PN-ABB-073

PROCEEDINGS OF A WORKSHOP

ON

CROP RESIDUE MANAGEMENT TO OPTIMIZE CROP/LIVESTOCK PRODUCTION AND RESOURCE CONSERVATION IN THE NEAR EAST REGION

AMMAN, JORDAN

31 JANUARY - 2 FEBRUARY

1988

PN-ABC-072

FORWARD

The workshop which was organized by NCARTT, JHADP, ICARDA, and the USDA/USAID Dryland Management Project and held in Amman, Jordan during 31 January-2 February 1988 represents a major contribution in several respects. Firstly, it brought together, perhaps for the first time, some of the leading experts in dryland/rainfed agriculture, including the critically important disciplines of animal production and management, natural resource economics and soil, water and crop management. These experts were able to discuss in detail the various problems and constraints to increased crop/livestock production in Jordan. Secondly, the agencies that were represented at the workshop all have a vital interest in the development of more effective crop residue management systems to enhance soil and water conservation and the efficiency of crop/livestock production in the Jordan drylands. Several of the agencies that participated, i.e. ICARDA, USAID, and ACSAD are involved in the transfer of new technologies throughout the Near East Region. Thirdly, the excellent discussions during the workshop provided some new perspectives and strategies for resolving some of the problems and constraints to production through multidisicplinary cooperative research.

We have attempted to capture some of these perspectives, strategies and research approaches in these Proceedings. We are indeed grateful to all of the participants who contributed so much of their time and valuable information to the workshop. It is our sincere hope that these Proceedings will provide a basis for fruitful scientific cooperative research in the Near East Region for many years to come.

Finally, we extend our thanks and appreciation to those scientists who reviewed this document for technical merit and scientific validity. These included Dr. L. H. Hardesty, Department of Forestry and Range Management, Washington State University; Dr. J. R. Males, Department of Animal Sciences, Washington State University; Dr. W. R. Butcher, Department of Agricultural Economics, Washington State University; Dr. K. E. Saxton and Dr. D. K. McCool USDA-ARS, Pullman, Washington, U.S.A.

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CONSIDERATIONS FOR RESEARCH PLANNING ON CROP RESIDUE MANAGEMENT TO OPTIMIZE CROP/LIVESTOCK PRODUCTION AND RESOURCE CONSERVATION IN NEAR EAST DRYLANDS.

SYNOPSIS

A workshop was organized by JHADP, NCARTT, and USDA/USAID and held in Amman, Jordan on 31 January - 2 February, 1988 to plan research on crop residue management to enhance soil and water conservation and the production efficiency of crop/livestock systems in the Jordan drylands. The proposed research was designed to be a part of a much broader USAID "ribbon" project on soil and water management which is to be extended to other countries of the Near East region. The underlying goal of the soil and water "ribbon" project is to 1) provide economically feasible technology that can increase the amount of water available for production, both crops and animals, and at the same time conserve soil resources of dryland areas, and 2) develop an information and scientific contact network, linking scientists conducting dryland soil and water research in developing countries within a region and the United States.

A strong consensus of a regional workshop on soil, water, crop and livestock systems for the Near East region held in Amman in January, 1986 was that a major problem throughout most of the drylands is lack of application of effective soil and water conservation practices. The participants of the 1986 workshop strongly recommended that a regional research project be initiated to determine the relative value of crop residues for soil and water conservation, maintenance of soil fertility and productivity, and feed for small ruminant animals. Since the use of residues for water conservation and erosion control would be in direct competition for use as animal feed it is necessary to know what compromises and trade-offs are possible for the benefit of both.

This research planning workshop was in part a follow-up to the 1986 regional workshop. The specific objectives were to develop 1) research criteria, experimental plans, and methodology that will provide a set of common results from different participating locations for evaluating how crop residues are best managed in crop/livestock systems to optimize economic return, and resource utilization and protection, and 2) a plan of action for implementing, coordinating, and reporting the interdisciplinary, multilocation research, and for maintaining a high level of cooperation among the working scientists and ensuring high quality scientific results.

This report contains considerations for planning research and designing experiments that can serve as a multilocation interdisciplinary research project to study residue management for profitable crop and livestock production and efficient use of soil and water resources.

BACKGROUND

Agroclimatology

Most of the rainfed cereal-growing areas in the Near East Region have a Mediterranean semiarid climate with precipitation averaging between 200 and 500 mm annually. The rainfall is often distributed during a short rainy season in unpredictable amounts and frequently occurs as intense storms that can cause severe water erosion. Wind erosion is also a serious problem in many areas during the dry months. Barley/livestock is the main production system in the drier areas where the barley is an important source of animal feed.

Many soils in the dryfarmed areas of the Near East region have low fertility status. However, the full potential benefits of improved fertility such as can be achieved by fertilizer application often cannot be realized without improved water conservation. Thus, the management system should strive to maximize the available water supply as a means to increase the yield potential.

Traditional grazing practices

A common practice in most of the dryland areas is complete grazing of crop aftermath by sheep and goats following grain harvest. Weeds may also be allowed to grow during fallow to supply additional forage. The intensive grazing with animal traffic leaves the soil bare and compacted between crops and highly vulnerable to wind and water erosion. The removal of stubble, and weedy fallow is also costly in terms of water loss through increased runoff and evapotranspiration, particularly during the winter rainy season. With less available water, the yield of the following cereal crop is reduced, primarily at the expense of animal production.

Low levels of cereal production

Barley grain yields with the livestock grazing system generally range from lows of 200 to highs of 1000+ kg/ha in the different rainfall zones. Residue amounts associated with these grain yields are estimated to be 300 to 1500+ kg/ha. At such low levels of production, and with animal grazing it is likely that the amount of crop residues available during the rainy season for effective water conservation and erosion control would often be inadequate. In some cases, yields with present farming systems can be increased by application of improved technology that increases the transpiration efficiency (e.g., improved fertilizer practices, early planting) as has been demonstrated in Turkey and Syria. However, in many situations substantial improvements in yields can come about only by increasing the supply of available water in the soil.

Potential value of crop residues for water conservation and soil improvement

The value of surface stubble for water conservation is well documented and depends on a number of factors. First, relatively low amounts of residues are effective in enhancing infiltration by reducing runoff and surface crusting, but greater amounts are necessary to significantly reduce evaporation. Second, surface residues are most effective in slowing evaporation during the rainy season and have little or no effect on evaporative loss after the soil surface layers dry unless unusually heavy amounts of residues are present. Surface retention of stubble may also improve the crumb structure of soil in the shallow layers which can markedly improve infiltration. Other factors affecting residue efficiency for water conservation include residue color, surface configuration (standing vs. flat, etc.), stubble height, and rate of decomposition.

If crop residues are removed and the soil is left bare when rains occur, the water lost from evaporation and runoff can significantly decrease the overall productivity of the farming system. Moreover, weed growth for animal feed can be expensive because many weeds use water inefficiently and produce low-quality forage.

Perspectives for improved crop-livestock production systems

The question is: What is the short- and long-term productivity, and economic and resource efficiency of the intensive grazing-crop production system with weedy fallow compared with alternatives such as controlled grazing or no grazing, with or without weed control and surface retention of crop residues? Yields of winter wheat in some areas of the USA drylands tripled (e.g., increased form 500 to 1500 kg/ha in western Nebraska) during the 1940's when stubble grazing was eliminated, and mulch tillage and improved weed control were introduced in the fallow system. Fertilizer usage was a secondary factor contributing to this yield increase. The change in farming practice amounted to a "snowball" effect, i.e., without grazing, there was more surface stubble and this coupled with good weed control substantially increased the available water for the following crop, which in turn produced more crop residues for additional water conservation benefits. The increase in yield in most of the USA dryland areas was sufficient on an economic basis to justify separating the production of livestock and grain on the same land which to a large extent is the practice today. Moreover, retention of some stubble may reduce water and wind erosion markedly, which helps to sustain the long-term productivity of the soil. The USA system of cereal small grain production represents one extreme and it is likely that some alternative system with managed grazing and weed control during fallow may be equally or even more water-use efficient with regard to productivity of the farming system.

Research needs and priorities

Studies are needed on the effects of surface stubble management, weed growth, and tillage on productivity of crop/livestock systems in low rainfall environments. Experiments should be conceived and designed to provide data for evaluation of the production, economic, and resource efficiency of crop residue systems. These data will provide for verification of conservation, production, and economic models that can be used to analyze and compare the experimental results at different locations in the Near East Region, and to extrapolate the results to a range of agro-climatic conditions. The following information which is the results of the workshop discussions is intended to aid in developing field research to address the issue of the relative value of crop residues for soil and water conservation and animal feed in dryfarming systems.

QUESTIONS THAT THE RESEARCH SHOULD ADDRESS:

The workshop participants were asked to list what they considered to be the most important questions that the proposed research on crop residue management should address. These are as follows:

1. How much residue is needed to control wind and water erosion in different soil and crop management systems?

2. When do residues have their greatest value for water conservation and for control of wind and water erosion? That is, when are they most needed and most effective for these purposes?

3. What are the effects of time, depth, method and frequency of tillage on water conservation?

4. How does the nutrition value/quality of different crop residues (aftermath) as animal feed change with time after grain harvest? With grazing and without grazing?

5. How do crop residue management practices affect water conservation for different soils?

6. What are the relative agronomic and economic values of crop residues for water conservation and for animal feed?

7. What is the effect of crop residues on long-term soil productivity and sustainability of agricultural production?

8. How should crop residues be managed in arid and semiarid agroecological zones to optimize water conservation, and crop and animal production?

9. What is the contribution of crop residues to the production and yield of subsequent crops?

10. How can crop residues be managed to increase water use efficiency by crops? What is the potential for increased biological yields, i.e., increased residue production for animal feed?

11. What quantity of forage that is of value as animal feed is provided by crop residues in each year of typical crop rotation cycles and what are the decomposition rates over time if grazing is excluded?

12. When in animal production cycles are residues used, and what alternative forages are available at these times?

13. How does the nutritional quality of residues when used compare with the nutritional requirements of animals at that time and are feed supplements needed?

14. How can crop residues best be used along with other soil and water management practices to 1) enhance the economic profitability of crop and livestock production on the drylands; 2) serve farmer's and herder's non-economic goals such as food security; 3) optimize other inputs (land, labor, capital) that low-resource producers have available; 4) reduce weather related risks; and 5) achieve sustainable long-term agricultural development objectives?

RESEARCH OBJECTIVES

1. Determine the effect of tillage, crop residue management and weed control in combination with other soil and water management practices on available water supply, crop water use efficiency, and crop yields in a barley or wheat-based rotation.

2. Determine for different grazing intensities the quantity and feed value of crop aftermath for small ruminant animals in a barley or wheat-based rotation.

3. Conduct an economic evaluation of a barley or wheat-based rotation/animal production system with crop residues grazed at different intensities giving primary emphasis to crop/livestock productivity, farmer/herder income, and long term soil conservation to ensure a sustainable agriculture.

SUBOBJECTIVES

1. Determine the relationship between nutritive value of crop aftermath and quantity remaining during grazing by small ruminant animals.

2. Determine a) how quantity and placement of crop residues affects their value for soil and water conservation; b) the time when residues are of greatest benefit for soil and water conservation; and c) how rapidly residues decompose if not grazed.

3. Determine the relationship between the nutritive value of crop aftermath and the nutritional requirements of animals during the grazing period.

4. Determine crop residue management x tillage interaction on soil water conservation and wind and water erosion control.

5. Determine the effect of crop residue management on long-term soil productivity and sustainability of agricultural production.

EXPERIMENTAL TREATMENTS

1. Grazing level and crop residue management

   a) Heavy grazing of cereal stubble, to achieve at least 90% utilization. Under this treatment, grazing of stubble will cease when sheep have lost 10% of their initial body weight.

   b) Moderate grazing of cereal stubble. Under this treatment, grazing of stubble will cease when about 50% of initial stubble or biomass has been utilized.

   c) Ungrazed control.

   d) Stubble mulch--achieved with sweep plow (no grazing).

   e) Stubble incorporation--achieved with chisel plow/disk (no grazing).

2. Tillage options

   a) Type - (chisel plow, moldboard, rotovator, disk).

   b) Depth - (shallow, deep).

   c) Timing - (early, late).

   d) Frequency - (several operations to one)

3. Weed control (complete control with tillage and/or chemicals vs. no control, i.e., weeds used for grazing).

4. Crop rotations--use a rotation common to either wheat-based or barley-based farming systems. This might include fallow, wheat or barley, forage legume, sorghum, or summer crop.

   Examples:

   a) Arid Zone--barley-fallow

   b Semiarid Zone--wheat-legume-summer crop.

EXPERIMENTAL PROCEDURES

1. Plot Size--plots should be large enough to accommodate tillage/crop residue management/weed control operations, and

animal grazing at suitable stocking rates to accomplish objectives.

2. Residue Removal--can be accomplished by animal grazing, machine harvesting, or hand harvesting.

3. Residue Analysis--use standard method(s) to measure in-vitro digestibility, total digestible nutrients, crude protein, Ca, K, P, and Mg.

4. Experimental Site(s)--the study could be conducted by national research stations. However, it may be best to conduct it off-station on farmer's land where animals have traditionally grazed residues and have actually impacted the crop production system. The land should be controlled (fenced if necessary) for the entire experimental period.

5. Duration--the study period should be at least 6 years.

   A proposed procedure for the animal component of the study for Jordan is as follows:

   a) Three locations: Maru and Meshagga (semiarid) and Ramtha (arid).

   b) Two replications of the three grazing treatments at each location.

   c) 30 breeding ewes and 2 rams in each grazing treatment/replication (120 ewes per location).

   d) Grazing fields at each location will have the same stocking rate. Size of fields for a location will be determined by the average stubble biomass and a grazing period of about 60 days under heavy grazing. For example, preliminary estimates indicate that grazing fields at Meshagga should be about 20 dunums each. Fields at Ramtha would need to be larger.

   e) Grazing treatments will begin after cereal crop harvest in June. The length of the grazing period will vary from year to year depending on initial stubble biomass. The grazing period for the heavy grazing treatment will be approximately twice as long as for moderate grazing, and is expected to range between 30 and 90 days. Animals will receive a minimum length protein supplement to be administered after 30 days of grazing.

   f) All animals will receive adequate health care treatment. Animals will be combined into one flock at the end of the grazing treatment and experience identical conditions for the rest of the year. Since the grazing of cereal stubble coincides with the breeding season, economic value of the crop aftermath will be expressed through breeding success, i.e., the value of lambs born per ewe, and costs of replacement feed.

There are several options for combining the grazing and agronomic studies into a single experiment. These are described under the section on "Proposed experimental plans for the Ribbon Project" page 16.

DATA TO BE COLLECTED

1. Climatic Data

These data should be obtained near the plot site or as second choice from a "near-by" meteorol gic station if not available at the site.

Essential measurements:

a. Air temperature--maximum/minimum (C)

b. Air humidity--wet bulb temp (C)

c. Wind travel (m/s)

d. Solar radiation (W/m^2)

e. Precipitation (mm)

Desirable measurements:

a. Downward-facing solar radiometer or net radiometer over selected plot surfaces to define radiation albedo (moderately high priority).

b. Wind travel at 1 or 2 lower heights would assist in defining the wind profile and surface roughness.

Notes:

a. The first three sensors under "Essential measurements" should be at the same height, preferably 2 meters above the soil surface.

b. Hourly sensed values are highly desirable. Daily mean and total values are acceptable.

2. Soil Profile Data

The soil profile water and thermal characteristics (capacities and conductivities) for the general site are needed. The number of samples depends upon spatial variability of the soil and the profile layer variation. General values can be estimated from basic measurements, but specific measurements on site will improve the accuracy of modeling studies.

Essential measurements:

a. Profile textures by horizons (% sand, silt, clay)

b. Bulk density profile (Mg/m^3)

c. Soil water profile (% volume)

d. Soil organic matter in rooting profile at the beginning and at the end of the experiment (% weight).

Desirable measurements:

a. Soil temperatures (C)

b. Soil properties for selected horizons

Saturated conductivity (bore-hole method), ($kg \cdot s/m^3$). Air entry potential (air entry permeameter) (J/kg).

Tension-moisture content measurements (filter paper method) (for fitting to previously defined equations).

Thermal conductivity (heat flux plates, newly developed transient heat probe) ($W/m \cdot k$).

Notes:

Texture, structure, organic matter, and permeability of the surface soil is needed to estimate the soil erodibility factor. Describe roughness and clodiness before and after each tillage. For wind erosion, measure percent surface soil not passing a 20-mesh sieve during times that wind erosion would be a hazard.

a. The bulk density of the tilled layer must be measured occasionally with time to define the tillage effects.

b. Soil moisture is needed at the beginning of the study and occasionally thereafter for verification in predictive models.

c. The measurement depths of soil water and soil temperature should have increments to provide 5 to 10 measurements per profile (20 maximum) and closer spaced near the soil surface. For example measurement depths might be 7.5, 15, 25, 40, 55, 70, 85, 100, 125, and 150 cm. below the soil surface, plus just beneath the soil surface.

Soil temperatures at the same depths as soil water measurements, initially at start of the experiment and several times after (even hourly or daily would be useful).

3. Residue and Soil Cover Data

The soil cover is very important to the energy and water exchange with the atmosphere. This is often more descriptive than documented values, although some measurements are essential.

Essential measurements

a. Residue quantity (by air dry weight of 0.5 m^2 areas) (kg/ha).

b. Residue thickness (average height above soil surface) (m) and configuration (% standing, % on surface).

c. Soil cover (percent soil surface shaded at noon, 0 = bare soil). Use beaded string method or veritical photos with a grid.

d. Greeness index (percent of plant material which can transpire).

e. Rooting depth (estimated maximum rooting depth of living plants).

Notes:

All of these surface condition measurements will change over time as residues decay, are harvested, or grazed and as plants grow. Thus these measurements will need to be repeated often enough to document the time distribution and character of the surface material. Occasional vertical photos on a shaded plot and including a scale or grid would be very useful.

4. Additional Site Data

Essential measurements

a. Soil slope, %

b. Slope aspect, degrees (0 = N, 90 = E, 180 = S, 270 = W)

c. Latitude, degrees (0 = equator, N or S)

Notes:

There may well be other site and plot characteristics that should be provided to describe the physical energy and water budgets of the research plots. Please include any extra information notes that would enhance the application of the SHAW model for data analysis and future predictions.

5. Measurements of the plant biomass and animal production

Essential measurements:

a. Energy and water budget for different soils and cropping systems.

b. Water use efficiency by crops and by rotations.

c. Vegetative growth, grain and forage yields of the crops (kg/ha).

d. Weed forage yield (kg/ha)

e. On animals: bodyweight, conception date, reproductive effort, intake, and diet selection by animals.

f. On crop aftermath: amount of stubble (weed growth) before and after grazing (and on the control); quality of aftermath (proximate analysis and Van Soest digestibility parameters).

6. Economic data needs

Basic data needed to conduct the required economic analysis fall into the following four categories:

1. Crop and Livestock Enterprise Budget Data.

   a. crop and livestock output yields per unit of land under alternative cases.

   b. input requirements.

   c. input and output prices.

   d. impact on long term yields.

   Special care must be taken to identify the timing of input use through the growing season, and the intra-seasonal soil-water-crop response relationships through the season when estimating yields associated with different planting dates and calendars of operations. In addition, the intra-seasonal impacts of residue management and other soil-water conservation measures must be reflected in appropriately specified budgets, e.g., budgets based on the rotation.

Since weather and soil characteristics strongly influence both yield and input mix and level, these site characteristics must be specified for each budget. The range of variability in computed yields due to weather variability must be given with each budget. A basis must be established for transferring (adjusting) experimentally generated budget data to a representative farm situation (to be modeled from data collected in farm surveys).

2. Whole Farm Data

   a. calendars of operation

   b. costs of production

   c. resource availabilities (land, labor, capital)

   d. yield and production levels

   e. marketing and home/farm consumption

   f. farm soil and weather characteristics

These data are to be collected for the purpose of constructing representative whole-farm models encompassing both crop and livestock activities. Grazing by nomadic herders is an important activity to be included in these models.

3. Livestock-Herder Data

   a. numbers, types, and characteristics of animals that normally graze in the area.

   b. types of ownership.

   c. feed source types and rations.

   d. seasonal grazing patterns on and off farms.

   e. livestock production.

   f. livestock output and input prices including especially prices paid for feed and grazing rights.

4. Market Data

   a. Market structure

   b. Market infrastructure

   c. Commodity income and price elasticities

   d. Input supply elasticities

DATA MANAGEMENT--ANALYSIS AND INTERPRETATION OF RESULTS

To the fullest extent possible P-C oriented data base management systems should be utilized. These should be fully compatible with agency and project data processing systems.

Standard statistical techniques (e.g., analysis of variance, regressions) will be applied to analyze soils, agronomic and animal production results. The analysis should emphasize estimating the rate effects of treatments and not just significant differences among treatments.

Considerations for economic analysis include the following:

1. Budgets will be compared to eliminate from further consideration technology packages that are clearly undesirable on such grounds as poor profitability, high resource demand, high variability, and complicated management.

2. Whole farm optimization modeling techniques such as linear-programming, and dynamic programming are potential modeling methodologies. Analysis will seek to identify the economically optimal farm and livestock production plan encompassing the various soil-water conservation options considered potentially beneficial as determined by the crop/livestock budgets, and subject to non-economic objectives and resource limits.

3. The modelling analysis should be carried out so as to estimate short-run impacts of soil-water conservation measures as well as long-run impacts. Both private (farmer-herder) and social valuations of impact should be made.

4. Emphasis should be given to simple modeling techniques in the initial stages of the research, e.g., linear programming. However, special attention needs to be given to variability in yields due to weather and to farmers' reaction to risk of loss. As data and analytical experience improves, more sophisticated approaches may be utilized. Use of long time horizon bio-economic simulation models falls into this latter category.

5. Aggregation of whole-farm models will be necessary to address the large scale impacts of technological change. This should be a second-phase effort following successful development and use of the simple farm models.

6. Statistical techniques of analysis, such as multiple regression analysis, will be required to estimate commodity and input demand and supply parameters.

For purposes of data validation in the economic analysis the following should be considered:

1. Experimentally generated enterprise budgets should be compared against farm survey generated budgets to the extent possible.

2. Base-case solutions generated by the whole-farm models should be compared to the conditions found in the farm surveys and the input-output status of representative farms where the new technologies are not in use. Where new technologies are in use, model solutions based on these same technologies can be compared to these situations.

EQUIPMENT AND PERSONNEL

Equipment and personnel needs are dependent on the scale and scope of the actual experiments and analyses to be performed. Some specific equipment needs will include complete weather station automated with a data logger, no-till drill, neutron moisture probes, hand held calculators, lab-top computers, and P-C's with appropriate operating systems and software packages. Equipment specific for the animal studies will include electric fencing, sheds, yards, troughs, weighing scales, facilities for chemical analysis, fecal collection bags, ear-tags, and other standard items. Vehicles and equipment repair and maintenance will be necessary for field plot work and field surveys. Personnel needs include field enumerators, data processors, research assistants, and research leaders.

COORDINATING COMMITTEE AND COOPERATORS FOR THE RIBBON PROJECT

Good coordination of research and interaction among researchers at the different participating locations is deemed highly crucial to the success of the ribbon project. The workshop participants recommended that a Ribbon Project Coordination Committee be organized which would provide guidance and leadership for facilitating cooperation and coordination of the work effort. The Coordinating Committee, for example, could provide technical counsel to scientists in developing research proposals, and review proposals if requested by project administrators. The Committee should also assume leadership in arranging for project leaders and associated personnel to meet at least once a year to compare results and discuss any changes that may be needed in the experimental plan. Annual reports summarizing the results could be exchanged at this time.

The Workshop participants nominated the following individuals to serve on the Coordinating Committee for the Ribbon Project in Jordan. Cooperators and their respective organizations are also recognized.

A. Coordinating Committee

1. NCARTT
   - Dr. K. Abu Salah
   - Dr. K. Tadros
   - Dr. N. Haddadin

2. JHADP
   Dr. J. D. Maguire

3. University of Jordan
   Dr. M. Harb
   Dr. S. Khattari

4. Jordan University of Science & Technology
   Dr. A. Jaradat
   Dr. M. Muwalla

B. Cooperators

1. ICARDA
   Dr. H. C. Harris

2. USDA
   Dr. R. I. Papendick
   Dr. J. C. Day

3. USDA/USAID
   Dr. J. F. Parr

4. ACSAD
   Dr. M. J. Al-Ahmad

PROPOSED EXPERIMENTAL PLANS FOR THE RIBBON PROJECT

During the course of the Workshop several experimental plans emerged that appeared to have considerable potential for fulfilling the goals and objectives of the Ribbon Project as set forth by the Workshop participants. It was widely recognized that the cooperating scientists at various locations in the Near East Region would probable not be able to conduct identical experiments because of site specific conditions and limitations in available resources. The participants felt that this was not a major constraint to the development of a regional network for the Ribbon Project as long as the objectives of each experiment were to determine the best management practices and relative agronomic and economic values of crop residues for soil and water conservation maintenance of soil fertility and productivity, and feed for small ruminant animals.

The experimental plans that were discussed in detail during the Workshop are summarized here to provide background information for developing an acceptable experimental plan for the Ribbon Project to be implemented by NCARTT in Jordan and which would involve grazing animals, i.e. sheep.

A. RIBBON PROJECT FOR NORTHWEST SYRIA TO BE CONDUCTED BY THE FARM RESOURCE MANAGEMENT PROGRAM, ICARDA

GOAL

To improve the productivity and sustainability of barley/livestock systems in the drier areas of the ICARDA region by improvement in soil structural stability, soil water relations and water use efficiency of crops.

OBJECTIVES

To examine the potential for the agronomic and economic improvement of crop and livestock production in barley/livestock systems for the dry areas of Syria through the use of:

1. Alternative stubble management systems,

2. Alternative tillage practices,

3. Alternative crop rotations.

METHODS

An experiment will be established on a semi-permanent off-station site at Breda, approximately 35 km south of Aleppo. The mean annual rainfall is 285 mm. The soil is deep, is typical in texture of much of the drier areas of Syria, and has been thoroughly characterized.

Breda has been used for ten years by ICARDA and the local villagers understand ICARDA's aims, and cooperative fully whenever research trials are conducted. This will be important for the management of the long-term trial which is envisaged.

It is proposed that three rotations will be established:

1. A barley/fallow rotation in which alternative crop residue management treatments will be imposed.

2. A barley/fallow rotation in which alternative tillage practices will be tested.

3. A barley/vetch rotation in which residue management following harvest will be the same as in rotation 1, but vetch for spring grazing will replace the fallow year.

TREATMENTS

Rotation 1

The residue treatments will be as follows:

a. Farmer practice of hand harvesting in which all crop biomass is removed and stored for winter feeding (Control 1).

b. Farmer practice in which barley is combine harvested and the stubble is intensively grazed (Control 2).

c. Controlled grazing to retain a proportion of the stubble following combine harvesting.

d. No grazing

The plots will be split for weed control with objective of complete control on half of the plot. Weeds on the other half will be grazed in treatments a and b; in treatments c and d they will form part of the retained biomass. Uniform fertilizer applications will be made on all plots.

Rotation 2

The tillage treatments will be as follows:

a. Till in autumn following the crop and at planting following the fallow.

b. Till in late spring-early summer at the close of the rains in the fallow year to control weeds and at planting following the fallow.

c. Till in the early spring of the fallow year with the objective of crust formation (the hypothesis is that the crust will reduce soil evaporation) and at planting following the fallow.

d. Till whenever crusting occurs to maintain a dust mulch on the surface.

Weed control and fertilizer application will be as for Rotation 1, and stubble management will be as for treatment b of Rotation 1.

Rotation 3

Residue management, weed control, fertilizer application and tillage will be the same as in Rotation 1, but a vetch crop will replace the fallow year. This will be grazed in the spring (from early March) with weaner lambs for fattening.
The experimental layout for the ribbon trial is presented in Fig. 1.

STATISTICAL DESIGN

Within rotations an orthogonal comparison of treatments will be carried out. Rotations 1 and 3 will be compared in an orthogonal analysis of rotations x treatments. Individual treatments of Rotation 2 will be compared with treatment b of Rotation 1 (Control 2).

The trial will be replicated three times, and both phases of the two course rotations will be included each year.

MEASUREMENTS

1. Baseline measurements of soil physical status (aggregate stability, porosity, infiltration rates, bulk density) and soil chemical status P_2O_5, N, $CaCO_3$, organic matter, EC, etc.) will be made at the start of the trial.

2. Crop residue weight, fraction of ground cover, residue layer thickness, and other characteristics at the start of the rainy season.

3. Weed biomass and the dynamics of weed species composition at intervals during the trial.

4. Soil water dynamics throughout each year, including recharge patterns during rainfall, and discharge under crops, stubble and fallow.

5. Crop total biomass and grain yields.

6. Soil characteristics as in 1 at intervals during the trial.

7. Animal production, either as live weight response and milk yield, or in terms of grazing days.

8. Costs of all operations including tillage, planting, harvest, weed control and fertilizer.

9. Returns from crops and animals.

10. Net revenue.

A meteorological station is maintained at the site and ten years of daily record of rainfall, solar radiation, evaporation, wind run, humidity, and air and soil temperatures are available, The recording will be continued. In addition 25 years of daily rainfall data are available from a Government recording station 1 km from the site.

CULTURAL METHODS

1. Plot Size: It is essential that animal production and grazing effects be monitored. Thus, it is necessary that the plots be large enough to allow this. Individual plot size will be 60 x 12.5 m.

2. Planting Method: Barley will be drilled with an ICARDA designed single pass planter, or with a zero till planter as appropriate. There is an argument for using a more conventional seed drill for vetch in that narrower rows give better production from legumes. The economics of this need to be examined as the extra dry matter can only be produced at the cost of an extra tillage.

3. Cultivars: Initially the barley cultivar, Tadmor, will be used. This is an improved line selected from a local landrace and adapted to dry areas. It may be quickly replaced by a new line selected from similar material but with greater resistance to the major disease, powdery mildew.

   Local vetch will be used.

4. Seed and Fertilizer Rates: Seeding rates will be 100 kg/ha for barley and 120 kg/ha for vetch. Phosphate will be applied at 60 kg P_2O_5/ha to the barley phase. Twenty kg N/ha will be drilled with the barley, and additional N will be topdressed according to seasonal conditions, soil tests and rotations. These fertilizer rates have been experimentally determined as suitable rates for Breda.

5. Stocking Rates and Sheep Management: Theoretical calculations suggest that a barley/fallow rotation should be able to support 4 ewes per hectare in the Breda area (an average of 4 t ha^{-1} total biomass, yielding about 35000 MJ of metabolizable energy/ha/crop year; ewe requirements are about 4000 MJ/head/year). Some protein supplement may be necessary to achieve this (feeding of cottonseed cake, legume straw, etc. serves this purpose and is common practice). However residue management initially can be expected to reduce the amount of stubble available by approximately one-third. Tillage treatments may do the same.

   It is therefore proposed to use a flock of 6 Awassi breed ewes per rotation (1.8 ha) to measure animal production. The same flock will utilize the crop products for all treatments within a rotation, and the contribution of each treatment (and replicate will be calculated on the basis of records of consumption of stored grain and straw, and grazing days on stubble, vetch or fallow (according to the rotation). A flock size of 6 should be large enough to prevent the social problems which occur with small groups (minimum 4) of this gregarious breed of sheep. The animal data will be unreplicated but short of quadrupling the size of the experiment this seems to be unavoidable. However, on the positive side this plan provides opportunity for flexibility in the management of the sheep. If it appears what the stocking rate is too high it could be reduced without causing social disruption in the flocks. If this is too conservative and more sheep could be supported, sheep can be brought in, either permanently or seasonally for fattening. The latter also is a common practice within the sheep production systems of Syria.

6. Fencing Requirements: The trial will need to be fenced to secure grazing management.

TIME OF ESTABLISHMENT

The experiment should be timed to begin in the 1988/89 crop season. This means that preparation of the site (fencing, etc.) should begin in October 1988.

DURATION

It is proposed that the trial should run for at least six years. This length of time will be required to assess the slow changes which are expected to occur in response to the treatments.

PERSONNEL

The trial will be carried out by the Farm Resource Management Program of ICARDA. Overall responsibility will rest with Dr. P. J. M. Cooper, Program Leader, and Dr. Hazel C. Harris, Agronomist. It is proposed that a Post-Doctoral Fellow be employed to oversee the day-to-day running of the trial. It is further envisaged that once the trial has been running for two years it will provide a venue for research projects of graduate students, and we will actively seek to recruit students with interests in soil physics, soil chemistry, soil fertility, soil microbiology and soil water relations to work on aspects of the trial. This will be done through ICARDA's Training Program.

The economic study will be under the supervision of Dr. T. L. Nordblom, Economist with the Farm Resource Management Program. It is also anticipated that there will be opportunity for graduate studies on economic aspects of the trial.

Further, the trial will provide hard data for the verification of simulation models of barley growth and of soil water dynamics under different residue and tillage managements. These models are being used by Mr. W. Goebel, Agroclimatologist, for the purpose of characterizing environments within the ICARDA region. It is anticipated that Mr. Goebel will also be closely involved with the trial, and again the opportunity will exist to use the data in the training of regional scientists in agroecology.

Dr. E. F. Thomson, Livestock Scientist with the Pasture, Forage and Livestock Program of ICARDA, will supervise studies of feed intake and feed quality. The trial will provide an opportunity to study these factors in experimental flocks in the drier areas. Previous work has been carried out in the wetter Tel Hadya environment. As in other aspects of the trial, it is planned to seek student involvement, and the data will provide for the validation and calibration of models of livestock performance in barley/livestock systems.

B. RIBBON PROJECT WITH SIMULATED GRAZING TO BE CONDUCTED COOPERATIVELY BY JORDAN UNIVERSITY OF SCIENCE AND TECHNOLOGY AND NCARTT

OBJECTIVES

In arid areas: 250-300 mm of annual rainfall.

1. To introduce the barley-livestock system with modifications to suit the Jordanian socioeconomic situation.

2. To improve water use efficiency by crops in the rotation.

In semiarid areas: 350 mm of annual rainfall.

1. To improve the productivity of the cropping systems.

2. To improve water use efficiency by crops.

TREATMENTS

Four cultural practices will be tested as to their effects on the productivity of the cropping systems in arid and semiarid regions of Jordan. These are:

1. Residue management: at two levels, i.e., simulated intensive grazing and no grazing.

2. Tillage: at two levels, i.e., traditional tillage as to implements, frequency, and depth; and minimum tillage using chisel plows.

3. Fertilizer usage: at two levels, i.e., no fertilizers, and optimum rates for the area as recommended by the Jordan Cooperative Cereal Improvement Project.

4. Weed control: at two levels, i.e., no weed control, and best management chemical weed control.

APPROACH

1. Arid Region: Two adjacent pieces of land with a total area of about 0.7 ha in a representative barley growing area will be selected. A barley-fallow rotation will be established on one piece and a barley-vetch rotation on the other. The experiment

will be a confounded factorial experiment with two blocks each of 8 plots. The layout of the experiment is shown in Fig. 2.

2. Semiarid Region: Two adjacent pieces of land, with a total area of about 1 ha, will be selected in a representative wheat growing area. Two crop rotations will be used to test the four cultural practices listed above. The crop rotations are:

   a. Lentil-Wheat-Fallow

   b. Lentil-Wheat-Sorghum.

The experiment will be a confounded factorial with one replication, two blocks each with 8 plots. The basic layout will be similar to that in Fig. 2.

The improved cultural practices which have been developed by the Jordan Cooperative Cereal Improvement Project for arid and semiarid regions in the country will be compared with traditional cultural practices which are employed by farmers.

STATISTICAL DESIGN

The experiment is a factorial one with four factors, each at two levels. The statistical design, however, is a flexible one. It allows comparisons within and among rotations and sites. The single degree of freedom for each factor in the experiment allows for flexibility of comparisons. A new statistical analysis approach, known as Nearest Neighbor Analysis (NNA), in addition to classical statistical analysis approaches, will be used. NNA will be used especially for the statistical analysis over years and sites. It will help draw a soil fertility/soil moisture map of the experimental plots and compare different management practices regardless of orthogonality.

MEASUREMENTS

1. Crop residue weight at harvest, rate of decomposition and residue left prior to the rainy season.

2. Weed biomass and spectrum.

3. Water content throughout the year.

4. Grain and straw yield of the crop.

5. Digestible energy of crop residues.

6. Cost of all cultural practices.

7. Meteorological measurements: daily precipitation, maximum and minimum temperature, air humidity, solar radiation and wind run.

8. Soil: soil temperature, texture, bulk density, water release curve, hydraulic conductivity function and thermal conductivity.

SITE CHARACTERIZATION

Both experimental sites will be characterized as to soil description, fertility, organic matter content, and average yield of the surrounding area.

Collected data will be used to assess the effect of different cultural practices on measured variables and to initiate a comprehensive modeling study in cooperation with ARS-Pullman and FRMS-ICARDA. The modeling effort will be directed to develop alternative cropping/management systems for arid and semiarid areas of the country. The experiment should be run for a minimum of 6 years and always on the same plots.

PERSONNEL

The study will be carried out cooperatively by JUST and NCARTT. The principal investigator will be Dr. A. A. Jaradat of JUST assisted by a field crops specialist and soil specialist from NCARTT. A research assistant is suggested to be employed to oversee the day-to-day running of the experiment. Also, certain aspects of this experiment will be used by graduate students at JUST as research projects.

C. RIBBON PROJECT WITH SIMULATED GRAZING BEING CONDUCTED IN EASTERN WASHINGTON STATE, USA, BY THE AGRICULTURAL RESEARCH SERVICE, USDA

OBJECTIVES

1. Primary objectives: To compare the water use efficiency, and agronomic and economic yield of intensively grazed livestock-crop production system with alternative systems including:

   a. Controlled grazing without weed control, and with complete weed control during fallow,

   b. No grazing without weed control, and complete weed control during fallow.

2. Secondary objective: To determine the effect of tillage, crop residue management, and weed control on fallow efficiency and crop yields.

APPROACH

Experimental plots have been established in a representative cereal area on wheat or barley stubble after grain harvest with all crop residues remaining. The average annual precipitation is 330 mm. The soil is sufficiently deep to store precipitation and does not have a history of unusual manuring or fertilization, or weed infestation. Grazing is simulated by mechanically harvesting crop residues and weed growth.

TREATMENTS

Three main residue treatments have been established:

1. Simulated intensive grazing: All crop residues and weed growth are removed after grain harvest so that the plot is bare before the rainy season begins which is usually in late October. Additional weed growth is harvested just before the early spring tillage (mid March) and, as appropriate, just before the late spring tillage (early May).

2. Simulated controlled grazing: All crop residues and weed growth are harvested just before the early spring tillage. Additional spring weed growth in the late tillage treatment is harvested just before the tillage in early May.

3. No grazing: No residues or weed growth are removed at any time. All plots in treatments 1, 2, and 3 would be split with no weed control to the time of tillage on one half, and complete weed control on the other half beginning immediately after harvest. Residues alone and residues plus weeds on treatments 1 and 2 would be collected, dried, weighed, and analyzed for digestible energy.

   In the spring, a set of tillage treatments will be superimposed across the residue and weed control plots:

   a. Early tillage fallow: Initial tillage is performed soon after the end of the rainy season with a sweep plow to a depth of 16-20 cm. This is followed by two or three secondary operations during the spring and summer with a rodweeder to kill weeds and establish a tillage mulch about 10 to 13 cm deep. A final cultivation is made just before seeding in early fall.

   b. Late tillage fallow: Initial tillage is performed about 3 or 4 weeks after he early spring tillage with a sweep plow to a depth of 16-20 cm. One secondary operation with a field cultivator or rodweeder is made just before seeding in the fall. Summer weeds are controlled with herbicides.

   c. No-till fallow. Weed control is accomplished entirely with herbicides and would begin at the time of the late spring tillage on treatments 1 and 2 on the half of the plot that had received no weed control previous to this time, and continued as on the original weed-free plot.

The entire plot area would be sown to a recommended wheat variety at the appropriate rate and time for seeding. If there is difficulty with seeding the no-till plots with available equipment, a light shallow disking or tillage with another suitable implement could be performed just ahead of drilling to facilitate operation of the planter. Fertilizer will be applied as recommended for maximum yields. Weeds in the wheat crop will be controlled with recommended herbicides. A summary of the major plot operations is presented in Table 1.

STATISTICAL DESIGN

The experimental design incorporates three simulated grazing treatments, three tillage treatments, and two weed control treatments. The plot layout for one replication with dimensions presented in Figure 3. The design is a split block with the grazing treatments stripped across the tillages. The subplot is the weed control treatment, and the sub-subplot is the grazing treatment. Each treatment is replicated four times. The AOV is presented in Table 2.

MEASUREMENTS

1. Crop residue weight, fraction of ground cover, and residue layer thickness just before the rainy season.

2. Weed and residue weights during incremental harvest.

3. Description of weed spectrum and densities at the beginning of the experiment and several times afterwards as changes occur.

4. Water content of the soil profile after grain harvest (before the rainy season), late winter (just before spring warm-up), and at the time of seeding. (volume percent and mm).

5. Grain and straw yield at harvest. (kg/ha)

6. Digestible energy of harvested crop residues and weeds. (K cal/kg)

7. Replacement feed cost of harvested residues and weeds.

8. Cost of herbicide, fertilizer, tillage, planting, and harvesting on a per hectare basis.

9. Meteorological: precipitation by event and cumulative (mm), daily maximum and minimum temperatures (C), air humidity (%), daily solar radiation (W/m^2) and daily wind run (m).

10. Soil: soil temperature, soil texture, bulk density, water release curve, hydraulic conductivity function, and thermal conductivity for tilled and untilled soils (upper 15 cm) and undisturbed subsoil below.

SITE CHARACTERIZATION

1. Soil description.

2. Crop yield information for the surrounding area.

3. Nutrient status (N, P, K, S) at the beginning and at the end of the experiment.

4. Organic matter content at the beginning and at he end of the experiment.

5. Average annual precipitation, temperature, wind, pan evaporation, and solar radiation data.

6. Soil slope, slope aspect, and latitude.

ANALYSIS

1. Animal value of residues/weeds for the simulated intensive grazing and controlled grazing treatments.

2. Grain and straw yield for the different residue use, weed control, and tillage systems.

3. Water use efficiency defined as the yield of product per unit area and unit water (kg/ha/mm) for the different residue use, weed control, and tillage systems.

4. Economic analysis of the different residue use, weed control, and tillage systems.

MODELING

This project will be allied with modeling studies on the water-conserving and erosion control benefits of various levels of surface residues. This will require collecting meteorological and soil data in addition to the usual field agronomic measurements. The agronomic data will be incorporated into a comprehensive modeling study on economics and long-term sustainability of agricultural production of the intensive grazing livestock-crop system vs. the other alternatives with more residue left on the land where soil erosion is a hazard. This study will require the collaborative effort of the following disciplines: agronomy, soil science, animal nutrition, and agricultural economics.

DURATION

The experiment should run for a minimum of 6 years and always on the same plot site. Hence, two blocks of land are being used so that the simulated grazing/fallow and wheat components are being carried out each year. Both blocks of land are in close proximity to each other.

D. EXPERIMENTAL PLAN FOR A RIBBON PROJECT IN JORDAN INVOLVING GRAZING ANIMALS

A strong consensus of the Workshop was that the two highest priority areas of agricultural research in Jordan are (1) crop residue management and (2) tillage. Currently, the types of tillage implements used in Jordan are the rotavator, disk plow, chisel plow and moldboard plow which are generally used to accomplish relatively deep tillage. The workshop participants expressed the need to conduct tillage research that would investigate the interactions of time, frequency and depth of tillage resulting from various types of implements, with particular emphasis on the effects of shallow tillage to manage residues for more effective conservation of soil, water, and energy.

The suggested treatment variables for crop residues agreed upon by the participants include (1) intensive grazing, (2) controlled grazing, (3) no grazing, (4) stubble mulch, and (5) incorporation of crop residues.

The animal scientists pointed out that rather large plots would be necessary since a certain minimum number of animals are required to reduce the variability in sampling and to obtain reliable data. For example, 12 animals are recommended for weight gain performance studies whereas 20 to 30 would be needed for reproduction studies.

Thus, there was considerable discussion on how to bring the agronomic component and the livestock component into a single experiment that would ensure statistical validity, overcome animal variability, and accommodate animal grazing without confounding either component, and without expanding the land and labor requirements beyond practical reason. It was decided that the plot sizes for grazing treatments would be 40 dunums in the arid zone and 20 dunums in the semiarid zone.

Two basically similar experimental designs were proposed. Both incorporate 5 residue management treatments and 4 tillage treatments. The design is a split block with tillage treatments stripped across the residue management treatments (Figs. 4 and 5). Animals would begin grazing the residues soon after harvest and would remain on the plots for 60 to 90 days. During this same time the stubble mulch treatment would be established with undercutter tools (e.g. a sweep plow) and the incorporated stubble with a chisel or disk plow. The 4 tillage treatments would be imposed the following spring. It is likely that weed control treatments would also be included. If not, blanket herbicide application could be used for weed control. The analysis of variance for the experimental designs of Figs. 4 and 5 is shown in Table 3.

In the experimental layout of Fig. 4 and 5 the grazed areas are of a specified size to meet requirements for measurment of animal production. The nongrazed areas could be considerably smaller, i.e., just large enough to meet agronomic requirements. In the design of Fig. 4 the tillage would be stripped across the entire block. An alternative scheme to the design in Fig. 4 is shown in Fig 5 for the same treatments. Again, the plot size for the nongrazed treatments can be considerably smaller than for the grazed treatments. However, the experimental tillages are stripped across only a very small percentage of the large grazed areas to provide just enough area for soil and agronomic measurements. Although not shown this way in Fig. 5, the nongrazed areas actually need to be only large enough to satisfy agronomic requirements. Any bulk area (particularly in the grazed areas) can be agronomically managed using one of the tillage systems in the test area (e.g., either disked, moldboard plowed, etc.). An advantage of using the design in Fig. 5 over Fig. 4 is that it accommodates the required number of animals but scales down the tillage subplot sizes so that they can be more easily managed. This may be important at locations that may not have the labor and equipment to impose treatments completely over the relatively large grazed areas. As in the Fig. 4 design the animals would graze each of the large plots (except for the no grazing treatment) for 60 to 90 days after grain harvest and would then be removed. The tillage treatments would be imposed in the spring. Weed control could be treated as a variable, or uniform control could be imposed over the entire area.

Table 1. Summary of major plot operations

Operation	Grazing Treatment	Tillage Treatment	Time
Harvest all residues and weed growth	IG	EST, LT, NT	After harvest-before start of rainy season
Harvest all residues and weed growth	CG	EST, LT, NT	End of rainy season-just before EST
Harvest winter weed growth	IG	EST, LT, NT	End of rainy season-just before EST
Conduct early spring tillage	IG, CG, NG	EST	End of rainy season
Harvest spring weed growth	IG, CG	LT, NT	4-6 weeks after EST
Conduct late spring tillage	IG, CG, NG	LT	4-6 weeks after EST
Apply glyphosate to all NT plots	IG, CG, NG	NT	4-6 weeks after EST
Conduct secondary tillage	IG, CG, NG	EST, LT	Summer
Sow wheat	-- all plots --		Just before winter rainy season

IG = intensive grazing
CG = controlled grazing
NG = no grazing

EST = early spring tillage
LT = late spring tillage (4-6) weeks after EST)
NT = no-till

Table 2. Analysis of variance for Figure 3 plot layout (4 replications).

Source	d.f.[1]	MS[2]
Replication (r)	3 (R-1)	-
Tillage (T)	2 (T-1)	-
Error a (E_a)	6 (R-1)(T-1)	E_a
Weed control (W)	1 (W-1)	-
T X W	2 (T-1)(W-1)	-
Error b (E_b)	9 T(R-1)(W-1)	E_b
Grazing (G)	2 (G-1)	-
T X G	4 (T-1)(G-1)	-
W X G	2 (W-1)(G-1)	-
T X W X G	4 (T-1)(W-1)(G-1)	-
Error c (E_c)	36 TW(R-1)(G-1)	E_c
Total	71	

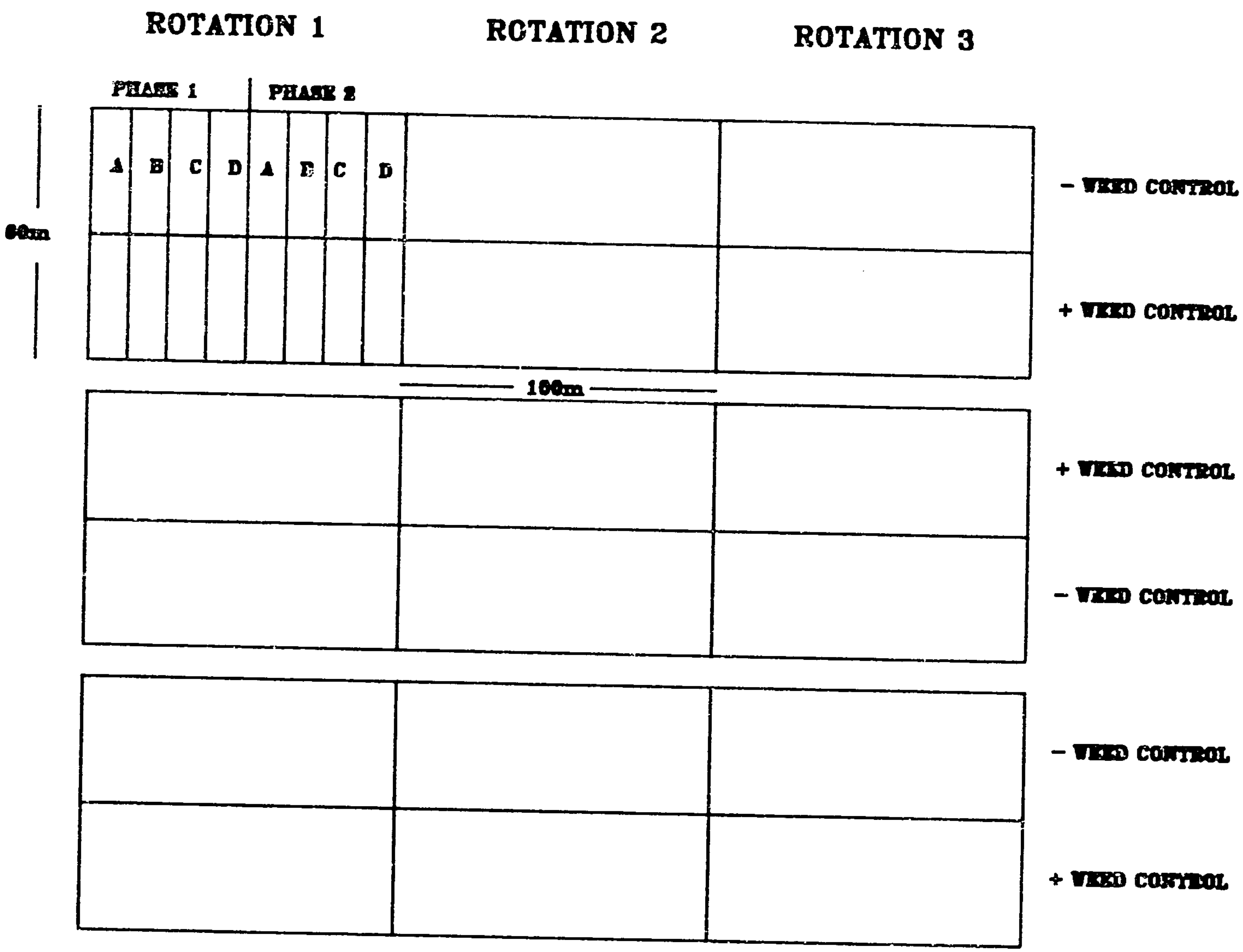
[1]Degrees of freedom

[2]Means square

Table 3. Analysis of variance for Fig. 4 and Fig. 5 plot layout (2 replications).

Source	df*
Replication (R)	1 (R-1)
Residue Treatment (RT)	4 (RT-1)
Error A	4 (R-1)(RT-1)
Tillage Treatment (TT)	3 (TT-1)
RT X TT	12 (RT-1)(TT-1)
Error B	15 RT(R-1)(TT-1)
Total	39

* Degrees of Freedom



NOTE: ROTATIONS AND TREATMENTS WITHIN ROTATIONS TO BE RANDOMIZED.

Fig. 1. EXPERIMENTAL LAYOUT FOR RIBBON TRIAL AT BREDA, NORTHWEST SYRIA.

Fig. 2.

LAYOUT OF ONE REPLICATION OF A CONFOUNDED FACTORIAL EXPERIMENT TO BE CONDUCTED COOPERATIVELY BY J.U.S.T. AND N.C.A.R.T.T. USING THE NEAREST NEIGHBOR STATISTICAL ANALYSIS.

T	FWR	F	WRT
FWT	R	W	FRT
WT	FR	FT	FW
FWRT	(1)	RT	WR

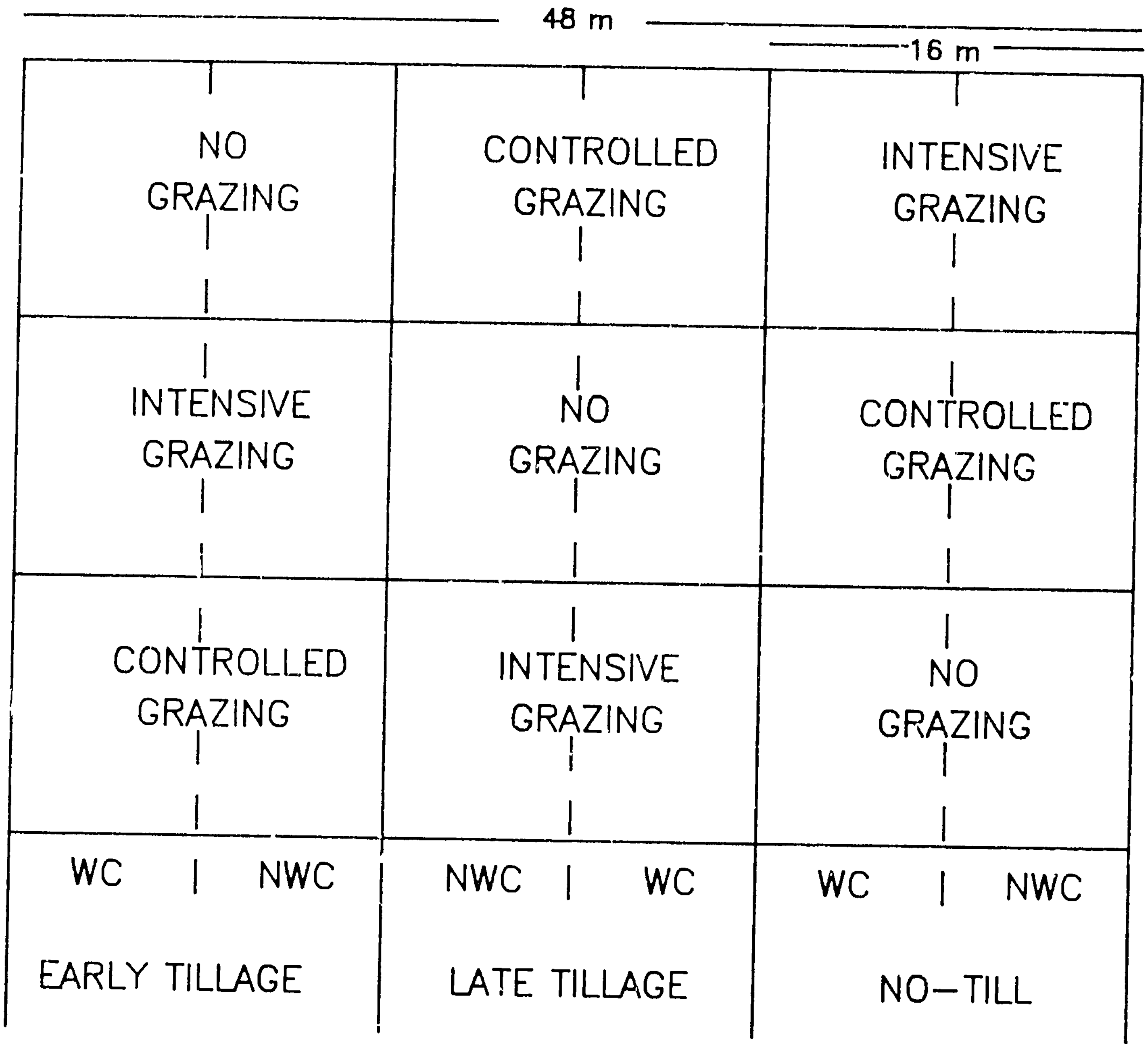
7.5 m

— 5 m —

T= TILLAGE
R= RESIDUE
F= FERTILIZER
W= WEED CONTROL

Fig. 3.

EXPERIMENTAL LAYOUT FOR SIMULATED GRAZING X TILLAGE X WEED CONTROL TRIAL AT WINONA, WASHINGTON, USA.



WC = weed control
NWC = no weed control

Fig. 4.

PROPOSED EXPERIMENTAL DESIGN AND PLOT LAYOUT FOR RIBBON PROJECT INVOLVING GRAZING ANIMALS.

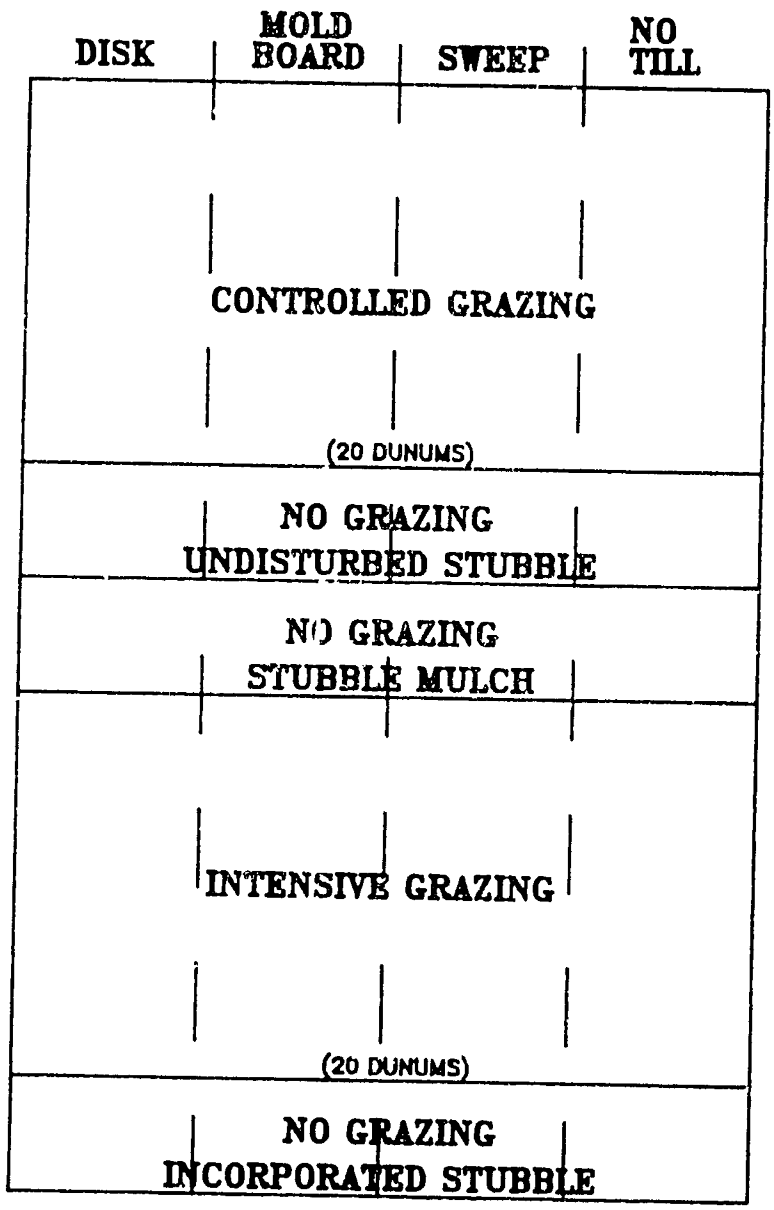
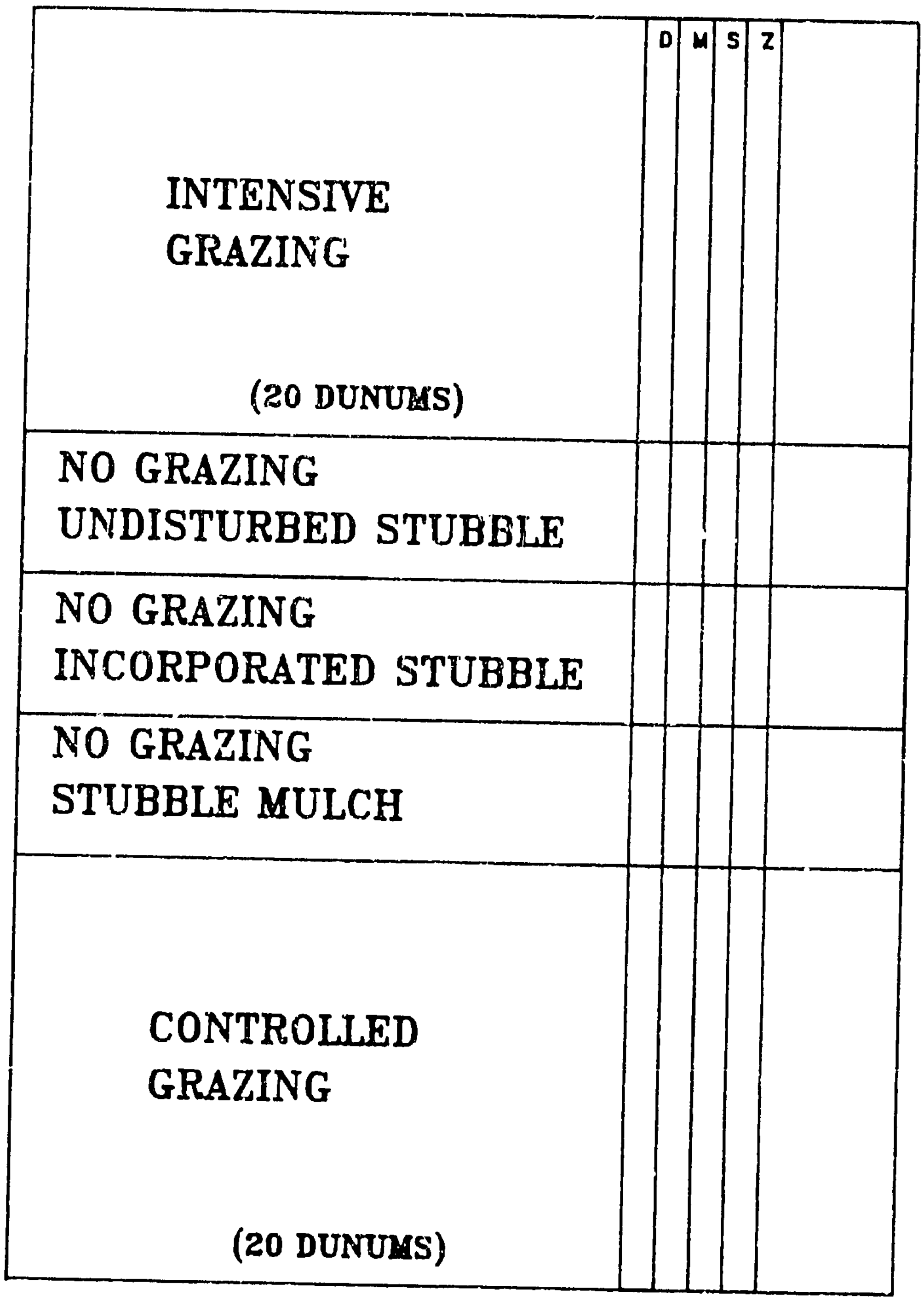


Fig. 5.

ALTERNATIVE EXPERIMENTAL DESIGN AND PLOT LAYOUT FOR RIBBON PROJECT INVOLVING GRAZING ANIMALS.



TILLAGES: D=DISK
M=MOLDBOARD
S=SWEEP
Z=NO-TILL