Lecture Notes

BY

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1908

SCHOOL OF AGRICULTURE,

NATAL.

FIRST YEAR.

SESSION I.

DIGEST OF NOTES:

Principles of Agriculture.

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Principles of Agriculture.

Lecture I.

DRAINAGE OF ARABLE LANDS.

We drain land to remove *surplus* moisture, and to fit it for tillage and the cultivation of crops.

The roots of crops require air and warmth as well as moisture. If the soil be full of stagnant water the roots are both suffocated and poisoned, *e.g.*, yellowing of maize in swampy ground.

There are two kinds of water in the soil:—

(*a*) *Capillary water* is the water brought up from below by capillary attraction (*e.g.*, a naturally or artificially drained soil is moist near the surface long after rain). This water is a blessing and necessity in agriculture.

(*b*) *Hydrostatic water* is that which falls on the surface and completely saturates the soil, filling all the large pores which should contain air. If this water of saturation remain in the surface soil for many hours much damage is done; if for several days it is fatal to the crop. Hydrostatic water responds to gravity, capillary water works against it.

The healthy circulation of water in well-drained soils is due to the opposing forces of gravity and capillarity. Heavy rains falling on the surface obey the laws of gravity and sink into the subsoil, from which water is again drawn to the surface during times of drought by capillary action.

Cold and heavy soils hinder this free circulation, and therefore frequently require draining. A cold soil is one overlying an impermeable subsoil. A heavy soil is one containing a large proportion of clay. A clay soil contains a large proportion of small, closely packed particles which hinder the passage of water.

Sandy and gravelly soils, on the other hand, show a number of large open pores, through which rain-water passes rapidly, as gravity acts nearly unobstructedly.

All soils do not, therefore, require draining. If there is no surplus moisture because the land is already under-drained by nature, as in the case of sandy loams with a gravelly subsoil, it is only wasted expenditure to attempt draining.

What lands require draining ?—There are certain external signs of the need of draining :—

1. Water standing in the furrows some hours after rain.
2. Soil sticking to the boots, or to the hoofs of horses, and puddles collecting in the foot-marks thus made.
3. A crust forming on the surface after sunshine, which opens in small cracks, and holds the roots of plants like a vice.
4. Damp patches in the field when the surface is at a slightly low level, remaining moist several days after rain.
5. A stick pushed into the soil forms a hole in which water collects, while a ball of putty-like clay is withdrawn.
6. When it has been found necessary to grow crops on ridgés.
7. When maize and other crops show an unhealthy yellow colour.
8. When the roots of crops and trees lie near the surface and do not penetrate.
9. When typical marsh plants are seen to be flourishing, *e.g.*, Sedge, Plantain, Rush. Bugle, Ranunculus Bulbosus, St. John's Wort, Agrimony, etc.

Preliminary steps to drainage :—

1. Survey and preparation of a contour map.
2. Determination of the lie of the water after heavy rains, and the presence of springs.
3. Construction of a drainage map.

"*Surplus moisture must be removed down through the soil and not off along its surface,*" because underdraining :—

1. Facilitates all tillage and harvesting operations. Open drains are better than none, but greatly impede the work of the farm.
2. Removes not only surplus on surface, but also surplus in soil and subsoil. The surface may, on rolling ground, dry off and yet the soil be so water-logged as to hinder all cultivation, and to cause the death of the crop.
3. Prevents loss of fertility by surface wash; this takes with it, not only fertilisers applied to the field, but soluble salts and fine soil originally present. Surface wash puddles and cakes the surface.
4. Adds fertility to the soil with each rainfall. Rain contains nitrogen and the soil acts as a filter, straining this fertilising matter and allowing the water to escape through the subsoil drains.

5. Warms the soil by removing surplus water which by evaporation chills the soil. It allows warm air to pass up from the subsoil in winter, and warm showers to soak down in spring. Undrained clay soils are "cold" soils, and sandy loams are "warm" soils, for this reason: that the former have poor, and the latter good natural subsoil drainage.
6. Increases the extent of root-pasturage. Crops and trees do not send their roots below the level of frequent saturation.
7. Increases pulverisation of sub-soil. A dry soil breaks up more quickly than a wet. A saturated clay sets into a solid puddled mass if tramped by stock or worked by implements. On drying this sets to a brick-like consistency.
8. Helps the crops to resist drought. A well-drained soil has an open sponge-like character, capable of absorbing and holding a far larger amount of water than an undrained clay soil, which, when saturated, becomes so puddled and compacted that no spaces or interstices remain to be filled with water. During the dry season such soil cracks into great solid clods, which contain little water and are not penetrated by roots.

Lecture II.

METHODS OF DRAINAGE.

1. *Open Drains.*—Not to be recommended except for :—

(*a*) Catchwater ditches on a steep hill-side, when it is otherwise impossible to prevent washing of surface.
(*b*) Main drains receiving outlets of tile or stone drains.
(*c*) Cases where the expense of closed drains is prohibitive.

Open drains must not be of equal width at top and bottom, as the sides will in such case inevitably collapse. Angle of equilibrium varies with nature of soil, but 33° will meet most cases. On pastures the slope may be increased, and drain grassed to bottom. Minimum width of 2 feet at bottom to allow for removal of soil which will inevitably fall into it. Open drains should be cleared out yearly.

2. *Brush Drains.*—Consisting of bundles of brush or faggots of sticks laid at bottom of drain and covered with soil.

Advantage : Cheapness, where timber and brush are plentiful and cheap.

Disadvantage : Short life of drain, as it early silts up or rots. Field mice and rats invariably use brush drains for nests ; make burrows from the surface, through which fine silt works and chokes drain. In heavy clay and swampy ground the life of drain may be eight years ; in sandy soil, which dries out in winter, brush rots within three or four years. Holes thus formed are dangerous to cattle.

Method of Construction :

(*a*) Open trench to required depth. Lay poles at bottom with spaces between, and fill to within one foot of surface with brush, the coarsest at the bottom, butt ends up-stream. Cover with inverted turf sods, and pile earth a foot above surface, as this will sink.

(*b*) At bottom of drain place stout pegs, crossing diagonally and resting on sides of trench. Tie brush into tight faggots, and fill drain as before.

3. *Plug Drains.*—Only used in stiff clays. Trench is dug and a series of wooden blocks, connected by a chain, laid in bottom. Clay is then filled in and plugs withdrawn by means of a lever, and a further length similarly filled in.

4. *Mole Drains.*—Open in stiff clays by means of a Mole Plough. This has a sharp-pointed wedge or roller carried on a broad, sharp shank three feet in length. The cut made by the

shank closes after the plough, while that made by the roller becomes a water-channel, carrying off excess moisture. Ten acres a day may thus be drained, and the channels in stiff clay will last for years. No good in rocky or sandy soils.

5. *Box Drains.*—Constructed from timber, four narrow planks being nailed together, and pierced at sides and below with holes to admit water. Where timber is very cheap may take the place of tiles.

6. *Stone Drains.*—Constructed from loose stones without matrix.

Disadvantages :

1. Require greater width of ditch than tiles.
2. Take longer to lay.
3. Require more carting.
4. Silt up more quickly.
5. Displace more earth, which has to be removed.

Advantage : Where suitable stone is abundant the cost of tiles may outweigh the above drawbacks. Fissile stone, such as shale, slate or sandstone, most suitable.

Method of construction best illustrated by diagrams. Pebbles useless. Filling of small stones above the duct is expensive and useless, as they check the flow of water and invariably get clogged.

7. *Tile Drains.*—May be made of clay and burnt, or of concrete. The latter material coming into general use, as more durable, cheaper, and less liable to warp, as no burning is necessary. Draining bricks are going out of use altogether.

Forms of Tiles :

(*a*) Tubular.
(*b*) Tubular, with sole.
(*c*) Hexagonal.
(*d*) Horse-shoe, with and without sole.

The tubular or round pipe, without or without collars, is superseding all others on account of its cheapness. Others are expensive, not so strong, nor so easily laid, and do not discharge water so well as tiles with a round bore.

Collars are used whenever there is a sudden descent in the drain, or where it passes through loose sand. There is less difficulty with collars in adjusting tiles in a straight line, and less danger from roots and silt. In clean cutting clays, however, collars are an unnecessary expense.

Size of Tiles: Larger tiles are necessary where the rainfall is crowded into a few months in the year and heavy storms prevail. In England, where rainfall is evenly distributed, two-inch tiles are in general use. In South Africa a larger tile is required to free the land quickly from storm water.

The main drain must have sufficient capacity to conduct all water from lateral drains. Carrying capacity of tiles depends upon their diameter and the fall of the drains. The capacity of round water-pipes is in proportion to the square of their diameters. A two-inch pipe carries four times as much water as a one-inch pipe, and something more, for the friction is less in proportion to the larger size of the pipe. All sudden turns or angles increase friction and lessen capacity of drains.

How Water enters Tile Drains: Water should enter drains from bottom and not from top. The deepest drains flow first and longest. Drains flow when water-table rises to their level. It is not desirable that rain water should enter top of drains and then flow down the tiles, the joints of which are therefore covered with building paper or closely-tamped clay, and the soil heaped up over the drain to turn aside the surface water.

Lecture III.

The Position of Drains.—We have already discussed kinds of lands which require draining, and now come to the question of the exact location and direction of the main and lateral drains.

1. *Main Drains* should follow general direction and location which main body of water takes after heavy rains to get off the land, *i.e.*, the path of least resistance. But course should be straightened, curves lengthened to avoid sharp angles, and the grades levelled. This still further lessens resistance, and allows surplus water to escape more rapidly (*c.p.*, railroad track.)

2. *Lateral Drains* should similarly follow, but straighten courses taken by surface-water in times of flood. If the slope is not very rapid, convenience may demand that the laterals vary slightly from the direct line down the slope. Lateral drains laid diagonally across slope are of far less service than those laid straight down the slope. The water carried off by this drain depends upon its "suction range," which is one-sided in the former case. *"There should be no down-hill and practically useless side to a tile drain." Soils are more porous horizontally than vertically.*

Distances apart of Drains.—Two rival theories—"deep drainage" and "thorough drainage." Question depends upon soil, climate, and cost of labour and materials.

(*a*) *Soil:* Water percolates readily through sand and sandy loams. These may require draining because they lie on stiff sub-soil. A smaller number of drains with larger bore and large "suction range" will suffice. Water percolates slowly through stiff clays, therefore closer drains with smaller bore desirable.

(*b*) *Depth* may increase efficiency of drain. The deeper the drain the sooner it commences and the longer it continues to flow, but in stiff soils the water takes too long to percolate to widely-spaced, though deep, drains.

(*c*) *Climate:* When heavy storms are experienced closer draining is demanded to carry off flood water before crops are injured.

(*d*) *Price of Labour and Materials:* The last foot of depth in a 4ft. drain costs as much as the first three! It may therefore be economical to lay more frequent drains at a lesser depth. Where labour is cheap, however, and tiles are dear, it is true economy to dig deep and lay few tiles.

Depth of Drains.—A four-foot drain costs twice as much to dig in ordinary soils as a 3ft., because at surface an additional foot in width must be removed. Material has to be thrown further and over a higher bank. There are, however, following points in favour of draining to 4ft.:—

1. They are more secure and durable, there being less danger from silt and sinking of line of drain.
2. They give wider feeding-ground to roots, which are not so liable to penetrate joints.
3. Better filter for percolating rain-water and furnish a larger reservoir for heavy rains.
4. Are beneath reach of subsoil plough, which in a 12 inch furrow may penetrate to depth of 3 feet.

Cost of Draining, determined by

1. Laying out, or engineering.
2. Cost of excavation and filling.
3. Cost of tiles or other materials.

1. No one can, without instruments, form any safe opinion of the fall of a given piece of land. Mistakes in levels are very costly, but expense of taking out levels is a relatively small matter, say, 5s. per acre.

2. Labour of excavation depends upon nature of soil and depth of drain, but, on an average, a boy should open and fill again 60 feet of earth to a depth of three feet, at cost of 1s.

3. Length of tiles required per acre depends upon interval between drains; so:—

Intervals between Drains.	*Feet of Tiles required per acre.*
30 feet	1,452
36 feet	1,210
42 feet	1,037

Cost of tile draining at intervals of 30 feet per acre.

	£	s.	d.
Laying out drains	0	5	0
Excavating and filling	1	4	2½
Tiles at 2½d. per foot	15	2	6
	£16	11	8½

N.B.—Drained land should be pick of whole farm and additional increase of crop more than sufficient to pay 10 per cent. interest on this capital outlay.

Lecture IV.

IRRIGATION (Introductory).

The practice of irrigation is older than civilisation itself, and dates from the dawn of agriculture; 2,700 years before Christ an Egyptian ruler called Menes, turned the waters of the Nile, rich with silt, onto higher ground, at the very point where to-day is reared the stupendous Assouan dam, one of the greatest marvels of modern engineering. The population of two-thirds of the land surface of the earth depend for their very existence upon irrigation waters. Northern Africa, including Lower Egypt, China, India, the great central plateau of Asia, and vast regions of North America and Australia, would be sterile and uninhabitable without the intervention of systems of irrigation, while in more favoured countries irrigation supports an increased population by rendering intensive cultivation possible, enhances the value of land frequently a hundredfold, improves the quality and adds to the quantity of grain, fruits, and vegetables, enriches the soil from year to year, renders the farmer independent of rainfall, and thus insures him against loss, leads to the production of two or more crops during the year in place of one grown under rainfall, and, in short, makes a prosperous country.

Irrigation has been fancifully described as "the wedding of the sunshine and the rain." In hard scientific language it amounts to the control and employment to the best advantage of rain and surface waters, while drainage, which forms the complement of irrigation, is concerned with the control of water in the soil. Irrigation is a higher and more scientific industry than rain farming. The soil must be more carefully prepared, and crops must be raised which will yield a high return per acre. More labour is demanded and far higher profits reaped.

No country stands more in need of the advantages to be secured from irrigation than South Africa. The majority of farmers are dependent for their very livelihood upon a precarious summer rainfall, and during the last few years not only have summer crops failed from prolonged drought, but stock have died from poverty in large numbers, a disaster whose consequences are felt for years. And yet an acre of irrigated kafir corn will carry 50 sheep for four months; an acre of irrigated lucerne will fatten 60 to 70 sheep, or feed five ostriches for a year; and even irrigated veld grass will carry two breeding ewes per acre through the winter or a period of drought. The future of South African agriculture depends directly upon the organisation of extensive schemes of irrigation.

Advantages of Irrigation.—

1. Insurance against drought and loss of crops and stock.
2. Possibility of a two-crop year and increased annual profits.
3. Improvement in character of soil when accompanied by drainage.
4. Increase in yield of crops and improved quality of produce.
5. Increase in market value of land.
6. Possibility of closer settlement as a result of intensive cultivation.

That these advantages are very real is seen from quotations for irrigated land in Cape Colony, and prices are rising rapidly with increased appreciation of such advantages :—

	Per Acre.		
At Douglas, Cape Colony, first auction of irrigated lots, April 1896, prices averaged	£10	18	3
At third auction, 1897	53	11	5
Highest price paid	94	0	0
1901. Land valued by Chief Inspector, P.W.D., when dry 10s., under irrigation	200	0	0
In Oudtshoorn District 6 acres sold at £851, or	140	0	0

P.W.D. Blue Book.

At Warrenton, Cape Colony, irrigated land lets at £12 per acre per annum, with water rate of £6, and returns upwards of £100 worth of produce per annum.

Function of Irrigation Water.—A rainfall of 12 inches yields 27,878,400 cubic feet of water over every square mile. A greater or smaller proportion of this is absorbed by the soil according to its character, less by clays and more by sands. The remainder runs off the surface, finding its way into streams, and thence, by rivers, into the sea. This is a dead loss, not only of water, but of the soluble plant food washed out by these surface waters. As already explained, drainage controls the passage of rain-water by filtering a larger proportion through the soil and robbing it in transit of its fertilising ingredients. Irrigation furthers and completes this work by regulating the passage of water to suit the requirements of cultivated crops. A combination of these two operations should effect a complete control over the water supply, which is made to yield its utmost value to the farmers' benefit. Not a drop of water should be allowed to reach the sea until the crops, stock, trees, and even grass of the country have received a supply equal to their full requirements. Irrigation is the only means of obviating the disadvantage of a dry winter season, and allows farming activity throughout the year. There are then no "off seasons" and no

"off years." "A river farm is a gold mine, if the owner knows how to develop it."

Supply and Duty of Irrigation Waters.—Practically only a small percentage of the total rainfall can be conserved for irrigation; part is absorbed, part is evaporated, and part lost through seepage or leakage. The proportion will largely depend upon the lie of the land. Natal is very happily situated, with basin-shaped hollows at foot of watershed. The ground over which water is collected is called the catchment area, and the land which this water is capable of irrigating, its "duty." The amount of land which can be irrigated by a given quantity of water depends upon (1) the length of the dry season, (2) the moisture-retaining character of the soil, (3) the requirements of particular crops. These features have to be studied by every individual farmer until he finds the quantities of water which give the best results. Too much water is as harmful as too little.

Lecture V.

DANGERS OF OVER-IRRIGATION.

Crops may be damaged as well as benefitted by irrigation. If irrigation water be used too frequently, or too abundantly, the salutary habit of deep-rooting will be abandoned and the crop will come to depend upon frequent rains or leads of water, and also, owing to the small bulk of soil upon which it can draw for nourishment, upon frequent and abundant fertilisation.

The effects of prolonged drought rarely extend to a level of four feet below the surface of the soil. The deeper subsoil will often be found plastic and moist. In such ground *fruit trees require little irrigation.* Water-logged soil is one of the curses of unscientific irrigation, and over-irrigated roots are choked, which is a frequent cause of fruit dropping off.

Winter cereals, if over-irrigated, suffer diminution of yield owing to shallow rooting, rust may be induced even during the dry season, and the grain softens and loses its milling value.

Effective cultivation and subsoil drainage are of greatest value to the irrigation farmer. They allow rapid penetration of water to the subsoil, prevent evaporation, and reduce to a minimum the amount of water required. They also prevent accumulation of alkaline matter in the surface soil, which is frequently responsible for the ruin of irrigated lands.

Golden Rules :

1. Let the duty of your irrigation water be as high as possible ; that is, let it serve as large an acreage of ground as is feasible.

2. Give thorough soakings at prolonged intervals rather than small leads at frequent intervals.

3. As far as possible subsoil and drain all irrigated land.

4. Surface cultivate after each watering to prevent evaporation and caking.

N.B.—In many countries a low duty has deteriorated lands and reduced their yield, while a higher duty, due to enforced economy, has given better results.

South African Experience.—Few careful experiments have yet been made in South Africa as to the quantity of water required to give the best results. From a Rhodesian case, where the results were eminently satisfactory, we may take 150,000 cubic feet as the best quantity to apply to certain crops in that country per acre during the year, and construct the following table :—

30in. rainfall per annum yields per sq. mile, 69,696,000 c. ft.
Available for storage and irrigation, say, 6 %. 4,180,000 c. ft.

$$\frac{\text{Available storage}}{\text{Requirement per acre}} = \frac{4,180,000}{150,000} = \begin{cases}\text{27 acres irrigated for each} \\ \text{square mile of catchment.}\end{cases}$$

A rainfall of 30in. is sufficient in this case to ensure that each square mile of catchment is capable of supplying enough water for 27 acres of irrigation.

Water measurement in the Furrow.—The above method is applied where catchment water is conserved in a storage dam. It may be, however, that the irrigation water is secured from a furrow or canal, in which case a different estimate must be made. Here the unit of water is one cubic foot per second as measured in the furrow, and it has been found that a supply of one cusec is generally sufficient to amply irrigate 285 acres of land. This is equal to a rainfall of 2½ inches per month, which is sufficient for the majority of crops grown in South Africa. The water is not, of course, delivered in a continuous flow, but in considerable quantities at regular intervals.

Rainfall of					Acres per cusec.
1 inch	per month	is equivalent	to a duty	of	713
2 ,,	,,	,,	,,		356
2½ ,,	,,	,,	,,		285
3 ,,	,,	,,	,,		237
4 ,,	,,	,,	,,		178

The flow of water in a furrow or canal is measured by inserting in the weir or sill a notch with perpendicular sides and a level base of definite length. On the upstream side of this is placed a measuring rod with a zero mark made dead level with the lip of the notch, and giving height of water above this in decimals of inches and feet. The following are the quantities of water in cusecs flowing over a weir in a straight notch 2 feet wide :—

Height of Surface of quiet water above lip of weir. Inches.	Quantity of water in cubic feet per second flowing over a weir two feet long.
·3	·0267
·6	·0747
·9	·1360
1·2	·2099
1 5	.2949
1·9	·3874
2·1	·4880
2·4	·5962
2·7	·7116
3·0	·8334
3·3	·9614
3.6	1·1053
3·9	1·2353
4·2	1·3906
4·5	1·5306
4·8	1·6834
5·1	1·8474
5·4	2·0126
5·7	2·1826
6·0	2·3570
6·3	2·5360
6·6	2·7194
6·9	2·9066
7·2	3·0987
7·5	3·2940
7·8	3·4934
8·1	3·5974
8·4	3·9046
8·7	4·1154
9·0	4·3300
9·3	4·5486
9·6	4·7700
9·9	4·9954
10·2	5·2246
10·5	5·4566

Lecture VI.

STORAGE RESERVOIRS.

The reservoir is the farmer's savings bank, holding the water of a wet season, or wet year, for use in a dry season, or dry year. A general system of reservoirs would obviate the danger of floods, and would also temper the climate during the dry season. An irrigation system depending upon storage, when the work is well carried out, is the most reliable of all.

(*c.p.* Diversion Weirs.)

Selection of Site for Reservoir :—

Considerations :

1. Area and character of land to be irrigated and its distance from proposed reservoir.
2. Area of the catchment.
3. Maximum and minimum rainfall.

(If large reservoir be built the rainfall of several wet years may be conserved for use in times of drought. They require, however, to be well built, or are a source of danger.)

Distance from Lands.—Reservoirs near lands have

Advantages :

1. More easily managed and water regulated.
2. Smaller loss of water by seepage and evaporation.

Disadvantages :

1. The country will be more open with fewer ridges and cost of construction therefore greater.
2. Catchment area will have gentler slopes and less run-off.

Selection of Site of Dam :

1. The best site is usually one which has ridges running down from high land on both sides of stream. Cost of dam is determined by its length and height. Ridges should not be too narrow or they will leak.
2. Also below the junction of two streams.
3. Where materials for construction are abundant.
4. Where a suitable storage basin lies above site.
5. Where a good natural foundation occurs.

The Storage Basin may be :

1. A natural lake or depression.
2. A line of drainage.

Its storage capacity will be determined

1. By longitudinal slope above proposed dam : a slope less than 10 feet in mile good, from 10 to 20 feet fair, above 20 feet poor.
2. By nature of side slopes and subsidiary basins.

N.B. The fall of river above proposed dam can be roughly determined by pools and rapids, windings or straight course and sharp bends.

Calculation of Storage Capacity :

$$Q = \frac{H}{3} (A + a + \sqrt{A \times a})$$

Q = Storage capacity in cubic feet.
A = The area of a contour in square feet.
a = That of an adjacent contour in square feet.
H = Vertical distance between them in feet.

Other things being equal, a narrow, deep storage basin is preferable because :—

1. Loss due to evaporation is relatively small.
2. Cost of dam if built into natural ridges will be small.

Kinds of Dams.—

1. Purely earthern embankments.
2. Earthern embankments with stone toes.
3. Masonry dams.
4. Composite dams.
5. American types of dam.

Earth Dams : Advantages.—

1. The cheapest type. They can be constructed quickly with unskilled labour.
2. They do not require expensive and solid foundations.
3. The materials are necessarily close at hand, or they are not feasible.
4. They can be raised from time to time to meet a demand for more water, or loss of storage capacity due to silt.

Methods of Construction.—

1. A puddle wall at centre or on water slope.
2. A hearting supported on each side by less stable material (this is practically a very wide puddle wall).
3. A homogeneous section without puddle wall.

Puddling.—Uncompressed clay will allow the passage of water; if compressed when dry and after allowed to absorb water the particles expand so as to become watertight, and the greater the pressure of water the more satisfactory the results. Therefore use no more water when puddling than is necessary to compact the mass.

Object of Puddle Trench.—No subsoils are perfectly watertight, especially under such pressure as is exerted against a storage dam. The object of a puddle trench is to interpose a watertight wall to prevent passage of water though the dam, which would eventually lead to fissures and finally the destruction of the whole work.

Position of Puddle Trench.—The trench should be as far upstream as possible so that the dry material downstream may be as large as possible. But

1. Water will fall on top of dam and saturate the whole mass.

2. Settlement of the material will occur, and chiefly through centre line of dam. So this centre line is almost always selected for the puddle trench, which is still further compressed by settlement of the whole mass.

Depth of Puddle Trench.—The trench must intercept subsoil flow which would otherwise carry away particles of subsoil and eventually cause the undermining and destruction of the dam. The necessary depth depends on porosity of subsoil and presence or absence of sound, unfissured rock near ground level. Rules:—

1. When sound, unbroken rock is near surface, carry trench at least one foot into this.

2. When rock lies deep, carry trench at least two feet into good, compact, watertight, clayey soil.

3. If neither of the above occur, trench must be carried deeper and pass through all sandy and loose layers. If these exist to a great depth, abandon the idea of making a dam at that point.

N.B. Trial pits should always be first sunk on the centre line of the dam.

Bottom Width of Puddle Trench.—Should not be less than 10 feet in width so as to give space for a roller to work.

The puddle trench should be carried up into the slopes or ridges of the surrounding hills until it reaches the level of the top of the proposed embankment.

Filling the Puddle Trench.—The bed of the trench should be roughened, so that the filling may be thoroughly bonded with it and a line of division prevented. The most retentive clay obtainable within half a mile should be employed. This should show as little grit as possible. The filling should be done as quickly as possible, so that no drying or cracking takes place, each layer of a few inches being rolled or tramped by cattle or sheep. No more water should be used than is necessary to compact the mass.

Crossing the River Bed.—If a river-bed be crossed, the puddle trench should at this point be given a hearting of fine concrete projecting vertically some distance into the body of dam and laterally as sloping ramps into the flanks. The puddle filling should be widened out to overlap it on both up-stream and down-stream sides.

Lecture VII.

Masonry Core to Earth Embankments.—

Disadvantage :

More expensive than Puddle Trench.

Advantages :

1. If properly constructed is absolutely water-tight.
2. Supports weight of and makes good connection with discharge pipes.
3. Forms a dam in itself, the embankment on either side simply supporting it. Should be carried to height of escape-way sill. Should be as thin as possible to reduce cost, but sufficiently heavy to be self-supporting when settlement of embankment takes place. Safe rule to give top width of 4 to 5 feet and increase in thickness towards bottom at rate of 1 foot in 10 feet. Should be constructed of concrete composed of sharp, broken stone, mixed with clean sand and Portland cement. The up-stream surface should be well plastered with cement.

Embankment Material.—The best material with which to construct an earth dam is such a mixture of gravel, sand and clay that the sand shall fill all coarser spaces between gravel, and the clay all the finer spaces in the sand. Such an arrangement would lead to an almost water-tight embankment. Pure sand or gravel has stability but lacks cohesion; clay is sticky or cohesive, but is apt to slip when wet. A mixture such as the following is desirable :—

Coarse gravel	...	...	1·00 cubic yards
Fine gravel	...	...	·35 " "
Sand ...	...	...	·15 " "
Clay ...	...	...	·20 " "

In practice these materials would be carted and spread out in layers, mixture being effected by harrowing and rolling.

Construction of Embankment.—Clear off all soil to a depth penetrated by grass-roots, bushes and trees. Score the foundations with shallow, longitudinal trenches, to give adhesion between embankment and foundation. Material should not be excavated from bed of reservoir, as this may lead to excessive sub-soil percolation. The shallow trenches which are parallel with the puddle trench should be filled with retentive clay. Then proceed to deposit embankment material in layers, which should be thicker towards outside of dam than at the centre or puddle trench.

1. *Watering.*—The only use of water is to unite the different layers of material into one solid mass, and a sufficient quantity should only be used to moisten the top of the completed layer, into which the dry material of the next may be forced by harrowing and rolling.

2. *Mixing and Spreading.*—The clay should first be evenly deposited and then covered with the gravel and sand. The whole should then be thoroughly mixed by means of a heavy tooth-harrow and repeatedly rolled.

3. *Thickness of Layers.*—As the greatest pressure is exerted against the lower part of the embankment, the layers here should be thinner, say, 3 inches, so as to be better consolidated by rolling, while towards the top 5 inch layers may be deposited.

4. *Slope of Layers.*—There is a natural tendency for earthworks to slip and slide outwards, so layers should be formed with slopes inclined downwards to the foot of centre line of dam.

5. *Edges.*—As it is not possible to thoroughly roll the extreme edges of the embankment, the original width should exceed that finally required by about two feet. This excess can be trimmed off after raised a few feet and employed in the upper layers.

Dimensions and Slopes of Embankment.—

1. *Top width* of 6 feet is a minimum. If the dam be over 50 feet in height top-width should be at least 10 feet. As the dam settles its top should be built up by adding material to the required height. The height of the dam above the crest of the discharge weir should always be several feet above the highest flood mark in order to prevent waves topping it.

2. *The outer slope* may vary between 1 on $1\frac{1}{2}$ to 1 on $3\frac{1}{2}$, according to material. Light sand requires the flattest slope. A firm mixture of gravel and clay will stand a slope of 1 on $1\frac{1}{2}$.

3. *The inner slope* should be given a lower inclination than the outer. Thus if the outer slope will stand with an inclination of 1 on $2\frac{1}{2}$ the inner slope should be 1 on 3.

Lecture VIII.

Pitching.—The inner slope of the dam should always be paved with cobble-stones or dry rubble to protect it against the action of the waves to below the level of the outlet sluices. The stones should be placed with their broad end downwards and hammered into bank. Roughly squared stones are preferable as they fit more closely together. All spaces should be packed with smaller stones and chips. The outer slope should be sown with grass or turfed to prevent washing. Both banks are more staple if broken by a level terrace or bench, and the top six feet of the inner slope should have a steeper slope than the rest to prevent flood-waters slopping over crest of embankment.

Wasteways or Wasteweirs are essential in every dam. They are to a reservoir what a safety-valve is to an engine. They may be classified :—

(*a*) The entire dam, if of well-built masonry, may be used as a weir. Quite unsuitable to earth dam, the outer slope of which is its weakest part, and if water be permitted to top it will be speedily cut away.

(*b*) One end of a masonry dam may be similarly employed. Equally unsuitable for earth dams.

(*c*) Weirs built in the hillsides at some distance from or at one side of dam. This form is alone suitable for earth embankments.

Position of Wasteways in relation to Earth Dams.—

(*a*) Flank wasteways at the immediate flank and in continuation of the dam embankment.

(*b*) Saddle wasteways, separated from the dam by high ground. Always preferable where possible.

Character of Wasteway.—Calculation should be made of greatest known flood likely to be passed and a margin allowed for safety. A long wasteway is safer than a deep and narrow one, but somewhat more expensive. Its discharge capacity increases much more rapidly with a rise in flood level. The difference in height between the crest of the dam and the wasteway will generally vary between three feet and ten feet as limits. A short deep wasteway necessitates an increased height of dam to give same capacity. Where floods are regular in their occurrence the height of the wasteway may be temporarily raised during the dry season by heavy wooden shutters fitted into rolled joist uprights. The use of these, however, is attended with some risk.

Flank Wasteways are less safe than saddleways, as the discharge water is likely to outflank and injure the dam. A wing wall is required on the up-stream side and a lining wall on the down-stream side. The latter is necessary to divert the floods from the dam, and should be continued well beyond the toe.

Saddle Wasteways do not require such protective works, as they discharge clear of the dam, but should have masonry flanks on each side raised at least two feet above high flood level. These may be used as Safety Flood Cuts to carry off abnormal floods.

Approach Channel.—This must be perfectly clear and unobstructed: of the same width as the crest of the wasteway, and is better dug out 12 inches lower than crest level to avoid friction.

Tail Channel.—There must be a clear outlet for the water and a rapid fall from the crest to allow free discharge of water. The water should be confined, especially in the case of flank wasteways, by means of lining walls or embankments until it can no longer injure the dam, cultivated lands, etc.

Water Cushions.—The discharge waters will in soft earth or rock rapidly cut their way back until a waterfall is formed and the wasteway undermined. This must be prevented by building curtain wall or cushion in concrete right across the channel to break the fall of the water.

Dam Building in Flowing Streams.—Expense of building a dam is much increased by the necessity of handling flowing water. Method used will depend upon discharge of the stream:—

1. An under or scouring sluice in the dam will answer the purpose if the quantity be small. This is first built so that the water may pass off through it while the remainder of the work is being completed.
2. If the discharge of the stream be large, wasteways at various heights are left in the crest of the dam.
3. It may sometimes be necessary to build a temporary dam above the main structure.
4. A temporary channel may be cut for the stream around the dam.

Lecture IX.

CANALS AND HEADWORKS.

Parts of an Irrigation System.—

1. Reservoir or Diversion Weir.
2. Irrigable Lands.
3. Main Canal.
4. Head and Regulating Works.
5. Control and Drainage Works.
6. Laterals and Distributaries.

Alignment.—Having determined the site of the reservoir and the position and area of irrigable lands, the next question is the line to be followed by the proposed canal. This must be drawn so that the canal may reach the highest point of the irrigated lands with the least length of line and at a minimum cost of construction.

First compile a careful contour map of country lying between dam and irrigable lands. By this means it may be found possible to save a considerable length of line by making short tunnels or deep cuts through to some low divide. Having drawn into the map a line based upon this contour survey, the final location of the canal may be made on the ground by means of short trial lines.

Surveys will be

(*a*) Preliminary; (*b*) Location; (*c*) Construction.

Obstacles to Alignment.—

1. Streams, sluits, dongas.
2. Unfavourable, swampy, or low-lying soils.
3. Rocky barriers.

Methods of Passing Obstacles.—

(*a*) Carry canal round these.

(*b*) Cross them by aqueducts, flumes, or inverted siphons.

(*c*) Cut or tunnel through ridges.

(*d*) Drainage dam or escape.

Determination of Method.—Careful study should be made of each case, with estimates of cost of construction and maintenance. In crossing swamps or sandy soils the loss of water may be so great that it would be cheaper to carry the canal in an artificial channel through such places. In hillside work it may be cheaper if water be abundant to build an embankment on lower side rather than excavate channel.

Velocity of Canal, Slope and Cross Section.—Having determined the quantity of water which the canal will be required to carry, its capacity will be regulated by the velocity of the water, the slope of its bed, and the cross-section.

Carrying capacity can be increased by

1. Increasing the slope or fall; or
2. By increasing the cross-sectional area.

Considerations:—

(*a*) If the material in which the channel is cut is firm and not liable to erosion, it is well to give high velocity, as this prevents deposits of silt and growth of weeds.

(*b*) A steeper slope, however, has the disadvantage that water cannot be brought out so high on irrigated lands.

(*c*) In rock or hill-side a larger cross-section increases cost, for the material is expensive to work.

(*d*) Too great velocity will erode banks and bed of channel, ∴ relation of slope to cross-section should be such that velocity is neither too great nor too low, and the amount of material to be removed a minimum.

In light, sandy soil	2·3	to	2·4	feet per sec.
„ firm „ loam	3	„	3·5	„
„ firm gravel, rock or pan ...	5	„	7	„
„ broken stone or brick paving ...		15		„

Much higher grades are required in small than in large canals to produce the same velocity. Small channels will stand slopes of from 2 feet to 5 feet per mile according to the material and dimensions of channel.

Cross Section.—

Water may be :—

1. Wholly in excavation.
2. Wholly in embankment.
3. Partly in excavation and partly in embankment.

(1) Half in cut and half in fill is cheapest method as far as cost of construction is concerned. (2) But level may be raised by keeping entirely in embankment, material borrowed from outside. This must be impermeable. (3) If ground undulates both methods, or all three may have to be employed. (4) Wholly in embankment—loss from leakage and danger of breaches. (5) Wholly in cut—rock may be encountered near surface at any point, and cost of excavation greatly increased.

Lecture X.

A berm or terrace may be left at a level with the ground surface, or constructed in excavation or embankment, to prevent destruction of slopes by giving a bench on which the upper bank may slide. It also serves as a tow or footpath.

Cross-section of Channel.—

1. The most economical channel has vertical sides and a depth equal to half bottom width. This is only possible in firm rock.
2. In very firm soil best section is where width of water surface is double the bottom width and equal to the sum of the side slopes (1 on 1).
3. In ordinary soil the side slopes should be as steep as possible without danger of caving in, say 1 on $2\frac{1}{2}$, but 1 on 4 in sand.

Hillside Canals.—

(*a*) Greatest difficulty is in carrying canal along steep hillsides. Remember the less the cross-sectional area of channel the smaller the cost. Capacity may be increased by increasing velocity. So when suitable soil is found choose on hillsides the greatest possible velocity which the material will permit.

(*b*) Increase depth of channel and diminish water surface.

(*c*) Equalise cut and fill.

Avoid sharp curves and bends by making steps in your canal.— These should be built of masonry or concrete and furnished, if of considerable fall, with water cushions, as explained for wasteways.

Depressions may be crossed by

(*a*) Siphons.

(*b*) Flumes.

In South Africa, where timber suitable for flumes is expensive, iron-pipe siphons will in nearly all cases be found the most economical.

Lecture XI.

Canal Headworks.—Headgates of the canal should be at right-angles if possible to line of dam and wasteway so that silt is scoured away from face of gates.

Headgates may be classified as

1. Flashboard gates.
2. Gates raised by hand lever.
3. Gates raised by chain and windlass.
4. Gates raised by screw gearing.

1. *Flashboard Gates.*—

1. Can only be used where pressure of water is low.
2. They should be set back a little from entrance of canal and the bottom of the channel and side walls protected on both upper and lower sides by timber or masonry.
3. The gate or gates should be similarly set in a stout framing of timber or masonry.
4. The height of the gate must exceed crest of wasteway to prevent flood waters topping it and destroying canal, and the whole structure firmly built to resist pressure of floods.
5. A drift fender should be built in front of the gate at entrance of canal.

2. *Gates raised by hand lever.*—Simple lifting gates consisting of boards laid together horizontally and braced with iron to make a firm shutter. Above this extends an upright bar with holes in it, into which the point of a hand lever is inserted, the gate can thus be raised. It slides vertically between upright timbers and is held in position by the insertion of an iron plug into the lever holes.

3. *Gate raised by chain and windlass.*—Will cope with a greater body and pressure of water than either of the above.

4. *Gate raised by gearing or screw.*—This gate is used where there is great pressure and are slow in action. As a consequence, simple lifting gates are generally inserted in a few of the openings to be used when pressure is light, and the remainder are screw gates to be operated under pressure.

Escapes.—Answer two purposes :

1. Provide for the discharge of flood water which might endanger the canal.

2. Allow of the flushing of the canal and the removal of silt.

Escapes are short cuts from the canal to some natural line of drainage. They should be provided at intervals along whole line of canal and especially above weak points such as embankments, flumes, etc.

The first or main escape should be situated within a short distance of the gates, so that in case of accidents to the gates all the water may be drawn off from the canal. N.B. The gates regulate the quantity of water flowing down the canal. This main escape also acts as a flushing gate for the removal of silt, and should be provided with a sand box.

The *Sand Box* is constructed by sinking the level of the canal floor opposite main escape and by placing a narrow board across floor of canal immediately below. This checks silt which is deposited in box and afterwards flushed out by opening escape.

Design of Escape should be similar to that of headgates. It should have sufficient capacity to discharge all water likely to be present in canal during floods. N.B. The greatest danger of injury to canals occurs during local rains, when the farmer ceases to irrigate, leaving the canal full, while its discharge is increased by flood waters.

Lecture XII.

APPLICATION OF IRRIGATION WATERS.

Application of Water.—Irrigation may be defined as the application of water to soil at such times, in such amounts and so accompanied by cultivation of the soil as to produce the condition best suited to plant growth.

Irrigation waters have a definite monetary value, *i.e.*, they are the return to large sums expended in the introduction of an irrigation scheme. There should, therefore, be no waste of water, in other words, its duty should be as high as possible. Water may be conserved by

1. Cultivation and fertilisation of the soil so as to enable it to absorb the moisture which reaches it.
2. Decreasing evaporation from the surface through a proper tilth or mulching.
3. Decreasing evaporation from the plants by wind breaks where hot dry winds are experienced.

N.B. Every drop of water which flows off the surface or from the subsoil of irrigated land shows either

1. That too much water has been applied; or
2. That the soil is not in a proper physical condition. In the latter case
   - (*a*) The surface slope must be changed by grading and terracing; or
   - (*b*) Deeper ploughing or subsoiling must be resorted to.

Proportion of Water to Soil.—The water-holding capacity of soils depends upon the amount of space between the soil particles, and averages between 40 °/ₒ and 60 °/ₒ of the total soil volume. When the water in the soil amounts to more than 80 °/ₒ of this capacity it is injurious to plant growth. Therefore the amount of water in the soil should average about 25 °/ₒ of the total solid volume, and there should be about the same percentage of air space, *e.g.*, the amount of water in soil most favourable to the growth of wheat is 15 to 20 lbs. in each 100lbs. weight.

Influence of Texture of Soils.—Texture of soils is determined by the amount of clay and the way in which the clay particles are arranged. Pot clays, in which little will grow, may have same percentage as soils derived from decomposed limestone, but in the former case the particles are so regularly arranged

that the water can hardly circulate between them, while the particles of lime in the latter adhere so closely to the particles of clay that large spaces are left in the soil through which water and air can freely circulate, *i.e.*, lime flocculates the soil, and renders heavy soils looser and friable. Liming is often desirable when irrigating.

Rules for Irrigating :—

1. Do not apply too much or too little water, but just sufficient to about half-fill the soil spaces.
2. This water should be applied in such manner as to be most evenly distributed throughout the soil, in order to encourage root growth in all directions.
3. The soil should be so cultivated as to create the loosest texture, and thus enable it to hold the largest proportion of both air and water without settling and becoming soggy.

Effect of Time of Application of Water.—

1. *Grain Crops :* Early and late watering produces larger crops of grain and but little less straw. The crop absorbs a large amount of water when making stem and leaf. Water given shortly before harvesting forces the grain, makes it ripen rapidly, and produces a greater proportion of grain to straw, but the grain may be softened and rendered less valuable.
2. *Potatoes :* The opposite effect is seen from early and late watering. This crop suffers much if watered early and before the plants require it; and if watered late the tubers are softened and rendered less valuable.

Therefore water grain crops early and late, but potatoes in mid-growth.

Effects of Method of Applying Water.—

1. *Flooding :* If evaporation is great and quantity of water applied small, shallow root-growth is the result.
2. *Sub-surface Irrigation :* If water be supplied from small holes in subsoil pipes, root-growth is encouraged towards the pipes only.
3. *Deep Furrows :* If at some distance from one another, root growth is made towards furrows: but where crops are grown in ridged rows, such as potatoes, celery, etc., this method leads to best root development.

Therefore grower must determine for himself by experiment, guided by the above considerations of the effects of moisture and texture of soil on plant growth, the time of application and amount of water required by each soil, crop and climate.

Lecture XIII.

Preparation of Ground.—Careful grading by means of a levelling machine is essential to successful flooding. Land once properly prepared can easily be kept in good condition, and one man can handle water over 10 acres. If the surface be uneven the water will stand in pools and the crop will be patchy. If the slope be too steep the furrows and drills will quickly be eroded. Small ditches should be run down the slope with steps or falls placed at intervals, and the water turned into lateral furrows and drills at the required angle. When the slope is so small that the water is all evaporated or absorbed before reaching lower end, flooding by means of levees should be resorted to.

The Grader.—This may be constructed as a strong wooden frame on wheels carrying a 2 inch by 8 inch plank 12 feet long. With four horses 20—25 acres per diem can be completed.

Flooding by Checkerboard and Contour Checks.—When the slope is very gentle levees some 8 inches in height may be thrown up, either following lines of contour or in squares with opening leading from the area above to that below. If properly built these checks will last for years.

Furrow Irrigation of Vegetables and Grains.—The field is laid off with shallow ditches across the upper slopes. From these ordinary plough or V shaped laterals radiate down the slope at various angles so that the fall shall not be too great. The water is then turned into a few furrows at a time by blocking the lateral.

Sub-surface Irrigation.—The idea in this system is to replace seepage from above by capillary attraction from below. Tiles or pipes are laid a foot below the surface provided with small apertures at intervals.

Quantity of Water.—1,000 gallons per minute will irrigate 1 acre an hour of furrow crops.

Lecture XIV.

Irrigation of Orchards.—The direct flooding of trees brings the roots to the surface and enfeebles them, besides inducing collar-rot and kindred diseases. Water should not be allowed to touch trunks of trees. The best method is to draw two or more furrows between, and at a distance of at least 3 feet from, the lines of trees. If flooding must be resorted to, owing to level character of ground, throw up ridges to protect trees at a distance of 3 feet. Water then percolates downward and sidewards to roots and does not draw them to the surface. Very small quantities drawn gradually down furrows at frequent intervals are better than heavy leads of water. A minimum of water should be given to deciduous fruit trees, which require a period of rest during winter. Indeed water should only be given when they are obviously suffering from drought, or to sustain early spring growth.

Irrigation of Special Crops.—

Potatoes.—In some districts it has been found that neither maize nor potatoes could be successfully irrigated on ordinary upland soil without injuring aftergrowth and yield. A rotation with lucerne, however, brought about a great improvement, the lucerne stubble preventing caking and cracking of the soil after watering.

1. The ground may be irrigated before ploughing, or immediately after planting, furrows being drawn between the lines left by the planter.
2. If ground is so hard after planting that the sprouts would otherwise never get through, the field should be irrigated.
3. If in early growth the tops get "black in the face" and come to a standstill, irrigate.
4. In general never water, unless necessary, until crop is in flower, when the tubers will be set and the vines will shade earth round crowns.
5. If the spring be cold and backward, the sub-soil will be lacking in warmth, and water would be fatal.

Precautions.—

1. If once irrigated, the crop must never be allowed to dry out, a "set back" being more injurious than a drought.
2. Each watering should be immediately followed by thorough cultivation to prevent land from baking.

3. Never let water rise to crown of plants. Roots not tubers are to be watered. Use short furrows and frequent laterals. See that there is a free opening at end of each furrow.

4. In sandy soil only run water for three or four hours, in clays for eight or ten.

N.B.—If ground be allowed to dry after irrigation and growth stopped, and then water again applied, a second crop of tubers will be started and a large number of small potatoes harvested. When irrigated before tubers set, a larger number will be set than the plant can support, and there will be few good-sized potatoes. When tubers are allowed to form first fewer will be set, but these will all be large and marketable.

Maize.—Land should be irrigated before ploughing if not sufficiently moist, but never when newly ploughed, nor to germinate seed, much of which would be destroyed and growth enfeebled. At times irrigation may be highly desirable, but excessive leads of water check growth. Maize requires far less water than the majority of staple crops, until tasseling, at which time drought is very injurious. In most seasons not more than two leads of water can be given with advantage, one at six weeks from planting, the second at tasseling. When it is intended to irrigate, maize may be planted on the ridges made by opening up the furrows.

Rice.—

(*a*) Best grown on level ground marked off by levees. When the crop is six inches high the whole field is flooded to a depth of 2 inches, and as the rice grows the water is raised correspondingly. The heads, however, should not be submerged. The water is retained until the grain firms, when it is drawn off, and the crop harvested with reaper and binder.

(*b*) As soon as plants are a few inches above ground, the fields are gradually flooded, the water being kept just below the tops of the plants. When the latter are about six inches high the water is withdrawn and the fields thoroughly cultivated by hand. The crop is then allowed a period of "dry growth," which lasts from 20 to 30 days. After this the plant should begin to joint, when the "harvest flow" is turned on. The water is now raised until it almost touches the rice heads, and is kept at that level until the grain is almost ripe.

Wheat.—Winter wheat wants in colder districts little water if there be enough moisture in the soil to start healthy root-growth. Both spring and winter wheat should receive irrigation when commencing to stool. First watering should never be given until the crop covers the ground fairly well. If irrigated

earlier the ground will be baked. Afterwards the crop protects the soil from the sun, and the surface dries out gradually. The last irrigation should not be given after the grain is in the dough, or its grinding qualities will be spoilt.

Oats require more water than any other grain crop excepting rice, and if dry weather be experienced should be irrigated every fortnight during earlier stages of growth. Success depends upon rapid early growth and no set-back. A larger lead should also be given than for wheat, and 12 inches is not too much for the principal flooding when the crop is six inches high. From the time the plants begin to head they should be almost continuously watered in a dry country.

Barley wants not more than half the water required by oats and less than wheat. Water is most required when the grain is filling. It should, however, have a lead when standing about six inches high to prevent premature heading.

Rye is the most drought-hardy of the cereals and will do well with one light soaking when half-grown.

Beans require frequent watering in dry weather, say, every 10 days, and especially when in flower. After the pod is set it will be unnecessary to give further water.

Celery requires more water than any other garden crop. Soak the well-manured plot before planting to give the crop a good start. Afterwards irrigate once a week, cultivating thoroughly in the intervals.

Onions may be flooded a month after planting to a depth of an inch with good results if followed by cultivation. Afterwards give a light lead of water every week. When the tops begin to fall stop irrigating. They may also be irrigated by means of furrows, but these should be very small and the water only allowed to run for about six hours at a time, as excessive moisture leads to the dividing of the bulb (scullions) and to badly storing onions.

Cabbage and Cauliflower should be irrigated on alternate days for a week after transplanting, but the plants should never be flooded, furrow irrigation only being permissible. After the heads are half-formed no more water should be given or these may burst. Cauliflowers require rather more water than cabbages.

SCHOOL OF AGRICULTURE,

NATAL.

FIRST YEAR.

SESSION I.

DIGEST OF NOTES:

PRINCIPLES OF STOCK MANAGEMENT.

E. R. SAWER, PRINCIPAL.

Principles of Stock Management.

Lecture I.

STOCK FEEDING.

The stock owner has to determine how much and what kind of of food is needed to supply the needs of the different classes of animals he may have on his farm. Before he can do this with any certainty, or even intelligently, he must understand the nature of the materials available for food; their suitability to the various purposes of feeding, and the way in which they are made of use by the animal.

(*a*) *Plants and their products, directly or indirectly, constitute the food of animals.*—It is the function of plant life in the general economy to elaborate complex food substances from simple inorganic matter. The animal cannot avail itself of these simpler compounds. Energy which determines all vital processes is furnished by the breaking up of these complex bodies into their original simple components. Plants are enabled by their nature to avail themselves of the energy present in the sun's heat and light for the building up of these complex substances. Vital processes may be compared to the revolutions of a watch, of which the spring supplies the energy. In the plant the spring is wound up—in the animal it unwinds and gives out just as much force as was used in winding it up. The process forms a complete cycle.

(*b*) *How plants gather food.*—

1. *Carbonic Acid* from the air. An acre of growing wheat will gather through its leaves and stems during four months one ton of carbonic acid gas.
2. *Water* from the soil. Half-grown clover plants may contain 92 per cent. water, or more than that found in skim milk.
3. Through the roots is absorbed sap containing in solution *nitrogen compounds* and *mineral matter*.

O = Oxygen. H = Hydrogen. C = Carbon.

Taken in by Plant:		*Changed by plant into:*	
Carbonic Acid.	Water.	*Starch.*	*Oxygen.*

$$12(CO_2) + 10(H_2O) = C_{12}H_{20}O_{10} + 24O$$

Starch by the addition of one part of water becomes cane sugar :—

$$\underset{\text{Starch.}}{C_{12}H_{20}O_{10}} + \underset{\text{Water.}}{H_2O} = \underset{\text{Cane Sugar.}}{C_{12}H_{22}O_{11}}$$

Starch ... Cane Sugar ... Cellulose or Fibre	Grouped as "carbo-hydrates," because in each case there are two atoms of hydrogen to one of oxygen.

Vegetable oils and fat only differ from the carbo-hydrates in containing a larger proportion of carbon :— $C_{57}H_{104}O_6$.

The addition of nitrogen and sulphur compounds leads to the production of protein, a complex substance of which albumen is a well-known representative.

(*c*) *Typical Analyses of Feeding Stuffs.*—

	Water. %	Carbo-hydrates. %	Fats.	Protein.	Mineral Matter.
Fresh grass ...	75·3	17·3	·9	4·0	2·5
Mangolds ...	90·9	6·4	·2	1·4	1·1
Maize	10·6	72·4	5·0	10·3	1·5

During the earlier periods of growth of plant all food substances are devoted to building up the organism and bringing it to perfect maturity. When this stage is reached the supply is devoted to reproductive parts, whether these be seeds, tubers or bulbs.

A cow fed on maize containing in every 100 lb.	72 lb. carbo-hydrates :	5 lb. fat :	10 lb. protein.
gives milk containing in every 100 lb.	5 lb. carbo-hydrates :	3½ lb. fat :	3½ lb. protein.
or	5 lb. milk sugar :	3½ lb. cream :	3½ lb. casein.

"The plant is the organism which converts carbonic acid, water and ammonia (N.H.) into organic tissues and heat-forming material: the animal system is the medium by which these substances are converted into higher tissues, heat, and energy. All substances used as food by animals can be traced back, directly or indirectly, to the vegetable kingdom."

(*d*) *Digestion of Food Materials by Animals.*—"Food is digested, that is, converted into soluble substances, in order that it may be absorbed. It is absorbed, that is, passes in soluble form into the blood, in order that it may be assimilated. It is assimilated by becoming part of the living body." It is obvious that the body of any animal is the result of the food assimilated during its life history, and as might be expected there is a close similarity between the composition of vegetable and animal tissues.

Vegetable Tissues.	Animal Tissues.
Starch (stored in roots, tubers, bulbs, etc.)	(Acts as fuel by which muscular energy is rendered possible.)
Sugar (Fruits, cane, beets, beans, etc.)	(Muscles, blood, milk, and nearly all organs.)
Fats (Oily seeds and fruits, etc.)	(Almost all tissues of animal.)
Protein (Aleurone layer, and gluten of wheat, etc.)	(White of egg, milk, muscle, digestive juices.)
Lime (clover hay)	(In bones as calcium phosphate.)
Magnesium (oats) as phosphate	(In muscle.)
Sulphur (in ash of all plants)	(Hair, horns, and skin.)
Iron (colouring matter in plants)	(Colouring matter, hair, skin, bile, etc.)

(*e*) *Requirements of a Suitable Diet.*—The substances present in both vegetable and animal tissues may therefore be divided into :—Carbo-hydrates, Fats, Protein, Mineral Matter or Ash. A healthy and suitable diet for any animal must possess the following characteristics :—

1. It must contain the proper amount and proportion of these different constituents.
2. These must be present in suitable bulk and digestible form.
3. The diet must be adapted to the climate ; to the class and age of the animal, and to the work done by it, whether this takes the form of labour, or the production of meat, milk, hair, etc.

It has been proved that carbo-hydrates are not equal in value, weight for weight, to either fats or protein. Neither fats nor carbo-hydrates contain nitrogen, which, supplied by the protein, goes to form the tissue of the muscle, tendon, nerve, blood, etc., but the former are useful in that they economise the protein of the food by furnishing all the necessary heat and energy, and so allow all the protein to be used in repairing and increasing the tissues.

When comparing the relative values of different foodstuffs, one must therefore ascertain the proportion of protein to carbo-hydrates and fatty matter. By experience it has been found that one part of protein to six or nine of carbo-hydrates and fatty matter is the most useful and economic proportion.

Fats and oils give off more heat during combustion than the carbo-hydrates because they contain more carbon and are therefore more valuable as food, supplying, as they do, greater energy to the animal.

(*f*) *Valuation of a Mixed Ration.*—To determine the actual feeding value of any mixed ration, multiply the pounds of food by the percentage of each ingredient and divide by 100; this gives the actual weight in pounds of each constituent. Multiply the fats by 2·29, and add to carbo-hydrates. Compare total with amount of protein = nutritive ratio. *e.g.*:

	Protein.	Fats.	Carbo-hydrates.
	%	%	%
Maize, 10lbs.	8·4 × 10 = ·84	4·8 × 10 = ·48	57·8 × 10 = 5·78
Lucerne Hay, 20lbs.	12·3 × 20 = 2·46	·9 × 20 = ·18	31·4 × 20 = 6·28
Oat Forage, 10lbs.	1·3 × 10 = ·13	·2 × 10 = ·02	8·9 × 10 = ·89
	3·43	·68	12·95

·68
2·29
612
136
136
1·5572
12·95
3·43)14·5072(4·22
13·72
787
686
1012

Nutritive ratio, 1 : 4·22.

1lb. protein to every $4\frac{1}{4}$lbs carbo-hydrates and fat reduced to value of carbo-hydrates.

We thus see whether a feeding ration is properly "balanced." It remains to show that certain foods are suitable or unsuitable to the different classes of stock; *e.g.*, wheat and barley are best possible food for pigs, but injurious to horses and mules.

Farmer must Feed his Stock according to:—(*a*) Class of work at which it is employed; (*b*) time of year, whether winter or summer; (*c*) sickness or pregnancy; (*d*) age of animal; (*e*) ruling prices of food.

Lecture II.

FEEDING OF HORSES.

To feed a horse properly one must understand his digestive arrangements.

Food masticated and acted on by saliva enters stomach through œsophageal opening. This is surrounded by powerful muscles, and prevents vomition, *i.e.*, a horse cannot be sick. *Half* surface of stomach lined with glands, which pour gastric fluid in food. Horse's stomach is small—contains about 25 pints. No absorption here. Hence need of small and frequent meals. Food passes from stomach to small intestine, a tube some 70 feet in length. Into it opens, just beyond stomach, duct leading from liver and pancreas or sweetbread, from which bile and pancreatic juice are poured onto food. The bile renders fats capable of absorption and lubricates intestine. Pancreatic juice converts starch into sugar, protein into substances which are more readily absorbed, and helps to split up fats into very minute particles capable of absorption. It also renders acid contents of stomach alkaline. A proportion of the food is actively absorbed by the walls of the small intestine, and the rest passes into the cœcum or large intestine. This is a third duct about 3 feet in length, containing about eight gallons, and forms a reservoir for liquids. The water which a horse drinks does not remain in the stomach, but passes rapidly through the small intestine to the cœcum, taking from five to fifteen minutes to travel the 70 feet. *Hence the golden rule that horses should be watered first and fed afterwards.* Food takes from four to six hours to reach cœcum. The small intestine enters the large intestine as a funnel into a barrel, and here the cellulose is digested. The exit is above the entrance and the residue of the food works upwards against gravity to enter the next portion of the intestine—the *colon.* Here the food is very quickly absorbed, changing suddenly from a condition like thick pea soup to solid matter, which is the indigestible portion of the food. As this moves towards the anus it becomes drier and drier, and is formed into balls by the action of the bowel sacs, which squeeze the mass into round or oval shapes. In the rectum these collect into masses, which are forced out of the body at the next evacuation.

Lessons from Digestion of Horse.—

(*a*) Stomach small: therefore small and frequent meals.

(*b*) Entry and exit close to one another. When a succession of foods is given, that eaten first passes out first. Concentrated foods such as grains remain longer in stomach than bulky foods, such as hay. Hay and forage should therefore be given first and grain afterwards.

(*c*) Water passes straight to large intestine or cœcum. If given after food, washes latter into small intestine and causes trouble.

Colic.—Chief cause of colic is injudicious feeding. (1) Stomach is small and if a heavy meal be given much of the food passes unaltered by gastric juices into small intestine. Small frequent meals essential to health. (2) Water given after food carries unaltered food into small intestine and sets up inflammation. (3) Gorging with young grass in spring: no escape for gas by way of mouth. (4) New oats and mealies or sour food. (5) Putting to work too soon after a heavy meal. (6) Watering and feeding too freely when exhausted. (7) Poisonous veld plants, such as Tulip, induce colic.

Suitable Rations for Horses.—

(*a*) *Transport Horses*:

Mealies, 6 lb.
Oats, 2 lb.
Oat Forage or Manna Hay, 4 lb.
Hay, Grass . . . ad lib., say 20 lb. ; or

Mealies, 8 lb.
Oat Forage or Manna Hay, 4 lb.
Grass Hay ad lib., say, 20 lb.

The grain and forage are divided into two feeds, for morning and evening—3 lb. crushed mealies and 1 lb of crushed oats are given at each meal. The forage is best chaffed to ½ inch and fed before the grain. Hay is kept constantly before the horses. The first meal should be given at 6 a.m., and the last about 5.30 p.m. Water should be given at 9 a.m., 2 p.m., and 5 p.m. Maize should be broken or cracked. Horses do not relish mealie meal. Maize should not be fed for four months after harvesting. Oat forage should contain some grain in the ear and be slightly green in colour.

(*b*) *Race Horses:*

5 lb. Oats, a few Carrots, 6 a.m.
10 lb. Oat Forage (½ inch), at 11 a.m.
5 lb. Oats, 4 p.m.
10 lb Forage (½ inch), at 7 p.m.
Water at 9 a.m,, 11 a.m., 4 p.m., and 7 p.m., before food.
A quantity of green barley or a bran mash once a week as a laxative.

N.B.—When expense is not a serious matter oats are a better feed than maize for horses. V.S. at Bulawayo used to say "mealies are only intended for pigs and kafirs." Oats weighing 50 lb. to bushel are finest horse feed in existence.

Lecture III.

FEEDING OF MULES, DONKEYS AND SICK ANIMALS.

The feeding of mules should bear close relation to nature of their work, and differ according as they are employed in slow, heavy transport work, or in light cart work.

Golden Rule: "*Feed early*" in morning—never later than 6 a.m., and if going on trek, at least 1½ hours before starting. Do not give more than 4 lbs. of mealies at first feed, and this after a few handfuls of chaffed hay or forage. Do not give mealies alone, and do not give unchaffed hay or forage. Colic will often result in either case after a few miles of fast travelling.

Watering.—Mules will not drink before early meal, nor before 8 o'clock in morning, so water at first outspan.

Trekking.—On a journey of say 30 miles with a light cart, the first trek should not exceed ten miles. Do this as early as possible, outspan and water mules. Outspan again after second ten miles, and finish journey as late in afternoon as possible. By starting early it is then possible to allow eight hours' grazing during the day. It is unnecessary to give second meal until journey is finished. This should consist of another 4 lbs. of grain, though it is preferable to give 3 lbs. in morning and 5 lbs. at night. Always carry a little forage to give before grain.

With a wagon trek of 20 miles, do the first ten early in the morning and last ten as late as possible in the evening. This gives ample time for grazing in the day.

During the wet season, when grass is good, grain ration may be reduced from 8 lbs. to 6 lbs. per diem.

The work to be obtained from donkeys varies directly with the amount of grain added to their grazing or hay ration: 5 lbs. per diem is an economic minimum.

Other Foods suitable for Horses, Mules and Donkeys.—All animals benefit by an occasional change of diet, and as alternatives to maize the following may occasionally be used:—

1. *Beans,* such as soy, lima and field beans, are valuable substitutes for maize, owing to their high proteid content. May be fed to horses or mules in same quantities as maize, and even take its place if abundant in supply.
2. *Munga or Bulrush Millet* is valuable on account of its oily character for fattening beasts out of condition. It is best fed to horses or mules crushed or ground, as the seed coat is thick, and the whole grain may prove indigestible.

3. *Sweet Potatoes* are much appreciated by horses, mules and donkeys, especially in winter. May take the place in warmer districts of swedes, turnips and carrots, on account of heavier yield.

4. *Pumpkins* are very useful in the dry season when green forage is unobtainable or expensive. They are succulent, and assist in digestion of the dry part of the ration.

5. *Sunflower Seed* mixed with other grain is a good fattening food and easily grown. The crop is, however, very exhausting to soil.

Feeding Sick Animals.—Rule: Give a little tasty food at frequent intervals. Do not offer a sick animal too much at a time, and do not let the food lie if not eaten. If refused it should be removed. Easily digested rations are required to keep up animal's strength until appetite is regained and body returns to its normal tone.

Green Mealie Stalks.—Sick animals are very fond of young green mealie stalks, which should be cut up in chaff-cutter. They will often eat this food when refusing everything else.

Green Barley is a good food if cut quite young, before beards begin to form.

Lucerne.—Every farm should have its patch of lucerne, which is an excellent sick diet. Animals will generally take a few handfuls of this, and it is nutritious and strengthening.

Bran Mashes.—In South Africa animals do not appear to relish bran, but if well and carefully mixed and given with other appetising food it should be eaten. Never make a big stodge of bran mash and allow this to stand until cold and sour. Warm bran is nutritious and laxative.

Boiled Linseed.—Boil half-a-pint of dried linseed in two quarts of water to consistency of gruel, and sick animals will generally drink it readily. It is nutritious and laxative.

Linseed Tea.—Water drained off from the boiled linseed is often relished by sick horses.

Salt should always be supplied regularly to horses, mules and donkeys, and all stacks of hay and silage should be salted at levels of three feet.

Lecture IV.

FEEDING OF CATTLE.

The digestive processes differ in the case of cattle from those seen in the horse and mule, and are determined by certain features of the stomach. Cattle are sometimes said to have four stomachs:—(1) rumen, or paunch, (2) reticulum, (3) omasum, (4) abomasum. Pure digestive changes only occur in the fourth, the abomasum. *This is the true stomach.*

1. *Rumen, or paunch, and reticulum,* capable of containing sixty gallons, are divided by strong muscular partitions. The gullet opens into the rumen, which in turn communicates with the second compartment, or *reticulum,* a small stomach, the lining of which resembles honeycomb. This reticulum possesses a marvellous structure known as the "gullet groove," by means of which food which has already been swallowed and stored in the first two stomachs, is returned to the mouth through the gullet and re-masticated. It is then swallowed again, and the process may be repeated. Finally, by shifting of a guarding flap, the food is allowed to pass from reticulum to the third stomach or *omasum.* In the rumen and reticulum the food is mixed with a large quantity of saliva and water, and softened; starches are converted into sugar; cellulose becomes decomposed, and protein is split up by ferments into digestible substances called peptones. No food is, however, absorbed in these stomachs, and little or no gastric juice is added to the food. At times fermentation of the food in the paunch may be set up, and the gases formed accumulate until the animal becomes "hoven" or "blown." Relief may be afforded in severe cases by inserting a trochea through the body-wall into the paunch, by which the gas is allowed to escape. At other times saliva is not secreted in sufficient quantity, and the food collects in hard balls which cannot be digested, and inflammation may be set up.

2. In the third stomach, or *omasum,* the food is compressed and ground small between the powerful toothed muscular leaves into which the lining membrane is is folded. The contents of this compartment are dry, the fluid being squeezed into the fourth stomach or *abomasum.* Here true digestive processes are set up, gastric juice is secreted from the wall which further changes the proteid, the casein of milk is clotted by a ferment called renin, and the milk sugar is changed into milk, or lactic, acid, which is readily digested.

The abomasum opens into the small intestine, and the remaining parts of the intestinal canal are similar to those found in the horse, except that the ox possesses a large gall-bladder, wherein gall formed by the liver is stored until required, whereas in the horse no gall-bladder is found, the gall passing straight from the liver to the intestine.

General Conditions of Cattle Feeding in South Africa.—The dry winter season compels the farmer to make choice between:—

(*a*) Raising an inferior class of animal which will live through the hardships of the dry season without additional food. Native breeds do stand out better, and come through the winter in better condition than imported or improved breeds.

Disadvantages:

1. Such cattle are in very poor condition every year, and for months not one among hundreds is fit for the butcher. A system of cattle-raising can never be said to be successful which can only provide butcher's meat at a certain season of the year, when prices will be very low.
2. The maturity of such cattle is very protracted, and it is the fifth or sixth year before young stock can be sold. The turnover on capital is therefore very small, and the number available for sale each year very low.
3. The quality of meat and carcase is very inferior, and prices realised consequently unsatisfactory.
4. It is impossible to improve such stock to any extent by crossing with better or imported blood, because any consequent improvement in the progeny lessens their powers of undergoing winter hardships.

(*b*) The employment of improved stock and the provision of winter feed and such further rations as may be required during the summer for furthering milk-production, fattening or finishing butchers' stock, and other special purposes.

Advantages:

1. Stock are kept growing throughout the year with consequent early maturity. They can be sold to the butcher whenever prices warrant sales.
2. They have a hereditary tendency to put on meat at the right points and give a better return to a given quantity of food consumed than do native cattle.

3. The turnover of capital is much more frequent and profits consequently higher.
4. The carrying capacity of a given acreage is increased, and closer settlement rendered possible.
5. When prices of grain fall, a better profit can be made by feeding same than by marketing, and further reductions in value are thus prevented.
6. The farmer who is feeding stock can arrange a better rotation of crops, which will maintain fertility of soil.

Dairy Farming and Breeding for Slaughter.—These should be regarded as two distinct industries governed by different rules and principles. A farmer will make his choice between them according to (*a*) the breed and type of cattle owned, (*b*) relative price of beef and dairy products, (*c*) his distance from market, railway, separating station, or creamery, and (*d*) available labour.

In Europe and America types of cattle have been developed to serve the purposes of a mixed system in which dairying and feeding methods are combined. For South Africa, however, the dual purpose beast has little to recommend it, and the stock-owner should definitely decide which branch of the work is likely to give him the best results, and organise a system of management accordingly.

Lecture V.

REARING OF CALVES.

The general South African practice is to draw the milk from the cows morning and evening, leaving some still in the udder for the calf to live on. Good calves cannot be made by such a system. What is gained in dairy produce is more than lost in calf-rearing.

Two alternative systems:—

(*a*) Allow calf to run with cow and suckle every time it feels inclined.

(*b*) Hand-rear with a fortified skim-milk ration in which the fat extracted as cream by separator is replaced by some such cheap vegetable fat as is found in linseed meal.

Birth weight of Calves.—

Light-weight calves	48—66 lbs.
Average calves	66—92 lbs.
Heavy calves	97—110 lbs.
Very heavy calves...	115—128 lbs.

Feeding for Beef.—Here the calf is usually allowed to draw its milk directly from the udder, which is the most natural process and few precautious are necessary. Few South African cows yield more milk than the calf can readily digest. In the case of exceptionally heavy milkers, however, the owner should see that the calf does not get too much milk as this causes indigestion. In such instances the cow should be stripped clean night and morning after the calf has been allowed to have only part of the milk. This is better than partly milking and then allowing calf access to teats, for the last milk is the richest, and it is the richness as well as the quantity which causes trouble. Or two calves may be put with each cow that yields a good flow of milk. Where calves are separated from their dams, at first let them suck three times daily, soon reducing it to twice a day. *The greatest danger in this system comes at weaning time,* when, if the calf has not been properly taught to eat solid food, it is apt to pine and lose weight. To avoid this, teach it to eat a little ground maize, bran, oil meal or hay daily.

Gain in weight from use of whole milk.—The sucking calf should gain 3 lbs. per diem for the first month, 2½ lbs. for the second month, and 2 lbs. for subsequent months. 6 lbs. of whole milk are required during the first month, 8 to 10 lbs. during the second month and from 16 to 20 lbs. during the third and following months to make 1 lb. of gain.

Feeding the Dairy Calf.—When a dairy or separating station is within reach, the fat of milk has too high a value to be used for calf-feeding, and experience has shown that dairy stock of the highest quality can be produced on fortified skim-milk. The calf is allowed to draw milk from the udder for two or three days only, early weaning being preferable for both cow and calf. The calf should always get the first milk (colostrum) as this is necessary for properly clearing the bowels and starting the digestive functions. Warm, full milk is then fed from a pail not less than three times daily until the calf is three weeks old, after which skim-milk is gradually substituted. A fortnight should pass in changing from full to skim-milk.

Quantities of milk to be fed :—

(*a*) Full milk per diem :
10 lbs. for first 10 days after weaning.
15 lbs. for rest of period.

(*b*) Skim-milk (fortified) per diem :
18 lbs, daily until five weeks old.
24 lbs. until placed on solid food.

Precautions when feeding skim-milk.—

1. Do not overfeed, *i.e.*, never give more than 24 lbs. per diem.
2. Do not feed less than three times a day until four or five weeks old.
3. Always heat the milk to blood temperature and use a thermometer.
4. Feed regularly at stated hours.
5. Avoid using sour milk pails, which are the cause of nine-tenths of poor results.

How to fortify skim milk.—Skim milk naturally contains the protein of full milk and it is unnecessary and even dangerous to add substances rich in this ingredient. Fats are required to replace the cream which has been removed. Linseed meal is one of the most suitable foods available. This may be converted into a jelly by adding boiling water, and is relished by calves who soon learn to look for it at the bottom of the pail. At first a tablespoonful of meal added to the mixed full and skim milk is sufficient, and this may be gradually increased to half a pound per diem. Mealie meal, shorts and oatmeal also make excellent and cheap additions to skim milk for calves.

Hay Tea.—If hay be thoroughly boiled the soluble nutritive elements are all extracted, and this extract contains all the food substances required to grow the animal, and is as digestible as milk. This is an old expedient to rear calves when milk for any reason is not available. If the hay be cut early when it has most soluble matter and is of good quality the tea will grow good calves. The extract, however, may have too little protein and fatty matter, and it is well to boil it down until there is not too much water to dry substance, and add during the process to each gallon of tea $\frac{1}{8}$-lb. linseed and $\frac{1}{8}$-lb. wheat middlings. Two gallons of the mixture should be fed to each calf until thirty days old, and the quantity of middlings may be gradually increased up to 1 lb. per diem.

Feeding for Veal.—Veal should carry not only a considerable amount of fat, but the flesh must show that no coarse food has been eaten by the calf from birth to time of slaughter. Whole milk only is the recognised feed, and growth must be pushed on as fast as possible, for the calf must be slaughtered before the flesh shows any of the coarser character of beef. The white of the eye should show no yellow tint, and the insides of the eyelids, lips and nose should be perfectly white.

Scotch Method.—Strathaven is famous for its veal; the calves are fed on fresh cow's milk, the youngest receiving the first drawn and the oldest the best and richest milk. After third week they are fed as much milk twice a day as they will take. They are bedded down in a warm, dark stable and supplied with lumps of chalk. They are slaughtered at five to seven weeks at a dressed weight of 100 to 127 lbs.

Lecture VI.

FEEDING FOR BABY BEEF.

The road to increased profits from the production of beef lies by way of early maturity. Good blood is a paramount necessity. Well-bred animals respond to feed. They have inherited a habit of laying on flesh when well fed. From good grade breeding cows with Shorthorn blood and a Hereford bull steers can be and are being raised, which at 20 months weigh 1,200 lbs., and furnish meat commanding top prices.

Method.—The cow is allowed to go dry in winter : her calf is dropped in spring, and allowed all the milk through the summer, is forced through the winter on lucerne or bean-hay and a liberal ration of maize or kafir corn, and fattened on the following summer's grass for the butcher. This calf learns to eat grain before fully weaned, and goes into a lucerne pasture or bean field at weaning time. The whole secret of success lies in a well-balanced ration for the only winter during which expensive feeding is required. The steer is young and cannot handle hay in cartloads, and not a day is to be lost. At least one-half of the rations should be concentrates. The muscles and bones are rapidly forming ; they need more flesh and blood forming food—more protein. Lucerne or bean-hay furnishes this, even to excess, and is balanced by maize and kafir corn, heat and energy food, with which are fed stover or silage to prevent scouring.

Disadvantage :

Growth made upon expensive concentrated food, which might be made upon grass alone.

Advantages :

1. Beef is made on young animals, which always costs less per lb than on mature steers ; steers are forwarded to the Chicago markets at 30 months which have made 100 lbs. gain for 650 lbs grain fed.

2. Rapid turnover increases carrying capacity of farm and amount of business done by farmer.

N.B.—Cows employed for this purpose are such as are useless for dairy purposes, and are simply kept over the winter in fairly good condition to raise a calf They must be scavengers and live on cheap food. The winter picking on the veld is supplemented by mealie stalks or stover and grass hay. The cow should, however, be at least graded from a beef type.

FEEDING MATURE STEERS.

1. *How to supply Protein cheaply.*—Cheap and abundant fodder crops can easily be grown to supply carbo-hydrates and fats. Earlier the difficulty was to find a cheap food containing a sufficient quantity of protein. It was long believed that this must be supplied in a concentrate, and oil-cake, gluten, cotton-seed meal, and wheat bran were bought at high prices for fattening steers. Of recent years it has been found that protein can be supplied in the form of roughage at a much lower cost than if purchased in a concentrate. Hay made from legumes, such as soy-bean, cow-pea, and kafir-bean, is rich in protein, and also improve fertility and mechanical condition of the land on which they are grown.

2. *Silage as an element in the ration.*—Succulent food during the winter is essential to the general thrift and health of the steer, and is most cheaply and conveniently supplied in the form of silage. Effect is seen in soft elastic hide, hair glossy and oily to the touch, and in a far better carcase after slaughter. Stover or hay-fed steers, on the other hand, show rough, dry and shaggy coat and an inferior carcase. An acre of maize silage gives feed for 320 days. In an experiment, stover-fed cattle consumed 6·02 lbs. concentrates to each lb. of gain in live weigh, and silage-fed cattle only 4·5 lbs. Fifteen head fed on succulent rations for 120 days made 761 lbs. more gain in weight than the same number fed on dry roughage.

3. *Concentrates.*—Where bean-hay and silage supply the roughage, maize and kafir corn make a well-balanced ration, and oil-cake, bran, gluten, etc., can be dispensed with if high-priced.

4. *Roots and Pumpkins.*—Roots are largely used in European countries in place of maize silage, and are an effective substitute. Sweet potatoes may be found to be the cheapest form of root to grow in our warmer districts. Even when silage is available it would be well to give an occasional ration of sweet potatoes as a laxative. When larger quantities are employed, barley should be fed to avoid scouring. Roots should be pulped or sliced. In Canada stock-feeders pulp the roots and mix with chaffed hay, allowing the mass to stand a day before feeding. Steamed potatoes are an excellent fattening diet, but should not be fed to excess or digestive troubles occur. They should never form more than half the total dry matter of ration.

Pumpkins, in view of their high water content, are rather a digestive than a food, but very valuable for that reason in the winter.

5. *Shelled Maize and Meal.*—Mealie meal is a heavy, rich feed, and should be lightened with mealie bran or cob meal.

This should be fed in the morning. All mealies should, if possible, be crushed or ground, as when exposed to the air they become dry and less palatable. Less energy is likewise expended on their digestion. A part of the ration, however, may be fed as shock corn, preferably in the evening, for the cattle will work it over in the night and eat some of the stalks with the grain. When a shedder is available, however, it is better to run the shock corn through this.

Shelter.—The fattening steer is blessed with a heat-retaining layer below the skin, and requires less shelter than the milking cow, who carries little superfluous tissue. Housing is rarely necessary in this climate.

Lecture VII.

MANAGEMENT OF FATTENING CATTLE.

Importance of Maize.—Feeders in South Africa are handicapped by a dry winter, during which grass pasture is scarce, while in England grazing can be obtained all the year round. The advantage, however, of the maize crop offsets this, and should place us at the front in beef production. No concentrate is so relished by cattle as maize, the kernels of which carry considerable oil, rendering them palatable to a degree not equalled by any other grain. They are also loaded with starch, a fat-former, and if fed in conjunction with bean or peas, furnish the nutriment necessary for filling the tissues steer's body with fat, and for rendering the muscles tender and juicy. The development of a successful industry in steer feeding in Natal depends upon cheap maize and cheap bran.

Turning to Pasture—Early grass is watery and furnishes little nutriment, and if steers are turned from the feeding stall during the spring onto pasture they will shrink badly. Early grass, however, has an excellent effect on digestive system and prepares animal gradually for the change from dry feed to pasture, so turn cattle to early grass, but keep up heavy feeding for some time.

Grain Feeding on Pasture.—All experience points to the fact that on good grazing in the summer stock will make almost as much gain without as with additional grain feeding. It is therefore not economic to give maize during summer, when steers should be allowed to subsist entirely on natural herbage.

Salt.—Animals fed large quantities of nutritious food show a strong desire for salt. This should be satisfied by reasonable supply. Excessive use of salt leads to heavy consumption of water and increased flow of urine, which is undesirable. One ounce per diem at beginning of fattening period, $1\frac{1}{3}$ ounce at middle, and $1\frac{2}{3}$ ounce at the close is ample.

Suitable Rations for Fattening Steers:—

		Pro.	C.H.	Fat.
1. Maize Silage ...	30 lb. ..	·27	3·39	·21
Oat Straw ...	5 lb. ...	·06	1·93	·04
Bran	10 lb. ...	1·22	3·92	·27
Maize and Cob Meal	4 lb. ...	·18	2·40	·12
Cotton-seed Meal ...	2 lb. ...	·74	·38	·24
		2·47	12·02	·88

2. Maize Stover ...	8 lb. ...	·20	2·77	·03
Lucerne ...	2 lb. ...	·13	·72	·03
Maize	14 lb. ...	1·09	9·34	·60
Oil Meal	4 lb. ...	1·17	1·31	·28
		2·59	14·14	·94

Roots and Barley :

3. Hay	12 lb.
Roots	46 lb.
Bran	5 lb.
Barley	11·25 lb.

Roots and Maize :

4. Hay	9·5 lb.
Roots	34 lb.
Bran	3·5 lb.
Maize	9·25 lb.

Frequency of Feeding.—Young animals should be fed at least three times a day. Those nearly ready for butcher twice a day. At middle of feeding penned steers should be given grain once a day, in evening, and allowed roughage to run to as often as they like.

Feeding Sheds.—It is unnecessary to keep steers tied in stall. A dry yard with a roofed shed on windward side forms an ideal place for feeding.

Large and Small Summer Pastures.—A single large pasture is better than a number of small ones. Grasses are never the same over the whole of a large pasture, and steers satisfy their desire for variety by ranging from one spot to another. This leads to less irregularity and unrest, and increases gain

Dressed Weight of Carcases of Different Breeds :—

	Average Live Weight.	Daily Gain.	Average Dressed Weight.
Hereford ...	1,515	1·54	65 °/o
Red Polled ...	1,520	1·52	65·2 „
Aberdeen Angus ...	1,493	1·53	64·8 „
Shorthorn ...	1,011	1·50	64·4 „
Devon ...	1,021	1·35	63·6 „
Ayrshire ...	1,095	1·20	63·3 „
Holstein ...	237	1·57	62·6 „
Jersey ...	1,058	1·36	60·5 „
Native ...	1,038	1·26	60·2 „

Lecture VIII.

FEEDING DAIRY COWS.

"The cow is a more economical producer of food for human beings than the ox or the pig. A fattening steer, gaining 15 lbs. weekly, yields 1·13 lb. nitrogenous matter or water-free lean meat, while the dairy cow when yielding 10 quarts daily returns in the milk 6·6 lbs. casein and albumen, or six times as much. The steer adds 9·35 lbs. of fat to his carcase, while in the milk of the cow there are 6·33 lbs. of fat or two-thirds as much. During this time, however, the cow has also given in the milk 8·32 lbs. milk sugar, against which there is no similar substance in beef."

When population grows dense, the ox is the first beast to disappear, because he is not an economical producer of human food, while the dairy cow will remain.

A good dairy cow will yield in one year 6,600 lbs. of milk in which there are :—

	285 lbs. of fat
	376 lbs. milk sugar
	220 lbs. of casein and albumen
	49 lbs. ash
Total	930 lb. solids

These substances are all practically digestible.

Two pounds of milk (less than a quart) contains the same amount of solid food as one lb. of beef, while the cost is much less.

The Milk Supply.—The richness of milk (*i.e.*, fat content) is a constitutional character, inborn, and not to be appreciably affected by the character of the food. The quantity of milk is determined largely by the nature of the ration fed.

Effect of Food on Churnability.—While the composition of milk is little, if any, altered by a change in food, the "churnability," *i.e.*, the proportion of butter which can be obtained from the milk produced by different foods varies according to the nature of the food :—

Grazing and bran	91·16 %
Grazing alone (summer)	86·64 %
Hay, mealie meal and bran	84·18 %
Hay and bran	81·37 %
Ensilage	81·25 %
Hay and mealie meal	74·63 %
Ensilage and mealie meal	65·69 %
Hay and gluten	63·89 %

Effect of the quality of Food on the quantity of Milk.—

(*a*) Feeding an insufficient ration always decreases amount of milk given.

(*b*) Heavy feeding induces largest flow of milk, but may not be profitable (*c.p.*, fat hens do not lay).

Effect of character of Food on quantity of Milk.

(*a*) The nutritive ratio will affect flow of milk.

Rule: Every cow should receive per diem for every 100 lbs. live weight, 2½ lbs. digestible protein and 13¾ lbs. (or 5½ times as much) carbo-hydrates, *i.e.*, ratio of 1 : 5·5.

(*b*) Succulent feeds give a larger milk-flow than dry feeds of same composition. Slops, however, that is meal, etc., wet with water, lead to a smaller milk flow.

Examples of Proper and Improper Rations.—

1. Silage, 50 lbs.; hay, 6 lbs.: bran, 5 lbs. Nutritive ratio, 1 : 8·4. A very fair and frequently employed ration.
2. Silage, 30 lbs.; oat-straw, 20 lbs.; hay, 10 lbs. Nutritive ratio, 1 : 25·6. All coarse feed and far too little protein.
3. Hay, 20 lbs ; oilcake, 4 lbs.; cotton-seed meal, 5 lbs. Nutritive ratio, 1 : 3·9. An over-supply of protein; food too rich and heavy.
4. Hay, 20 lbs.; pea meal, 4 lbs.; oatmeal, 5 lbs.; mealie meal, 8 lbs. Nutritive ratio, 1 : 6·8. Contains an excess of nutrients; too expensive to be profitable.

1.—Resulted	in yield	of	29·7 lbs.	milk	per diem.
2.—	„	„	21·8 lbs.	„	„
3.—	„	„	29·3 lbs.	„	„
4.—	„	„	31·8 lbs.	„	„

Suggested Rations—

1. 20 lbs. silage, 20 lbs. bean hay, 4 lbs. mealie meal, 4 lbs. mealie bran.
2. 20 lbs. silage, 10 lbs. bean hay, 10 lbs. grass hay, 4 lbs. wheat bran, 2 lbs. cotton seed.
3. 20 lbs. grass hay, 10 lbs. green barley, 10 lbs. sweet potatoes, 20 lbs. brewer's grain.
4. 20 lbs. silage, 10 lbs. bean hay, 10 lbs. oat-straw chaffed, 8 lbs. mealie and cob meal, 2 lbs. cotton seed.

Lecture IX.

FEEDING OF SHEEP.

The shortest road to success in sheep-farming is the reduction of the mortality rate among lambs. A high death-rate is in nine cases out of ten due to starvation. A late or dry spring means that the throats of thousands of lambs must be cut. Results depend largely upon care and management of breeding ewes during winter.

Date of Lambing.—The lamb dropped in late winter or early spring is more valuable than one coming in early summer or autumn. It is weaned in time to make most of spring and summer grass, and makes good growth and a reserve of fat before following winter.

Period of Gestation.—On an average ewes carry their lambs for 152 days or 21 weeks and five days Therefore tupp in April for September lambs; a little earlier in lambing pens can be provided; a little later if no accommodation is forthcoming.

Flushing the Ewes.—With mutton-breeds especially, twin lambs are very desirable, and to secure a large percentage of these, the ewes are given an extra supply of palatable food for two or three weeks before breeding. Well-fed ewes have more twin-lambs than those poorly nurtured.

Drafting of Flock for Winter.—Aged breeding ewes, shearling ewes, and ewe lambs should be drafted into separate flocks for winter feeding, so that each sheep may have an equal chance at feeding trough.

Feed for the Breeding Ewe.—Ewe's milk is much richer than of the cow, and the yield will be from 100 to 150 lb. during the year, the period of lactation being from four to six months. Westphalian sheep give four quarts daily for four months.

	Protein.	*Fat.*	*Sugar.*
Average Ewe's Milk ...	6·52	6·86	4·91
„ Cow's „ ...	3·55	3·69	4·88

Four ewes require as much feed as one dry cow. To winter them on hay and no grain is to perpetuate a flock which will steadily degenerate.

Rations :—

Roughage.	*Concentrates.*
2 lb. Grass hay.	
3 lb. Maize Silage.	
1 lb. Lucerne or Bean Hay, or 3 lb. Grass Hay or Maize Stover.	½ lb. of Bran, Mealie Meal, or Bean Meal alternately. 1 Tablespoonful Linseed Meal.
3 lb. Roots.	
1 lb. Lucerne or Bean Hay.	

Lambing Time.—The ewe can stand a considerable degree of cold, but must be kept dry as to coat and feet. A dry, well-ventilated lambing pen which may be opened to the sheltered side is very desirable. A little personal attention at lambing time may be the means of saving a considerable percentage. If the young lamb is unable to draw milk within a few minutes of birth the ewe should be held and the lamb given a teat. The weaker of twins will also require assistance to its full share of food. Lambs may be reared successfully on cow's milk fed from a tea-pot with a rubber nozzle, or from a nursing bottle. This should be given at first every hour, and later six times a day. After the first fill of milk from the ewe the new-born lamb becomes comfortable and can generally fend for itself. For two or three days after lambing the ewe should be given only short rations of dry food. Afterwards succulent feed should be supplied to meet the demand for milk. In a dry spring, when the ewe's milk is in short supply, hand-rear the calves on hay-tea, as described for calves.

Teaching Lambs to Eat.—After a fortnight strong lambs will begin to nibble at the food-trough, and a lamb-pen opening out of that holding the ewes by a "lamb-creep," should be furnished with a low, shallow trough, in which should be sprinkled a little bran, mealie-meal and ground linseed. The trough should always be cleaned out and scalded between feeds or scouring will result. The food left may be given to the pigs.

Changing to Pasture.—Let the ewes and lambs run for a few hours daily on the new veld grass while it is short, maintaining the ordinary winter ration for a time. When the grass becomes ample, drop the pen feeding altogether for the ewes, and also for the lambs, nnless they are to be fattened for early marketing. In the latter case increase the ration fed in the lamb-pen, adding lucerne or bean hay.

Weaning.—At four months the lambs should be removed from the ewes and taken to a distance. The ewes should be kraaled for a few days and fed on hay or other dry feed to check the milk flow. Their udders should be examined, and, if necessary, drained off a few times to prevent inflammation. At this time the lamb should be given an extra grain ration to compensate the effects of weaning,

Lecture X.

Butcher and Woolled Sheep.—Woolled sheep will in any ordinary farming system be fed on grass alone in the summer, and carried through the winter on a minimum ration. Of recent years the feeding and forcing of butchers' sheep has been found a very profitable operation. To secure the greatest profit from the latter it is desirable to have the gain made as rapidly as possible. As in the case of steers, the younger the animal the cheaper the cost of gain.

Feeding Type Bringing Most Profit.—The most demand is for a lamb which, when fat, weighs about 100 lbs. This weight must be made within the year. Such a lamb has the quickest sale at the highest price per lb. It should not be too heavy-boned nor large-framed, but requires only a medium amount of flesh to make the carcass smooth and plump at the weight of 100 lbs. It is the low-set, thick type which possesses the desired qualities.

Teeth as Indication of Age.—Milk teeth can be always told from permanent incisors by the fact that they are narrower.

First pair of permanent incisors	...	12-13	months.
Second pair ,, ,,	...	24	,,
Third pair ,, ,,	...	27-28	,,
Fourth pair (full mouth)	...	48-56	,,

Feeding Maize to Fattening Lambs.—Lambs averaging 80 lb. in weight at commencement of feeding period, which should last about 13 weeks, will make a gain of 20 lb. for 100 lb. maize and 80 lb. hay fed. Lambs make better gains on dry than soaked maize owing to greater flow of saliva in former case. Increase should be 3/13ths lb. per diem. More oats and twice amount of bran required to make same increase.

Maize Silage versus Roots.—Maize silage and roots have about an equal value for fattening lambs. Sugar beets are slightly more, and ruta-baga and turnips slightly less valuable than silage. Feeding roots or silage cuts down grain required by 25 °/₀ to 40 °/₀. The use of roots alone without grain cannot be recommended, since root feeding is more expensive than a combination of roots and grain.

Rape.—An acre of rape will last 15 lambs for 60 days without additional feed, and will give an increase in weight of from 20 to 25 lb. in that period. An additional grain ration will not much increase weight, but a change to grass pasture is beneficial.

Lucerne, Maize and Roots.—By feeding lambs $1\frac{1}{3}$ lb. lucerne hay per diem with maize and roots lambs may make a gain of 35 lb. in fourteen weeks. Lucerne hay is one of the most valuable feeds for fattening sheep.

Oat Straw is a valuable roughage for fattening lambs, and is more suitable than maize straw.

Millet Hay.—More care is necessary in feeding millet hay to fattening lambs than any other roughage. Unless fed in small quantities it induces scour. Not more than $\frac{1}{2}$ lb. per diem should be given.

Maize Straw.—When fed in bundles from racks lambs waste a large amount of maize stalks or straw. The only satisfactory method is to cut stalks in chaff-cutting machine, silage cutter or shredder, and feed from racks. $1\frac{1}{4}$ lb. may be given per diem. It then makes a good roughage.

Protein Rations.—Lambs fed on bean hay and bean meal make more gain and show a higher percentage of dressed weight than those fed on a carbo-hydrate ration.

Suitable Ration for Fattening Lambs :—

Concentrate.	Roughage.
Maize Meal $\frac{2}{3}$ lb. Bran ,, $\frac{1}{3}$ lb.	$1\frac{1}{2}$ lb. grass hay and 3 lb. roots, or $1\frac{1}{3}$ lb. lucerne hay and 3 lb. roots, or 1 lb. oat straw and 3 lb. roots, or 2 lb. maize silage and 1 lb. grass hay, or 2 lb. maize silage & $\frac{1}{2}$ lb. lucerne hay, or $\frac{1}{2}$ lb. millet hay and 3 lb. roots, or 1 lb. bean hay and 3 lb. roots, or 1 lb. bean hay and 2 lb. silage.

Lecture XI.

FEEDING OF PIGS.

Treatment of Breeding Stock.—Before service sows should be in a vigorous, healthy condition, neither over-fat nor poor. Exercise is important and a paddock of sweet potatoes, beans, barley or rape very desirable. Failing this, scatter grain ration thinly over the ground to compel sows to move about to gather it. No one grain contains food in proper proportion for healthy growth. If breeding sows are fed largely or entirely on maize flabby and weak suckers will often be obtained which will only live a few hours.

Good Ration.—

Roots	6 lbs.
Whole Oats	2 lbs.
Maize siftings	1 lb.
Maize...	2 lbs.

N.B. A sow very thin at time of breeding will farrow pigs which are hard feeders; if sow very fat weak pigs will result.

Young sows should be served at eight months so as to have their litter at a year. "3 months, 3 weeks, 3 days" from service to farrowing.

Unless skim milk can be fed it is best to breed only once a year.

A week from farrowing place sow in a good, warm pen and feed laxative food, such as roots, raw potatoes, warm bran mash, etc.; this prevents fever. Allow excercise right up to farrowing taking care that she does not make a bed away from pen. Round the sides of the pen nail boards edgeways at a height of 8 or 10 inches from ground to prevent pigs from being crushed against wall.

Feeding the Sucking Pigs.—If the sow occupies more than an hour in farrowing, give the pigs that have arrived two teaspoonsful of warm milk with a little pepper in it. When farrowing is completed, take the pigs to the sow and give each of them a teat. If sow quiet leave pigs with her, if rough, take them at intervals to nurse.

Feeding the Mother.—Allow sow very little food for 24 hours after farrowing, and not all that she can eat for two or three days, as too much food will make her feverish, and the overheated milk will make the pigs scour. A little bran or meal mixed with water or skim milk will give good results. After three or four days, if the litter be a large one, give all the food she can eat, changing the ration to oats and barley if possible.

If litter be small do not feed so heavily. If the pigs get scoured at once diminish sow's feed. Sods of earth with the grass on are also a good remedy. After twelfth day feed all sow will eat of anything to hand, avoiding only too much maize.

Feeding the Pigs.—Pigs should now be growing steadily at rate of 1 lb. per diem. After a fortnight they will learn to drink a little meal water or wash from the trough. A small quantity of maize soaked in skim milk or water should then be scattered over the floor of run. This should not be renewed until cleaned up. A small run opening out of farrowing pen is very useful with entrance only large enough to let suckers through. Here the ration of soaked maize and oats may be gradually increased until they are fed all they can clean up twice a day. Culled potatoes cooked in skim milk are also a useful addition. If this method be followed the growth will not be checked at weaning time. A pig can do very well on this mixture all its life and the famous Irish bacon is almost entirely produced by such feeding. Whatever food be given it should be mixed and served while sweet in frequently scalded metal troughs. At eight weeks remove sow from pen, allowing pigs to remain until weaning is completed.

Feeding the Hogs.—Three periods of growth :—

1. From birth to weaning.
2. Frame and muscle development.
3. Finishing and fattening.

2. For period between weaning and finishing, plenty of exercise and abundance of green forage and roots are essential. *The pig is by nature a grazing animal.* It is impossible to turn a profit upon sty-raised hogs fed largely on maize at its present value. A constant maize ration is injurious to health, is too fattening, makes greasy pork and does not supply sufficient material for the growth of frame, lean meat and muscle. Paddocks of bean, pumpkins, lucerne, rape, sweet potatoes, pea-nuts, buckwheat and paspalum are essential, and with a small daily ration of maize, oats, barley, or meal siftings, in as great variety as possible, will furnish pork at the lowest possible cost and of the best obtainable quality. It has been often shown that while it takes from $4\frac{1}{2}$ to 6 lbs. grain sty-fed to make 1 lb. pork, the same gain can be made from 1 to 2 lbs. grain and as much green forage and roots as a hog will eat. Pigs kept in paddocks are less trouble, thrive better and fatten more rapidly than sty-fed animals.

Lecture XII.

FEEDING OF PIGS—(*continued*).

3. After eight or ten months of frame and muscle development the breeder should be in possession of healthy, well-conditioned hogs, scaling 120 to 160 lbs., ready for fattening and finishing. This process consists in laying on a covering of fat to the extent required by the buyers.

Method.—Exercise should be limited to an hour a day. Gradually increase ration of maize or meal until double the former allowance is given, if well cleaned up. Skim milk will tempt the appetite, as will also a frequent change of diet, maize being alternated with oats, barley, ground-nuts and other fattening foods. Six weeks of such diet should see hogs ready for shipment to the factory in a condition to warrant payment of top prices.

Suitable Food for Pigs.—A ration that puts on 1 lb. of pork at least cost may not be the most profitable, for the quality of the meat may be very inferior, and the selling price low.

1. *Maize.*—A number of experiments show that it takes, on an average, 500 lbs. maize to make 100 lbs. gain in weight of pig.

   Grinding the maize makes the feed more digestible, and 479 lbs, meal has been found equal in value to 500 lbs. whole grain. Against this gain must be set cost of grinding. Soaked maize is preferable only by a very small percentage to raw grain.

   Cooking maize is no longer regarded as an economic practice, except for sick animals or breeding stock. The additional expense outbalances the gain in feeding value. Pigs fed entirely on maize become over-fat and unhealthy; the pork is soft and less valuable. Use maize alternately with other grain.

2. *Barley.*—About same weight of barley is required as of maize, to make given increase in live weight, but barley produces a much firmer and better quality of pork. As a finishing food it has given better results than any other grain. Danish bacon, which is rated as the best on the markets, is the result of barley feeding.

3. *Kafir Corn.*—A slightly heavier quantity of kafir corn is required than maize to make given weight. It is found to be constipating when fed alone, and pigs tire of it sooner.

4. *Monkey or Ground Nuts.*—380 lbs. of ground nuts, as against 500 lbs. of maize, were required to make 100 lbs. gain. On light, sandy soils the yield of ground nuts is so much greater than that of maize that the feeding value per acre was found to be about four times as much as that of maize. The pork made by the ground nuts, however, is soft and inferior, and they are a better food for growing animals than for those being fattened for slaughter.

5. *Soy Beans and Cowpeas.*—410 lbs. peas are required to make 100 lbs. gain, as compared with 500 lbs. maize. Feeding value per acre about the same. Sty-fed cowpeas yield soft pork, but cowpeas with maize and pasture have a hardening effect.

Sweet Potatoes.—3,247 lbs. required to make 100 lbs. gain. They should not be fed alone, but with grain. The best root crop for pigs, and when animals are allowed to do own harvesting, produces pork at a very low cost per lb.

Skim Milk.—One of the most valuable foods for keeping pigs healthy and in good condition, economising grain, and making pork of best quality. 400 lbs. milk will replace 100 lbs. grain, fed in proportion of 3 lbs. milk to 1 lb. grain. It has not proved to be an economy to feed very large quantities of milk.

Pumpkins.—When fed with skim milk, 4,520 lbs. pumpkins and 750 lbs. milk are required to make 100 lbs. gain. Pumpkins are a digestive rather than a food.

Mixed Rations always give greater economy in pork production than feeding a single food, *e.g.*, 471 lbs. kafir corn fed alone required for 100 lbs. gain; mixed with cowpea or soy bean amount of mixed grain required is only 409 lbs. In one case 586 lbs. maize, sty-fed, required, and only 307 lbs. when fed in a cowpea pasture, *i.e.*, an acre of cowpea will replace eight bags of maize. The cowpea can be grown at far less expense.

Lecture XIII.

FEEDING OF POULTRY.

Ratio in Foods.—The body temperature of poultry and activity is higher than in mammals, therefore high nutritive ratio in foods is required. Experience shows that 1:5 gives best and most economical results. Eggs contain nearly as much protein as fat, and this must be provided.

Method of Feeding.—Grain is more slowly digested than soft foods, such as mash, and should therefore be given in the evening when it will give warmth and support to the birds during the night. If fed mash in the evening this will be early digested, and the birds will remain with an empty stomach during the cold hours. In the morning, on the other hand, it is desirable to get into them a quickly digested food required after the night's fast. Green food, which is all-important, should be fed, finely chopped, at mid-day.

Quantity of Food.—Safe rule is to give all the food they will eat eagerly, which is far less than what they would readily eat. Birds should always run to their food as if starving. Over-feeding leads to the production of fat and cessation of egg-laying. Exception must be made of birds fed or crammed for table purposes.

Mash.—The soft food should be mixed, overnight if possible, with boiling water or skim-milk, and is thus partially cooked. It should only be fed warm, not hot. A mixture of several kinds of food is better than one or two, as variety induces egg-production. Suitable rations are :

1. Equal parts of mealie meal, ground oats, bran and middlings, mixed with skim-milk; a sprinkling of bone meal.
2. Ten parts mealie meal, 20 parts ground oats, 15 parts bran and $\frac{1}{8}$ part dried meat scraps, mixed with skim-milk; a sprinkling of bone meal.

Green Food.—This is essential to health and is more readily eaten when finely chopped than when given whole: chopped lucerne or clover are very suitable, also minced cabbage, turnip tops, or kale in winter.

Grain.—Grain ration is better given unmixed, though frequent changes are beneficial.

Beans and Peas are especially useful owing to their high protein content; ratio often being 1:2½.

Wheat has too low a ratio, less than 1:6, and also a deficiency of fat : Note habit of eating bread and butter. A sandwich is a scientific combination.

(*Bran* is better, containing as it does, more protein and fat, but if fed largely may cause digestive troubles.)

Buckwheat is largely employed for feeding pheasants in England and fowls in France; nutritive ratio is low, 1:6½, but fat content is high.

Barley is the most deficient in fat of all the grains.

Maize of a selected variety has a high oil content, but results in yellow fat, which is undesirable in table birds. It also frequently leads to scouring and cholera if fed to excess.

Sunflower Seed, one of the best poultry foods, with high fat content.

Munga, or Bullrush Millet, found to be one of the best grains in South Africa for poultry for the same reason.

Animal Food.—In a state of nature fowls secure a large proportion of insect food, which is not forthcoming in artificial confinement. Hence best results are obtained when meat scraps or dried meat meal is employed in small proportion.

Lime.—The formation of egg-shells necessitates a large supply of lime in some form or another. Cut bone not only supplies this material, but is also a source of protein, and a small bone-crusher should have a place on every poultry farm. Bone further supplies the other mineral salts which are required, but not found in such substances as mortar. For this reason oyster-shells, well pounded, form the best substitute for bone.

Lecture XIV.

FEEDING OF CHICKENS.

Newly hatched chickens are naturally furnished with a 24 hours supply of food, ∴ give no additional feed for that period. First day give finely minced hard-boiled egg mixed with stale bread-crumbs and moistened with milk Weakly chickens should be given egg in the form of custard—not hard-boiled. Beat three eggs in half-a-pint of milk and heat to a thick curd, strain off the whey and feed the custard, at first by itself and, after three days, mixed with oatmeal. Never feed hard-boiled egg for more than a day as it will constipate chicken. The custard may, however, be given as a first meal for a month. The second meal during this time should consist of equal parts of stale bread-crumbs, oatmeal and chopped grass or lettuce. Chopped groats (or hulled oats as they are called) may be given in the evening. The green food is essential to prevent diarrhœa and liver disease. At first, meals should be given every two hours, and after three weeks four times a day. Never give more than is cleaned up. After the first month vary the food grain by giving millet, wheat, chopped sunflower seed and buckwheat.

Water for Chickens.—Where custard, lettuce and other moist foods are given chickens do better during the first five weeks with little or no water. If given at all they should be allowed a few sips after the first meal and the water should then be removed.

Feeding or Fattening Table Birds.—In America a large trade is done in chickens from 8 to 12 weeks old (broilers). In England surplus cockerels or capons are often killed at four months, after a fortnight's fattening in a darkened coop. A third method is the "cramming" of adult birds which is an important industry in many parts of England. As much as 3 lbs. may be added to weight of a bird during three weeks of this treatment, while the flesh is rendered softer and of a better colour.

(*a*) *Half-fattened Fowls* are fed in cages 7 feet 6 inches in length and 2 feet in width, the sides, bottoms of which which are made of bars of wood which allow the droppings to fall through and the birds to have access to the food trough which is hung outside. The top of the cage is made of corrugated iron covered with furze or grass.

(*b*) *Cramming* is either done by hand or machine. The food used is in all cases of a soft nature, as it is more readily digested. Strict confinement is also necessary to rapid increase in weight. In England ground oats

and milk are principally employed; in Belgium buckwheat meal; and in France a mixture of buckwheat meal, barley meal and mealie meal. Note that the mealie meal forms yellow oily fat and spoils appearance of bird. The milk secures whiteness of flesh and should be allowed to go sour before use. Suet or scrap fat is often mixed with the food at the rate of ½ ounce per diem for each bird. This should be first melted. The food should be mixed with the sour milk and be allowed to stand for some hours when a slight fermentation sets in, which assists fattening process. A slight dusting of sulphur in the food will assist to keep caged birds in health during process. If they go off their feed and are already fairly fat, the best thing is to kill them at once.

Killing Fattened or Crammed Fowls.—Never send live birds to market, but kill and clean on farm. No food should be given for 24 hours before killing, to empty crop and intestines. Birds killed after starving will keep much better and the flesh is in better eating condition. Killing is best effected by passing a knife, sharpened on both sides, up through the roof of mouth to back of skull; this causes instant paralysis and loss of feeling, and the bulk of the blood is withdrawn from the flesh.

Lecture XV.

FEEDING OF TURKEYS, GEESE AND DUCKS.

Turkeys.—Confinement in any form is fatal to turkeys. A closed house is poison to them, and the best results are obtained when they are allowed to roost in trees. If shelter must be given the house should be entirely open on the side facing the morning sun. The perches should be low and at an equal level or they will fight for the top one. The nest should be without bottom and placed on the ground, with slooping roof to prevent them roosting on it. Closed runs are out of the question. Turkeys require little or no feeding when full-grown, for they are untiring foragers, and if given a free range will pick up nearly all they require.

Feeding the Chicks.—If hatched by the hen the chicks should not be removed for forty-eight hours, but raw egg and breadcrumbs may be placed within reach. After the third day they may be removed to a coop, and should be given chopped green stuff, fed with raw egg and oatmeal. Limit the food, but give water at least four times a day. After three weeks get chicks gradually onto small seeds such as manna, munga, and kafir corn. Dry feeding answers best in a hot climate, but if scoured feed chicks on fresh boiled rice. When twelve days old examine heads for lice, and, if found, dress with kerosine and sulphur mixed with a little lard. After ten or twelve weeks chicks will begin to "put the red," and will have passed through the delicate stage Never let chicks get wet or the majority will die.

N.B.—Turkeys flourish beston high, dry land with light and even poor sandy soil, but rarely flourish on rich meadow land. Do not rear turkeys and poultry on the same range, as the former require ground as sweet as possible.

Ducks.—Like turkeys, ducks require a well-ventilated house, but a dry floor is very essential, as they readily contract cramp. Sloping concrete or slates raised two or three inches above the ground, with half inch between each two make a suitable bed if well covered with dry straw. A few bricks on the floor make as good nests as anything, or the ducks may be allowed to lay on the loose straw. It is best to shut laying ducks up in the house until nine or ten o'clock, as otherwise they are apt to lay away anywhere. If given a good pond and wide range stock birds do not require much feeding. If confined they require an ample supply of animal food. Eggs are better set under a hen or in an incubator. Slime should be removed from shell before setting. Ducklings may be fed on same diet as chickens, but additional animal food should be given after a few

days, such as soaked dry meat. Care should be taken to keep them out of hot sun as they are very liable to sunstroke. A wetting in a cold shower is often fatal to unfledged ducklings, especially if raised in an incubator.

Geese.—Unlike ducks, geese naturally live on vegetable rather than animal food, and will graze a pasture closer than sheep. They should therefore have a large run or common, when they will only require a little grain in the morning. They spend far less time in the water than ducks, and a small pond or sunk tub will suffice for a bath. A dry house well bedded down with straw is required. The eggs are best placed under a turkey hen or in an incubator. For about a week the goslings should be kept in a closed run, but at the end of this they will begin to forage for themselves, and only require housing at night. They will require abundance of chopped green food from the first, with chopped eggs and breadcrumbs or oatmeal, but no additional animal food. Turned into stubble or turnips. Fattened on crushed white oats.

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