoeing; 2 - hoeing with three sweeps; 3 - hoeing with fertilizing; 4 – hilling or making irrigation furrows; 5 - loosening

Rotary tillers

Rotary tillers are also called power tillers because the power is transferred to the tiller from the tractor via the power-take-off drive. A shaft containing blades is located at 90° to the line of travel and rotates in the same direction as the forward travel of the tractor. Since the shaft turns at a rate that is considerably faster than the corresponding tractor speed, soil pulverization is accomplished.

Also, the tiller pushes the tractor forward and generates a negative draft. Consequently, lighter tractors can be used for rotary tillage operations. Total power requirements for rotary tillers are generally higher than for conventional plows. However, one rotary tillage operation may be equivalent to several conventional tillage operations as far as the quality of the seedbed is concerned. Figure 75 and figure 76 shows two different types rotary tillers.

The rotary tiller is widely considered as very important implement as it provides a fine degree of soil pulverization. It is directly mounted to the tractor and operated. The benefits of the rotary tiller are a) effective pulverization of soil ensures good plant growth b) cutting and mixing of stubbles and roots and mixing with soil and c) leveling of the field.

The functional components include rotor fitted with L shaped steel blades, gearbox, power shaft, sprocket - chain drive, universal joint, leveling board, shield, depth control arrangement, and three-point hitching provision. The power from the tractor engine is transmitted to the rotary tiller through PTO (Power Take Off) of the tractor.

Fig. 75. Rotary tiller with horizontal shaft

Fig. 76. Rotary tiller with vertical shafts

A leveling board is attached to the rear side of the unit for leveling the tilled soil. Two numbers of adjustable brackets are provided one each on either side of the unit for controlling the depth of operation. The rotor is operated at 180- 200 rpm.

Structure of rotary tiller with a horizontal shaft

The *rotary tiller* consists of a shaft 2 (Figure 77) on which the L-shaped steel blades 1 are attached. The shaft and the blades form the tilling drum which is surrounded by a casing 13 and a shield 5 to prevent soil particles from spreading during operation.

The drive of the tilling drum is forced - through PTO (Power Take Off) of the tractor. The cardan shaft drives a rotatable motion to the spline shaft 11 and rotates the drum (shaft 2 with blades 1) by means of a gearbox 8, shaft 7 and a gearbox 6.

The maintenance of a constant depth of work of the blades is accomplished by the sliding supports 3, placed on the left and right of the machine.

The position of the sliding supports can be changed with the regulator 4 and this affects the depth of operation of the machine. The shield 5 takes on the impacts of the soil particles ejected from the blades, reflects them and aligns the surface of the treated soil.

The *rotary tillers* have knives of different shape and position.

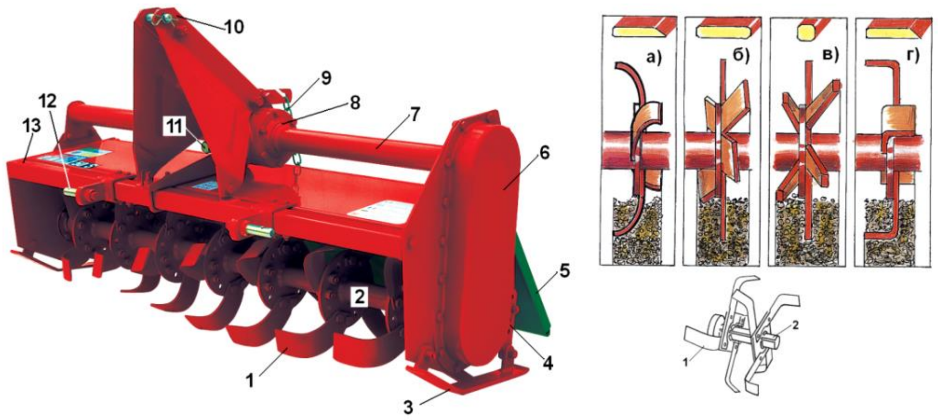


Figure 77. Structure of a rear-mounted full-width rotary tiller with horizontal shaft:
1 - L-shaped steel blades; 2 - shaft; 3 - sliding support; 4 - depth regulator; 5 - shield; 6 - gearbox; 7 - tube with drive shaft; 8 - conical gearbox; 9-chain; 10 and 12 – hitching device; 11 - spindle shaft; 13 - casing.

Structure of rotary tiller with vertical shafts

This type rotary tiller includes a plurality of vertically spaced rotary bodies consisting of hubs 2 (Fig 78) on which are mounted the working blades 1, shafts 3, bearings 4 and gear-weels 6. The working blades are usually two on the hub and differ in the space with the opposite rotating blades of the adjacent hub.

In this way, there is an overlap of the tilled areas and intensive fragmentation of the soil aggregates. The propulsion of the vertical rotors is made by a conical gearbox 9 and a spindle shaft 8 which is connected to the PTO (Power Take Off) of the tractor by cardan shaft.

A number of studies have shown that the shear power of the rotary tillers increases sharply with increasing working speed. The reason for this is the increased total area of the soil cutting by the working bodies of the machine. That is why the energy consumption of the soil is 2-3 times higher than in plowing. The calculated area of the cuts per unit volume of the tilled soil with the rotary tiller is 3-6 times greater than that of a moldboard plow.

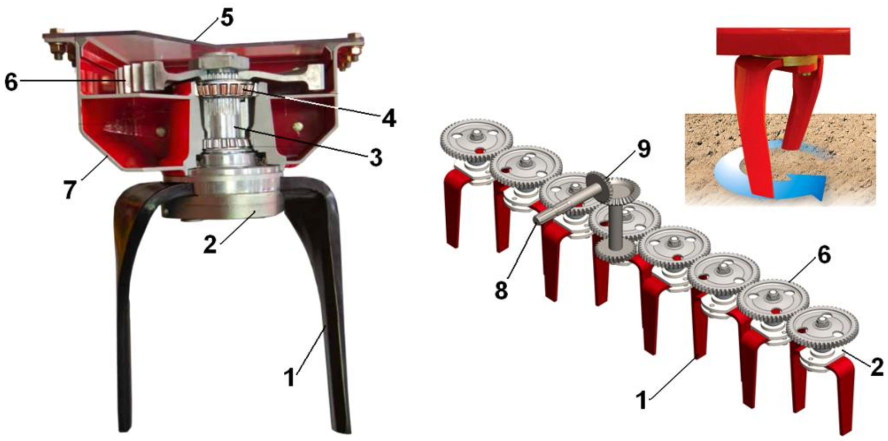


Figure 78. Structure of a rotary tiller with vertical shaft:
1 - working blade; 2 – hub (flange); 3-shaft; 4 - bearing; 5 - cover; 6 – gear-wheel; 7 - body;
8 - spindle shaft; 9 - conical gearbox

The adjusting for the work of the rotary tillers is limited to: checking for the functionality of the machine in general; attachment of the machine to the tractor hitching system; horizontal alignment of the machine in the transverse and longitudinal directions; adjusting the working depth of the work blades, adjusting the tilling step according to the condition of the soil (by changing the working speed of the tractor and by changing the rotation speed of the tilling drum).

Rotary hoes and rotary cultivators

Rotary hoes and cultivators, unlike rotary tillers, are not powered. They are both designed to operate at shallow depth and are used for weed control in row crops, breaking soil crests for better seedling emergence, and mixing of fertilizer.

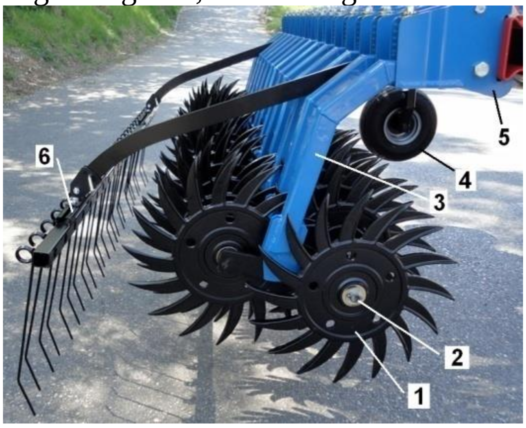


Figure 79. A rear-mounted rotary hoe with in-line sections on spring-loaded arms:1 – star wheels (spiders); 2 - shaft; 3 - mounting bar; 4 - supporting wheel; 5-frame; 6 - additional bar with spring teeth

Figure 80. A rear-mounted, row crop rotary cultivator with ground-driven finger wheels

Rotary hoes are made of several star wheels 1 (Fig. 79), often called spiders, mounted on a shaft 2 at a spacing of about 15 cm to form a group. Each spider has 10 to 16 teeth and the tip diameter ranges from 45 to 50 cm. Two staggered parallel groups make a section and provide a working width of about 8 to 10 cm. Several sections are used in a given implement. The section width is such that they fit between the rows for row crop cultivation.

The teeth in a rotary hoe have a forward curvature for more aggressive cultivation. A rotary hoe is shown in Figure 79.

Rotary cultivators have spiders similar to rotary hoes but the teeth are twisted and the ends are shaped like chisels. This creates a sideways movement of the soil. Only two spiders are mounted on a shaft, and each shaft is located at an angle from the forward line of travel. The spider wheels turn backward as the implement is pulled forward creating the necessary tilling action. The cultivator may be arranged to cultivate row crops or the entire field. A rotary cultivator is shown in Figure 80.

Spike-tooth, tine-tooth, and spring-tooth harrows

These tillage tools are used in the final seedbed preparation. They are also used for post-planting operations to break up soil crust and remove weeds. In a spike-tooth harrow, the spikes are rigidly mounted on a frame (Figure 81). The angle of the spikes may be altered to change the aggressiveness, with vertical orientation being the most aggressive. Tine-tooth harrows use spring tines that create an additional action for soil breakup. The tines are closely spaced, about 4 to 5 cm apart, compared to spikes in spike-tooth harrows.

Spring-tooth harrows (Figure 82) use round wire teeth made of spring steel. Due to the spring action, these harrows are more suited for stony ground. However, their lack of depth penetration limits their use to less than hard soils. All of these harrows may be used as attachments to other tillage tools such as moldboard plows and disk harrows because of their low draft requirements. Some units may be up to 16 m wide with fold-up frames for road transport.

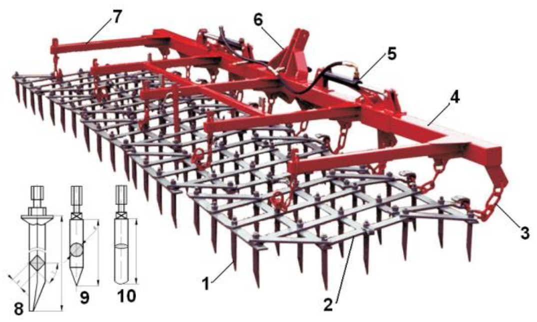


Fig. 81. Mounted spike-tooth harrow: 1 - tooth; 2 - frame; 3-chain; 4 – main frame; 5 - hydraulic power cylinder; 6 - hitching device; 7 - holder; 8 - a square tooth; 9 - a tooth with a circular cross-section; 10 - flat tooth

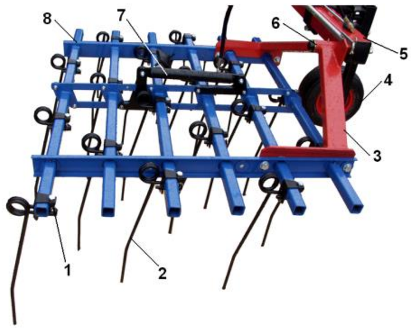


Fig. 82. Section of spring-tooth harrows: 1 - bracket; 2 - a spring tooth; 3 - holder; 4 - supporting wheel; 5-frame; 6 - joint; 7 - power hydraulic cylinder; 8 - frame

Power tooth harrow (vibrating harrow)

The vibrating harrow (Figure 83) has active working bodies. It consists of a frame on which vibrating beams 2 with rigid teeth 1 are located. The beams are reciprocated drive by arm 3 in a horizontal direction, across the movement. The movement is obtained from the PTO (Power Take Off) of the tractor by cardan shaft. These vibrating teeth very well destroy the large soil aggregates and prepare the soil for sowing.

Fig. 83. Power tooth harrow:1 - tooth; 2 - vibrating beam; 3 - drive arm; 4 - hitching device; 5 – cardan shaft guard; 6 - hitching device; 7 - additional machine (roller)

6. Combined soil cultivation machines

In order to make the soil in the state of a degree of suitability for further operations, such as sowing, planting, etc., it is necessary to process it repeatedly with different types of machinery. This leads to the extension of the period of soil preparation, its trampling and destruction. This eventually makes production more expensive and has led to the idea of creating combined soil cultivation machines.

This type of machines (Figure 84 and Figure 85) are capable with one movement on the field tilling the soil so good that the next operation (seeding, planting etc.) is carried out. In that:

- *the duration* of the operations is reduced, which guarantees a high quality of the work done;

- *the labor productivity* has increased many times, with indicators such as reduced total working time, reduced number of tractor-drivers and other workers, reduced total fuel consumption for combined processing, etc .;

- *the compaction of the soil* is reduced due to the fact that it is affected once. This is favorable for the physico-mechanical properties of the soil, which leads to an increase in yields from agricultural crops.

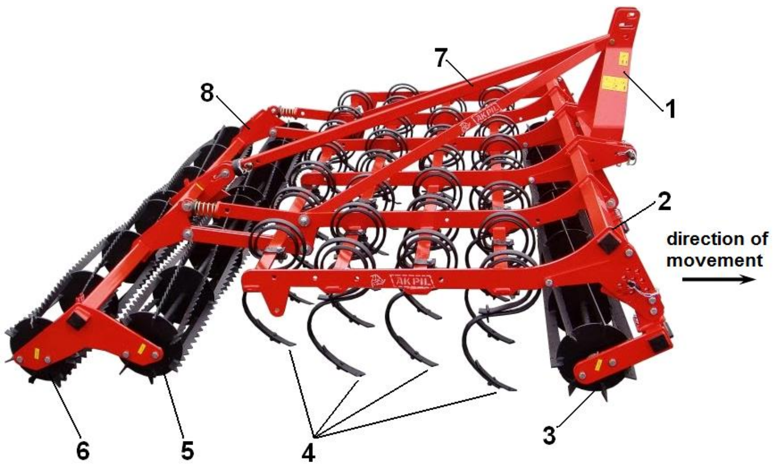


Fig. 84. Combined tillage machine "Roller-cultivator-roller":
1 - hitching device; 2-frame; 3 - first toothed roller; 4 - four rows of cultivating bodies with spring stands; 5 and 6 - two rows of toothed rollers; 7 - stabilizing beams; 8 - additional frame

The machine „rotary tiller-cultivator-land leveler-roller" (Figure 85), in addition to preparing the soil for sowing and planting, reduces energy consumption by up to 30% compared to individual operations. This is because the rotating blades strike not in hard soil but in soil previously cultivated by the cultivator organs.

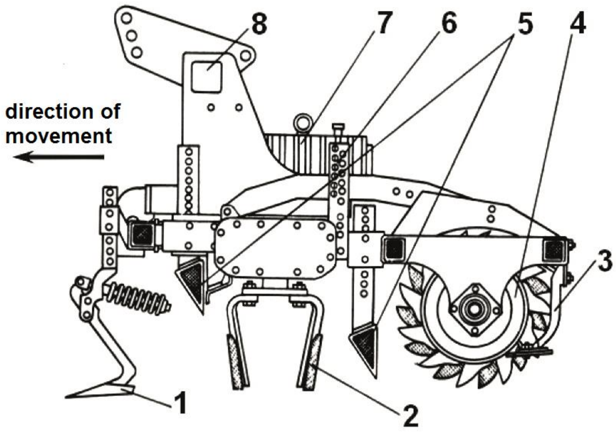


Fig. 85. Combined soil cultivator "Cultivator-vertical rotary tiller-land leveler-roller": 1 – cultivator blades; 2 - vertical rotary tiller; 3 - scraper; 4 - roller-packer; 5 - leveling beams; 6 - plate for adjusting; 7 - gearbox; 8 - frame

Tillage in conservation tillage systems

Conservation tillage systems are designed to conserve soil, water, and/or energy. In areas prone to wind soil erosion, it is advisable to leave the surface cover on the soil to prevent or minimize soil erosion. Any primary tillage operation that turns the soil over and buries the surface residue under the soil is eliminated. In heavy soils subjected to compaction due to wheel traffic, it is recommended that primary tillage performed during the wet spring season be eliminated.

In this situation, weed control is accomplished by use of herbicides. Generally, conservation tillage systems require some other changes to be made in the methods and equipment. For example, planter changes are needed to cut through the surface residue in order to plant seeds. This is accomplished by adding a fluted coulter ahead of the furrow openers.

There are different levels of conservation tillage: minimum tillage, strip tillage, and zero tillage. Zero tillage system consists of no primary or secondary tillage operation.

In a strip tillage system, a small band or strip of soil is tilled and the crop is planted in this strip. Elimination of any primary or secondary tillage operation results in the minimum tillage system.

THEME 7. MACHINES FOR GRAIN CLEANING AND GRAIN SORTING

1. General information. Characterization of the starting mixture

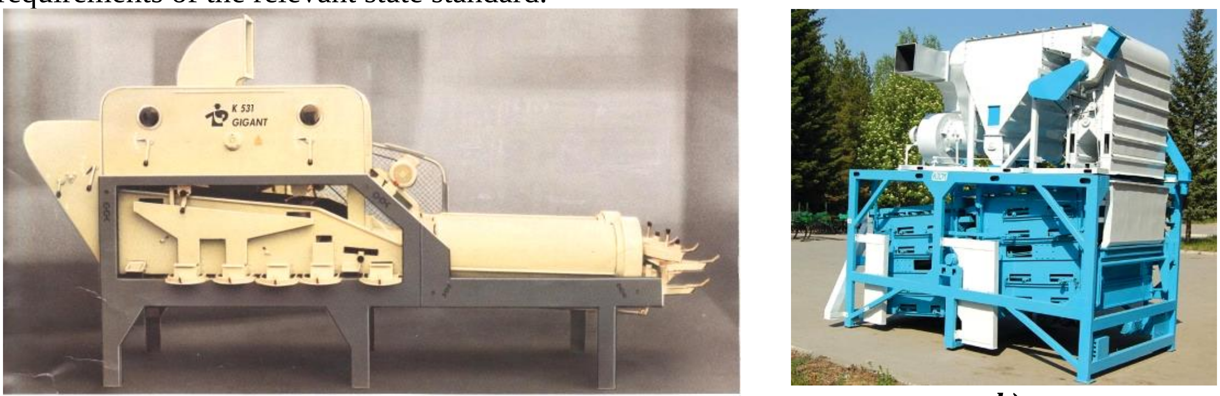
The grain harvested from combine harvesters is a multi-component mixture. It contains grain from the main crop, which can be solid (whole), broken, damaged, wrapped grain (non-threshed), undeveloped grain, etc. The mixture contains more: grains than other crops; weed seeds; organic impurities such as parts of stems, wrapping leaves, etc.; mineral impurities such as pebbles, soil clumps, dust, etc .; metallic impurities such as metallic pieces, bolts, nuts, etc.

The purity of the grain material is determined by the percentage of impurities left therein after the cleaning.

The purpose of cleaning and sorting is to bring the grain to purity, meeting certain requirements - industrial, consumer and agro-technical. The tasks of cleaning are to meet the industrial and consumer requirements and the sorting - the agro-technical ones.

The principles of cleaning and sorting are based on the difference in physico-mechanical properties of the individual components in the starting material. The physico-mechanical properties are very different and depend on many factors: the type and variety of the crop, the soil-climatic conditions and the way of farming. The grain characteristics relevant to the process separation are: size, aerodynamics, bulk density, shape, surface nature, elasticity, color, electrical and magnetic parameters, etc.

Grain intended for industrial and consumer needs is cleaned with grain-cleaning machines and the seed is cleaned and sorted with seed-cleaning and sorting machines (Figure 86). Depending on their purpose, machines must ensure the quality of cleaned and sorted grains according to the requirements of the relevant state standard.



a) ***b)***

Fig. 86. Grain cleaning machines: a - seed-cleaning and sorting machine; b - grain cleaning machine

2. Seed-cleaning and sorting machines

Their main difference from the grain-cleaning machines is that they also include drum-type cylinders (trior cylinders). These machines consist of the following working organs: a feed hopper 1 (Figure 87), dosing roller 2, an aspiration system, an upper sieve 6 and, a bottom sieve 7, a sloped plate 8, trior cylinder 17 and outlet openings.

The aspiration system consists of a blower 27, a dust duct housing, settling chambers 23, 21 and 20, two aspiration channels – first 26 and second 18, grids 5 and 13. The light impurities are entrained by the air stream, pass through the aspiration channels 26 and 18 fall into the settling chambers 23 and 20 from where they go out through the valves, and the dust flows through the blower dust pipe.

In the trior cylinder a collecting chute 16 is attached. This shute separates short grain impurities.

The multi-component mixture pouring into the hopper 1 (Figure 87) passes through the dosing roller 2 and the grid 5. Here it is subjected to the air flow from the first aspiration channel 26 - sucking and separating the light impurities (dust, straws, etc.).

The remainder of the mass falls into the upper sieve 6. It holds off the large impurities (pebbles, lumps, metallic pieces, etc.) that flow through it and go out through the chute 19 (exit "large impurities"). The remaining mixture falls into the lower sieve 7, which passes through its openings the small impurities (broken seeds, sand, etc.) that go through the chute 12 (output "small impurities").

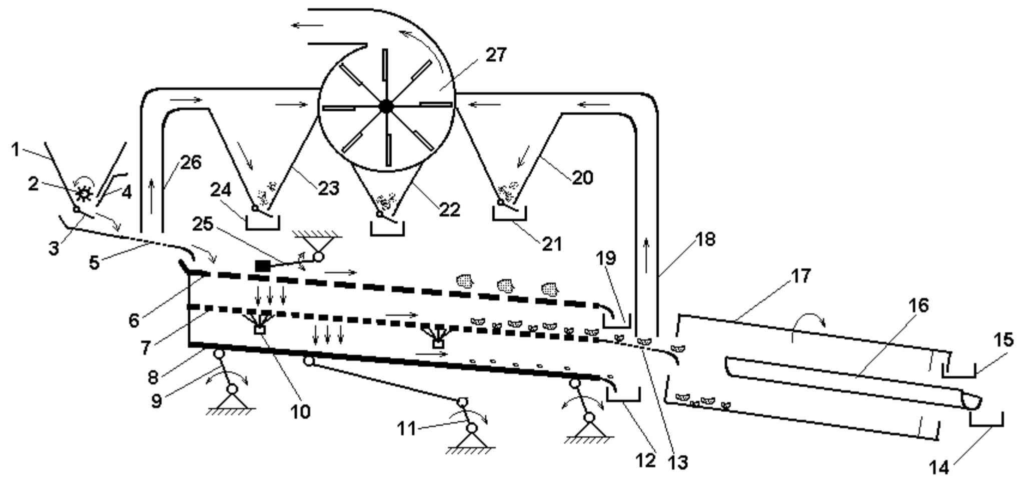


Fig. 87. Technological scheme of seed-cleaning and sorting machine: 1 - hopper; 2 - dosing roller; 3 - removable bottom; 4 – shutter plate; 5 - grid; 6 - upper sieve; 7 - bottom sieve; 8 – sloped plate; 9 – swing plate; 10 - brush; 11 - knee-rod mechanism; 12 - output "small impurities"; 13 - grid; 14 - "short grain" output; 15 - output "fit grain"; 16 – collecting chute; 17 - trior cylinder; 18 - second aspiration channel; 19 - exit "large impurities"; 20 - settling chamber I; 21 - "shriveled" seed output; 22 - settling chamber II; 23 - settling chamber III; 24 - "light impurities" output; 25 - vibrating hammer; 26 - first aspiration channel; 27 - blower

The remaining mass (short impurities and grains of basic culture) flows through the lower sieve and falls on the grid 13 under the second aspiration channel 18. From here, the mass falls into the trior cylinders 17.

The short impurities are directed to the collecting shute 16 and then through the opening 14 (Figure 87). The grains of the main culture flows down the bottom of the triore cylinders and goes out through the outlet 15 (“grain for seeds”). When there are no short impurities in the starting mixture, a lid is mounted on the chute and the grain of main culture goes out through the side opening and the triore cylinders are turned off. The vibrating hammer 25 clean the upper sieve, and the brushes 10 clean the bottom sieve.

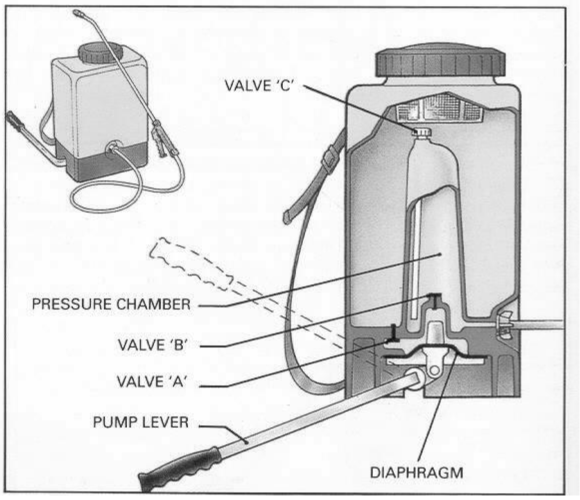
Basic machine settings:

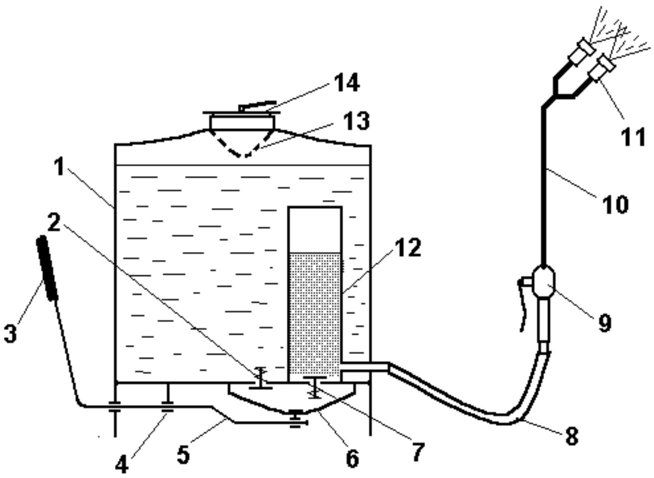
- adjusting the dosing shutter plate 4 (determines the machine's productivity);
- selection of top and bottom sieve (by size and shape of the holes using tables);
- setting the fan speed (gradual - by changing the pulleys);
- airflow in the first aspiration channel;
- airflow in the 2nd aspiration channel;
- adjusting the impact force of the upper sieve hammer 25;
- adjusting the position of the brushes 10 for the bottom sieve;
- adjusting the slope of the collecting shute 16 in the trior cylinders 17.

EXERCISE GUIDE FOR STUDENTS

EXERCISE № 1

1.Structure of a lever-operated knapsack sprayer



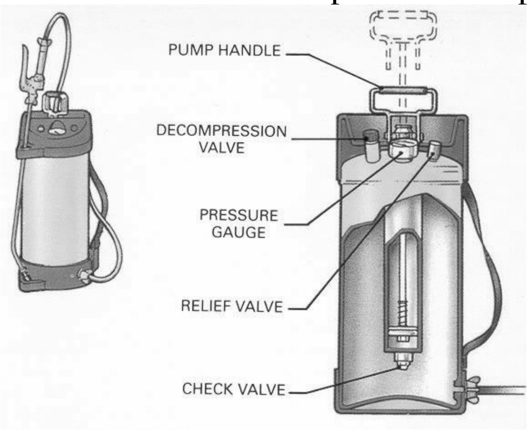


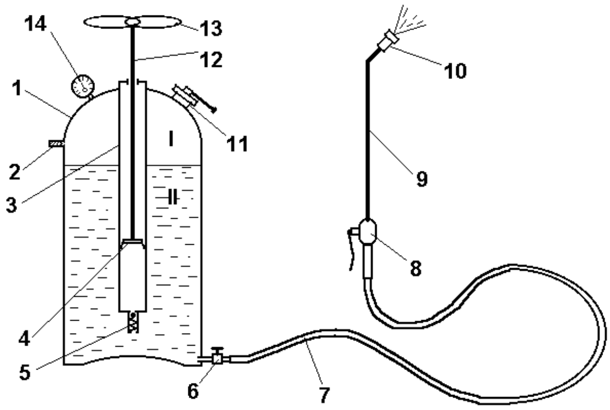
1 -	2 -	3 -
4 - sliding bearing	5 - crank	6 -
7 -	8 -	9 -
10 -	11 -	12 -
13 -	14 - lid	

General characteristics

1. Pressure regulator.
2. Large filter with viton seals in the lance handle and rustproof spring.
3. Shut-off handle fastener.
4. Screw-on hose connections to the handle and the chamber without clamps.
5. Attachment clip for the pump lever, lance and arm, for easy transport and storage.
6. Wide filling mouth. Cover with anti-drip valve.
7. Wide, deep filter in filling system with contents indicator.
8. Lubricated screw-on guide with sealing washer.
9. Pump lever with ergonomic handle.
10. Adjustable padded straps.
11. Translucent level indicator.
12. High-capacity, very strong pressure chamber.
13. 95 cm fibre glass lance with cone nozzle (0.8 l/min).
14. Mechanical stirrer with a device for mounting the closing valve.
15. Synthetic seal (viton in Evolution 20 Super model). Replacement seals, one rubber, one synthetic.
16. Reversible, to be used with either hand.
17. Stainless steel balls in the valve and sleeve.
18. Strong tank with carrying handle, and a light-weight, ergonomic design thanks to the back separator. Internal tank reinforcements via structural rib.
19. Full-width base, shockproof and rustproof.
20. Connector for accessories. Orientable lance.
21. Adjustable cone nozzle. (0.8 l/min.)
22. Wide spectrum nozzles set (herbicides, insecticides and fungicides).
23. 100 ml Goizper dosage measuring jar.
24. 2 "Comfort" dust proof masks.

2.Structure of a compression knapsack sprayer

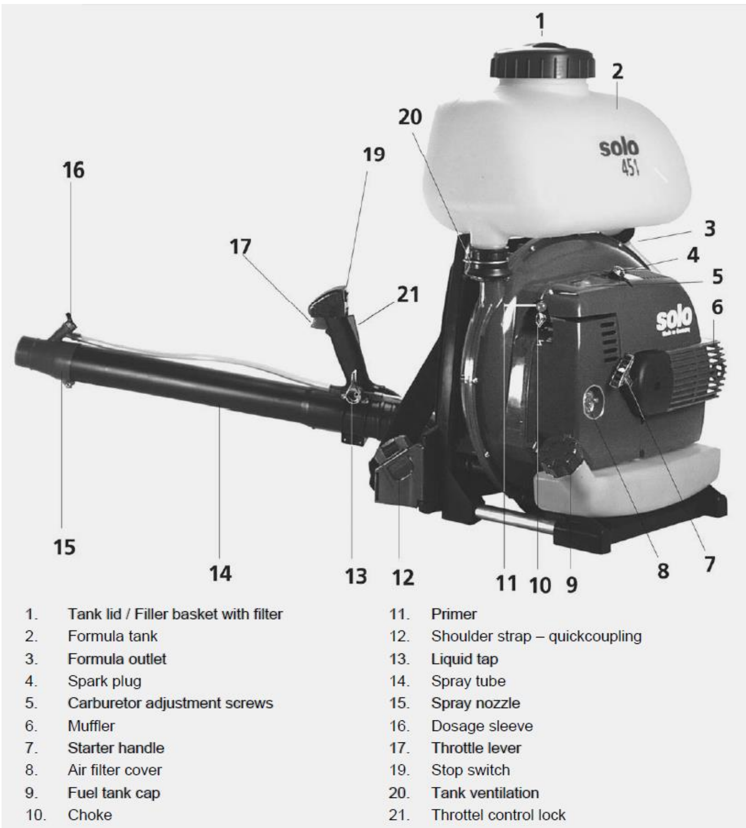




1 -	2 -	3 - air pump
4 - piston	5 -	6 – tap valve
7 -	8 -	9 -
10 -	11 - charging hole with cap	12 - rod
13 -	14 -	

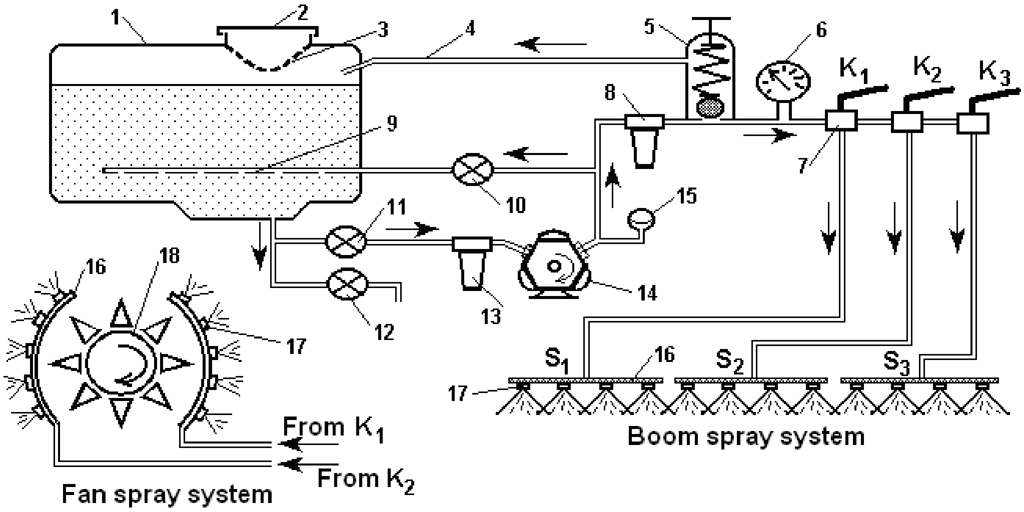
3.Structure of a motorised knapsack sprayer

1 –
2 –
3 –
4 –
5 –
6 –
7 –
8 –
9 –
10 –
11 –



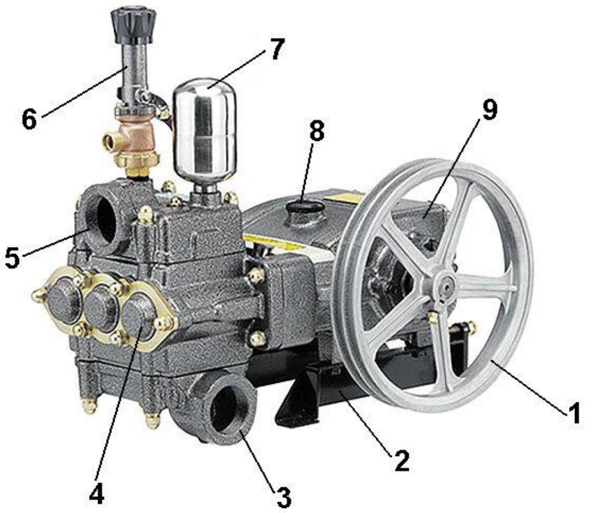
EXERCISE № 2

1.Technological sheme of a sprayer (boom and air-blast type)



(write the items to the corresponding number using Figure 18- page 14)

1 -	2 -	3 -
4 -	5 -	6 -
7 -	8 -	9 -
10 -	11 -	12 -
13 -	14 -	15 -
16 -	17 -	18 -



Piston pump:

1 –
2 –
3 –
4 –
5 –
6 –
7 –
8 –
9 -

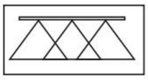
(write the items to the corresponding number)

outlet, stand, damper valve, inlet, oil cap, valve head, corps, belt pulley, pressure regulator,

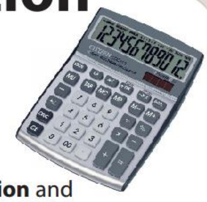
EXERCISE № 3

Subject "BOOM SPRAYERS"

Sprayer Calibration



Broadcast Application

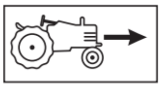


Sprayer calibration:
(1) readies your sprayer for operation and
(2) diagnoses tip wear.

Equipment Needed:

- Calibration Container
- Calculator
- Cleaning Brush
- One new Spray Tip matched to the nozzles on your sprayer
- Stopwatch or wristwatch

STEP NUMBER 1

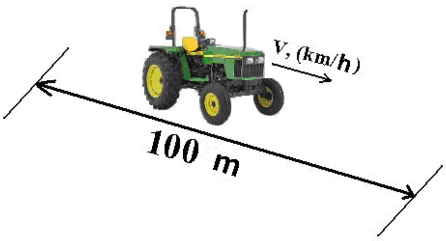


Check Your Tractor/Sprayer Speed!

Knowing your real sprayer speed is an **important** part of accurate spraying. Check the time required to move over a 50- or 100-meter strip on your field. Hold that speed as you travel between the "start" and "end" markers.

$$\text{Speed (km/h)} = \frac{\text{Distance (m)} \times 3{,}6}{\text{Time (seconds)}}$$

When the correct throttle and gear settings are identified, mark your speedometer to help you control this **vital** part of accurate chemical application.



STEP NUMBER 2

$$A = \frac{B+C}{D}$$

The Inputs

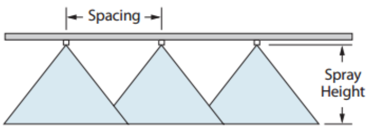
Before spraying, record the following: **EXAMPLE**

Nozzle type on your sprayer.................... TT11004 Flat Spray Tip
(All nozzles must be identical)

Recommended application volume ....***Q*** **=** 190 l/ha
(From manufacturer's label)

Measured sprayer speed ....***V*** **=** 10 km/h

Nozzle spacing...***b*** **=** 50 cm



STEP NUMBER 3

Calculating Required Nozzle Output

Determine q [l/min] nozzle output from formula

FORMULA: $\frac{Q.v.b}{60000}$, [l/min]

$$\text{l/min} = \frac{\text{l/ha x km/h x } \mathbf{cm}}{60\,000}$$

EXAMPLE: $\text{l/min} = \frac{190 \text{ x } 10 \text{ x } 50}{60\,000}$

ANSWER: q = 1,58 l/min

different cases

b – Nozzle spacing (in cm) for broadcast spraying

b – Spray width (in cm) for single nozzle, band spraying or boomless spraying

b – Row spacing (in cm) divided by the number of nozzles per row for directed spraying

STEP NUMBER 4

Setting the Correct Pressure

Turn on your sprayer and check for leaks or blockage. Inspect and clean, if necessary, all tips and strainers with brush. Replace one tip and strainer **with an identical new tip and strainer** on sprayer boom.

Check appropriate tip selection table and determine the pressure required to deliver the nozzle output calculated from the formula in Step 3 for your new tip.

Example: (Using above inputs) refer to table for TT11004 flat spray tip. The table shows that this nozzle delivers 1.58 l/min at 3 bar.

Turn on your sprayer and adjust pressure. **Collect and measure the volume of the spray from the new tip for one minute in the collection jar.** Fine tune the pressure until you collect 1.58 l/min.

You have now adjusted your sprayer to the proper pressure. It will properly deliver the application rate specified by the chemical manufacturer at your measured sprayer speed.

	bar	DROP SIZE	CAPACITY ONE NOZZLE IN l/min
TT11003 (50)	1.0	VC	0.68
	2.0	C	0.96
	3.0	M	1.18
	4.0	M	1.36
	5.0	M	1.52
	6.0	M	1.67
TT11004 (50)	1.0	XC	0.91
	2.0	C	1.29
	3.0	C	1.58
	4.0	M	1.82
	5.0	M	2.04
	6.0	M	2.23
TT11005 (50)	1.0	XC	1.14
	2.0	VC	1.61
	3.0	C	1.97
	4.0	C	2.27
	5.0	M	2.54
	6.0	M	2.79

STEP NUMBER 5

Checking Your System

Problem Diagnosis: Now, check the flow rate of a few tips on each boom section. If the flow rate of any tip is 10 percent greater or less than that of the newly installed spray tip, recheck the output of that tip.

If only one tip is faulty, replace with new tip and strainer and your system is ready for spraying.

However, if a second tip is defective, **replace all tips on the entire boom.**

This may sound unrealistic, but two worn tips on a boom are ample indication of tip wear problems.

Replacing only a couple of worn tips invites potentially serious application problems.

Banding and Directed Applications

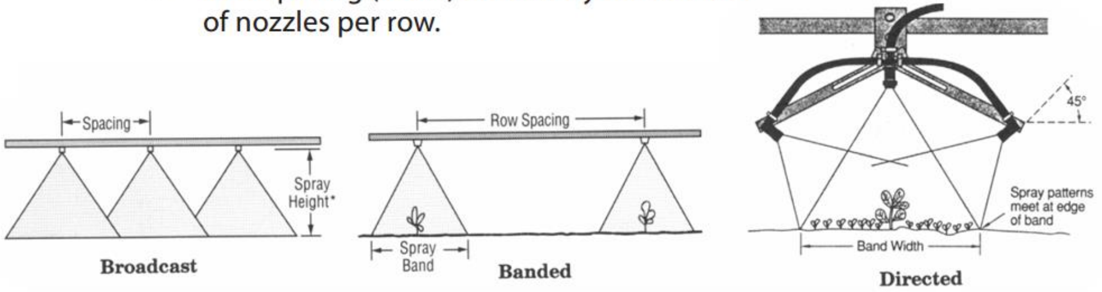
The only difference between the above procedure and calibrating for banding or directed applications is the input value used for "**b**" in the formula in Step 3.

For single nozzle banding or boomless applications:

b = Sprayed band width or swath width (in cm).

For multiple nozzle directed applications:

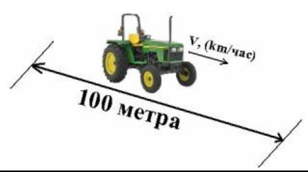
b = Row spacing (in cm) divided by the number of nozzles per row.

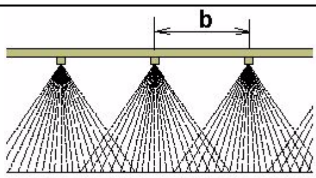


Task 1. It is necessary to perform a spraying with soil herbicide in a dose D = 2500 *ml/ha* = 2,5 *l/ha* on a field under the following conditions:

- spraying area - S = 8 ha;
- agregate - tractor and trailed boom sprayer;
- nozzles – flat spray tip, complete set of sizes;
- spacing between nozzles on the boom - b = 0,5 m;
- recommended application rate Q = 220 *l/ha*.

As a result of the task are determined: the working speed of the tractor-sprayer unit, the nozzle size, the pressure of the working solution, the quantity of the chemical for the entire area and the quantity of the working solution.

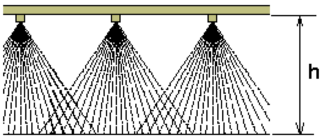
Sequence	Conditions and dependencies	Resolved example	New task
Step 1. Collecting preliminary information • Learn what area S (*ha*) should be treated • Read the package label of the chemical	Application rate Q (*l/ha*) Dose of chemical D (*l/ha*) Size of the droplets (fine, medium, coarse)	S = 8 *ha* Q = 220 *l/ha* D = 2,5 *l/ha* medium	S = 13 *ha* Q = 240 *l/ha* D = 2,2 *l/ha* medium
Step 2. Time ***t*** is measured (in seconds) to travel 100 meters from the tractor at the working speed.		t = 52 s	t = 48 s
Step 3. Calculate the speed of tractor *v* (km/h)	$v = \frac{100.3{,}6}{t} = \frac{360}{t}$	$v = \frac{360}{52} = 6{,}92 km/h$	$v =$

Step 4. Measure the distance between the nozzles on the boom (b = ? meters)	 	A distance of 50 cm is measured or b = 0,5 m	b = ……… m
Step 5. The minute flow rate of a single nozzle is calculated *q = ? l/min*	$q = \frac{Q.v.b}{600}$	$q = \frac{220.6,92.0,5}{600}$ *q = 1,27 l/min*	*q =* *q = ……….. l/min*
Step 6. Based on the calculated flow rate, the size of the nozzles and the pressure at which they will work will be selected according to the table. The table (Fig.119) is provided by the company that produced the nozzles.	On the table by Fig.119 a flow rate is selected q_{sel}, as closest to the calculated flow rate: q_{sel} = *1,29 l/min* on 2 bar (medium size of the droplets)	A nozzle is selected: XR11004 and filter 50 mesh q_{sel} = *1,29 l/min* on 2 bar (with medium size of the droplets)	A nozzle is selected: q_{sel} = *……………. l/min*

nozzle (filter)	bar	l/min	nozzle (filter)	bar	l/min	nozzle (filter)	bar	l/min
XR11001 (100 mesh)	1,0 1,5 2,0 3,0 4,0	0,23 0,28 0,32 0,39 0,45	XR11003 (50 mesh)	1,0 1,5 2,0 3,0 4,0	0,68 0,83 0,96 1,18 1,36	XR11006 (50 mesh)	1,0 1,5 2,0 3,0 4,0	1,37 1,68 1,94 2,37 2,74
XR110015 (100 mesh)	1,0 1,5 2,0 3,0 4,0	0,34 0,42 0,48 0,59 0,68	XR11004 (50 mesh)	1,0 1,5 2,0 3,0 4,0	0,91 1,12 1,29 1,58 1,82	XR11008 (50 mesh)	1,0 1,5 2,0 3,0 4,0	1,82 2,23 2,58 3,16 3,65
XR11002 (50 mesh)	1,0 1,5 2,0 3,0 4,0	0,46 0,56 0,65 0,79 0,91	XR11005 (50 mesh)	1,0 1,5 2,0 3,0 4,0	1,14 1,39 1,61 1,97 2,27	XR110010 (50 mesh)	1,0 1,5 2,0 3,0 4,0	2,28 2,79 3,23 3,95 4,56

Fig. 119. Minute flow rate of nozzles of different size and different working pressure.
(in parentheses is given the size of the filter holes)

Step 7. Recalculate the application rate of the solution Q in a new one Q_N for the selected size of nozzle and pressure	$Q_N = \frac{600.q_{sel}}{v.b}$	$Q_N = \frac{600.1,29}{6,92.0,5}$ $Q_{П}$ = *223,7 l/ha*	Q_N = Q_N = *…………. l/ha*
Step 8. Determine the quantity A in liters of the solution for the whole area	A = S.Q_N	A = 8.223,7 A = 1790 liters	A = A = …………. liters
Step 9. Determine the amount of B of the chemical for the entire area	B = S.D	B = 8.2,5 B = 20 liters	B = B = ……….. liters
Step 10. Prepare the working solution. This can be done either in the tank of the sprayer or in a separate tank of a mixer-machine.	• If, in the case, the sprayer has a tank of 1800 liters or more, pour 1770 liters of water and add 20 liters of chemical (to obtain a total of 1790 liters of working solution). • In a smaller tank, work proportional - eg. for a 600 liters tank the quantities are divided into three. 590 liters of water and 6,67 liters of chemical per charge.	Allow the sprayer agitator to work for 4-5 minutes until the solution is homogenized.	Allow the sprayer agitator to work for 4-5 minutes until the solution is homogenized.

<u>Step 11.</u> Place the selected nozzles on the sprayer boom and adjust the pressure as prescribed in the table		Place the selected nozzles on the sprayer boom. Adjust the pressure at 2 bar (2 bar = 0,2 Mpa).	Place the selected nozzles on the sprayer boom. Adjust the pressure at …………bar (…….. bar = …….. Mpa).
<u>Step 12.</u> Adjust the boom height **h** over the field or over the crop that you are spraying. It is necessary to provide 20-30% overlapping of the nozzle jets.	 	h = 55 cm	h = ……… cm
<u>Step 13.</u> Spray is carried out while maintaining the selected speed and the selected solution pressure.	The control devices and clogging of the nozzles are continuously monitored. If there are any problems, stop the sprayer and solving the problems. Working with a damaged sprayer and its components should not be allowed.	The speed is supported ***v*** = 6,92 km/h and pressure p = 2 bar	The speed is supported ***v*** = ……… km/h and pressure p = ……….. bar

B. Adjustment for spraying of strips (banding)

For difference to the spraying of the entire area, only strips of a precisely defined width are sprayed (Figure 121). This method of spraying can be applied to field crops for insecticide, fungicide and herbicide treatment, as well as to perennial crops for herbicide treatment in between the plants.

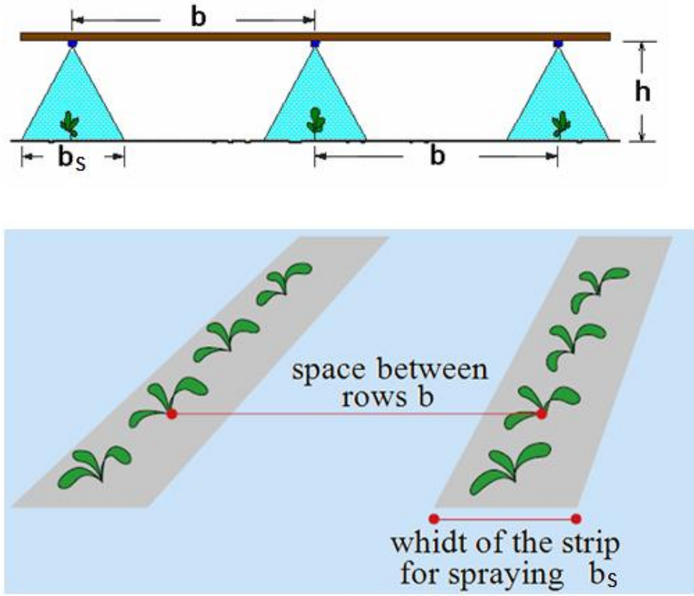


Fig. 121. Schemes for field crop spraying in strips (banding)

<u>Task 2.</u> It is necessary to spray field crop in strips with space between rows b = 70 cm = 0,7 m using a working solution made with powder insecticide: dose D = 3000 *g/ha* = 3 *kg/ha* on a field under the following conditions:

- total area for spraying S_T = 3,7 ha;
- agregate - tractor and mounted boom sprayer;
- nozzles – hollow-cone spray tips with a small spray angle (from 40^0 to 60^0);
- spacing between nozzles on the boom - b = 0,7 m;
- whidt of the strip for spraying $b_S \approx 0,32$ m;

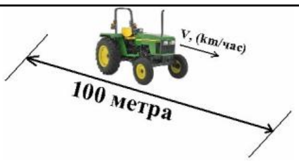
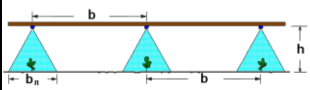
Sequence	Conditions and dependencies	Resolved example
Step 1. Collecting preliminary information • In what culture will work • Learn what area S_T (ha) should be treated • Measure between row space b (b = ? meters) • Select the whidt of the threated strip b_S = ? метers • Read the package label of the chemical	Application rate Q (*l/ha*) Dose of chemical D (kg/ha)	sunflower S_T = 3,7 ha b = 0,7 m $b_S \approx$ 0,32 m Q - from 25 to 35 l/ha D = 3 kg/ha
Step 2. Time *t* is measured (in seconds) to travel 100 meters from the tractor at the working speed	 	t = 62 s
Step 3. Calculate the speed of tractor *v* (km/h)	$v = \frac{100.3,6}{t}$	$v = \frac{360}{62} = 5{,}81 km/h$
Step 4. A table is used to combine the spray angle of the nozzle and the height of the nozzle, which produces the width of the sprayed tape closest to the desired width.	By Table 4 is selected the closest value to the width of the strip b_S , spray angle β_ϕ and height of the nozzle h.	We choose: b_S = 31,2 cm = 0,312 m $\beta_\phi = 55^0$ h = 30 cm = 0,3 m
Step 5. A nozzle is selected per table, which satisfies the conditions of operation.	By Table 5, the size of the nozzle, the swirl plate and the working pressure at which it is to be operated is selected. Record the minute flow of the nozzle q at this pressure.	Selected the nozzle D1,5 with swirl plate DC25 and orifice ϕ = 0,91 mm, spray angle $\beta_\phi = 54^0$ at pressure p = 10 bar and flow rate *q = 0,91 l/min*.

Table 4. Band width at combinations of spray angle and nozzle height
(Table applies to Teejet Company spray tips)

spray angle	nozzle height h [cm]					
	20 cm	30 cm	40 cm	50 cm	60 cm	70 cm
15°	5.3	7.9	10.5	13.2	15.8	18.4
20°	7.1	10.6	14.1	17.6	21.2	24.7
25°	8.9	13.3	17.7	22.2	26.6	31.0
30°	10.7	16.1	21.4	26.8	32.2	37.5
35°	12.6	18.9	25.2	31.5	37.8	44.1
40°	14.6	21.8	29.1	36.4	43.7	51.0
45°	16.6	24.9	33.1	41.4	49.7	58.0
50°	18.7	28.0	37.3	46.6	56.0	65.3
55°	20.8	31.2	41.7	52.1	62.5	72.9
60°	23.1	34.6	46.2	57.7	69.3	80.8
65°	25.5	38.2	51.0	63.7	76.5	89.2
73°	29.6	44.4	59.2	74.0	88.8	104
80°	33.6	50.4	67.1	83.9	101	118
85°	36.7	55.0	73.3	91.6	110	128
90°	40.0	60.0	80.0	100	120	140
95°	43.7	65.5	87.3	109	131	153
100°	47.7	71.5	95.3	119	143	167
110°	57.1	85.7	114	143	171	200

Table 5. Characteristics of hollow-cone spray nozzles
(Table applies to Teejet Company spray tips)

nozzle	swirl plate	hole mm	flow rate l/min										angle		
			0.7 bar	1 bar	2 bar	3 bar	4 bar	5 bar	6 bar	10 bar	15 bar	20 bar	1 bar	10 bar	20 bar
D1	DC25	0.79	—	—	0.33	0.40	0.45	0.50	0.54	0.69	0.83	0.95	—	49°	51°
D1.5	DC25	0.91	—	—	0.45	0.53	0.61	0.67	0.73	0.91	1.1	1.2	—	54°	55°
D2	DC25	1.0	—	0.37	0.51	0.62	0.71	0.79	0.86	1.1	1.3	1.5	32°	61°	61°
D3	DC25	1.2	0.39	0.45	0.63	0.75	0.86	0.95	1.0	1.3	1.6	1.8	47°	69°	69°
D4	DC25	1.6	0.57	0.68	0.94	1.1	1.3	1.4	1.6	2.0	2.4	2.8	63°	82°	82°
D5	DC25	2.0	0.64	0.81	1.1	1.4	1.6	1.7	1.9	2.4	2.9	3.3	70°	85°	84°
D6	DC25	2.4	0.87	1.0	1.5	1.8	2.0	2.3	2.5	3.2	3.8	4.4	77°	89°	88°
D7	DC25	2.8	1.0	1.2	1.7	2.0	2.3	2.6	2.9	3.7	4.5	5.1	83°	92°	91°
D8	DC25	3.2	1.2	1.4	2.0	2.4	2.8	3.1	3.4	4.4	5.3	6.2	89°	96°	95°

Step 6. Using the minute flow rate of a nozzle we calculated application rate Q B l/ha	$Q = \frac{60.q}{v.b_S}$	$Q = \frac{600.0,91}{5,81.0,312}$ *Q = 301,2 l/ha*
Step 7. Determine what a real part threated area S_R of the total area S_T will be treated.	$S_R = \frac{b_S}{b}.S_T$	$S_R = \frac{0,312}{0,7}.3,7$ *S_R =1,649 ha*
Step 8. Determine the quantity A in liters of the solution for the realy threated area.	$A = S_R.Q$	*A = 16,49 . 30,12* *A = 497 liters*
Step 9. Determine the quantity B of the chemical for the realy threated area.	B = S_R .D	B = 16,49 . 0,3 B = 4,95 kg
Step 10. Prepearing the working solution.	Put 492 liters of water into the reservoir and 4,95 kg of chemical, to produce 497 liters of working solution.	Allow the sprayer agitator to work for 4-5 minutes until the solution is homogenized.
Step 11. Place the selected nozzles on the sprayer boom and adjust the pressure as prescribed in the table.		Place the selected nozzles on the sprayer boom. Adjust pressure at 10 bar. (10 bar = 2 Mpa).
Step 12. Adjust the nozzle height **h** above the treatment surface so that the desired bandwidth is obtained.		Adjusting the boom height **h** = 30 cm
Step 13. Spray is carried out while maintaining the selected speed and the selected solution pressure.		Speed is maintained v = 5,81 km/h and pressure p = 10 bar

EXERCISE № 4

Subject " AIR-BLAST SPRAYERS (FAN SPRAYERS)"

Six steps to calibrate and optimize airblast sprayers

step 1. check speed

step 2. adjust the direction of the air

step 3. match the air volume and speed to the canopy

Spray should penetrate the canopy but not expel greatly from the other side. Many factors like wind, canopy density, and speed will affect the correct volume of air and ideally there should be an automated method to adjust the air volume as conditions change. However, significant improvements can still be seen with manual adjustments done just a couple times a season depending on crop growth. The steps below can be measured through the season for 1-2 years as the canopy develops and then recorded for future years.

step 4. calculate and record the expected nozzle output

1. Select the appropriate application rate of the working solution Q in l/ha.
2. Select the appropriate working speed *v* of the tractor/sprayer unit in km/h.
3. Select the way of moving the sprayer in the plantation (Figure 122).
4. Calculation of sprayer working width B_p in m

$$B_p = m.b,$$

where: *m* is the number of spray rows per one working move;
b – between row spacing, m.

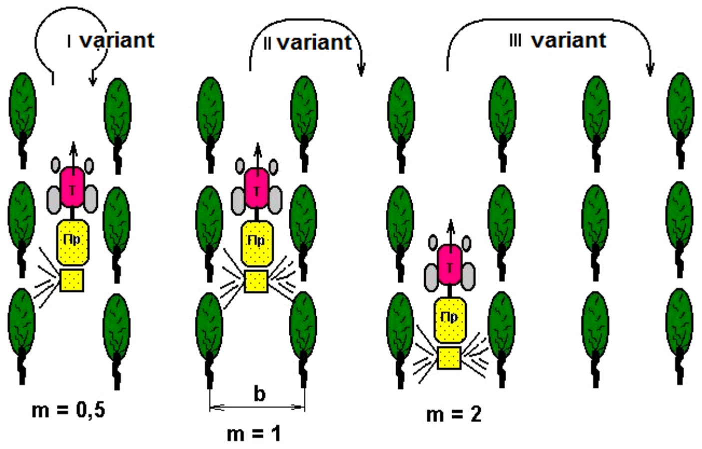


Fig. 122. Variants of motion of the sprayer in the plantation:
twice in one row (m = 0.5); one time in a row (m = 1); over one row (m = 2)

5. Calculation of the required minute flow rate *q* of a single nozzle in l/min:

$$q = \frac{Q.v.B_p}{600.n}, \text{ l/min}$$

6. Determination by a table (or graph) the size of the nozzles and the working pressure of the solution.

7. Preparation of the working solution (percentage solution or solution with a dose of the preparation per hectare).

8. Assemble the nozzles, adjusting their direction angle, starting the sprayer, adjusting the pressure.

step 5. measure nozzle output

step 6. verify coverage

TASK № 1

Spraying in orchard against aphids

• between row spacing b = 4 m • tractor STEYER and sprayer "AGP-200ENU" • tank volume - …………. ***l*** • nozzles "Lehler -Hollow Cone Type" • plant protection product DECIS 25 EC K = 0,04 %	• number of nozzles - n = ………….. pieces • application rate Q = 450 *l/ha* • motion of the sprayer (m = ………) • area of the orchard - S = 1,8 ha

Speed *v* order of the tractor

Speed	I	II	III	IV	V	VI	VII	VIII	IX
Fast, km/h	2,5	4,3	7,2	8,9	10,5	13,3	15,2	17,9	33,4
Slow, km/h	1,9	3,2	5,5	6,7	8,0	9,3	11,4	13,6	25,2

Calculation:

1. Calculation of sprayer working width B_p in m

B_p = m.b = …………………… = ……….. m

2.Calculation of the required minute flow rate *q* of a single nozzle in l/min:

$$q = \frac{Q.v.B_p}{600.n}$$ ……………………………… = ……………..l/min

3. Determination by a table the size of the nozzles and the working pressure of the solution.

Lechler Hollow cone nozzles TR 80

nozzle	l/min																		
		[bar]																	
		2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	19.0	20.0
TR 80-005	60 M	0.16	0.20	0.23	0.25	0.28	0.30	0.32	0.34	0.36	0.38	0.39	0.41	0.42	0.44	0.45	0.47	0.49	0.51
TR 80-0067	60 M	0.22	0.27	0.31	0.35	0.38	0.41	0.44	0.47	0.49	0.52	0.54	0.56	0.58	0.60	0.62	0.64	0.68	0.70
TR 80-01	60 M	0.32	0.39	0.45	0.51	0.55	0.60	0.64	0.68	0.72	0.75	0.78	0.82	0.85	0.88	0.91	0.93	0.99	1.01
TR 80-015	60 M	0.48	0.59	0.68	0.76	0.83	0.90	0.96	1.02	1.07	1.13	1.18	1.22	1.27	1.31	1.36	1.40	1.48	1.52
TR 80-02	60 M	0.65	0.80	0.92	1.03	1.13	1.22	1.30	1.38	1.45	1.53	1.60	1.67	1.73	1.79	1.85	1.90	2.01	2.07
TR 80-03	60 M	0.97	1.19	1.37	1.53	1.68	1.81	1.94	2.06	2.17	2.28	2.38	2.48	2.57	2.66	2.75	2.83	2.99	3.07
TR 80-04	60 M	1.29	1.58	1.82	2.04	2.23	2.41	2.58	2.74	2.88	3.03	3.16	3.29	3.41	3.53	3.65	3.76	3.98	4.08
TR 80-05	25 M	1.61	1.97	2.28	2.55	2.79	3.01	3.22	3.42	3.60	3.77	3.94	4.10	4.26	4.41	4.55	4.69	4.96	5.09

- minute flow rate closest to the calculated value **q_R** = …..…………*l/min*
- spray tip (nozzle) ………………………………………
- working pressure ……………………….. MPa (1 Mpa = 10 bar)

4.Recalculation of flow rate **Q** for the new application flow rate Q_N:

$$Q_N = \frac{600.q_R.n}{v.B_p}$$ = …………………………… = …………….., *l/ha*

5. Determination of the amount of solution **A** in *l*:

A = Q_R.S = ……………………… = ……….. *l*

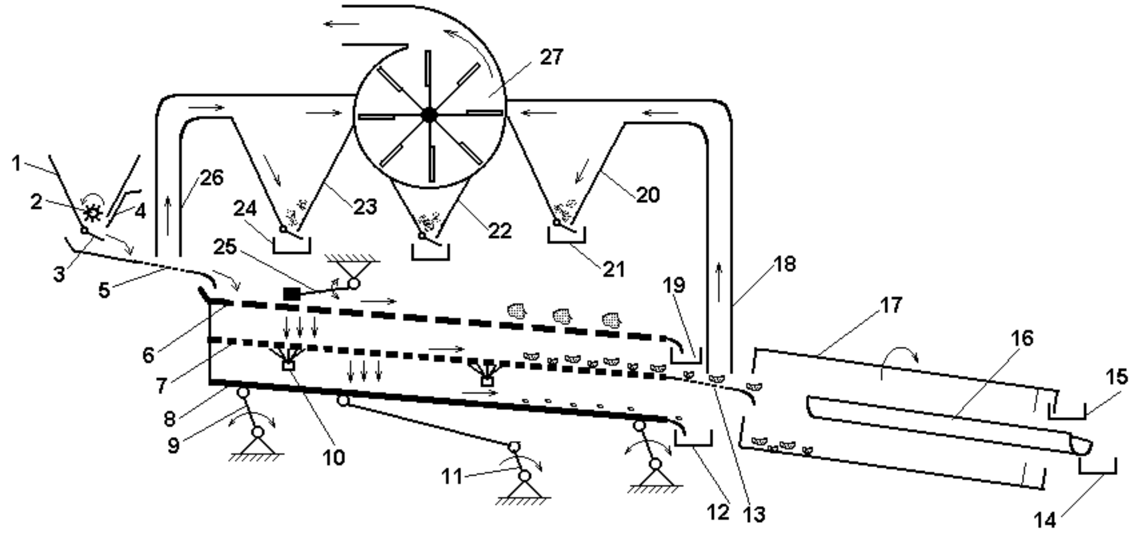
6. Determination of the amount of plant protection product **B** in *l*:

B = 0,01.A.K = ……………………………….= ……….. *l*

EXERCISE № 5

Subject: "MACHINES FOR GRAIN CLEANING AND GRAIN SORTING"

I. ***Technological scheme of seed-cleaning and sorting machine***



1.	2.
3.	4.
5.	6.
7.	8.
9.	10.
11.	12.
13.	14.
15.	16.
17.	18.
19.	20.
21.	22.
23.	24.
25.	26.

(*write the items to the corresponding number - for reference Figure 87, page 53)*

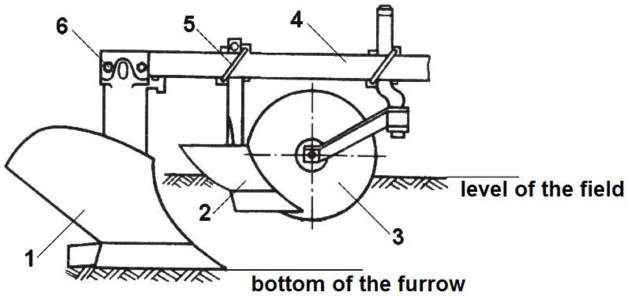
trior cylinder; settling chamber II; first aspiration channel; "shriveled" seed output; dosing roller; grid; sloped plate; knee-rod mechanism; "short grain" output; collecting chute; removable bottom;second aspiration channel; brush; bottom sieve; exit "large impurities"; grid; upper sieve; settling chamber I; "light impurities" output; vibrating hammer; blower; hopper; shutter plate; swing plate; output "small impurities";output "fit grain"; settling chamber III;

Basic machine settings:
- adjusting the dosing shutter plate 4 (determines the machine's productivity);
- selection of top and bottom sieve (by size and shape of the holes using tables);
- setting the fan speed (gradual - by changing the pulleys);
- airflow in the first aspiration channel;
- airflow in the 2nd aspiration channel;
- adjusting the impact force of the upper sieve hammer 25;
- adjusting the position of the brushes 10 for the bottom sieve;
- adjusting the slope of the collecting shute 16 in the trior cylinders 17.

EXERCISE № 6

1. Plow structure

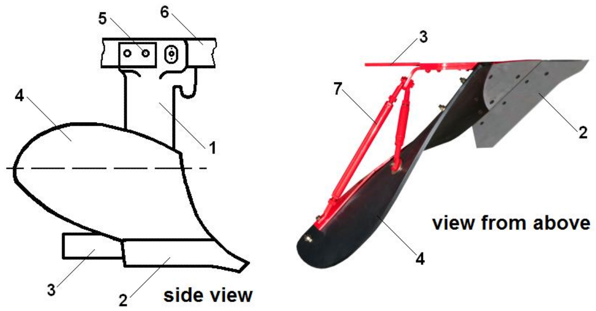
(*write the items to the corresponding number - for reference Figure 53, page 36)*



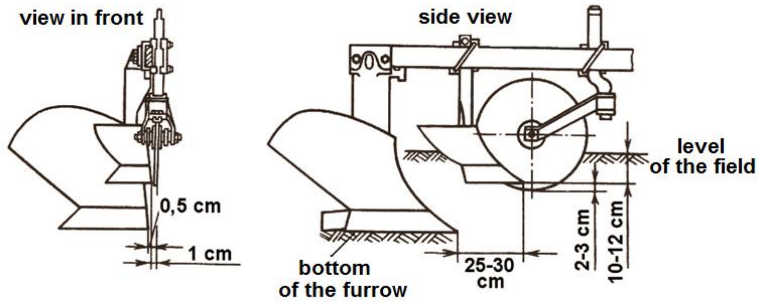
Scheme of plow

1 –
2 –
3 –
4 –
5 –
6 –

(*write the items to the corresponding number - for reference Figure 55, page 37)*

Scheme of plow bottom		1 - .... 2 - .... 3 - .... 4 - ....

2. Adjustment for work

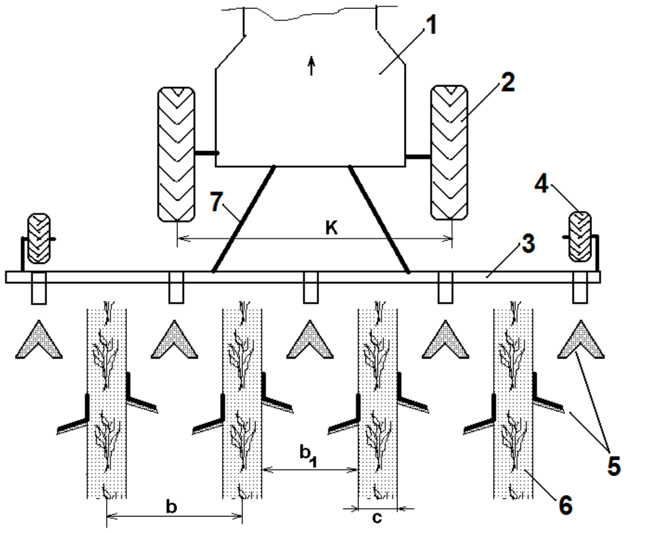
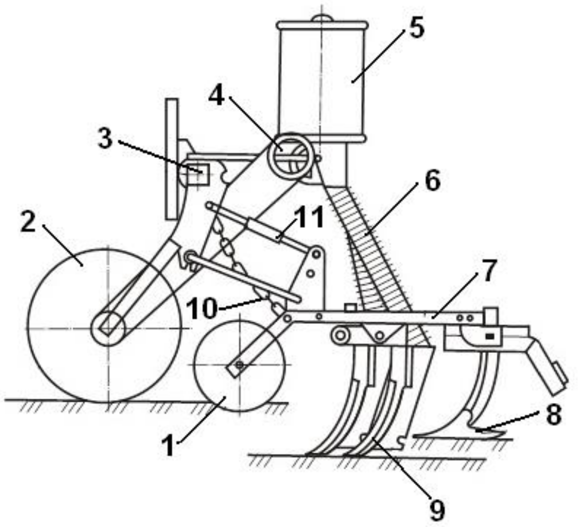


Scheme for the placement of the working bodies of a plow

EXERCISE № 7

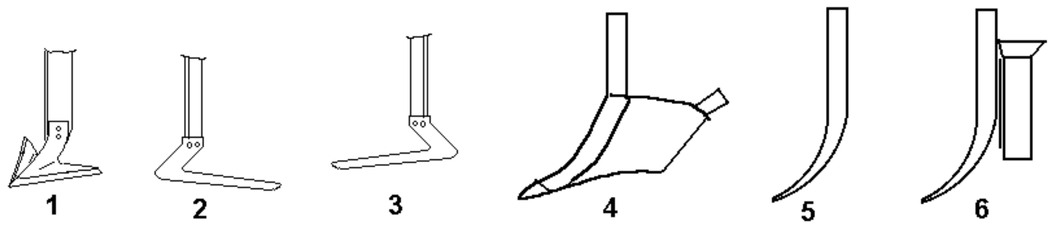
1.Cultivator for row crops cultivation – structure

(write the items to the corresponding number - for reference Figure 71 and 72, page 46)

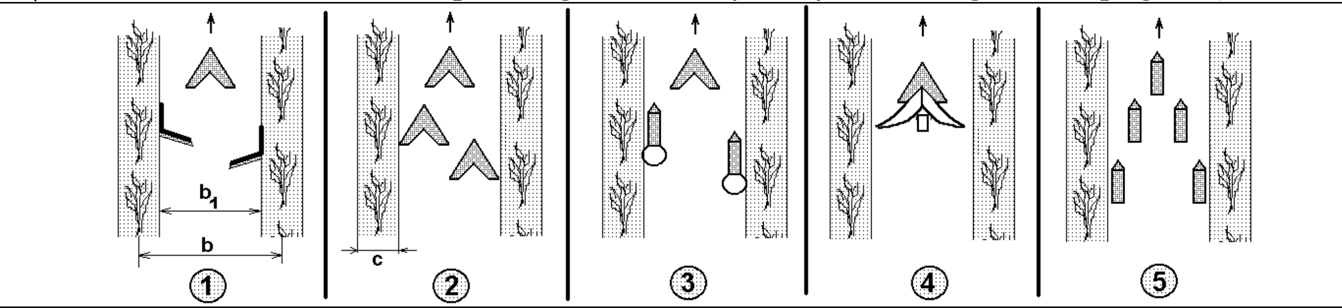
	
Describe the elements:	Describe the elements:

2.Types of working organs of a cultivator for row crop cultivation

(write the items to the corresponding number - for reference Figure 73, page 46)

Describe the elements:	1. …………………………………… 2. …………………………………… 3. ……………………………………	4. …………………………………… 5. …………………………………… 6. ……………………………………
		

3.Types of operations for row crop cultivation
(*write the items to the corresponding number - for reference Figure 74, page 46)*



variant 1 –
variant 2 –
variant 3 –
variant 4 –
variant 5 –

REFERENCES

1. *Демирев, Ж., Братоев, К.* Земеделски машини I. Русенски университет „А. Кънчев", Русе, 2012.
2. *Капустин, В. П., Коновалов, Д. Н.* Сельскохозяйственные машины. Тамбовский государственный технический университет" (ФГБОУ ВПО "ТГТУ") Тамбов, 2012.
3. *Трифонов, А*. Земеделски машини. Пловдив, Акад.изд. на Аграрен университет, 2016.
4. *Мандраджиев, С*., Трифонов, А. и др. Ръководство за упражнения по растителнозащитна техника, Земиздат, 1993.
5. *Ревякин, Е. Л., Краховецкий Н. Н.* Машины для химической защиты растений в инновационных технологиях. Москва, ФГНУ «Росинформагротех», 2010.
6. *Dr. Jason Deveau*. Six Elements of Effective Spraying in Orchards and Vineyards. Field Crop Conditioning and Environment, OMAFRA, Stratford, 2009.
7. *Matthews, G. A.* Pesticide application methods. Longman. Essex, 1992.
8. *Weij, H.G. van der, Speelman, L.* Spuitdoppen en vloeistofverdeling (Nozzles and liquid distribution). Inst. voor Biologish, Holland. Landbouwmechanisatie, p. 311-319 Apr. 1972.
9. www.claas.de; www.perla.dir.bg; www.teejet.com; www.vaderstad.com; www.sprayingsistems.com; www.grupponardi.it; www.lurmark.com;
10. www.delavan.co.uk; www.micron.co.uk; www.berthoud.fr; www.cimaitalia.com; www.maltehagro.bg; www.lemken.de;
11. www.amazone.de; www.johndeere.com. www.vogel-noot.info; www.gaspardo.it; www.kverneland.com; www.newholland.com; www.kuhn.com;
12. www.nasda.org/PesticideManual/Ch11.pdf - Pesticide Application Procedures.
13. www.nasda.org/PesticideManual/Ch10.pdf - Planning the Pesticide Application.

For connection:

Assoc. Prof. Angel Trifonov, phD,
mechanical engineer

Agricultural University – Plovdiv
Department "Mechanization of agriculture"

mail: trifonov56@abv.bg
telephone number: 0886 747 259