ANNUAL REPORT

OF THE

ICRISAT FARMING SYSTEMS RESEARCH PROGRAM

APRIL 1973 - MARCH 1974

(An in-service report)

BY

B. A. KRANTZ, J. KAMPEN & ASSOCIATES

AUGUST 1974

INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

(ICRISAT)

NOTE TO THE READER

This in-service report is being written (1) to provide a permanent record of the year's activities, data and observations for the information of the Staff of ICRISAT (2) to provide for interested colleagues a more detailed account than that given in the ICRISAT annual report.

In this report many preliminary observations are recorded which will need to be further tested before the information would be released for general distribution.

C O N T E N T S

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SUMMARY

The 1973-74 season has been a year of great expansion for the Farming Systems Program at ICRISAT both in terms of staff and with regard to the scope of the program. Six Research Assistants joined the farming systems team. A number of catchments were developed and the watershed-based phase of the program was initiated. A Farming Systems Research Program document was written and circulated to interested colleagues for comments. Plans were initiated for an International Workshop to be held in November 1974. A weather observatory was established. In contrast to the drought of the 1972 monsoon season (49.0% of normal) the rainfall during the 1973 monsoon (June - October) was 8.0% above normal and fairly well distributed. The total for the year (April '73 - March '74) was 754.4 mm or 94.0% of normal. Since ICRISAT is located about midway between the Hyderabad and Sangareddy weather stations, the "normals" are taken as an average of these two stations.

1/ The following Farming Systems Support Staff have all made valuable contributions to the research reported in this publication.

S.K. Sharma	.. Sr. Research Technician	L. Mohan Reddy	.. Field Assistant
J. Hari Krishna	.. Research Associate	N.V. Subba Reddy	.. Field Assistant
S.N. Nigam	.. Research Associate	Iqbal Ahmed	.. Field Helper/Driver
R.C. Sachan	.. Research Associate	Rama Krishna	.. Field Helper
K.L. Sahrawat	.. Research Associate	Charles Menezes	.. Field Helper/Driver
Prem N. Sharma	.. Research Associate	Ramchandra Murthy	.. Field Helper
Piara Singh	.. Research Associate	Harbans Raj	.. Field Helper/Driver
Sardar Singh	.. Research Associate	K.K. Kanta Rao	.. Field Helper
Mrs. S. Nakra	.. Secretary	T. Somiah	.. Field Helper
K.Manohar Reddy	.. Field Assistant	M. Vidyasagar	.. Field Helper

The Farming Systems Staff acknowledge with thanks the excellent support in its research program of Messrs. E.W. Nunn, D.S. Bisht, B.K. Sharma and D.N. Sharma of the Division of Farm Operations & Development.

The following statements are based on the results and observations of research conducted during the season.

1. Intercropping

   a. Climate at the ICRISAT research site permits two distinct crop seasons - the monsoon or kharif season, typically from June through early October, and the dry or rabi season, October to the onset of hot summer in February. However, with indigenous tools and power, ground preparation necessary to plant may be difficult and sometimes impossible.
   Pigeonpea, a slow-starting plant, offers one kind of solution to that problem. It can be grown as an intercrop, planted at the same time as the kharif crop and left to make its main growth and production after the kharif intercrop is harvested in September or early October.

   b. In the pigeonpea - pearl millet intercropping experiments large yield differences due to planting patterns were observed. The planting patterns were (1) solid plantings with 4-rows of each crop 45 cms apart (2) alternate row plantings 45 cms apart and (3) alternate paired rows of pearl millet 22.5 cms apart in between pigeonpea rows 67.5 cms apart. In the latter system there was a crop row every 22.5 cms as compared to every 45 cms in treatments 1 and 2. The alternate paired row plantings consistently gave the highest yields of pearl millet in both the grain-fodder and fodder-grain systems. On black soils the pearl millet grain yields for treatments 1, 2 and 3 were 14.3, 16.9, and 27.9 q/ha, respectively. The pigeonpea yields were likewise significantly higher in the alternate paired row plantings. The average pigeonpea yields for treatments 1, 2 and 3 were 4.2, 6.5 and 9.0 q/ha, respectively. Although the general yield of pigeonpea was low due to a heavy pod-borer infestation, the response to intercropping was still apparent. It appears that the fast growing pearl millet is very compatible with the slow establishing and later maturing pigeonpea in the various alternate row plantings.

c. In the ragi-pigeonpea intercropping studies on the black soils, the ragi yields for treatments 1, 2 and 3 were 15.4, 17.3 and 26.1 q/ha, respectively. However, the ragi was later maturing than the pearl millet and thus more competitive with the pigeonpea, resulting in reduced yields of pigeonpea. The low stature mung bean and soybean also appeared to be compatible with the taller growing pigeonpea. However, due to disease and other factors the yields of mung bean and soybean were very low. Germplasm evaluation trials are being conducted on mung beans and soybeans as well as many other crops to find suitable germplasm to fit in with various intercropping patterns.

d. Intercropping systems would be difficult to manage in mechanized agriculture, but they appear to be well suited to the labor-intensive and animal power systems of the Semi-Arid Tropics. Further investigations are planned to develop various intercropping systems which could be useful to small farmers.

2. Relay cropping

a. Relay cropping is another practice designed to use the second season in the semi-arid tropics, another way of utilizing residual moisture left after the kharif crop. The term "relay" connotes the practice of planting the second crop before the kharif crop has been harvested.

b. There was no significant difference in the yield of chickpea and safflower when relay planted in standing sorghum, compared to plantings made at the same time in plots which had been fallowed during the monsoon season. Thus, the fallowing not only resulted in the loss of the monsoon sorghum crop but also resulted in an economic loss due to the cost of several tillage operations to control weeds during the monsoon season.

c. Relay planting of rabi crops in standing sunflower, appeared preferable to relay planting in sorghum. In the case of the sorghum there was considerable regrowth of the sorghum stubble after harvest, while in the case of sunflower the stubble died immediately and furnished no competition to the relay crop seedlings. Since maize, like sunflower, does not regrow when harvested at maturity, it will be used in the coming season for further relay planting investigations.

3. Response to Fertilization

a. In a black soil trial, sorghum and millets showed a marked response to nitrogen and phosphorus applications, during the monsoon season. In a rabi season trial, sorghum, pearl millet and setaria showed marked response to phosphorus applications in the red soil. There was no response to potassium or zinc in either the red or black soil sites during either the monsoon or post-monsoon seasons.

b. In the black soil watersheds severe nutrient deficiency symptoms were observed in areas where the surface soil had been removed. Problems were observed in three situations: (i) In areas where the top soil had been removed to elevate the experiment station boundary road, (ii) where field bunds were removed to restore the original lay of the land, and (iii) in severely eroded areas along old gullies. In areas where no nitrogen or phosphorus was applied at planting, the growth was severely stunted due to the lack of both nitrogen and phosphorous. In areas where nitrogen and phosphorus application were made at planting, zinc deficiency symptoms were observed. In areas of severe nutrient deficiency there was a marked synergistic effect with shootfly damage. The stunted nutrient-deficient seedlings remained in the seedling stage for a longer period and thus suffered greater damage by shootfly than did normal seedlings.

c. In a chickpea fertilization and inoculation trial there was a marked seedling response to nitrogen application on both the red and black soils. However, the magnitude of this response diminished and had practically disappeared by the flowering stage and there was no final yield response to the nitrogen application. Likewise there was no yield response to phosphorus application or added inoculum. Observations indicated that there were a substantial number of nodules even in the uninoculated soil, particularly in the black soil area. It is surprising to find this high degree of nodulation in the uninoculated treatments, since there is no recent history of chickpeas being planted in these areas.

d. Foliar applications of urea to chickpea at the pre-flowering stage showed no positive visual growth response or yield response.

4. Ratoonability of Pearl Millet

a. Pearl millet tillers profusely. When part of the plant is removed during the growing season, other tillers shoot upward. This characteristic permits the practice of ratooning. Numerous harvests can be taken from the same plants.

b. In the 1973 season a comprehensive trial was established to test the ratoonability of three pearl millet varieties in a series of multiple harvest treatments. In the red soil all three varieties reached the heading stage in 41 days and were then harvested for fodder. In a continuous fodder harvest system four additional fodder harvests were made at about 3 to 4 week intervals. Comparisons of grain yields in the different harvest systems indicated that the highest yield was obtained when the first crop was harvested for grain, with progressively lower yields after additional fodder harvests.

c. There was relatively little difference in ratoonability of the three pearl millet hybrids. All showed excellent regrowth when ratooned for fodder at heading stage. However, one of the disappointing features of all of the hybrids was the poor regrowth (ratoonability) after harvest of a grain crop. In the coming season a ratoonability screening trial is planned in cooperation with the crop improvement staff using a wide range of pearl millet and sorghum germplasm.

5. "Life saving" supplemental irrigation

During the 1972 monsoon season a 5 cm-irrigation was found to be very effective during the prolonged drought period. During the 1973 monsoon season the rainfall was about normal and no supplemental irrigation treatments were necessary on either black or red soil. During the post-monsoon (rabi) season, one 5 cm irrigation significantly increased the yield of both chickpeas and safflower on the red soil. Similar irrigation treatments gave a significant yield increase in chickpeas in the black soil but no response in the case of safflower.

6. Preliminary Root Studies

Roots of all major crops except setaria were found to penetrate to a depth of 180 cms in the black soil. Rooting depths in the red soil varied from 150 to 180 cms depending upon the nature of the "murrum" in the lower profile. The number of root segments per unit of soil was by far the greatest in the upper quarter of the root zone and decreased progressively at the lower depths. However, the lowest depth (135 to 180 cms) contained 5 to 8% of the total numbers of root segments. With receding moisture during the post-monsoon season, it is believed that the importance of roots at lower depth increases during the maturation period. In the coming season detailed studies are planned to investigate this point further.

7. Preliminary Soil Moisture Extraction Studies

During the monsoon season, in studies on moisture extraction at different fertility levels, it was observed that a nitrogen application increased the water uptake, particularly in pearl millet and sunflower on the red soil. In studies during the rabi season on moisture extraction by safflower planted on black soil at different dates, the earlier plantings appeared to have the ability to withdraw much more moisture from the profile than the later plantings.

8. Rainfall Patterns

The maximum one-hour rainfall intensity observed at ICRISAT during the past season was 43 mm/hr. Extreme variability was found to exist in single storm precipitation events, observed at closely spaced raingauges (exceeding 100% in variability). This observation results in special requirements regarding the intensity of the raingauge network in all studies on water utilization. Variability in space contributes to insecurity in farming and severely depreciates the value of weather predictions.

9. Runoff & Infiltration Patterns in Black-soil Watersheds

a. A total seasonal runoff of 45 mm was recorded for black soil watershed BW1 (average slope of the ridge and furrow system .6%). The surface runoff observed for watershed BW5B (average slope of the ridge and furrow system 1.8%) amounted to 122 mm. Therefore, the hypothesis, that ridge and furrow systems can be used to manipulate runoff and infiltration of precipitation under the conditions of the Semi-Arid Tropics, through varying the average slopes, seems justified and will be further investigated.

b. On the black soil there was no drainage problem even at the lowest average slopes of ridge and furrow systems tested (.6%). This was true notwithstanding a monsoon season characterized by several long-duration wet periods. Also, no "breakthroughs" across ridges occurred at the low grades under the rainfall intensities of the past season. The relationship between furrow slopes and infiltration will be further tested during the coming seasons.

c. The runoff observed from the bunded watersheds BW2 (traditional kharif cropping) and BW4 (kharif fallow) was 11 and 59 mm, respectively. These data give an indication of the crucial importance of vegetative cover in runoff processes. Although additional quantitative data need to be collected, there is considerable evidence that the field bunds provided a substantial "internal storage capacity", increasing infiltration over a relatively small portion of the total watershed.

d. The effect of the internal storage capacity created by bunds is indicated by a comparison of runoff from the black soil watersheds during five selected high intensity, long duration rainfall storms. These storms contributed about 1/4th of the total seasonal rainfall. The five storms caused only about 25% of the total seasonal runoff on watershed BW1, 64% on BW2, only 29% on BW3B, 68% on BW4 and 46% on BW5B. The internal storage capacity created by conventional bunds is apparently least effective during high intensity, long duration rainfalls.

e. Variations in infiltration of rainfall under different management systems could not be detected in soil moisture determinations. On all black soil watersheds the moisture present in the upper 180 cms of the profile was at a maximum in early November. Fallowing during the past season evidenced no substantial advantages over monsoon-cropped watersheds, in terms of moisture conservation, at the beginning of the rabi season.

10. Soil Erosion

The erosion observed on watersheds under a ridge and furrow system with an average slope ≤ 0.8% (BW1 and BW3B) was about 3 metric tons per Ha (T/ha) while on watersheds BW2 and BW4 with traditional bunded fields 2 and 4 T/ha were recorded respectively. At average ridge and furrow slopes ≥ 1.1% erosion appeared to be considerably increased. Average grades of ridge and furrow systems of 0.5, 0.6 & 0.8% have now been selected for further study during subsequent seasons.

11. Groundwater levels

The groundwater levels in the black soil watershed area, observed at a number of piezometers, increased by approximately 2 M, primarily during the latter half of the monsoon season. The general depth of the phreatic level below the soil surface in most of the watershed area would seem to exclude appreciable direct influences of the groundwater on the moisture status of the soil profile.

12. Grassed Waterways

Several grasses, tested in the drainage ways of watershed BW1, BW3 and BW5 showed considerable variation in original stand establishment, erosion resistance and contribution to forage production. Local grass sod proved superior in erosion protection; Dicanthium Annulatum and Cenchrus Ciliaris performed reasonably well. Additional work, particularly on stand establishment early in the monsoon is urgently required.

13. Water Storage & Utilization

a. Runoff water was collected in storage ponds in watershed BW3 and BW5A. The observed seepage losses ranged from 0.5-2.5 mm/day depending upon the water level in the tank. Evaporation from the storage pond was about 20% lower than evaporation observed from a standard (U.S.W.B. Class A) evaporation pan at the ICRISAT weather station. The total losses amounted to about 5 mm/day from August to January.

b. The harvested runoff water was recycled on the land during the rabi season (in the monsoon season there was no need for supplemental water). However, the response of rabi crops to supplemental water was disappointingly low this past season. About 6.7 ha in the BW5 watershed were provided with a 50 mm supplemental irrigation; only 1.4 ha of the BW3 watershed was supplementally irrigated.

c. A first approximation (uncertainly exists primarily with regard to the groundwater component of the water balance equation) of the "rainfall use efficiency" of some of the systems of farming monitored, resulted in a computed rainfall use efficiency of approximately 70% on watershed BW1 (double cropped on a monsoon ridge and furrow system at0.6% grade) and of less than 50% on watershed BW4 (kharif fallow, rabi cropped).

14. Crop yields on Watersheds

Production research on watershed-based farming systems indicated that in terms of total production the farming systems characterized by high levels of management and inputs were far superior to the traditional systems of farming. (A maximum yield of 44.1 q/ha of pearl millet in kharif and 23.0 q/ha of safflower in rabi was obtained from watershed BW3 versus a maximum yield of 12.8 q/ha of sorghum on watershed BW4). However, a much more critical analysis in terms of the economics of the different systems of farming will have to be made before improved and more stable systems can be selected. Such studies are planned for the 1974-75 season.

INTRODUCTION

The Farming Systems Annual Report is being written to provide a permanent record of the year's activities, data and observations mainly for the information of the Staff of ICRISAT. Since this in-service report will be condensed, edited and combined with other divisional reports for a printed report for the whole Institute, more details are recorded than would usually occur in an annual report. Also many preliminary observations are recorded which will need to be further tested before the information would be released for general distribution.

Establishment of the Agro-Meteorology Station and Weather

An Agro-Meteorology Station at ICRISAT was commissioned in June 1973. It is located at the top of the ridge of watershed BW-7 across the road from the Southwest corner of field B-8 (fig.1)[1/]. The choice of the site was made by the ICRISAT staff in consultation with Dr. C.R. V. Raman, Director, Agricultural Meteorology, Poona and the observatory also serves as one of the approximately 35 stations of the agro-meteorology network in India.

Mr. T.S. Govindswamy, Assistant Meteorologist of the Agricultural Meteorology Division at Poona assisted in the installation of the instruments. Mr. J. Hari Krishna was deputed to the Meteorological Office at Poona for a week's familiarisation training with the instruments and reporting forms.

1/ The figures referred to, follow the typewritten section of the report.

The following instruments have been set up at the Meteorological station:

1. Windvane for determining wind direction
2. Anemometer for measuring wind velocity
3. Microclimatic post for measuring temperature and humidity at various levels over the soil surface.
4. Soil and earth thermometers
5. Stevenson screen containing dry bulb, wet bulb, maximum and minimum thermometers
6. Dew gauge
7. Sunshine recorder
8. Self-recording raingauge
9. Ordinary raingauge
10. USA class A pan evaporimeter
11. Double size Stevenson screen for thermograph and hydrograph.

Electrically recording equipment for wind direction and wind velocity has arrived while equipment for radiation measurement has been ordered. These will be installed as soon as electrical power is available at the Agro-Meteorology station. A wiremesh fence has been constructed around the Meteorological Station. A Weather Information Board has been installed at the Site Office and the City Office where weather data are reported daily for the information of the Staff.

The monthly rainfall during the period of record (April 1973 - March 1974) and the values compiled as long term averages for Hyderabad have been given (table 1). The daily data during the monsoon season (kharif)[1/] have also been summarized (fig. 2).

Table 1 - Monthly rainfall in 1973-74 at ICRISAT and percent of average normal rainfall in the area.

Month	ICRISAT	% of normal	Normal Rainfall (mm)		
		Hyd.& Sang'dy	Hyderabad	Sangareddy	Mean of Hyd. & Sangareddy
April	-	-	24	24	24.0
May	3.0	11	30	23	26.5
June	62.4	54	107	124	115.5
July	161.0	99	165	178	171.5
August	230.8	147	147	165	156.0
September	68.9	38	163	199	181.0
October	216.4	324	71	63	67.0
November	10.6	45	25	22	23.5
December	1.3	22	6	6	6.0
January	-	-	2	9	5.5
February	-	-	11	11	11.0
March	-	-	13	12	12.5
Totals	754.4	94	764	836	800.0

In the past season the peak rainfall months have been August and October; normally July and September have the highest rainfall. The total annual rainfall is almost equal to what is normally expected. During the period of observation at the Agro-Met. observatory (June 1973 - March 1974) the maximum temperature recorded was 38.5°C (98°F) on March 18, 1974, while the minimum of 7.5°C (45.5°F) occurred on

[1/] In this report the terms monsoon season or "kharif" are used interchangeably for the rainy season. The words post-monsoon or "rabi" are also used interchangeably.

January 5, 1974. June was characterized by strong dry winds which caused crop damage, the maximum average wind velocity recorded over a 24 hr. period was 41 km/hr and occurred on June 15, 1973. Instantaneous velocities were in the order of 60 to 70 km/hr. The wind direction was primarily from West-North-West during June to October and from East-South-East after October. A maximum daily evaporation of 19.6 mm was recorded on June 19, 1973 while the total pan evaporation from June 15, 1973 to March 31, 1974 amounted to 1744 mm. Soil temperatures taken at depths of 100 and 150 cm ranged between 25°C (77°F) and 32°C (89.6°F). Small amounts of dew were recorded from October to January, a maximum value of .35 mm/night was recorded on November 8, 1973.

Farming Systems Program Document

A preliminary document was written to develop the frame-work for the Farming Systems Research Program at ICRISAT. This was the first attempt to bring together all facets of the Farming Systems Program. This write-up was circulated to the Program Committee of the Governing Board and to ICRISAT Research Staff in August. Many valuable comments were received; the document was revised in September and sent to interested colleagues for additional suggestions and discussion. A substantial number of those asked to comment responded with helpful advice; these comments and the results of this year's research will be used for an updated write-up. The task of development and reorientation of the research framework is considered a continuous process.

Preliminary Plans for the First ICRISAT Workshop

The first ICRISAT workshop on the Farming Systems Research Program will be held during November 18 to 21, 1974. The major objectives of the workshop are:

1. To outline the setting and problems related to farming systems in major areas of the Semi-Arid Tropics of the World.

2. To make a comprehensive review of relevant research information and research in progress in the major regions of the Semi-Arid Tropics.

3. To make a critical analysis of research needs including a suggested order of priorities.

4. To outline the delineation of responsibilities of ICRISAT in relation to national and regional programs.

Letters have been sent out to key individuals to obtain suggestions for possible participants in this workshop. In order to encourage discussion it is planned to limit the number of participants to 25. It is also planned to publish the proceedings of the workshop.

Farming Systems Research building

In late November a warehouse (D5) in the Industrial Estate at Patancheru was remodelled to provide temporary facilities for the Farming Systems Program. This includes an insulated air conditioned seed-cum-instrument room, office space, laboratory room and work room.

Farming Systems Seminar initiated

In addition to the Institute wide seminar series, the Farming Systems group initiated a seminar series in January 1974. The first seminar committee consists of Piara Singh, Chairman, R.C. Sachan and N.V. Subba Reddy.

Farming Systems working library

A small working library has been established for the convenience of the Farming Systems staff. This involves books on loan from the ICRISAT main library and some personal books provided by BAK and JK. The library committee consists of J. Hari Krishna, Chairman, Sardar Singh, S.K. Sharma and P.R. Murthy.

Slide set for briefing visitors

In November a slide set was established for briefing visitors in the Site Conference room. As new programs and information are developed the slide set is changed to keep the information current. (Slide sets have also been provided for RWC, JSK, EWN. C.F. Bentley and Representatives of the Ford Foundation and USAID). Illustrated talks on various ICRISAT programs were given at the Andhra Pradesh Agri cultural University, Osmania University, Hyderabad YMCA, Hyderabad Rotary Club and the University of California, Davis.

Plant Nursery established

Early in 1973 a small nursery was developed with the initial objective of producing ornamental trees and shrubs for campus landscaping. The activities have been expanded to include the following items: a nursery for establishing grasses for drainage ways, grasses for lawn development, horticultural trees and vines for the Farming Systems Program, and forest trees for windbreaks; the present nursery also includes pot cultures for the Crop Improvement Program and the production of quality vegetables for sale to ICRISAT staff.

OBJECTIVES

One of the three stated objectives of ICRISAT is "To develop Farming Systems which will help to increase and stabilize agricultural production by optimization of the use of natural and human resources in the seasonally dry Semi-Arid Tropics of the world". This objective forms the basic framework for the Farming Systems Research Program which is envisaged as being "resource centered" and "development oriented".

Water is the major constraint to increased and more stabilized agricultural production in the Semi-Arid Tropics. Alleviation of the effects of this barrier is the ultimate aim of the Farming Systems Program and was the central focus of activities during the past year. Thus, the basic objectives of each small-scale experiment or of the integrated watershed-based phase of the Farming Systems Program is to study means to make optimum use of the annual water resource while maintaining or improving the soil resource.

Temperature conditions of the Semi-Arid Tropics are generally favorable for a year-round growing season. However, only a small fraction of this growing season is used in traditional agriculture, due to the water constraint caused by erratic and seasonal rainfall. The aim of the Farming Systems Program is to develop management systems which will help to stabilize and improve agricultural production under the given rainfall conditions. The approach is to develop soil, water and crop management systems which will provide for optimum crop production starting at the onset of the monsoon (kharif) season and continuing as long as possible into the post-monsoon (rabi) season. Experimental approaches during the past year involved investigations of intercropping, double cropping, relay cropping and multiple harvest using many crops with a wide range of growth characteristics. During the past year the following crops were included: sorghum, pearl millet, pigeon pea, chick pea, ragi, setaria, sunflower, safflower, soybean, cowpea, mung bean and numerous grasses for erosion control and forage production in the grassed waterways. In the future the crop investigations will be increased to include horticultural, forest and vegetable crops as well as other agronomic and forage crops. Since the land capabilities of the soils in the Semi-Arid Tropics vary greatly, investigations will also include development of alternative, economically productive farming systems which will provide the best long term land use for each soil.

OBSERVATIONS ON MANAGEMENT OF RED AND BLACK SOILS

The following is a list of preliminary observations made during the growing season. It is recognised that further investigations and testing will be required before any conclusions can be drawn; these observations are recorded to help provide leads for future investigations.

Land preparation and planting

Preliminary observations indicate that the best time to prepare land for the next monsoon season is immediately after harvest of the previous crop. This tends to leave the land in the rough cloddy condition which seems to have many advantages from the standpoint of water conservation, prevention of wind erosion and moisture infiltration. In the black soils, the hard dry clods do not appear to cause problems during sowing because upon wetting and drying in the pre-monsoon showers, they crumble and slake down to form an excellent seed bed.

During the past season the planting operations on the red and black soil sites and the black soil watersheds were started at the onset of the monsoon during the period of June 6-11. During the week following planting there were light showers of a few mm every few days. A marked difference in the reaction of the two soils which would seem to have important implications was observed.

In the red sandy soils the intermittent small showers moistened the soil to a depth of 8 to 10 cms at an early stage. Thus all of the seed germinated, but because of the small total quantity of water available some seeds failed to emerge while others emerged and died during a week of high velocity winds and dust storms starting June 14. During the period of June 23-28, 29 mm of rain fell and the soil was moistened to over 15 cms depth. On June 28 and 29, all experiments on the red soil were replanted. With the residual moisture, plus subsequent rains on the evening of June 29 and 30, an excellent stand was obtained from the second planting.

In contrast, on most of the black soils, the light showers during the period of June 4-22 moistened only the surface 2 cms and between rains the surface dried out sufficiently so that the next shower did not penetrate beyond the original 2 cms. This process was repeated many times; however, the seeds were not moistened and did not germinate, and they therefore escaped the fate of those on the red soils. In both cases the seeds were planted about 5 cms deep. In one area of watershed 'E' the rainfall during the latter half of June was slightly greater and there was sufficient moisture penetration to reach the seed zone but not beyond it. These seeds germinated but were able to carry through a 7 day dry period without showing signs of stress. Thus in this case it appears that when the black soils are wetted to only a 5 or 6 cm depth, they retained enough soil moisture to maintain the seedlings through the seedling stage in spite of high velocity drying winds. It is recognized that these observations must be further checked, but from this experience with the black soils, the preliminary conclusion may be drawn that planting in the dry or slightly moist black soil during the early onset of the monsoon shows promise. This is fortunate because in the case of a heavy or prolonged rain the black soil would become too wet to plant and operations could be delayed for an extended period. The red soil will dry fairly rapidly after rain and allow planting relatively soon even when heavy or prolonged rains have occurred. Thus, our present observations indicate that in the red soil with its low water holding capacity, planting should be delayed until the soil has been moistened by the early monsoon rains to at least 20 to 25 cms depth.

Although these observations need further investigation, this year's planting experience has enriched the understanding with regard to these two soils. It is planned to study the weather data to determine the probabilities of droughts occurring just after the onset of the monsoon. This type of information will be obtained not only for Hyderabad but also for other areas of the Semi-Arid Tropics where similar soil conditions exist.

Wind and "sandblast" damage in red soils

This season also provided an opportunity to observe the problem of sandblast injury to crops in red soils and to compare the vulnerability of various species to sandblast injury. As discussed in the section above, the experiments in the red soils had to be replanted on June 29 due to the drought as well as sandblast injury during the June 14-22 windstorms. During this period there was a combination of high velocity winds and relatively low moisture reserves in the soil. However, in July a repeat of the sandblast injury occurred even though the soil moisture status was ample. The Farming Systems red soil experiments and the Crop Improvement red soil sorghum breeding experiments were planted on June 29. At the time of planting about 11 cms of soil had been moistened and almost daily rain occurred from June 30 thru July 8th; the total rainfall in this nine-day period was 96 mm. On July 9th, only one day after the rain stopped, heavy winds reoccurred and some sand movement was observed. This became progressively worse on July 10, 11 and 12 and by that date there was severe damage in both the sorghum breeding fields and on the south side of the Farming Systems red soil site. In both cases the plantings were made on top of low ridges which made the plants vulnerable to sandblast damage.

Observations on different species indicate that cowpeas and pigeon peas were the most severely damaged, followed by mung beans and soybeans. Pearl millet, ragi and sorghum leaves were injured, however, with these crops the growing point was usually below ground level and most plants recovered, although the growth was definitely delayed. Sunflower appeared to be the least affected of any species. The small weeds which emerged in the "wind shadow" on the east side of the low beds in the red soil Farming Systems site showed no injury, while weeds on the top of the bed or beyond the "wind shadow" showed severe injury. Severe injury was also noted in the sorghum breeding fields in which the rows were planted parallel to the wind direction. In another red soil field, a general crop of horsegram was planted which emerged during this same period. The crop was planted with the grain drill travelling around the field which gave opportunities to observe varying planting orientations and protective ridges as the drill turned at the corners. Again the "wind shadow" effect was very evident in the horsegram and a record of these observations is preserved in colored photographs. As a result of this experience, an experiment was designed and planted on July 12th with treatments involving flat planting, planting on ridges, and planting in the bottom of a lister furrow both perpendicular to and parallel to the prevailing wind direction. The experiment involved four crops: sorghum, pigeonpea, cowpea and mung bean. However, before the seedlings emerged the wind velocity had receded and no differences were observed from any treatment. It appears, however, from these observations and reports from other workers that planting on top of the ridges or beds should be avoided in the red sandy soils in this area. From the standpoint of wind damage, planting in the bottom of the lister furrow would be most advantageous. However, work in the Great Plains of Texas and Oklahoma indicates another hazard due to the possibility of washing from heavy rains or the filling of the furrow with sand during sand storms. Therefore the so-called "plateau planting" procedure for cotton and sorghum was developed in the Great Plains. It is planned to investigate this problem further in 1974 by similating the plateau planting procedure in shallow lister furrows.

Even though the wind velocity was the same, there was absolutely no sand-blast injury in the black soil plantings and no visual plant injury was observed due to the high wind velocities.

Land preparation and planting techniques for rabi crops after a kharif crop.

During the past season, rabi crops (safflower, chick pea and setaria) were easily established following sunflower by planting two weeks before the sunflower harvest (relay planting). When the sunflower was harvested, the stubble died and the sunflower did not compete with the rabi relay crops. However, in the case of monsoon sorghum and pearl millet, stubble regrowth took place and the stubble had to be uprooted and killed to avoid competition with the relay rabi crop. Thus the presently available varieties of sorghum and pearl millet appear to be poorly suited for relay cropping techniques.

In later trials in the watersheds, the land was disced and replanted to rabi crops. In fields where long stubbles were left, the seed bed preparation was difficult. In a few cases where the stalks had been cut just above ground level, land preparation was much easier. Another problem was encountered when heavy rainfall occurred immediately following a discing. In this case the sub-surface soil was very slow to dry out sufficiently to allow land preparation to be continued. Also, by the time the sub-surface soil had dried out sufficiently to facilitate tillage, the surface soil was too dry and cloddy to allow uniform germination. Based on these observations the following procedures will be investigated further in the black soil watersheds during the coming season:

1. Cut the sorghum and pearl millet stalks close to the soil surface at the time of physiological maturity of the crop.
2. Disc the stubble as soon as the stalks are removed and plant as soon as possible thereafter.

Again, just as with the monsoon crop, timeliness appears to be the key word in land preparation and planting for a second crop in black soils.

DISCUSSION OF RESULTS

The results of this year's investigations will be discussed under the following five headings:

1. Production Research in small-scale field experiments.
2. Root and Soil Moisture Studies on various crops.
3. Watershed Development
4. Research on Land and Water Management
5. Production Research on watershed-based farming systems.

PRODUCTION RESEARCH IN SMALL-SCALE FIELD EXPERIMENTS

For convenience of discussion the results will be grouped by subject matter areas. These may involve several experiments and numerous crops. In this manner it is possible to compare the response of various crops to a given set of treatments in both crop seasons.

For the purpose of this report the term "stalks" indicates harvest of the stem and leaves which remain after the grain heads have been removed. The term "green fodder" used in trials 1, 2 and 3 refers to the harvest of the whole plant at flowering stage. All fodder yields are given as fresh weights. All grain and stalk weights are given on an air-dry basis. All yields are recorded in quintals per hectare (q/ha). Values given are averages of four or more replicates. The dates of planting, emergence, thinning, heading and harvesting for the kharif and rabi seasons are given in tables 2 and 3 (pg. 14 and 15).

Intercropping Experiments

As a follow-up of last year's intercropping studies with pigeon pea two experiments were established. Trial 1 involved pearl millet and pigeon pea intercropping with the following four systems of harvest; GF, FG, FFG & FFF (G refers to a grain

Table 2 - Dates of Planting, Emergence, Thinning, Heading & Harvest during Kharif 1973.

FS Trial No.	Crop	Planting date	Emergence date	Thinning date	Flowering or Heading date	Harvest date
Red Soil						
1	Intercrop	June 29		July 16	Sept. 15	Oct. 20
2	Pigeon Pea	" 29	July 5	" 16		Nov. 28
3	Pearl Millet	" 29	July 2	" 16	Aug. 18	Sept. 14
4	Sorghum	" 29	July 3	" 16	Aug. 23	Oct. 5
5, 6 & 7	Sorghum	" 29	" 3	" 16	Aug. 20	Sept. 28
" "	Pearl Millet	" 29	" 2	" 16	Aug. 13	Sept. 7
" "	Sunflower	" 29	" 5	" 16	Sept. 4	Oct. 5
" "	Pigeon Pea	" 29	" 7	" 16	Oct. 20	Jan. 6
Black Soil						
1	Pearl Millet	June 26	June 29	July 7	Aug. 14	Sept. 20
1	Pigeon Pea	" 26	" 30	" 7	Oct. 24	Nov. 4
2	Intercrop	" 26	" 29	" 7	Aug. 30	Oct. 19
2	Pigeon Pea	" 26	July 1	July 7	Oct. 12	Nov. 30
3	Pearl Millet	" 26	June 29	" 7	Aug. 19	Sept. 20
4	Sorghum	" 26	June 30	" 7	Aug. 26	Oct. 7
5, 6 & 7	Sorghum	" 26	July 7	" 9	Aug. 29	Sept. 29
" "	Pearl Millet	" 26	June 30	" 9	Aug. 8	Sept. 9
" "	Sunflower	" 26	July 1	" 9	Oct. 6	Oct. 13
" "	Pigeon Pea	" 26	July 1	" 9	Oct. 10	Dec. 19
8	Pearl Millet	" 26	June 30	" 9	Aug. 10	Oct. 9

Table 3 - Dates of Planting, Emergence, Thinning and Harvesting during Rabi 1973-74

Trial No.	Crop	Planting date	Emergence date	Thinning date	Flowering or Heading date	Harvest date
Red Soil						
5 & 7	Chick Pea	Sept. 24	Sept. 29		Nov. 19	Jan. 22
5 & 7	Setaria	Sept. 24	Sept. 29		Nov. 20	Dec. 27
6	Chick Pea	Sept. 24	Oct. 1		Nov. 20	Jan. 28
6	Safflower	Sept. 24	Oct. 1		Dec. 24	Jan. 29
17	Chick Pea	Oct. 8	Oct. 13		Dec. 5	Jan. 12
18	Sorghum	Oct. 8	Oct. 14	Oct. 24	Dec. 10	Jan. 28
18	Pearl Millet	Oct. 8	Oct. 14	Oct. 24	Nov. 20	Jan. 11
19	Sorghum	Oct. 11	Oct. 17	Oct. 26	Dec. 10	Jan. 28
19	Pearl Millet	Oct. 11	Oct. 17		Nov. 21	Jan. 11
19	Setaria	Oct. 11	Oct. 17		Dec. 5	Jan. 11
22	Chick Pea	Nov. 6	Nov. 12		Jan. 2	Mar. 3
23	Chick Pea	Nov. 6	Nov. 12		Jan. 8	Mar. 3
Black Soil						
5 & 7	Chick Pea	Sept. 25	Sept. 29		Nov. 24	Jan. 1
5 & 7	Setaria	Sept. 25	Oct. 2		Nov. 27	Jan. 15
6	Chick Pea	Sept. 25	Oct. 2		Nov. 23	Jan. 28
6	Safflower	Sept. 25	Oct. 2		Dec. 12	Feb. 7
17	Chick Pea	Oct. 15	Oct. 21		Dec. 15	Feb. 14
18	Sorghum	Oct. 19	Oct. 25	Nov. 16	Jan. 5	Feb. 18
18	Pearl Millet	Oct. 19	Oct. 25	Nov. 16	Dec. 17	Feb. 18
19	Sorghum	Oct. 15	Oct. 27	Nov. 16	Jan. 6	Feb. 18
21	Mixed	Oct. 19	Oct. 22	Nov. 16	Dec. 18	-
24	Chick Pea	Oct. 19	Oct. 25		Dec. 11	Feb. 6

harvest and F refers to a fodder harvest). In all these systems solid plantings with 4-rows of each crop 45 cms apart were compared to alternate row plantings 45 cms apart and alternate paired rows of pearl millet 22.5 cms apart in between pigeonpea rows 67.5 cms apart (Figure 1).

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M         M         M         M         P         P         P         P    Solid
M         P         M         P         M         P         M         P    Alternate rows
M    M    P    M    M    P    M    M    P    M    M    P    M    M         Paired rows
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Figure 1. Row layout for methods of planting in intercropping experiments. P indicates row in pigeonpea; M refers to millet. In trials with other crops, the companion was planted where pearl millet is shown in this illustration.

Note: In paired rows system, there is a row of one crop or the other every 22.5 cm. Row spacings in solid or alternate rows are 45 cm apart.

The grain, stalk and fodder yields given in table 4 are on an area basis for each crop so the totals given for each crop must be added together in order to get the total yield for the intercropping system.

The alternate paired row plantings consistently gave the highest yield of pearl millet in the grain-fodder system as well as in the various fodder-grain systems. In many cases the yield was about double that of the solid plantings. The yields of alternate row plantings at 45 cms were significantly higher than those of the solid plantings in most of the harvest systems. The pearl millet grain yield for treatments 1, 2 & 3 was 14.3, 16.9 and 27.8 q/ha, respectively.

The pigeonpea yields were significantly higher in the alternate 45 cms rows compared to solid planting and the yield in the alternate paired-row plantings was significantly higher than that of the alternate row plantings. The average pigeonpea yields of the four harvest systems for treatments 1, 2 & 3 were 4.2, 6.5 and 9.0 q/ha, respectively. In other words, the yield of the alternate paired rows was twice that of the solid plantings. As in the case of other experiments in the black soils, the general yield for pigeonpeas was low due to a heavy pod borer infestation. In spite of this, the overall increase in yield from intercropping is very apparent. It appears that the fast growing pearl millet is very compatible with the slowly establishing and late maturing pigeonpea. This was most noticeable in the early stages as shown by the green fodder harvested on August 14 (table 4). The fodder yields for treatments 1, 2 & 3 were 66, 102 and 151 q/ha, respectively.

Table 4 - Yields of Ratooned Pearl Millet and Pigeonpea Intercropped by Three Planting Systems. Black soil. Hyderabad 1973

	AUGUST	SEPTEMBER			OCTOBER		NOVEMBER			Pigeon-
	Fodder	Fodder	Grain	Stalk	Fodder	Grain	Fodder	Grain	Stalk	pea
GRAIN-FODDER										
Solid			14.3	28.1	14.4					4.0
Alternate			16.9	32.2	15.4					6.0
Paired rows			27.8	49.8	29.2					7.7
F Value			25.0	12.7	19.1					
LSD (05)			5.0	11.1	6.5					
FODDER-GRAIN										
Solid	65.8					5.1				4.1
Alternate	101.7					5.6				5.9
Paired rows	151.3					8.2				8.3
F Value	28.1					75.0				
LSD (05)	27.8					0.7				
FODDER-FODDER-GRAIN										
Solid	65.8	27.9						1.8	6.6	4.9
Alternate	101.7	39.4						2.0	6.9	6.5
Paired rows	151.3	66.1						4.1	10.1	10.0
F Value	28.1	50.0						23.3	4.1	
LSD (05)	27.8	9.8						1.0	NS	
FODDER-FODDER-FODDER										
Solid	65.8	27.9					11.6			3.9
Alternate	101.7	39.4					17.2			7.3
Paired rows	151.3	66.1					28.8			9.9
F Value	28.1	50.0					6.5			
LSD (05)	27.8	9.8					11.8			

For intercropping pattern, see fig. 1.

Varieties: Pearl millet, HB-3; Pigeonpea, Pusa Ageti

Fertilizer treatment: 205 kg/ha of 28-28-0 at planting plus 42 kg/ha of nitrogen at first harvest or a total of 100 kg of nitrogen and 25 kg of phosphorus.

In another trial pearl millet J 1270 was intercropped with pigeonpea and harvested in a FFG harvest system, (table 5). Again, as was true with HB-3 in table 4, alternate row planting 45 cms apart was consistently better than the solid row planting in both soils. Likewise, the yields of alternate paired row plantings were about double those of the solid plantings. The pigeonpea yield in alternate row planting was also significantly higher than in solid planting in both soils, and the alternate paired-row yields were higher than those of the alternate single rows of 45 cms. The general yield level of pigeonpeas on the black soil was consistently lower than that observed on the red soil due to a heavy infestation of pod borer in the black soil. This is the reverse of what was expected, since the general growth pattern of pigeonpea on the black soil was far superior to that observed on the red soil. Additional studies are being conducted involving a new upright pigeonpea variety (Hy-3) obtained from Dr. N.G.P. Rao.

Intercropping studies of pigeonpea were carried out with four additional crops; mung bean, soybean, sunflower and ragi (tables 6A & 6B). The general yield level of mung beans was low in both soils due to the presence of yellow virus disease. In the soybeans, general growth conditions were quite good, particularly in the black soil. However, the final yield was low due to seed deterioration because of rains during the maturation period (table 6A).

Excellent yields of ragi were obtained on both soils, particularly in the paired row plantings. The competitive effect of ragi upon the pigeonpea plant was apparent, especially on red soil, where the pigeonpea yield was only about half of the yield of pigeonpea in the soybean and mung bean systems. The increased yields of both crops in the alternate paired row systems appear to be due to the greater plant density compared to the solid planting or alternate 45 cms row systems. In treatment 3

Table 5 - The effect of 2 methods of intercropping of pigeonpea (Pusa Ageti) and pearl millet (J 1270) compared with solid planting of each crop upon the yield of pigeonpea and pearl millet in a (FFG) harvest system in red and black soil. (FS Trial 2 kharif 1973 - all yields in q/ha).

Intercropping pattern[1/]	Pearl Millet Intercrop yield				
	Green Fodder	Green Fodder	Ratooned Grain	Ratooned stalk dry	Pigeonpea Intercrop
Red Soil					
1. Solid planting	129.9	70.8	4.5	9.0	8.8
2. Alternate row planting	183.3	75.7	5.1	9.6	10.6
3. Alternate paired rows of Pearl Millet	291.6	140.3	8.3	15.6	13.5
F Value	17.9**	23.3**	22.8**	99.7**	59.3
LSD (05)	66.7	27.8	1.4	1.3	1.0
Harvest date	Aug.9	Aug.30	Oct.20	Oct.20	Nov. 27
Black Soil					
1. Solid planting	122.7	61.1	2.4	9.0	2.3
2. Alternate row planting	137.2	68.2	2.5	10.3	3.1
3. Alternate paired rows of P. Millet	221.3	110.4	4.0	15.2	5.4
F Value	62.6	48.2	25.0	1.5	73.3
LSD (05)	23.5	13.3	0.2	N.S.	0.7
Harvest date	Aug.20	Sept.3	Oct.19	Oct.19	Nov. 30

1/ Intercropping patterns (see figure 1).

Table 6A - Yields of Four Intercrop Combinations by Method of Intercropping with Pigeonpea. Black soil. Hyderabad 1973.

	Solid	Alternate rows	Paired rows	F. Value	LSD (05)
Mungbean-Pigeon					
Mungbean	1.7	1.8	2.7	19.3	0.4
Pigeonpea	3.8	4.4	6.8	25.0	1.1
Soybean-Pigeonpea					
Soybean	3.9	4.8	7.6	10.3	2.1
Pigeonpea	3.9	4.9	6.5	14.0	1.2
Ragi-Pigeonpea					
Ragi	15.4	17.3	26.1	108.0	1.9
Pigeonpea	3.9	4.9	8.2	52.5	1.1
Sunflower-Pigeonpea					
Sunflower	10.1	11.9	23.1	163.0	1.9
Pigeonpea	2.5	3.0	4.7	6.7	1.6

Table 6B - Yields of Three Intercrop Combinations by Method of Intercropping with Pigeonpea. Red Soil. Hyderabad 1973.

	Solid	Alternate row	Paired row	F.Value	LSD (05)
Mungbean-Pigeonpea					
Mungbean	2.1	2.3	4.0	13.3	0.9
Pigeonpea	9.0	11.0	16.7	44.3	2.1
Soybean-Pigeonpea					
Soybean	3.4	3.7	6.7	27.0	0.3
Pigeonpea	7.8	14.4	19.8	101.3	3.7
Ragi-Pigeonpea					
Ragi	10.1	16.4	24.6	73.0	5.2
Pigeonpea	5.1	5.5	8.5	57.2	1.5

For intercropping method pattern, see fig. 1
Harvest dates:
Red Soil - Mungbean, Aug. 27; soybean, Oct.20; ragi, Oct. 15; Pigeonpea Nov.28
Black soil - " " 27; " " 10; " " 20; " " 30, - Sunflower Oct. 19.
Fertilizer Treatment: All crops received 205 kg/ha of 28-28-0 at planting or a total of 100 kg of nitrogen and 25 kg of phosphorus.
Note: Red Soil Expt. also included sunflower-pigeonpea system, but sandblast injury to pigeonpea was so severe that yields were not included in the analysis.

the average row spacing of pigeon pea was 67.5 cms compared to 90 cms in treatments 1 and 2. The average row width of the intercrop was 33.75 cms or an actual row spacing of 22.5 and 45 cms.

A search is underway for better adapted mung bean and soybean varieties which can be grown as an intercrop with the slow growing pigeon pea. Observations from the past two years indicate that intercropping systems with pigeon pea have great promise for increasing the total yield per hectare over that of the solid planting systems. The intercropping system would be difficult to manage in mechanized agriculture, but appears to be well suited to the labor intensive, animal power systems of the Semi-Arid Tropics.

Relay cropping of rabi crops in kharif sorghum

An experiment was established to determine the optimum time of "relay"1/ sowing of two rabi crops in relation to harvest time of CSH-1 sorghum. In order to evaluate the competitive effect of the sorghum plant upon the young seedling before the sorghum was harvested, comparable plantings were made in an area which had been "fallowed"2/ all during the kharif season. There was no significant difference in yield of chick pea or safflower planted following sorghum vs plantings in a fallowed area in either the red or black soil (table 7a). The fallowing not only resulted in a loss of a crop season (41.6 or 34 q/ha of sorghum in the red and black soil, respectively) but it also resulted in a further economic loss due to the cost of several

1/ The term "relay cropping" as used in this report indicates the planting of a second crop in an area at some time before the first crop grown in that area is harvested.

2/ "Fallowing" describes a practice of not growing a monsoon crop in an area in an effort to conserve moisture for a rabi crop. The land is normally cultivated repeatedly to control weeds.

tillage operations to control weeds during the monsoon season. The fallowed area was also more vulnerable to erosion due to the lack of vegetative cover on the land during the heavy monsoon rains.

Since the rainfall distribution during the monsoon season was relatively good, a planned supplemental irrigation for treatment 2 in sorghum, was not applied. However, one 5 cms application of supplemental water was applied to safflower and chickpea on November 26 in the red soil and on December 3 in the black soil. In the red soil, there were marked visual differences in plant vigor and a significant yield response following this supplemental irrigation in both the chickpea and safflower. In the black soil there also was a visual vegetative response and the chickpea yield increase was almost significant. There was no increase in safflower yield due to the supplemental irrigation. The lack of response on safflower in the black soil is understandable since it is a deep rooted plant, the black soil has a high water holding capacity and the soil moisture status at the beginning of the crop season was good.

The safflower and chickpea yields were not influenced by the time of planting in relation to the sorghum harvest (table 7b). This is understandable as the effective date of emergence was not far different in the a, b, c and d treatments. Treatment 'a' was planted in dry soil 2 weeks before the harvest of sorghum and did not germinate until the first rains came at the time of the 'b' treatment planting. Thus, it was not possible to fully evaluate the effect of the sorghum plant competition on the second crop seedlings when planted prior to the sorghum harvest due to the rainfall distribution. The interaction of Previous crop x Dates was non-significant.

Similar trials were established in watersheds BW1, BW3 and BW5 in the standing kharif sorghum crop. Again there was no significant difference between the four time of planting treatments (table 8). Yields of safflower up to 23.5 q/ha and chickpea

Table 7 - The effect of time of relay planting upon the grain yield of rabi chickpea (BEG-482) and safflower (S-11) following kharif sorghum with and without 5 cm of supplemental water to the rabi crop Vs fallow planting in red and black soils (FS Trial 4 kharif & rabi - all yields in q/ha).

(Table 7a)

Previous Crop during monsoon[1/]	Mean of yields from treat. a - d			
	Safflower		Chickpea	
	Red	Black	Red	Black
1. Sorghum	10.8	12.8	3.9	8.6
2. Sorghum (5 cm of supplemental irrigation to safflower & chickpea on Nov. 26 in red soil & Dec. 3 in black soil).	12.4	12.7	5.8	10.8
3. Fallow	11.0	15.1	3.8	8.2
F Value	10.0*	1.2	7.9*	5.0
LSD(05)	0.7	N.S	1.0	N.S

1/ No irrigation applied to sorghum. The yield of monsoon sorghum crop (Rep.1-3 was 41.6 q/ha in the red soil and 34.0 q/ha in the black soil. The stalk yields of red and black soils were 50.0 and 59.1 kgs /ha, respectively.

(Table 7b)

Time of planting of safflower and chickpea in sorghum and fallow areas[2/]	Mean of yields from treatment 1, 2 & 3			
	Safflower		Chickpea	
	Red	Black	Red	Black
a. 2 weeks before harvest of sorghum	12.0	14.2	4.1	9.6
b. 1 week " " " "	11.0	14.0	5.3	9.4
c. Immediately after harvest	11.5	14.2	4.2	8.2
d. " " "	11.0	11.9	4.3	9.6
F Value	0.8	1.9	3.1*	0.5
LSD (05)	N.S	N.S	0.7	N.S

2/ The time of planting of relay rabi was determined by the estimated date of sorghum harvest. Treatment c & d were planted immediately after harvest. In treatments a, b & c sorghum stubble was removed by hand. In Treatment "d", the stubble was left in place but regrowth was removed by hand.

Table 8 - The effect of relay planting upon the grain yield of rabi chickpeas (BEG-482) and safflower (S-11) following Kharif sorghum (CSH-1) in Watersheds A, C & E* (FS Trial 4 kharif and rabi - all yields in q/ha).

Time of relay Planting of Chickpea & Safflower in kharif Sorghum[1/]	Safflower Yield			Chickpea Yield		
	Ws BW1	Ws BW3	Ws BW5A	Ws BW1	Ws BW3	Ws BW5A
1. 2 weeks before harvest of sorghum[2/]	15.1	8.3	6.9	8.9	12.2	8.7
2. 1 week " " " "	23.5	7.7	9.1	11.2	9.5	8.9
3. Immediately after " " "	18.1	8.2	10.2	11.6	12.6	9.3
4. " " " " "	15.5	10.5	7.2	9.2	10.5	8.6
F Value	4.7	2.8	2.3	0.8	0.9	1.5
LSD	5.7	N.S	N.S	N.S	N.S	N.S

1/ The average grain yield of kharif sorghum (CSH-1) in watersheds A, C & E* was 34.1, 37.6, 27.3 q/ha respectively. The average air dry sorghum stalk yield for watershed A, C & E* was 55.4, 63.1 and 48.4 q/ha, respectively.

2/ The time of planting of relay rabi was determined by the estimated date of sorghum harvest. Treatments c & d were planted immediately after harvest. In treatments a, b & c sorghum stubble was removed by hand. In treatment d, the stubble was left in place but regrowth was removed by hand.

* Watersheds A, C & E have been renamed BW1, BW3 and BW5A, respectively.

upto 12.6 q/ha were obtained. It is planned to repeat this experiment next year to get more information on the competitive effect of the kharif crop on the rabi crop seedlings. However, it is encouraging to observe relatively little difference due to time of rabi plantings, as it allows one to adjust the rabi plantings to the rainfall pattern any time during the last few weeks before harvest.

In trials 5, 6 & 7 (tables 9, 11 & 20) relay-plantings of setaria and safflower were made in standing sunflower 2 weeks before harvest while chickpea was relay planted in sorghum 2 weeks before harvest. This year's experience indicates that sunflower as a kharif crop lends itself better to relay planting than sorghum as a kharif crop, since sunflower stubble does not regrow. In the case of sorghum, however, the regrowth of the stubble competes with the relay rabi crop seedling for moisture during its establishment. Since maize like sunflower does not regrow when harvested at maturity, it will be used in the coming seasons for further relay planting investigations.

Methods of Planting

During the monsoon season a trial was established to observe the difference between ridge and flat plantings on four crops at a low and at an adequate level of nitrogen (table 9). In the black soil, sorghum and pearl millet yields showed a significant response to nitrogen application; however, there was no significant response to nitrogen in the red soil where the general yield level of sorghum was high (upto 60 q/ha). There was no response to nitrogen application in either the pigeonpea or sunflower on the black soil or on the red soil.

There was no significant yield difference between ridge and flat planting in any crop on either red or black soil. Likewise, the interaction between N and method of planting was non-significant. Reasonably well distributed rainfall and problems in maintaining differential drainage conditions between the ridged and flat treatments on relatively small plots are probable reasons for the lack of a yield response. A visual difference at the seedling stage was observed in the red soil due to "sandblast" injury during high velocity wind storms (July 9 to 12). There was more sandblast injury to the seedling plants on ridges as compared to flat-planting. This was particularly noticeable in pigeon peas which were more vulnerable to sandblast injury than the other three crops. The average pigeon pea stand counts taken on July 15 for treatments 1, 2, 3 & 4 were 21, 30, 20 and 29 respectively. Thus, in the two flat-planted treatments (No. 2 & 4) there were 44% more plants than in the ridge-planted treatments (No. 1 & 3). This indicates a considerably greater stand loss due to sandblast damage on the ridges as compared to the flat plantings.

As a result of these and other observations it appears inadvisable to plant on pre-formed ridges in red sandy soil at the beginning of the monsoon season. If flat plantings are made on the graded contour, the furrows and ridges can be established by the first cultivation to provide improved water infiltration and runoff and erosion control. (For further discussion on this subject see the section entitled "Wind and Sand blast damage on red soils", pg. 10).

The general yield level of pigeon pea was low, especially on the black soil due to a heavy infestation of pod borers. The average sunflower yield was 17 q/ha on the black soil which was 58% above that of the red soil.

In the sunflower trial area a relay planting of setaria was made about two weeks before the sunflower was harvested. There was no effect of the residual fertilizer treatment upon setaria on either soil. The average setaria grain yield on the red and black soil was 7.2 and 14.6 q/ha, respectively. The greater yield in the black soil appeared to be due to the greater water availability as compared to the red soil. Chick peas were planted as a relay crop in the sorghum experiment. The average chick pea yield in the red and black soil was 5.0 and 9.8 q/ha, respectively.

The chick peas and setaria were both grown on residual moisture and residual fertilizers remaining after the previous crops. In the pearl millet there was slight plant regrowth and a second grain harvest was made. The grain yield in the second harvest in the red and black soil was only 2.4 and 1.5 q/ha, respectively.

During the rabi season an experiment was established using sorghum and pearl millet to compare paired rows with single row plantings under both ridged and flat conditions (table 10). There was no difference in grain and stalk yield of either crop between paired row and single row plantings. However, there was a difference between ridge planting and flat planting in sorghum yield on the red soil (table 10b). This difference appeared to be a reflection of the difficulty of planting the paired row treatment on the edges of the narrow, newly formed ridges. However, there was no difference in pearl millet yield in the red soil and on the yield of either pearl millet or sorghum in the black soil as a result of ridge or flat planting.

Fertilization Experiments

Fertilization trials were conducted during the kharif and rabi seasons on a number of crops on the same red and black fields which were used in 1972, as well as in the research watersheds.

In the black soil, sorghum and millet showed a marked seedling response to both phosphorus and nitrogen, and there also was a significant yield response at harvest time (table 11). In the red soil, the general yield levels of sorghum were high with top yields of 57.5 q/ha and there was no yield response to any nutrient. It is thought that the lack of response on red soil may be due to the fact that this experiment was located at a place which had been uniformly fertilized with nitrogen and phosphorus last year in a soybean intercropping trial. It is interesting to note that in case of sorghum, the yields on the red soil were substantially higher

Table 9 - The effect of method of Planting and nitrogen application upon the grain yield of Sorghum (CSH-1), Pearl Millet (HB-3), Sunflower (EC68415) and Pigeon Peas (Pusa Ageti) on red and black soil (FS Trial 5 kharif - all yields in q/ha).

No.	Method	Fertilization[1/] N	P	Yields in Red Soil: Sorgh.	Pearl Millet	Sunf.	P.Pea	Yields in Black Soil: Sorgh.	Pearl Millet	Sunf.	P.Peas
1	Ridge	22	25	53.7	36.1	11.1	9.3	35.2	28.1	16.3	3.6
2	Flat	22	25	56.6	35.0	11.4	9.8	33.7	29.0	17.6	3.8
3	Ridge	80	25	60.2	34.0	10.1	10.8	39.1	38.6	16.5	4.5
4	Flat	80	25	60.6	36.1	10.4	11.7	41.4	36.5	17.4	4.8
	F Value			2.9	0.6	3.1	2.6	3.2	6.0	0.5	7.3
	LSD (05)			N.S	N.S	N.S	N.S	6.1	7.0	N.S	0.6

1. All treatments received 22-25-0 (124 kgs/ha of 18-46-0) at Planting in a band 5 cm to one side of the seed. Treatments 3 & 4 also received 58 kgs/ha of N as Ammonium sulfate broadcast just prior to planting.

Table 10 - The effect of paired row plantings (20-70 cm) & (25-65 cm) & a single row on 90 cm centers Vs 45 cm single spaced and a comparison of ridge Vs flat planting of paired rows with sorghum (CSH-1) & pearl millet (HB-3) on red & black soil (Trial 18 rabi - all yields in q/ha).

Row widths	Sorghum Yield: Grain Red	Grain Black	Dry Stalks Red	Dry Stalks Black	Pearl Millet Yield: Grain Red	Grain Black	Dry Stalks Red	Dry Stalks Black
Paired 20 & 70 cm	39.4	31.5	38.4	25.4	16.1	12.9	48.0	24.6
Paired 25 - 65 cm	36.2	31.8	38.4	25.3	15.6	12.0	45.5	25.9
Single 90 cm	36.7	32.6	35.8	24.8	16.9	12.6	46.4	26.5
Single 45 cm*	44.0	32.0	47.5	27.3	17.4	9.4	52.0	20.9
F Value	1.1	0.1	1.8	0.1	0.2	0.2	0.2	
LSD (05)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	
Paired rows Ridge Vs Flat								
Ridge	34.5	32.0	35.2	25.2	15.8	12.0	45.2	24.5
Flat	40.4	31.9	39.5	25.1	16.7	13.0	48.0	26.9
F Value	56.0	0.1	16.5	0.1	0.3	0.5	1.2	19.5
LSD (05)	2.6	N.S	3.0	N.S	N.S	N.S	N.S	5.3

*45 cm single row was used as a control and was not included in the analysis of variance.

than those on the black soil. However, in the case of sunflower and pearl millet the opposite was true. During a prolonged rainy period the sorghum plants in the black soil were noticeably affected by wet soil and shallow groundwater table conditions, while the sunflower and pearl millet appeared to be less affected.

There was no consistent response to either nitrogen or phosphorus in the sunflower and pigeon pea trials (table 11). The sunflower yield on the black soil was 16.8 q/ha which was 88% above the yield on the red soil. The general yield level in pigeon peas was poor, particularly in the black soil due to an extremely heavy infestation of pod borers.

There was no visual seedling response or yield response to potassium or zinc on any crop in the red and black soil sites.

In the sunflower fertilizer trial, a relay planting of setaria was made. The setaria was planted about two weeks before the sunflower was harvested. Sunflower appears to be well adapted to relay planting; i.e. no regrowth of the stubble occurs after the sunflower plant is harvested. The setaria showed no significant response to any of the residual fertilizer treatment applied to the sunflower. No fertilizer was applied to the setaria. The average grain yields on the red and black soil were 5.4 and 16.1 q/ha, respectively. The setaria variety used was H-1 which flowered in 60 days in the red soil and in 63 days in the black soil.

Relay plantings of chick pea were made in the standing sorghum crop about two weeks before the sorghum was harvested. One problem encountered in relay planting in sorghum was that there was regrowth of the sorghum stubble, thus competing with the chick pea seedlings. In order to eliminate this competition the sorghum stubble was removed by hand, a very time consuming job. The average grain yield of the chick pea following sorghum on the red and black soil was 5.8 and 12.0 q/ha, respectively. The chick pea variety used was BEG 42 which flowered in 57 days on the red soil and in 61 days on the black soil.

Table 11 - The effect of N,P,K & Zn application upon the grain & stalk yield of sorghum (CSH-1) and pearl millet (HB-3) and upon the grain yield of sunflower (EC68415) and pigeon peas (Pusa Ageti) on red and black soils (FS Trial 7 kharif - all yields are in q/ha).

	Fertilization[1/]				Sorghum		Pearl Millet		Sunflower	Pigeon Peas
					Grain	Stalk	Grain	Stalk	Grain	Grain
	N	P	K	Zn	Yield in red soil					
1.	0	25	0	0	46.2	48.2	32.0	41.0	9.3	8.8
2.	40	25	0	0	56.0	51.6	35.0	49.0	10.3	8.6
3.	80	25	0	0	56.8	54.3	35.3	48.5	9.4	10.3
4.	120	25	0	0	57.5	57.7	33.0	51.4	7.9	11.3
5.	120	0	0	0	51.4	44.8	37.5	54.0	7.5	7.3
6.	120	25	50	0	57.1	60.2	36.0	51.0	8.3	7.0
7.	120	25	50	10	57.5	57.5	31.5	51.0	9.7	8.6
	F Value				1.6	3.0	1.5	2.7	7.0	7.2
	LSD (05)				N.S.	9.4	N.S.	7.4	1.2	1.7
	N	P	K	Zn	Yields in black soil					
1.	0	25	0	0	27.8	76.6	33.3	59.8	18.8	3.2
2.	40	25	0	0	35.0	93.3	40.1	76.0	17.9	5.1
3.	80	25	0	0	36.3	75.4	43.4	86.4	16.6	4.4
4.	120	25	0	0	40.1	91.2	41.7	80.2	14.3	5.5
5.	120	0	0	0	24.4	78.3	33.1	64.8	15.1	4.6
6.	120	25	50	0	45.0	90.6	42.0	83.7	16.8	5.1
7.	120	25	50	10	46.4	91.8	41.5	77.5	17.2	5.1
	F value				8.9	3.2	5.3	11.1	3.4	4.2
	LSD (05)				8.2	13.5	5.4	8.7	2.5	1.1

1/ All the phosphorus and 22 kgs/ha of the nitrogen was applied at planting in a band 5 cm to one side of the seed as 124 kgs/ha of 18-46-0 in treatments 2, 3, 4, 6 & 7. (Treatment one was applied as 335 kgs/ha of granular superphosphate (0-17-0) and treatment 5 as 105 kgs/ha of ammonium sulfate. The K as potassium chloride, the Zn as Zinc sulfate and the balance of the N as ammonium sulfate was broadcast and disced just prior to planting.

In the pearl millet there was mediocre stubble regrowth and a second grain harvest was made. The yields, however, were disappointingly low, ranging from 1.3 to 2.3 q/ha.

During the rabi season a fertility trial was conducted involving sorghum, pearl millet and setaria. There was a marked seedling response and final yield response to phosphorus in the case of sorghum, pearl millet and setaria on the red soil (table 12). In most cases there was response to nitrogen, but in no case was there any visual or yield response to potassium or zinc on either soil.

The general yield level of pearl millet was outstandingly high for the rabi season (upto 32.7 q/ha). Normally the seed set in pearl millet is low during the rabi season due to cool weather conditions.

Top soil removal accentuates nutrient deficiencies

The black soil watershed areas afforded an excellent opportunity to observe nutrient problems due to disturbances of the soil profile under the following conditions:

a. Removal of top soil with a "dozer" to elevate the Experiment Station boundary road.

b. Removal of old field bunds to restore the original lay of the land

c. Reclamation of severely eroded areas near and in old gullies.

In all cases severe nutrient deficiencies occurred. Since phosphorus and nitrogen were applied at planting, zinc was the most prevalent deficiency observed. However, in a few areas at the beginning of the row where the operator was late in turning on the NP fertilizer, severe seedling growth reduction occurred due to the lack of N and P. A zinc foliar application (0.5% solution at the rate of 200 liters/ha) was applied immediately to help correct the zinc deficiency. Many of the problem areas later showed severe nitrogen deficiency while normal growth was observed in non-disturbed areas. The most severe zinc deficiency occurred in the area near the boundary road and in the eroded sloping areas in watershed BW5. There also was a marked "synergetic" effect with shootfly damage. The stunted zinc deficient seedlings remained in the vulnerable seedling stage for a longer period and were severely damaged. In the zinc deficient areas a much larger percentage of the plants were damaged by shootfly than in "normal" areas.

On the basis of this experience, an observational fertilizer experiment (FS trial 16) involving rates of nitrogen, phosphorus, zinc and potassium was established in an area where severe deficiencies were observed earlier. In these experiments the zinc rates used were 0, 10 and 20 while the phosphorus rates were 0, 25 and 50 (0, 57 and 114 kgs/ha of P_2O_5). Visual observations and seedling growth response indicated severe phosphorus deficiency in all crops (sorghum, pearl millet and sweet maize) and a marked zinc deficiency in the sweet maize. In all cases, however, there was no visual growth difference between 10 and 20 kgs/ha of zinc or 25 and 50 kgs/ha of P, thus indicating that a standard application of 10 Zn broadcast and 25P band placed is sufficient even for the eroded or disturbed areas.

Another small observational trial (FS trial 21) was established where an old field bund had been removed in the land planing process. In this trial single row observational plantings of 8 crops were made. Some crops showed a very marked visual response to phosphorus applications while others showed practically no response. A visual ranking of the magnitude of the phosphorus response is as follows: Sorghum = Sunflower > Pearl millet > Setaria > Sweet maize > Safflower and Chick pea = Pigeon pea. Again marked zinc deficiency symptoms were observed in the sweet maize seedlings but were not seen on any other crop.

Nitrogen top dressing in the watersheds

In the black soil watersheds a uniform application of 57-25-0 (205 kgs/ha of 28-28-0) was applied. Based on the 1972 results in the black soil area, it was assumed that this quantity of nitrogen and phosphorus would be sufficient. However, by mid-July nitrogen deficiency symptoms were observed on sorghum and pearl millet especially in watershed 'E' in the eroded areas.

On July 27, a series of simple top dressing experiments were established in plantings of various sorghum varieties and in pearl millet (HB-3) in watersheds BW1, BW3 & BW5. In sorghum there was a visual response to the topdressed nitrogen application in almost all cases. There was a small but consistent yield response due to the N top dressing in all varieties in all three watersheds (table 13). However, the response was statistically significant in only 3 cases (table 13). The greatest response occurred in the Swarna and CSH-1 sorghum varieties where the grain yield was increased by 5.9 and 4.7 q/ha, respectively. The sorghum varieties CSH-3, CSH-4 and PJ8K happened to be planted in eroded areas where the zinc deficiency and subsequent shootfly damage were severe; yields therefore were all far below what was expected. Variety 604 matured later than the hybrids and its yield was reduced by midge infestation and a fungal growth on the grain related to the late rains.

The effect of top dressing on the yield of pearl millet is shown in table 14. There was a small but consistent visual and yield response to the nitrogen top dressing application in both stalk and grain yield. The lack of statistical significance may be partially due to the low number of treatments (only 2). With only one degree of freedom for treatments, a relatively high 'F' value is required for significance.

Table 12 - The effect of nitrogen topdressing on yield of various sorghum varieties in watersheds BW1, BW3 and BW5A (FS Trials 14A, 14C & 14E kharif - all yields in q/ha).

Nitrogen* Kgs/ha	Ws BW1	Ws BW3	Ws BW5A	Mean of	Ws BW3	Watershed BW5A				Mean of all comparisons
	CSH-1	CSH-1	CSH-1	CSH-1	Swarna	CSH-4	CSH-3	604	PJ8K	
Grain yield										
0	31.9	34.3	20.6	29.0	24.1	13.4	3.1	6.7	5.6	13.61
40	34.5	39.5	24.2	32.7	30.0	15.0	5.2	8.3	7.0	16.4
F Value	0.58	4.47	34.82		28.7	14.8	4.6	4.4	2.77	
LSD (05)	N.S.	N.S.	2.0		3.2	1.3	N.S.	N.S.	N.S.	
Air dry stalk yield										
0	76.0	54.7	47.1	59.3	71.6	33.7	51.8	87.1	163.1	77.8
40	77.0	60.4	54.6	64.0	81.8	37.9	54.6	105.7	174.7	86.5
F Value	0.2	2.47	5.5		13.9	2.4	0.5	3.78	15.2	
LSD (05)	N.S.	N.S.	N.S.		8.5	N.S.	N.S.	N.S.	9.6	

*All plots received 57-25-0 (205 kgs/ha of 28-28-0) at planting. The 40N as ammonium sulfate was top-dressed on July 27, 1973.

Table 13 - The effect of nitrogen top-dressing on the yield of pearl millet (HB-3) in watersheds BW1, BW3 and BW5A during the monsoon season. (Trial 13A, 13C & 13E - all yields in q/ha).

Nitrogen Kg/ha*	Grain yields				Stalk yields			
	Ws BW1	Ws BW3	Ws BW5A	Mean	Ws BW1	Ws BW3	Ws BW5A	Mean
0	24.2	30.8	19.2	24.4	46.6	57.5	24.2	42.8
40	33.3	31.6	21.7	28.9	65.8	58.3	29.2	51.1
F Value	6.4	5.0	5.0	5.5	8.4	0.2	19.5	9.4
LSD	N.S.	N.S.	N.S.		N.S.	N.S.	3.7	

* All plots received 57-25-0 (205 kgs/ha of 28-28-0) at planting. Nitrogen top-dressing applied as ammonium sulfate on July 27, 1973.

On the basis of this year's experience in the black soil watershed areas, 10 kgs of zinc (44 kgs/ha of zinc sulfate) is being applied as a broadcast application in solution before discing. This uniform application of zinc should eliminate it as a limiting factor for the subsequent years. Also, the nitrogen application is being increased in an attempt to provide adequate levels of fertilization to facilitate the determination of soil and water management treatment effects.

Chick Pea fertilization and inoculation studies

As a follow-up of last year's chick pea fertilization and inoculation investigations, an experiment was established to study the effect of phosphorus application and nitrogen application with and without inoculum. There was a marked seedling growth and color response to nitrogen application in chick pea seedlings on both red and black soils. This response was noted and photographed within three weeks after planting time. However, as the season progressed the magnitude of the nitrogen response diminished and had practically disappeared by the flowering stage (60 days after planting). At harvest time there was no significant response to nitrogen application (table 15). There was a slight visual response to phosphorus application in the early stages in the red soil, but none in the black soil. However, no yield response to phosphorus was observed in any case. Dr. Sundara Rao and his Research Assistant found increased numbers of nodules in the inoculated treatments. However, there were substantial numbers of nodules even in the uninoculated soils and there was no yield response to inoculation. It was surprising to find this high degree of nodulation in these soils in uninoculated treatments, since there is no recent history of growing chick peas in the area.

Table 14 - The effect of Inoculant with and without Nitrogen and the effect of Phosphorus upon yield and flowering date of chick Pea (BEG 482) in Red & Black Soils (FS trial 17 - all yields are in q/ha).

	Treatments				Grain Yield		Days to 75% flowering	
	N	P	Zn	Inoculant	Red	Black	Red	Black
1.	0	25	10	0	7.2	6.4	60	62
2.	40	25	10	0	6.7	8.5	59	63
3.	80	25	10	0	6.8	6.1	57	61
4.	0	25	10	B 7	6.9	6.8	62	63
5.	40	25	10	B 7	8.1	6.7	58	62
6.	80	25	10	B 7	7.9	7.1	57	61
7.	0	25	10	B 7 + Lime	6.4	6.5	64	64
8.	0	25	0	B 7	7.6	6.8	61	62
9.	0	0	10	B 7	5.1	6.7	65	62
	F Value				1.45	0.50		
	LSD (05)				N.S	N.s		

Table - 15 The effect of foliar applications of urea upon the yields and days to 75% flowering of 2 chick pea varieties (Local & BEG 482). (FS Trial 24 - all yields are in q/ha).

	Grain Yield		Days to 75% flowering	
	Local	BEG482	Local	BEG482
1. No Spray	18.1	14.7	49	59
2. One spray with 1% urea solution	19.6	15.7	49	59
3. " " " 1% +, 2* more	20.3	16.0	49	59
4. " " " 5% urea solution	19.3	16.0	49	59
5. " " " 5% + 2* more	18.8	16.5	48	58
F Value	1.15	1.13	49	59
LSD (05)	N.S	N.S		

*First application made at pre-flowering stage and the 2nd & 3rd applications 3 & 6 days later.

An additional experiment was set up involving new Rhisobial strains which Dr. Subba Rao of IARI had obtained from Israel. These inoculants arrived too late for normal planting but an experiment was established in the red soil on November 6 to check the relative performance of these inoculants. The uninoculated treatment produced 6.5 q/ha and the various inoculated treatments ranged from 6.2 to 6.7 q/ha. There was no visual or yield difference between any of the treatments.

Another small trial involving a factorial of foliar trimming and inoculation was also established on November 6 on the red soil. Although the foliar trimming appeared to stimulate slightly increased branching, there was no yield response to any treatment.

An experiment was established to study the effect of foliar applications of urea at the pre-flowering stage upon the growth and seed yield of two varieties of chick pea (table 16). There was slight foliar burn on treatment 5 which received three applications of a 5% solution of urea. No foliar burn was observed on the other three treatments, shown in table 16. There was no positive visual response or yield response to any of the urea spray applications (table 16). Dr. S.K. Sinha has reported a response to potassium nitrate applied at preflowering stage. It is planned to check this point further by comparing urea and potassium nitrate during the next season.

Ratoonability of Pearl Millet varieties

In the 1972 kharif season, a rapid ratoon growth (regrowth) of pearl millet was observed following the harvest of the main stalk for fodder at the heading stage. In the 1973 season a comprehensive trial was established to test the ratoonability of 3 pearl millet varieties in a series of multiple harvest treatments, involving multiple harvest after a fodder harvest and after a grain harvest of the main stalk.

Table 16 - The effect of N,P,K & Zn application upon the average grain yields, air dry stalk yields of sorghum (CSH-1), Pearl Millet (HB-3) and Setaria (H-1) on red soils and sorghum only on black soils (FS Trial 19 Rabi - all yields in q/ha).

	Fertilization				Red Soil Site						Black Soil Site	
					Sorghum		Pearl Millet		Setaria		Sorghum	
	N	P	K	Zn	Grain	Stalks	Grain	Stalks	Grain	Stalks	Grain	Stalks
1.	0	25	0	10	35.0	36.0	19.8	33.2	15.9	24.8	24.4	20.3
2.	40	25	0	10	37.6	40.2	24.4	52.8	15.2	25.7	25.4	24.4
3.	80	25	0	10	41.7	40.2	26.5	58.5	18.0	28.1	27.7	28.0
4.	120	25	0	10	42.8	41.7	32.7	51.7	19.3	29.7	28.8	29.0
5.	120	0	0	10	23.0	33.1	16.6	33.1	11.7	20.3	20.6	22.8
6.	120	25	0	0	41.6	42.5	31.1	56.1	15.2	29.3	28.2	27.9
7.	120	25	50	10	43.4	41.2	29.6	60.1	16.7	25.6	28.0	29.2
	F Value				2.360*	14.3**	8.692	12.840	7.377	3.176	1.542	3.6
	LSD (05)				10.4	3.3	5.9	9.5	2.7	5.8	N.S.	4.2

1. All phosphorus and 22 kgs/ha of the nitrogen was applied at planting in a band 5 cm to one side of the seed as 124 kgs/ha of 18-46-0 in treatments 2, 3, 4, 6 & 7 (treatment one was applied as 335 kgs/ha of granular 0-17-0 & treatment 5 as 105 kgs/ha of ammonium sulfate. The K. as potassium chloride, the Zn as zinc sulfate, and the balance of the "N" as ammonium sulfate was broadcast and disced just prior to planting.

The six harvest systems investigated are shown in table 17. The letter 'G' represents a grain and stalk harvest taken at physiological maturity and 'F' represents a green fodder harvest taken at the 75% heading stage. The six harvest systems were as follows: GG, GFF, FG, FFG, FFFG and FFFFF. The last harvest system was planned as a FFFFG, however, there was no seed set in this last harvest so it was harvested for fodder only.

There was no appreciable difference between the fodder yields or the grain yields of the three hybrids grown on the red soil (table 17a). The growth habits of the plants were quite similar, except that HB-3 was slightly earlier maturing. It reached the 75% flowering stage in 48 days, while the other two hybrids flowered in 52 days. In the black soil, the pearl millet variety K559 was substituted for hybrid J1644. The number of days to 75% flowering for HB-3 and HB-4 and K559 were 50, 56 and 55 days respectively. In the black soil the yields of HB-4 were superior to the other two varieties in the GG system; however, in the FG system where the grain crop was taken following a fodder crop, HB-3 produced the best yield(table 17b). Since there was relatively little difference in the growth habits and ratoonability of the four varieties used, they will be discussed together in the various harvest systems.

In all cases there was excellent regrowth when fodder was cut at the heading stage about 41 days after planting. Since the plants possessed a profusion of tillers at this stage, the growth of the tillers was extremely rapid after the main stalks were harvested. In the red soil the first harvest was made on August 9th (41 days after planting) and there was a second fodder harvest 21 days after on August 30th. The third fodder harvest came 20 days later on September 19, the fourth 29 days later on October 18, and the fifth 24 days later on November 11. Although it must be admitted that the amount of fodder in the later harvests was small, there is a clear indication of rapid regrowth and development to the heading stage throughout

A comparison was made of the grain yields of HB3 and HB4 on both soils harvested as the first crop (G), as a ratoon crop (FG), as a ratoon crop after two fodder harvests (FFG), and after three fodder harvests (FFFG). The average yields were 27.6, 15.8, 6.8 and 3.0 q/ha, respectively. Thus, it is obvious that the general grain yield levels dropped progressively as 1, 2 or 3 fodder harvests were taken prior to the grain harvest. It is difficult to evaluate comparative total values of each harvest system without better data on the feed value of pearl millet green fodder (table 17c). One of the problems of the green fodder harvest system is the curing of pearl millet fodder or sorghum fodder during the rainy monsoon season. Another possible approach would be the ensiling of the green fodder. During the past season one silage pit was established. This system needs further investigation before any conclusions can be drawn.

One of the disappointing features of all of the hybrids was the poor regrowth or "ratoonability" after the first grain crop was removed in harvest system (GG). The second harvest was only 1.3 q/ha in the red soil (table 17). In the black soil, the second harvest was somewhat better (about 10 q/ha) but still not as good as would have been expected with ample moisture situation that existed in both soils due to the October rains. Under the present systems of fodder preservation and utilization prevailing in the Semi-Arid Tropics it is much easier to handle dry stalks than green fodder. Thus it appears that the greatest potential for multiple harvests would be to find varieties or hybrids with "ratoonability" which would produce a second grain crop after a high yielding first grain crop. Also, such a system with either pearl millet or sorghum would have a definite advantage in eliminating the problem of replanting the second crop during the transition between the monsoon and the post-monsoon season. A second crop could be produced at little or no additional expense, except for a possible nitrogen top dressing. This system would be particularly well adapted to black soils because of their higher water holding capacity. In

Table 17a - Grain, stalk and green fodder in Yields of three pearl millet varieties under six systems of ratoon harvesting. Red soil. Hyderabad 1973.

Variety	August		September			October			November		
	Green Fodder[1]	Green Fodder[2]	Grain[3]	Stalk[3]	Green Fodder[4]	Grain[5]	Stalk[5]	Green Fodder[6]	Grain[7]	Stalk[7]	Green Fodder[8]
GRAIN-GRAIN											
HB-3			27.1	47.7					1.2	2.6	
HB-4			28.4	48.8					1.3	2.5	
J1644			27.8	48.5					1.4	2.8	
LSD (05)			NS	NS					NS	NS	
GRAIN-FODDER-FODDER											
HB-3			27.1	47.7				7.4			6.1
HB-4			28.4	48.8				3.9			6.7
J1644			27.8	48.5				5.3			5.7
LSD (05)			NS	NS				2.4			NS
FODDER-GRAIN											
HB-3	229					12.9	21.4				
HB-4	229					13.7	21.7				
J1644	218					11.7	20.6				
LSD (05)	NS					NS	NS				
FODDER-FODDER-GRAIN											
HB-3	229	136				8.0	11.2				
HB-4	229	141				7.5	9.7				
J1644	218	152				7.7	10.0				
LSD (05)	NS	3.8				NS	NS				
FODDER-FODDER-FODDER-GRAIN											
HB-3	229	136			44.1				1.5	4.1	
HB-4	229	141			50.1				1.4	4.4	
J1644	218	152			41.6				1.4	4.2	
LSD (05)	NS	3.8			4.3				NS	NS	
FODDER-FODDER-FODDER-FODDER-FODDER											
HB-3	229	136			44.1			50.1			3.0
HB-4	229	141			50.1			36.3			1.9
J1644	218	152			41.6			45.6			1.7
LSD (05)	NS	3.8			4.3			7.4			0.7

Harvest dates for grain & stalk or fodder during August - November.

1/ August 9
2/ August 30
3/ Sept. 14
4/ September 19
5/ (FG) Sept. 27
(FFG) Oct. 18
6/ October 18
7/ November 9
8/ November 11

Table 17b - Grain, stalks and green fodder in yields (q/ha) of three pearl millet varieties under six systems of ratoon harvesting. Black soil. Hyderabad 1973.

Variety	August	September				October			November		
	Green Fodder[1]	Green Fodder[2]	Grain[3]	Stalk[3]	Green Fodder[4]	Grain[5]	Stalk[5]	Green Fodder[6]	Grain[7]	Stalk[7]	Green Fodder[8]
GRAIN-GRAIN											
HB-3			25.6	64.9					9.0	13.2	
HB-4			29.2	67.5					10.7	15.2	
K559			22.0	69.0					10.0	17.3	
LSD (05)			3.4	NS					NS	NS	
GRAIN-FODDER-FODDER											
HB-3			25.6	64.9				16.3			7.9
HB-4			29.2	67.5				5.1			2.7
K559			22.0	69.0				10.1			4.2
LSD (05)			3.4	NS				4.1			2.2
FODDER-GRAIN											
HB-3	174					21.7	38.3				
HB-4	182					15.0	40.5				
K559	153					17.5	41.4				
LSD (05)	16.7					3.1	NS				
FODDER-FODDER-GRAIN											
HB-3	174	124				5.4	9.1				
HB-4	182	141				6.2	9.4				
K559	153	119				6.5	10.4				
LSD (05)	16.7	8.8				NS	1.1				
FODDER-FODDER-FODDER-GRAIN											
HB-3	174	124			44.5				4.6	8.5	
HB-4	182	141			51.6				5.0	9.9	
K559	153	118			39.5				5.7	11.4	
LSD (05)	16.7	3.8			3.8				0.6	NS	
FODDER-FODDER-FODDER-FODDER-FODDER											
HB-3	174	124			44.5		39.7				16.4
HB-4	182	141			51.6		34.8				15.7
K559	153	118			39.5		37.5				15.6
LSD (05)	16.7	3.8			3.8		2.5				NS

Harvest dates for grain and stalk or green fodder (August - November)

1/ August 10
2/ September 3
3/ September 20
4/ September 25
5/ (FG) Oct. 18
(FFG) Oct. 18
6/ October 18
7/ November 11
8/ November 8

Table 17c - Total yields of pearl millet ratooned under six harvest systems. Hyderabad 1973.

Red Soil Harvest System	Yields - q/ha Grain	 Stalk	 Green Fodder	Date of last Harvest
Grain-Grain	29.1	50.9	--	Nov. 9
Grain-Fodder-Fodder	27.8	48.3	12	Nov. 11
Fodder-Grain	12.8	21.2	225	Sept.27
Fodder-Fodder-Grain	7.7	10.3	368	Oct. 18
Fodder-Fodder-Fodder-Grain	1.4	4.3	414	Nov. 9
Fodder-Fodder-Fodder-Fodder-Fodder	--	--	469	Nov. 11
Black Soil				
Grain-Grain	35.5	42.3	--	Nov. 8
Grain-Fodder-Fodder	25.6	67.1	15	Nov. 8
Fodder-Grain	18.1	40.1	170	Oct. 18
Fodder-Fodder-Grain	6.0	9.8	297	Oct. 18
Fodder-Fodder-Fodder-Grain	5.1	9.9	343	Nov. 11
Fodder-Fodder-Fodder-Fodder-Fodder	--	--	396	Nov. 8

Based on data presented in Table 17a & 17b.

the next season a ratoonability screening is planned in cooperation with the Crop Improvement staff using a wide range of pearl millet and sorghum germ plasm.

In the watersheds BW1, BW3 and BW5A a similar trial was conducted in which only two harvest systems were compared (grain only vs FFF). As was true on the black soil site, the grain yield of HB-4 was significantly higher than that of HB-3 or K559 in watershed BW1 (table 18). This trend was observed also in watershed BW3 and BW5A, but the difference was not statistically significant. Thus, in all cases on the black soil, with its high water holding capacity, HB-4 was superior to HB-3 or K559.

A preliminary ratoonability trial was established with CSH-1 sorghum in watershed BW3. The first fodder harvest made on September 1st produced an average of 176 q/ha of green fodder. The plan was to allow the regrowth to be harvested for grain. However, the seed set was very poor and a second fodder harvest was made on November 5th yielding 66 q/ha of green fodder. The companion crop which was harvested for grain yielded 30 q/ha. There was no significant regrowth after the removal of the grain crop.

Soil Management for Water Conservation

On watersheds BW1, BW3 and BW5 an experiment was conducted comparing several methods aimed at increasing infiltration of rainfall on black soils. The effectiveness of "tie ridging", chiselling alone and chiselling plus "vertical mulching" upon the yield of pearl millet was compared (table 19). These three treatments were applied in an area where the ridge and furrow system had been established first to see if these treatments had any effect upon water conservation in addition to that of the ridge and furrow systems. Although particularly on the steeper slopes (watershed BW5A) a slight increase in yield under the vertical mulch treatment was observed, no significant effects of any of the treatments could be found (table 19).

Table 18 - A comparison of yields of grain, air dry stalks and fresh green fodder in two harvest systems of black soil watersheds A, C & E* (FS Trials 3A, 3C & 3E kharif - all yields in q/ha).

Varieties	Grain and stalks harvest system (G)							
	Grain Yield				Stalk Yields			
	Ws BW1	Ws BW3	Ws BW5A	Means	Ws BW1	Ws BW3	Ws BW5A	Means
HB-3	21.7	37.0	17.0	25.2	32.2	81.1	32.1	48.5
HB-4	24.6	44.1	21.4	30.0	39.6	85.7	54.7	60.0
K-559	23.1	35.9	16.1	25.0	33.6	79.9	47.9	53.8
F Value	5.0	3.4	3.0		11.8	1.3	6.9	
LSD (05)	2.7	N.S	N.S		4.0	N.S	1.1	
Harvest Dates	Sept.26	Sept.26	Sept.26		Sept.26	Sept.26	Sept.26	

Varieties	Fodder plus Fodder plus Fodder harvest system (FFF)								
	Green Fodder			Green Fodder			Green Fodder		
	Ws BW1	Ws BW3	Ws BW5A	Ws BW1	Ws BW3	Ws BW5A	Ws BW1	Ws BW3	Ws BW5A
HB-3	176	256	103	147	145	116	45	116	61
HB-4	157	235	140	158	152	150	57	121	69
K-559	168	230	128	139	141	152	56	126	65
F Value	0.8	1.3	2.5	3.1	1.6	6.9	16.4	2.3	0.3
LSD (05)	N.S	N.S	N.S	N.S	N.S	1.9	5.8	N.S	N.S
Harvest dates	Aug.10	Aug.10	Aug.10	Sept.4	Sept.9	Sept.9	Sept.26	Sept.26	Sept.29

* Watersheds A, C & E have been renamed BW1, BW3 and BW5A, respectively.

Table 19 - The effect of vertical mulching and "tie ridging" on the grain and stalk yield of Pearl millet (HB-3). (FS Trial 8 kharif in watersheds BW1, BW3 and BW5A - all yields in q/ha.

Treatment 1/	Grain yield q/ha				Stalk yield q/ha			
	Ws BW1	Ws BW3	Ws BW5A	Means	Ws BW1	Ws BW3	Ws BW5A	Means
1. Furrow	24.5	24.9	22.7	24.0	49.2	38.3	39.5	42.3
2. " + tie Ridging	23.0	25.7	23.9	24.2	46.3	44.8	40.2	43.8
3. " + chiselling	25.3	24.2	23.2	24.2	540	40.5	35.8	42.6
4. " + " +V.M.	22.3	25.4	27.1	24.9	54.5	43.0	45.7	45.8
F Value	2.6	0.3	1.4		2.8	1.6	2.0	
LSD (05)	N.S	N.S	N.S		N.S	N.S	N.S	

1/ Treatments were established in the graded contour furrows starting at the upper edge of the watersheds so as to avoid an accumulation of water from above the experimental area. Tie ridging, chiselling and vertical mulch was accomplished by hand across the plots after planting.

Slots (30 x 30 x 10 cms) to similate chiselling were dug across the furrows at 3 m intervals with staggered placement in alternate rows in treatments 3 & 4. In treatment 4 the slots were filled with rice husks as a vertical mulch. Tie ridges (small earth dams in furrows) were built at 3 m intervals with staggered placement in ridges in the 6 row plots and harvests were made in the two center rows.

This is not surprising because the rainfall distribution during the past season and also the general rainfall intensities were such that the full storage capacity of the soil profile was probably met under all treatments. The grain yield of the four treatments ranged from 24.0 to 24.9 q/ha and the stalk yield level ranged from 42.3 to 45.8 q/ha. Plans are under way to study the effect of vertical mulching along the contour on a field scale in watershed BW-6 in 1974.

Supplemental Irrigation

An experiment was designed to study the effect of 1 or 2 "life saving" (5 cm) irrigations when necessary to break a drought during the monsoon season or to extend the rabi season. In addition to these two treatments, two other treatments were provided as checks; one with no water application and the other with "optimum irrigation" applied when 50% of the available soil moisture in the root zone was depleted. In the red soil two 5 cm applications were made in the "optimum irrigation treatments" (treatment 3 and 4) on sorghum, pearl millet and sunflower (table 20). However, this drought was not severe enough to justify the application of a "life saving" irrigation to treatments 5, 6, 7 and 8. Rain occurred just after the September 21st irrigation on the optimum irrigation plots so there was no appreciable effect of the irrigation. There was a small, but significant, increase due to irrigation in sunflower. However, irrigation had no significant effect on any of the other crops in the red soil. There was a highly significant response to nitrogen application in all crops except the pigeonpea in the red soil. There was no significant interaction between nitrogen and irrigation in any crop.

During the past monsoon season the soil moisture conditions were relatively favorable and no irrigation was applied in the black soil because the available soil moisture content never dropped below 50%. There was a highly significant nitrogen response on all four crops in the black soil.

The grain yields for the 0 & 100 treatments for the four crops were as follows:

	0 N	100 N
Sorghum	15.4 Kg/ha	37.3 kgs/ha
Pearl Millet	14.3	30.8
Sunflower	15.8	17.7
Pigeonpea	2.8	3.6

The growth of pigeonpea was good but yields were very low due to severe pod borer attack. Because of the generally favorable monsoon season rainfall in 1973, the objectives of this experiment were not realised. Therefore a similar experiment is planned for the 1974 season.

The monsoon season trial 6 shown in table 20 was continued in the rabi season with chickpeas being relay planted in standing sorghum two weeks before the sorghum harvest, and safflower being relay planted in standing sunflower two weeks before the sunflower harvest (table 21). The pigeonpea trial was continued into the rabi season and the pearl millet was ratooned for a possible second grain crop.

Chickpea yields were significantly increased by irrigation in both the red and black soil (table 21). In the red soil, it appeared that the first irrigation on November 30, ten days after flowering started, was effective in increasing yields. The second irrigation, which was given near maturation time (January 3rd) appeared to be completely ineffective. It appeared that the one 5 cm-irrigation increased yields from an average of 4.4 to 8.2 q/ha (table 21). The effect of irrigation on safflower was similar, but the degree of response was somewhat less. In the black soil the first irrigation 10 days after the flowering stage increased chickpea yields significantly; however, the January 5th irrigation given in the seed formation stage appeared to have a significant negative effect as shown in treatments 3 and 4 (table 21). In the black soil only one irrigation was given to safflower in treatments 3 to 6. This irrigation had no significant effect upon yield. There was, however, a marked nitrogen response to residual nitrogen from the differential nitrogen application given to the sunflower crop during the monsoon season.

Table 20 - The effect of irrigation and nitrogen treatment upon the yield of Sorghum, Pearl Millet and Sunflower in red soil. (FS Trial 6 kharif - all yields in q/ha).

No.	Water1/	Nitrogen2/	Sorghum		Pearl Millet		Sunflower
			Grain	Stalk	Grain	Stalk	Grain
1.	None	0	40.2	46.6	25.5	36.0	12.0
2.	None	100	48.7	51.8	33.4	44.1	11.2
3.	50%	0	44.6	53.0	22.8	33.2	16.3
4.	50%	100	52.5	53.7	34.8	44.1	13.3
	F Value (Treatments)		5.7*	0.7	23.0**	46.3**	38.8**
	F " N		13.5**	0.6	65.9**	133.0**	26.0**
	F " Irrigation		3.5	1.2	0.3	3.0	78.9**
	F " Irrig. x N		0.1	0.4	3.6	3.0	9.1*
	LSD (05) for treatments		7.2	N.S.	3.9	2.8	1.1

1/ The water applications planned were as follows:

Treatments 1 & 2 none
3 & 4 optimum Irrigation at 50% available soil moisture
5 & 6 One 5 cms supplemental "life saving" irrigation
7 & 8 Two 5 cms supplemental "life saving" irrigation.

The water application actually given were as follows:

The two irrigations (5 cm each) on September 6 and 21 were given to sorghum,pearl millet and sunflower in treatments 3 & 4. Treatments 5 & 7 were combined with treatment 1 and treatments 6 & 8 were combined with treatment 2 for analyses of variance, since no water application was made on treatments 5 - 8. Pigeonpea yields were omitted from this table since no irrigation was given to it. The average pigeonpea yield in the red soil was 10.3 q/ha.

2/ A uniform application of 25P ($57P_2O_5$) was given to all treatments during the monsoon season only.

Table 21 - The effect of one or two 5 cm - irrigations upon rabi relay plantings of chick pea in kharif sorghum and safflower in sunflower in red and black soils (FS Trial 6 rabi - all yields are in q/ha).

Water 1/	N.	Dates of Irrigation 2/		Chick Pea	Safflower
Red Soil					
1 none	0	none		4.7	7.5
2 none	100	none		4.1	8.4
3 50%	0	Nov. 30	Jan. 3	9.1	9.4
4 50%	100	"	Jan. 3	9.0	9.2
5 5cm	0	"	-	8.1	10.5
6 5cm	100	"	-	7.4	11.5
7 5cm (2x)	0	"	Jan. 3	8.9	10.8
8 5cm (2x)	100	"	Jan. 3	6.8	12.6
F Value (Treatments)				8.9	3.5
F "	N.			3.8	2.0
F "	Irrig.			18.6**	7.2**
F "	Irrig. x N.			0.9	0.4
LSD (05) for treatments				1.9	2.6
Black Soil					
1 none	0	none		13.4	11.4
2 none	100	none		13.8	16.3
3 50%	0	Dec. 3	Jan. 5	13.0	10.9
4 50%	100	Dec. 3	Jan. 5	13.4	16.2
5 5cm	0	Dec. 3	-	16.7	12.4
6 5cm	100	Dec. 3	-	16.8	18.4
7 5cm	0	-	Jan. 5	13.5	13.5
8 5cm	100	-	Jan. 5	13.3	16.8
F Value (treatments)				2.7	5.4
F "	N			0.1	33**
F "	Irrig.			6.3**	1.3
F "	N x Irrig.			0.1	0.5
LSD (05) (treatments)					

1/ The water applications planned were as follows:

Treatments 1 & 2 - None
" 3 & 4 Optimum Irrigation at 50% available soil moisture
" 5 & 6 One 5 cm supplemental "life saving" irrigation.
" 7 & 8 Two - 5 cms " " " "

A uniform application of 25 P(57P_2O_5) was given to all treatments during the monsoon season only.

2/ Two irrigations (5 cms) each were given on both crops to treatment 3, 4, 7 & 8 only one 5 cm irrigation to treatments 5 & 6 in the red soil.
In the black soil, the Dec. 3 (5 cms) irrigation (Treatments 3, 4, 5 & 6) was given to both crops, but the Jan. 5th, irrigation treatments 3, 4, 7 & 8 were given to chick peas only.

ROOT AND SOIL MOISTURE STUDIES

Preliminary investigations of rooting patterns of major crops were made in the red and black soil area and in three black soil watersheds. Samples were taken by 15-cms increments to a depth of 180 cms using a 2.5 cm soil sampling tube. The soil and root samples were soaked and washed to separate the roots and the number of root segments per three composite cores was recorded. The composite samples were taken in three replicates in order to measure variability. In the black soil roots were found at depths of 180 cms in all crops except setaria, (table 22). In the red soil, rooting depth varied from 150 cms to 180 cms (table 23). The variation in depths between the various crops was influenced by the presence and the nature of the "murrum" at lower depths.

As would be expected, the root density was greatest in the upper quarter of the profile and the number of root strands decreased progressively in the lower three quarters of the profile. However, with receding moisture during the later part of the post-monsoon season, the roots in the lower profile may become more important for water absorption. Further detailed studies are planned during the coming season to attain correlations between root distribution and water absorption at different depths throughout the growing season.

The data reported in table 22 and 23 were all obtained using the 2.5 cm diameter hand driven soil tube. After the arrival of the Giddings Core sampler, samplings were made using a 7.6 cm diameter tube. The Coring machine proved to be a much more satisfactory method of sampling from the stand-point of sample retrieval and sample compaction during sampling. In future studies it is planned to use the Coring machine wherever possible.

Table 22 - Comparison of the number of root segments per 100 cubic centimeter of soil for seven crops in the 0 - 180 cm depth. Values given are an average of sampling from the FS black soil site and the watershed areas. Samples of all rabi crops taken at late grain filling stage (early January)

Soil Depth (cms)	Sunflower	Pearl Millet	Chickpeas	Safflower	Sorghum	Setaria	Wheat
	Number of roots/100cc of soil						
0 - 15	52	25	46	31	29	54	46
15 - 30	38	24	40	22	23	33	32
30 - 45	27	26	26	21	29	35	22
45 - 60	22	19	24	20	20	28	17
60 - 75	16	14	20	17	18	13	14
75 - 90	17	15	19	19	17	10	8
90 - 105	12	9	15	13	17	5	5
105 - 120	12	9	10	11	15	3	4
120 - 135	10	3	9	9	6	2	5
135 - 150	8	4	4	7	6	0	5
150 - 165	7	2	4	3	3	0	3
165 - 180	1	2	3	4	1	0	3

Percentage of the total number of root segments which occur in each of the four quarters of the root zone

Soil Depth (cms)	Sunflower %	Pearl Millet %	Chickpeas %	Safflower %	Sorghum %	Setaria %	Wheat %
0 - 45	52.5	49.3	50.9	41.8	44.0	66.7	61.0
45 - 90	24.8	31.6	28.6	31.6	29.9	27.9	23.8
90 - 135	15.3	13.8	15.5	18.6	20.7	5.4	8.5
135 - 180	7.2	5.3	5.0	7.6	5.4	0	6.7

Table 23 - Comparison of the number of root segments per 100 cc of soil for four crops in the 0 - 180 cm depth. Values given are an average of samplings from the FS red soil area. Samples of all rabi crops taken at late grain filling stage (early January)

Soil Depth (cm)	Sorghum	Pearl Millet	Chick Pea	Safflower
0 - 15	27	63	164	35
15 - 30	29	51	101	25
30 - 45	26	45	86	35
45 - 60	28	34	60	35
60 - 75	21	19	45	23
75 - 90	26	9	39	19
90 - 105	16	8	18	19
105 - 120	5	4	12	11
120 - 135	5	4	7	6
135 - 150	4	5	4	4
150 - 165	2	3	0	0
165 - 180	0	4	0	0

Percentage of the total number of root segments which occur in each of the four quarters of the root zone.

Soil Depth (cm)	%	%	%	%
0 - 45	43.4	63.9	65.5	44.8
45 - 90	39.7	24.9	26.9	36.3
90 - 135	13.7	6.4	6.9	17.0
135 - 180	3.2	4.8	0.7	1.9

In another study a comparison was made between the number of root segments and total lengths of root segments in the sample. It is felt that the total length of roots strands would be a more meaningful criteria of root density in the soil. However, there was a direct correlation between number of root segments and the total length of root segments per 100 cm^3 of soil. These observations give further confidence in the earlier data in which only the number of root strands were recorded.

After this year's preliminary experience in techniques of sampling and analysis, plans are underway for refinement of techniques and correlation of root development of various crops with other parameters such as soil temperature, soil aeration and the relationships to various soil and water management treatments in the watersheds.

In an experiment to determine the effect of supplemental water on four crops (sorghum, pearl millet, sunflower and pigeonpea) with and without nitrogen fertilization (table 20) soil samples for moisture determination were taken throughout the kharif season on both the red and the black soils. Due to favorable rainfall conditions only two 5 cm irrigations were applied to the "optimum" irrigation treatment on the red soil, no supplemental water was applied on the black soil. The results of the moisture studies have been summarized separately for the red soil and the black soil sites (fig. 3 and fig. 4, respectively).

Early in the season, on the red soil all crops at each level of nitrogen fertilizer application appeared to have approximately the same quantity of moisture present in the upper 60 cms of the profile (about 110 mm). However, when the season progressed, substantial differences could be observed in moisture extraction patterns between crops and also between nitrogen treatments for the same crop (fig.3). In general the N fertilized treatments were much more efficient in extracting moisture from the profile; this appeared particularly true for pearl millet and sunflower.

On the black soil site, the total quantity of moisture present in the upper 180 cms of the soil profile early in the monsoon season ranged from approximately 540 to 550 mm (fig. 4). The differences in moisture extraction observed between crops and between different levels of N-application seemed less pronounced on the black soils than they were on the red soils. However, also in this case the fertilized crops appeared to be more efficient in extracting water from the soil profile than the unfertilized crops.

Moisture data were also collected on some of the crops grown in the research watersheds. With regard to safflower on watershed BW1 and sunflower on catchment BW3A a striking observation was made on differences in moisture extraction apparently related to variations in planting dates. At both planting dates good original stands were obtained while the moisture status of the soil profile was also similar. Safflower planted October 23 and harvested March 1 extracted about 230 mm from the profile,while safflower planted on November 11 and harvested March 22 was able to withdraw only approximately 180 mm (fig. 5). Sunflower planted in watershed BW3A on October 14 and harvested February 6 extracted about 220 mm while another planting sown November 8 and harvested March 12 obtained only approximately 130 mm from the soil (fig.6). Thus, it appears that dates of planting of the rabi crop may be a very important tool in optimizing moisture utilization.

Some additional observations on soil moisture will be made later when additional moisture data collected on the black soil research watersheds are discussed. Considerably increased attention will be paid to soil moisture phenomena under different cropping patterns in the 1974-75 season. Studies on optimum water utilization cannot progress until sufficient information is available on the moisture characteristics of both the red and the black soils and on the extraction patterns of different crops planted at alternate times under varying levels of fertility.

WATERSHED DEVELOPMENT

Introduction

New technology developed on specific production factors has to be integrated into improved systems of farming. Therefore, complete alternative farming systems are being carefully monitored on a realistic scale to evaluate the consequent requirements, production effects and water utilisation patterns of the different systems. The agro-climatic environment at ICRISAT is being used for the generation of principles which will assist in the development of integrated approaches toward improved systems of farming in different regions of the Semi-Arid Tropics of the world. This is a dynamic and not a static process, due to the fact that the requirements of and the inputs available for crop production systems are continuously changing.

There is a serious lack of hydrologic data which can be used to study optimum utilization of rainfall by agricultural crops, particularly for relatively small watersheds. The quantitative interrelationships between levels of soil and water management and control, effective utilization of rainfall, drainage, runoff collection and recycling for supplementing available soil moisture, soil conservation measures and systems of cropping are not adequately understood. Even less is known with regard to the effect of different levels of soil and water management on the economics of production or the social implications of integrated resource management and new systems of farming. A number of natural watersheds available at ICRISAT provide an excellent opportunity for quantitative research on all components of the water balance and other questions related to resource development and management.

The reasons discussed in the previous paragraphs have provided the justification for the initiation of the watershed based phase of the Farming Systems Research Program in early 1973. Five watersheds - BW1, BW2, BW3, BW4 and BW5 (fig.1) varying in size from 3.5 ha to approximately 15 ha were selected on black soils. Due to limitations in terms of time, equipment and staff, certain restrictions were placed on the precision, intensity and the interdisciplinary character of the farming systems research on natural watersheds during the past year. However, valuable data and experience have been gained during the 1973/1974 season which provide the basis for refinements, change and additions hopefully resulting in a continuously improving research program in succeeding years.

Watershed development and cropping patterns in 1973

To create a certain degree of variation between watersheds, the catchments were treated in different ways with regard to land and water management. During the monsoon season an identical cropping system of about 40% pearl millet and 60% sorghum was superimposed on each watershed to facilitate comparisons except in watershed BW4 in which traditional rabi cropping was simulated.

In watershed BW1 (3.5 ha) a surface drain with a cross-sectional area varying from .5 to 1 M^2 was constructed. This waterway was planted to different varieties of grasses (Chrysopogon fulvus, Dicanthium annulatum, Cenchrus cetigerus and Cenchrus ciliaris) for erosion protection and forage production. Slight grading was executed to smoothen the micro relief and to make feasible a ridge and furrow system graded at approximately 0.6% towards the drain. About 2 ha of the watershed was utilized for experimental plots with several sorghum and millet varieties. The moisture status of the soil at the beginning of the dry season held promise for a second crop, therefore the area was planted to safflower with a limited number of chick pea relay cropping trials.

In watershed BW the land (4.1 ha) has been maintained in its original state; small bunds surround all individual fields (of which there are 11) in this catchment. In this watershed, typical monsoon cropping of the Hyderabad region was simulated using bullock power and local technology in terms of varieties and fertilizers.

In the upper part of watershed BW3 called BW3A (4.4 ha) a surface waterway was constructed and then planted to a variety of grasses. Very minor grading was required to create a ridge and furrow slope of approximately .8% towards the drain. Approximately 2.5 ha of the watershed was used for experimental plots. A deep tank was constructed for storage of runoff water; its capacity is about .40 ha M (hectare meter). Excavated soil was used to construct roads. Approximately fifty fruit trees (mango, papaya, custard apple and chico) were planted near the tank. The watershed was planted to sunflower, safflower and chick pea during the post-monsoon season. In the lower part of this watershed, BW3B, (2.1 ha) the ridge and furrow system had an approximate slope of 1.1%.

Watershed BW4 (9.1 ha) was maintained in its original layout to have an opportunity to simulate a presently widely applied post-monsoon cropping system on black soils. The watershed was subdivided by the previous farmers into 13 irregular bunded fields. A natural drain of about 400 M length intersects the catchment. The watershed has been kept fallow during the wet season, the land being repeatedly ploughed with bullocks for weed control. Immediately after the monsoon this watershed was planted to sorghum, chick pea, safflower, sunflower and chillies.

Catchment BW5 (14.6 ha) consists of two partially separate sub-watersheds (BW5A and B), the sub-units were 6.5 and 8.1 ha respectively. Surface drains were constructed. All drains were planted to grasses, using in addition to earlier mentioned varieties also hybrid napier, para grass, Digitaria (creeping and bunch type), Brachiaria mutica, Cynodon dactylon, Sehima nervesum, legumes and local grass sod. Direct seeding was tried on some ditches as an alternative to transplanting of grass seedlings. A system of ridges and furrows under an average grade of 1.7% carried excess water to the drains on watershed BW5A, while the average furrow grade on watershed unit BW5B was 1.8%. Some grading was carried out to minimise chances of standing water due to micro relief.

A storage tank for runoff collection with an approximate capacity of .42 ha M (4200 M^3) was constructed in sub-watershed BW5A. Excavated material from the tank was utilized for reclaiming about .3 ha of severely eroded gullies which were 1 to 2.5 M deep and 5 to 10 M wide. During the monsoon season about 3 ha of the watershed was used for experimental plots. A total of 150 fruit trees (mango, papaya, custard apple and chico) were planted near the tank. In the post-monsoon season sorghum, chick pea, safflower, setaria, sunflower and wheat were planted as second crops.

Watershed development in 1974

The results of the studies on watershed-based farming systems during the last season, in terms of the hydrologic response of variations in land and water management technology and the repercussions with regard to agricultural production will be discussed in the next sections. These results have been the basis for additional activities on both the black and the red soil during late 1973 and early 1974. Numerous positive and helpful suggestions of colleagues at ICRISAT and other Institutions have also been important in developing the thinking with regard to further work on watershed-based farming systems.

The motivations for the changes and expansion presently being implemented can be summarised as follows:

1. The generation of data on the hydrologic response under different management systems is equally urgent (if not more) on the red soils than it is on the black soils.

2. The originally selected range of slopes for ridge and furrow systems appeared too steep, particularly with regard to the higher values both from visual observation and from recorded data on erosion and runoff.

3. The range of actual slopes of individual furrows on a watershed, compared to the average value for a catchment seemed too large to facilitate a valid interpretation of the results.

4. Some of the more conventional soil and water conservation measures in the Semi-Arid Tropics (in particular contour bunding and graded bunding) were not represented in the original set of management treatments.

5. Conventional sources of power and traditional or improved implements were not used in the implementation of alternative land and water management technology.

6. The field layout on watersheds with ridges and furrows was extremely different from the conventional land use patterns.

7. There was no separate evaluation of the effect of genetic-chemical and machinery innovations versus the effect of presumably superior land and water management techniques.

8. The number of replications of treatments was too limited for a valid extrapolation to different regions of the Semi-Arid Tropics at a later stage.

9. Substantial greater detail of measurement appeared necessary for a better understanding of the different hydrologic processes involved.

10. Too little attention was paid to data collection which would facilitate economic comparisons of different management systems.

In view of these considerations, development work has been started on two red soil watersheds and three additional black soil watersheds while a number of the catchments has been divided into sub-units. Adjustments are being made to some of the original BW1-BW5 black soil watersheds.

During the next few years an identical set of cropping patterns called "Crop Complex 1" will be superimposed on all research watersheds. This crop complex 1 consists of five different cropping patterns, each of which will occupy about 1/5 of the area of a watershed. The cropping patterns that will be applied during the 1974-75 season, and that will be rotated within each catchment during subsequent seasons, depending upon the moisture status of the soil and runoff recycling potential are:

1. Pigeonpea with several intercrops.
2. Sorghum with several rabi crops.
3. Pearl Millet with several post-monsoon crops.
4. Sunflower with several relay crops.
5. Maize with several relay crops.

A brief description of the present or planned status of each catchment will be given by watershed. In this description, "optimum technology" refers to the use of the best available varieties and fertilizer/pest protection practices. "Local technology" refers to the use of traditional varieties and local methods of management. The term "mechanical power" indicates the use of tractors and tractor pulled implements; "animal power" stands for the use of bullocks for all tillage and planting operations. When the term "supplemental water" or "irrigation" is used, the recycling of watershed runoff is intended. The method of land and water management, land preparation, slope of ridge and furrow systems or bunds, method of planting and the type of technology are given below for each watershed of sub-unit. Figure 15 shows the detailed layout of BW1-8.

A. <u>Black soils</u>:

1. Watershed BW1 (3.52 ha)
   Crop complex 1
   Optimum technology
   Land planed
   Ridges and furrows at 0.6%[1/*]
   Guide terraces cum field boundaries[2/*]
   Grassed waterways
   Mechanical power and implements

2. Watershed BW2 (3.55 ha)
   Crop complex 1
   Optimum technology
   Ridges and furrows at 0.6%[1/]
   Field bunds remain
   Animal power with improvement implements.

3. Watershed BW3A (4.28 ha)
   Crop complex 1 with supplemental water
   Optimum technology
   Land planed
   Ridges and furrows at 0.4%[1/*]
   Guide terraces cum field boundaries[2/*]
   Grassed waterways
   Mechanical power and implements

4. **Watershed BW3B (2.33 ha)**
   Crop complex 1 with supplemental water
   Optimum technology
   Land planed
   Ridges and furrows at 0.4%[1/]
   Guide terraces cum field boundaries[2/]
   Grassed waterways
   Animal power with improved implements

5. Watershed BW4A (5.07 ha)
   Crop complex 1 with supplemental water
   Optimum technology
   Flat planting along 0.4% graded bunds
   Graded field bunds at a 0.4% grade
   Mechanical power and implements

6. Watershed BW4B (3.61 ha)
   Kharif fallow
   Crop complex 1 (rabi only)
   Local technology (with plant protection)
   Flat planting going around the fields
   Field bunds remain
   Animal power and local implements

7. Watershed BW5A (6.86 ha)
   Crop complex 1 with supplemental water
   Optimum technology
   Land planed
   Ridges and furrows at 0.8%[1/]
   Guide terraces cum field boundaries[2/]
   Grassed waterways
   Mechanical power and implements.

8. Watershed BW5B (6.63 ha)
   Crop complex 1 with supplemental water
   Optimum technology
   Land planed
   Ridges and furrows at 0.8%[1/]
   Guide terraces cum field boundaries[2/]
   Grassed waterways
   Animal power and improved implements.

1/ Grades given for ridges and furrows are average grades as the land in the watersheds is undulating and the grades are not uniform. The range of acceptable grades for each average grade is as follows:

Average Grade	Range of Grades
0.4%	(0.2 to 0.6%)
0.6%	(0.4 to 0.8%)
0.8%	(0.6 to 1.0%)

2/ When the slope of the land changes so that the furrow grade would exceed the prescribed limits, the direction of the ridges and furrows is changed. At this line a grassed broad-based terrace and channel is constructed as a field boundary, a turnway, a drainage channel for breakthrough protection and as a guide for the future tillage, ridging and planting operations (fig.7). These grassed field boundaries will be harvested for forage throughout the season.

9. Watershed BW6A (1.54 ha)
   Crop complex 1
   Optimum technology
   Flat planting along vertical mulch lines
   Vertical mulching along contours; 3m between trenches
   Grassed waterways
   Animal power and improved implements

10. Watershed BW6B (6.40 ha)
    Kharif fallow
    Crop complex 1 (rabi only)
    Optimum technology
    Flat planting on the contour
    Contour bunds and outlets
    Grassed waterways
    Animal power and implements

11. Watershed BW6C (3.4 ha)
    Crop complex 1 with supplemental water
    Optimum technology
    Flat planting on contour
    Contour bunds and outlets
    Grassed waterways
    Mechanical power and implements.

12. Watershed BW7A (8.67 ha)
    Crop complex 1 (kharif only)
    Optimum technology
    Flat planting
    Animal power for watershed development during rabi season
    Grassed waterways
    Animal power and improved implements

13. Watershed BW7B (6.56 ha)
    Crop complex 1
    Optimum technology
    Flat planting approximately on contours
    Field bunds remain
    Animal power and improved implements.

14. Watershed BW8A (8.07 ha)
    Crop complex 1 (monsoon only)
    Local technology
    Flat planting
    Field bunds remain
    Animal power and local implements
    Land preparation after the first rains.

15. Watershed BW3B (5.12 ha)
    Crop complex 1 (monsoon only)
    Optimum technology
    Field bunds remain
    Mechanical power and implements

16. Watershed BW3C (8.25 ha)
    Crops: Upland rice and grass forage
    Optimum technology
    Flat planting
    Fields bunded and land planed after monsoon 1974
    Animal power and improved implements.

On the black soil watersheds the additional development work needed on the catchments BW1, BW2, BW3, BW4 and BW5 has essentially been completed. The availability of machinery and manpower will be the primary determining factor for the degree to which the plans for development of research watersheds on the other black soil catchments can be completed before the 1974 monsoon season. A schematic drawing of a catchment in ridges and furrows with guide terraces and with a facility for runoff storage is given in fig. 7.

B. Red Soils:

Unfortunately, the number of separate drainage units or well delineated watersheds available on the red soil at the ICRISAT experiment station is rather limited. For evaluating different land and water management techniques and associated systems of farming on red soils only 3 watersheds or parts thereof can be used. In the initial stages of development of research watersheds on red soils, the ridge and furrow system and cultivation of grain and pulse crops will receive primary attention. In a secondary stage other land and water management techniques and alternative cropping systems including grasses, fruit trees and fuel trees will be introduced.

1. Watershed RW1:

The total area included in this watershed is approximately 15 ha; about 4 ha of the watershed is located outside the ICRISAT boundaries and occupied by the relocated villages of Manmool and Kachireddipally (Shrinivasnagar). This part of the watershed has been designated RW_0; separate runoff measurements of this part of the catchment will yield some information on the hydrologic behaviour of urbanized areas. Another area of about 4 ha of the RW1 watershed is located within the experiment station but cannot be developed until the ICRISAT campus has been constructed; drainage of this area will be kept separate from the gauged parts of the watershed.

The remaining portion of the catchment (about 7 ha) has, on the basis of the original lay of the land and estimated permissible length of overland flow, been subdivided into 5 drainage units; RW1a, RW1b, RW1c, RW1d and RW1e. Two of the units (a and b) will be utilized for small scale experimental plots of the Farming Systems Program. The earlier described crop complex will be superimposed on units c and d during the next kharif. Alternate crop complexes may have to be developed for the red soils. Ridges and furrows at slopes varying from .2 - .6% will be formed on units RW1a-RW1d after planting, early in the monsoon. During the 1974 monsoon season, grasses and trees will be established on RW1e. Each of the drainage units will be monitored separately with regard to its runoff characteristics and other factors related to water use.

2. Watershed RW2:

The total size of watershed RW2 is approximately 80 ha; a relatively large portion (35 ha) is located outside the boundaries of ICRISAT; this portion has a cover of grasses and brush and is under uncontrolled grazing. The data on runoff from this part of the watershed (a concrete 7' Parshall flume has been constructed) will provide some initial information on runoff occurring under conditions typical for substantial uncropped areas in the Semi-Arid Tropics. A relatively small portion of the watershed (about 10 ha) is located in the precision farming area of the experiment station but can easily be monitored separately.

The remaining part of the watershed amounts to approximately 35 ha and consists of a mixture of shallow soils, rock outcrops, old pits used for excavation of brick material, broken tank bunds, etc. A beginning has been made with the reclamation of this watershed area. A new tank bund creating a pond with an approximate capacity of 4 ha M has been built. A number of terraces and drains have been constructed. The difficulties experienced in working the hard red soil during the dry season have forced the delay of further development activities until the 1974 monsoon season. Once completely developed, it is envisaged that watershed RW2 will provide opportunities for the hydrologic monitoring of several land and water management systems under alternative cropping patterns in which grasses and trees will play a more dominant role.

RESEARCH ON LAND AND WATER MANAGEMENT

Data have been collected on five complete black soil watershed units for a period of less than one year. The physical characterisation of these catchments has been given in the preceding section. At the outset of this discussion it has to be emphasized that one year of data is entirely insufficient to draw conclusions on the hydrologic behaviour of watersheds under several management systems planted to varying cropping patterns. The analysis of the information collected the past season has raised more questions than it has provided answers. There is an apparent need for greater accuracy and higher frequencies of data collection on some phases of the hydrologic cycle, in particular with regard to soil moisture, evapotranspiration, groundwater and erosion.

This year's hydrologic data for seven separate watershed sections (two of the catchments were divided into sub-units) have been summarised in table 25 (pg.72). The time period taken into account approximates last year's monsoon season. The "water year" at ICRISAT would ideally begin around May 1 and end on April 30 of any two successive years; in subsequent Annual Reports approximately this period will be used for data analysis. The following discussion of results is of a preliminary nature and any conclusions drawn at this stage will have to be reviewed in the light of the results of more refined studies in subsequent years.

Rainfall

A total of seven raingauges, two of which were of the continuously recording type, was installed on the black soil watersheds in such a manner that a Thiessen network application would result in satisfactory estimates of the average precipitation received by each watershed. Although the total rainfall during the season computed for each catchment is in the same order of magnitude (table 25), substantial differences between watersheds were observed during single storms, e.g. a storm occurring on August 19 resulted in computed average rainfalls of 13, 15, 16, 21 and 28 mm on watersheds BW1, BW2, BW3, BW4 and BW5, respectively. The impression of extremely variable precipitation during single shower rainfalls was substantiated when data collected at different gauges across the experiment station were compared; on August 3 a raingauge at the South West portion of the experiment station registered 79.1 mm while on the red soil research fields only 19.4 mm was recorded (fig.1). Where particularly in the watershed based research phase when the comparative effect of individual storms is studied an accurate estimate of precipitation is essential, the raingauge network will be intensified.

The total precipitation during the monsoon season June - October was 8% above the long term averages and was characterised by an unusually dry period in September (fig. 2). The annual rainfall during 1973-74 was 94% of what is normally expected (table 1). With regard to precipitation intensity, the continuous recorder data indicated a maximum intensity of 43 mm/hr; the two year-one hour maximum rainfall expected at Hyderabad is about 35 mm while the five year-one hour maximum rainfall amounts to approximately 50 mm. The maximum precipitation observed over any 24 hr. period during the past season was 51 mm which is substantially less than the 2 year-24 hr. maximum rainfall reported for Hyderabad (75 mm) or the 5 year-24 hr. maximum (100 mm).

Runoff

On most catchments the first runoff was observed on June 30; at this stage the quantity of effective rainfall was still very small and the soil was essentially dry beyond 5 - 7.5 cms depth. In the early part of the monsoon season a number of causes for error had to be corrected. The fluid connections between the Parshall flumes installed for runoff measurement and the continuous stage height recorders became repeatedly clogged by sediment during the final stages of a surface runoff event. Runoff from boundary roads caused an apparent watershed response, particularly during very brief high intensity rainfall periods at times when no runoff occurred from the actual cropped watersheds. These problems which were corrected where possible early in the season may have caused some variation in the number of storms during which runoff occurred on separate watersheds and also slight errors in the runoff estimates (table 25).

In a comparison of total seasonal runoff for the five watersheds (or sub-units) cultivated to a ridge and furrow system of predetermined grades it is clear that the quantity of surface runoff increases with steeper average furrow slopes. A minimum surface runoff value of 45 mm or 6.1% of the seasonal rainfall was observed on watershed BW1 while a maximum figure of 122 mm or 16.1% of the total precipitation was obtained for watershed BW5B (table 24). A relatively small portion of the latter figure may have been caused by the influence of a boundary road throughout the monsoon.

When individual hydrographs of runoff producing storms are compared the hydrograph appears steeper and extends over a relatively shorter period when furrow slopes increase. The results of runoff measurements on five selected high rainfall storms which contributed approximately 25% to the total seasonal rainfall, caused about 25% of the total seasonal runoff on watershed BW1, 64% on BW2, 29% on BW3B, 68% on BW4 and 46% on BW5B. These figures may give an indication of the influence of the "internal storage capacity" created by field bunds in watershed BW2 and BW4. This internal storage capacity would presumably be least effective during periods of high intensity relatively long duration rainfalls.

Table 24 Runoff from five selected high intensity storms on catchments BW1, BW2, BW3B, BW4 and BW5B.

Date	Aug. 6		Aug.16		Oct. 3		Oct.4		Oct. 26		Totals		
Watershed	P 1/	R 2/	P 1/	R 2/	P 1/	R 2/	P 1/	R 2/	P 1/	R 2/	P 1/	R 2/	R 3/
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	%
BW1	37.1	6.2	33.6	3.4	25.5	0 4/	36.2	4.2	27.6	4.1	160.0	17.9	11.2
BW2	38.7	4.5	31.9	0.7	23.0	0.8	32.3	0.1	27.7	0.9	153.6	7.0	4.6
BW3B	36.3	10.0	31.0	2.1	22.0	5.0	31.0	1.9	27.0	5.1	147.3	24.1	16.4
BW4	44.0	12.7	34.8	2.3	26.1	14.6	37.2	3.2	30.3	7.8	172.4	40.6	23.5
BW5B	41.3	15.0	34.5	9.5	24.9	17.8	36.2	5.6	30.6	8.7	167.5	56.6	33.8

1/ P = Precipitation

2/ R = Runoff

3/ R = Total runoff during the 5 storms expressed as a percentage of total rainfall during those storms

4/ Watershed BW1 had just been partly disced.

Therefore, it appears as if ridge and furrow systems applied to the land after a minimum of land smoothing, can be used to manipulate runoff. The indications are that the alternative ridge and furrow systems influenced infiltration opportunity time and therefore runoff and infiltration. The increased infiltration is not reflected in soil moisture data taken on the watersheds throughout the season (fig.8 and 10). This is not surprising because the rainfall distribution was such that the soil profile was probably filled to near capacity at most times during the latter part of the 1973 monsoon.

One important purpose of a ridge and furrow system presumably is the maintenance of adequate drainage conditions on black soils during long continuous wet periods in the monsoon. Visual observations during such periods in the past monsoon season have given no indication of serious drainage problems under low slope conditions, e.g. on watershed BW1 in comparison with ridge and furrow systems of steeper slope. Some problems associated with poor drainage conditions were observed on early rabi plantings of e.g. chickpea. The "post-monsoon" crops were planted flat and the early sowings were subject to substantial rainfall in October. Although lower slopes necessitate greater precision in laying out the ridges and furrows on land of variable topography (or would require additional earth movement) these indications encourage the testing of the hydrologic effects of lower average slopes for ridge and furrow systems in forthcoming seasons.

The two watersheds BW2 and BW4 on which traditional systems of farming were simulated were characterised by relatively small amounts of measured surface runoff of 11 and 59 mm respectively (table 25). Both watersheds are bunded and therefore although during rainfall there is runoff from individual fields,this runoff is stored above field bunds until a "threshold" value is reached or until the rainfall terminates.

An estimate of this total "internal storage capacity" on e.g. the BW4 watershed and of the number of times this storage capacity actually functioned would increase the runoff figure on BW4 to over 90 mm. The same process functioned even more pronounced in watershed BW2 (the 9.1 ha BW4 watershed is divided into 13 bunded fields; the 4.1 ha BW2 watershed consists of 11 separate bunded fields). Visual observations indicated rather severe drainage problems immediately above the bunds in the BW2 watershed and standing water above bunds on BW4. Subsequent to rainfall, the water accumulated infiltrated into the soil while a relatively small portion evaporated. However, in the two bunded watersheds the area over which this increased infiltration occurred amounts to less than 10% of the total area and moreover this added infiltration component takes place in an area where in most cases the crops grown are repeatedly subject to drainage problems.

A critical comparison of the ridge and furrow method with the traditional system of bunded fields has to await the results of additional seasons to monitor the response of different management systems under varying climatic conditions in a more refined manner. However, at this stage it appears feasible to design ridge and furrow systems which give no substantially greater total runoff than the bunded systems and which have the advantage of increasing infiltration of high intensity precipitation at the actual locations where the rain falls without causing a drainage problem. Bunded systems, although effective in runoff reduction, particularly during high intensity rainfalls of short duration appear to increase infiltration in only relatively small portions of the total watershed and to result in problems associated with excess water at those locations.

Erosion

All observed values on erosion for the past season are relatively small (table 25). The data were obtained from frequently taken water samples at the outlet of each watershed. The recorded erosion on watersheds BW1 and BW3B (slopes $\leq$.8%)

amounted to only about 3 T/ha (tons per hectare); similar figures were obtained from the watersheds with bunded fields. When the average slopes of ridge and furrow systems increased over .8%, erosion appeared to be also considerably increased. However, visual observations immediately after storms generating substantial runoff indicated serious erosion within individual fields on the bunded watersheds, this eroded material being deposited on the less steep portions of a field or above bunds. In the watersheds in ridges and furrows no examples of serious localized erosion were observed except in those cases where individual furrow slopes exceeded 2%; the length of furrows generally being less than 100 M. Excess water in these watersheds is led from the soil in many small streams at relatively low velocities not allowing the formation of concentrated flows of water. Therefore it again appears (as when considering rainfall and runoff) that a ridge and furrow system maintains more soil at its original location than do systems of field bunds.

Soil moisture

A large number of soil samples (upto 180 cm depth) was collected and analysed for moisture throughout the monsoon and post monsoon season to obtain a continuous record of the moisture status of the profile. Due to limitations in equipment and staff the frequency of sample collection was insufficient particularly for the BW2 and BW4 watersheds.

If a ridge and furrow system of a given slope decreases runoff and increases infiltration and if the total quantity of water infiltrated even under optimum conditions is insufficient to satisfy the total storage capacity of the profile, differentials in the moisture content of the rootzone along the direction of the ridge and furrow system would be expected. The results of moisture samplings during the monsoon and at the end of the rabi season gave no clear indications to this effect.

Table 25 - Hydrologic data from seven watershed units (June 1 - Oct. 31)

Watershed Code	Watershed Area (ha)	Slope (%)	Rainfall (mm)	No. of Runoff storms	Runoff mm	Runoff % of P.	Erosion (T/ha)	Tank cap. (ha/m)	Irrigated (ha)
BW1	3.5	.6[1/]	731	21	45	6.2	3.0	—	—
BW2	4.1	1.0-1.5[2/]	735	15	11	1.5	2.2	—	—
BW3A	4.4	1.1[1/]	739	—[3/]	71	9.6	8.2	.40	1.4
BW3B	2.1	.8[1/]	734	16	47	6.4	2.9	—	—
BW4	9.1	1.0-2.0[2/]	739	22	59	8.0	3.9	—	—
BW5A	6.5	1.7[1/]	757	—[3/]	91	11.9	11.3	.42	6.7
BW5B	8.1	1.8[1/]	755	26	122	16.1	13.3	—	—

[1/] The slopes indicated are average slopes of ridges and furrows on an entire watershed measured along furrows from the topographically higher point towards the outflow location at a drain. Due to the fact that minimum earth movement has been a self-imposed restriction on watersheds BW1, BW3 and BW5, considerable variation existed around the average. This is true not only when comparing furrows in different areas of the same catchment but also along many individual furrows.

[2/] Catchments BW2 and BW4 were maintained in their original layout and topography. Although the average slopes of the land on the basis of the entire watershed were in the ranges indicated, real slopes on individual bunded fields were less. A continuing process of erosion on these watersheds has resulted in some degree of "levelling" of separate fields. The existing bunds create an internal storage capacity in the watershed.

[3/] Although the total runoff collected was measured, no Parshall flumes were installed at the tank inlets, therefore the exact number of runoff producing storms for catchments BW3A and BW5A is not known.

The results of moisture determinations in July and at the end of the post monsoon crop season in January have been summarized in fig. 8 and fig. 9a-d for watershed BW1. Although a relatively dry zone at about 60 cms depth is very apparent from the July samplings, there is no significant difference along the direction of the furrows (fig. 8). The final moisture content at the watershed boundary ridge locations (North and South) and those observed midway between the boundary ridges and the drain showed small differences between the Northern and Southern half of the watershed (fig. 9a,b). These differences might be caused by local topography.

When all data collected near the boundary ridge (beginning of each furrow), near midway between the ridge and drain and near the ditch (the end of each furrow) were compiled, no significant differences were observed (fig. 9d). The moisture data obtained in July and at the end of the rabi season in watershed BW3A have been summarized in fig. 10 and fig. 11a-d. Also in this case there are no indications of differentials according to location along the furrows. In a year during which the rainfall distribution was such that the total storage capacity of the profile was probably satisfied at most times, no matter which techniques were used to increase infiltration, these results are not surprising. However, even in seasons in which the precipitation falls periodically short of meeting the storage capacity of the profile,it might be difficult to determine relatively small moisture status differentials between locations at the beginning and end of a furrow.

Samples taken at different times at approximately the same locations in watersheds BW1-BW5 were compiled to show a seasonal record of the moisture status in different watersheds (fig. 12). In early July after approximately 40 mm of effective rainfall had been contributed to the profile by early monsoon showers the total quantity of moisture in the upper 180 cm of the soil ranged from approximately 550 to 625 mm except for the BW2 watershed. The low moisture status in this latter watershed may have been due to the effect of a rabi crop planted by farmers in the preceding season.

The maximum quantity of moisture observed in the profiles of different watersheds occurred in early November and varied from 750 to 825 mm. These latter figures have to be regarded with reservations. Although generally a few days were allowed for the drainage of free water before moisture samples were taken, there are some strong indications of extremely slow internal drainage on the black soils.

It is interesting to note that in November hardly any difference was observed in the total quantity of moisture present in the profile of the watersheds cropped during the monsoon, compared to that of the fallowed BW4 watershed. Thus in the 1973 season, the efforts to conserve moisture by fallowing appear to have had little effect. The total quantity of moisture present in the upper 180 cms of the profile of watershed BW4 in early July was about 600 mm (fig. 12); in early November this quantity had increased to only 825 mm (fig. 12). The total measured rainfall on watershed BW4 was 739 mm (table 25). It may therefore be concluded that on this watershed more than 2/3 of the precipitation was lost for crop production; deep percolation, evaporation and runoff being the primary components of the loss. This occurred notwithstanding the fact that watershed BW4 was ploughed repeatedly to prevent transpiration losses from weeds.

During the rabi season soil moisture data were collected on watersheds BW1, BW3 and BW5 only; a relatively fast moisture extraction process is observed on these cropped watersheds until a minimum is reached at the end of the rabi season, at that time the total moisture content in the 180 cm deep profile varied between 475 and 525 mm.

It appears, that on watersheds BW1, BW3 and BW5 an appreciable extra contribution to evapotranspiration was gained from moisture stored in the profile at the beginning of the kharif season (fig. 12). It is recognized that this process, if real, cannot be repeated. Moisture data after the rabi seem to indicate a gain in the moisture present in the upper 180 cms of the profile, a gain that can only partly be explained by diffusion processes with deeper layers. Additional research is needed to provide for a better understanding of moisture related processes on the black soils.

Groundwater

Changes in the level of the groundwater were measured frequently at five piezometers installed in the watersheds. Just before the 1973 monsoon season, the general level of the groundwater in most of the black soil watersheds (except for the western portion along the main drain) varied from 7 - 9 M below the level of the land, increasing in the direction of the main eastern boundary ridge (fig.1). It appears that the groundwater begins to respond to the influx of precipitation in late July or early August after approximately 300 mm of rain had been received (fig. 13). At the end of the monsoon season the general phreatic level had increased approximately 2 M (fig. 13). The additional storage capacity or yield of the clayey murrum subsoils in the area is extremely low and can be estimated at less than 5%. The total contribution to groundwater from rainfall, even taking into account a slow discharge during the monsoon, therefore was probably less than 100 mm. Piezometers installed at shallower depths (2 M and 5 M) gave no evidence of occurrence of perched watertables due to layers of low hydraulic conductivity at any time during the season.

It is regrettable that the piezometer data seem to indicate that the watersheds are not separate units in terms of the groundwater basin. Furthermore it appears that the groundwater in the entire black soil watershed area is subject to influences of the much larger Manmool basin in which most of the experiment station is located. The initial data collected, indicate that the groundwater table in most of the black soil watershed area is of sufficient depth to exclude potential influences of the groundwater on the moisture status of the root profile. However, to obtain a closed water balance it will be necessary to apply direct methods for the measurement of deep percolation.

Two of the piezometers (No. 4a and 4k) were located near the runoff storage pond in the BW5A watershed to observe the effect of possible seepage from the tank on local phreatic levels. There are no indications of a substantial rise in groundwater due to the gradual filling of the tank from July 27 to October 31 or of appreciable decreases when water was used from the storage pond (fig. 13).

For the next season more detailed measurements on the actual shape of the groundwater contours are planned, while an analysis of the yield of relevant subsoils will be made. A number of additional piezometers has been installed for this purpose.

Grassed waterways and trees

A number of different varieties of grasses was planted in the drainage ways of watersheds BW1, BW3 and BW5 (Dicanthium Annulatum, Cenchrus Cetigerus, Cenchrus Ciliaris, Chrysopogon Fulvus, Cynadon Doctylon, Digiteria and Brachiaria Mutica, also tried were Hybrid Napier, "Paragrass", Pearl Millet and local grass sod. The determining factors considered for the selection of satisfactory grasses were: original stand establishment, erosion resistance, the ability to withstand prolonged wet conditions, quick regeneration after the dry season and the production of quality fodder. The evaluations are not complete and will be continued.

Serious difficulties were encountered in trying to obtain a reasonable stand before runoff events would start eroding the center section of the drainage ways. Direct seeding, early in the monsoon season failed. The use of grass seedlings sown in seedbeds at the end of the dry season under irrigation and then planted in the drains was unsuccessful without continued availability of supplemental water for a few weeks. Direct seeding in a mixture with fast establishing Pearl Millet was tried and of limited success. In early July a major portion of the drainage channels had still only very limited cover and erosion of the center ditch portions, particularly in sections with a slope greater than 1% became a serious problem. Finally, and as an emergency measure, well established grass sod, locally available from old runoff storage tank beds was used to protect the center sections of the steeper parts in the ditches. The side slopes were planted to seedlings of other grass varieties. This method proved successful in preventing erosion (at the runoff intensities experienced this season) even where the drain slopes exceeded 2%.

Stand establishment and erosion resistance were evaluated for sections of 50 M of the drains, which were planted to different grass varieties. Information on production of forage has been summarized in the section on production research. From this season's observations on erosion resistance and stand establishment, a provisional selection of local grass sod, Dicanthium Annulatum and Cenchrus Ciliaris for the center section of drains results, while Cenchrus Ciliaris, Digiteria and Hybrid Napier proved reasonably satisfactory on the side slopes. Additional work is planned for the next season in order to find better methods for early grass establishment (without irrigation) by the use of mulches and different seed mixtures.

The trees planted in small irregular areas near the storage ponds established well. However, about half of the papaya trees were eliminated due to poor drainage in the later part of the monsoon season. In the subsequent dry season the papayas seemed to suffer most from moisture stress. No fruits have been obtained from any of the trees and observations continue.

Runoff collection and recycling

In two of the black soil watersheds (BW3A and BW5A) a pond had been constructed for the storage of runoff water and subsequent utilization. The primary departure from conventional design in the construction of these tanks was that they were characterized by great depth ($\geq$ 4.00 M) and a relatively small surface area. The tank in the BW3A watershed (capacity .40 ha M) filled up to less than half of its capacity (the contributing area to this tank is presently being increased). The tank in the BW5A watershed filled up entirely and spilled a small quantity in late October (some water was used from this tank in September to provide better moisture conditions for germinating sorghum).

Evaporation data were collected for the BW5A tank from a floating evaporation pan,while also daily staff gauge readings were taken. The results have been summarized for four ten day periods during which no rainfall occurred (table 26). At near maximum capacity (design height is a staff gauge reading of 4.00) the seepage rate amounted to just over 2 mm/day while,when the storage pond was about half filled the seepage rate dropped to below .5 mm/day. Also, the evaporation rates measured in the tank compare very favorably with those measured of the Agro-Meteorology station (an approximate reduction of 20% was observed). Although no precise data were collected for the BW3A storage tank, periodical observations of the level of the water in this pond resulted in similar information with regard to seepage and evaporation. Runoff water was stored in the BW5A tank from July 27, 1973 to the end of January 1974. If the average total losses during this period are estimated at 5 mm/day the seasonal water loss would amount to approximately 90 cm, or less than 25% of the quantity collected. This figure would seem to be appreciably lower than the losses commonly observed at more conventional runoff storage facilities which are characterized by a large surface area and shallow depth. Where evaporation is by far the largest component of the loss, further reduction can be realized by recycling of the runoff water earlier in the post monsoon season. It may be concluded from this section that seepage rates under the given sub-soil conditions are extremely small and also, that further efforts to improve upon the design of water storage facilities (both with regard to reduction of losses and of the costs associated with pond construction) are justified.

The collected runoff water was used in supplemental applications to some of the post-monsoon season crops (sorghum, sunflower, chick pea and wheat). The water was applied by sprinklers as well as through furrow irrigation. The total area irrigated in the BW5A watershed (some crops received 2 or 3 applications e.g. wheat) amounted to approximately 6.7 ha. Each application consisted of about 50 mm of water. In the BW3A watershed the area provided with supplemental water was much smaller (1.4 ha), partly due to problems with irrigation equipment. The response of crops to supplemental irrigations was disappointingly low as will be discussed in the next section. Three reasons can be identified as probable causes: (1) the moisture conditions in the black soil were unusually favorable at the beginning of the post monsoon season due to the occurrence of late rains, (2) supplemental water applications may have been delayed too much, after substantial cracking of the black soil had occurred and (3) insufficient information on crops most

Table 26 - Evaporation and seepage at four stage heights in the BWSA runoff storage pond.

Date	Met. Station Evapn.	BWS tank Evapn. (I)	Fall in staff gauge reading (II)	Seepage (II-I)
	mm	mm	mm	mm
Oct. 10	3.2	2.8	5.0	2.2
Oct. 11	5.0	4.0	6.0	2.0
Oct. 12	5.7	4.0	5.0	1.0
Oct. 13	5.0	4.0	5.0	1.0
Oct. 14	5.0	4.5	5.0	0.5
Oct. 15	5.5	4.7	6.0	1.3
Oct. 16	5.3	4.0	5.0	1.0
Oct. 17	4.0	4.0	5.0	1.0
Oct. 18	5.2	4.0	5.0	1.0
Oct. 19	6.8	6.0	7.0	1.0
Total	50.7	42.0	54.0	12.0

Staff gauge reading Oct. 9: 335.5
Oct. 19: 330.1 Average seepage rate per day 1.2

Date	Met. Station Evapn.	BWS tank Evapn. (I)	Fall in staff gauge reading (II)	Seepage (II-I)
	mm	mm	mm	mm
Nov. 13	3.0	1.8	3.0	1.2
Nov. 14	3.0	1.0	4.0	3.0
Nov. 15	4.0	3.0	5.0	2.0
Nov. 16	4.0	6.0	8.0	2.0
Nov. 17	5.0	2.5	6.0	3.5
Nov. 18	4.8	5.5	10.0	4.5
Nov. 19	5.0	5.0	7.0	2.0
Nov. 20	4.0	2.9	4.0	1.1
Nov. 21	4.0	4.0	5.0	1.0
Nov. 22	4.3	4.0	6.0	2.0
Total	40.1	35.7	58.0	22.3

Staff gauge reading Nov. 12: 385.5
Nov. 22: 379.7 Average seepage rate per day 2.2

Table 26 (Continued)

Date	Met. Station Evapn.	BWS tank Evapn. (I)	Fall in staff gauge reading (II)	Seepage (II-I)
	mm	mm	mm	mm
Nov. 23	6.0	5.0	7.0	2.0
Nov. 24	5.7	3.5	7.0	3.5
Nov. 25	4.9	3.6	6.0	2.4
Nov. 26	5.3	5.0	7.0	2.0
Nov. 27	5.0	4.0	6.0	2.0
Nov. 28	4.0	4.0	6.0	2.0
Nov. 29	5.0	4.0	6.0	2.0
Nov. 30	4.0	4.0	5.0	1.0
Dec. 1	4.6	3.9	4.0	0.1
Dec. 2	4.5	2.4	7.0	4.6
Total	49.0	39.4	61.0	21.6

Staff gauge reading Nov. 22: 379.7
Dec. 2: 373.6

Average seepage rate per day 2.2

Date	Met. Station Evapn.	BWS tank Evapn. (I)	Fall in staff gauge reading (II)	Seepage (II-I)
	mm	mm	mm	mm
Dec. 19	4.5	3.0	4.0	1.0
Dec. 20	4.5	4.0	4.0	-
Dec. 21	5.0	3.0	3.0	-
Dec. 22	4.7	4.0	4.0	-
Dec. 23	4.0	4.0	4.0	-
Dec. 24	4.6	4.0	4.0	-
Dec. 25	4.3	2.8	3.0	0.2
Dec. 26	4.0	2.8	3.0	0.2
Dec. 27	5.0	4.0	4.0	-
Dec. 28	4.0	4.0	4.0	-
Total	44.6	35.6	37.0	1.4

Staff gauge reading Dec. 18: 254.8
Dec. 28: 251.1

Average seepage rate per day 0.1

responsive to supplemental water under the conditions of the Semi-Arid Tropics is presently available. This season's results show a clear need for further applied research on profitable means of runoff utilization.

Some preliminary observations on the water balance

In the past season, it has not been feasible to obtain a closed water balance (such that all components are directly or indirectly measured) and to gain an indication of errors from discrepancies in the water balance equation. This is primarily due to a lack of specific information with regard to evapotranspiration throughout the crop season and with respect to deep percolation to groundwater during the monsoon. Efforts to compute evapotranspiration rates from weather data have not proved satisfactory, primarily because of the uncertainties involved in estimating this factor under moisture stress conditions. Computations of evapotranspiration from subsequent soil moisture determinations during the monsoon resulted in unacceptably high estimates, probably due to slow internal drainage. Different means to improve upon the data collection on deep percolation and evapotranspiration will be tried the following season.

Some indication of the relative magnitude of the water balance components may be given at this stage, taking the BW1 watershed as an example. In early July the moisture content of the 180 cms deep profile was determined as 560 mm (fig.12). At the end of the monsoon crop season (early November) and the beginning of the rabi crop season the moisture content of the profile had increased to about 800 mm (fig. 12). The rainfall from early July to early November can be estimated at approximately 650 mm. Assuming that deep percolation and runoff in watershed BW1 amounted to 140 mm (pg.75 and table 25), the total evapotranspiration during the monsoon season would amount to 650-140 - (800-560) = 270 mm. Evapotranspiration in kharif most probably took place at near potential rates during much of the season because of favorable soil moisture conditions. Therefore, the estimate appears low; errors in the computed evapotranspiration would be primarily due to the evaluation of deep percolation. It may therefore be concluded that either the yield factor of the subsoils has been overestimated or that water table fluctuations in the black watershed area may occur as a result of external events.

The effective rainfall during the rabi season was negligible. The moisture content of the 180 cms profile at the end of the post monsoon season (March) amounted to about 525 mm. Therefore the evapotranspiration during the rabi season, assuming no contributions from the subsoils (deeper than 180 cms) can be estimated at 800-525 = 275 mm.

The total precipitation in the 1973-74 season was about 740 mm. The total quantity of moisture used by the cropping pattern of sorghum/pearl millet in kharif followed by safflower in rabi was at least 545 mm. Although the moisture present in the profile decreased by about 40 mm between early July and March, this factor is compensated by approximately 40 mm of effective rainfall which had occurred before the date of the first soil moisture determination in July. Thus, the "rainfall use efficiency" on watershed BW1 appears to have been around 70% $\left(\frac{545}{740} \times 100\right)$. This figure, although only a first approximation would seem considerably higher than the percentage of total annual rainfall used for evapotranspiration in more traditional systems of farming. A similar calculation for rabi cropping simulated on the BW4 watershed results in an estimated rainfall use efficiency of less than 50% (fig.12).

It is apparent from this discussion, that there is substantial scope for improvement in studies aimed at optimum water utilization. In the coming season primary attention will be paid to obtain better information with regard to evapotranspiration and ground water. Additional efforts will be made to gain more accurate data on other components of the hydrologic cycle.

The year 1973-74 has been rather favorable in terms of both total rainfall and rainfall distribution. This year's results therefore, have to be regarded with caution. However, this season's data do indicate considerable potential for realizing higher rainfall use efficiencies in the Semi-Arid Tropics, which is the basic goal of the Farming Systems Program.

PRODUCTION RESEARCH ON WATERSHED-BASED FARMING SYSTEMS

The average yields obtained from all crops grown in the black soil watersheds during both the kharif and rabi seasons have been summarised (table 27). It is regrettable that insufficient data were collected on time and cost factors related to land preparation, planting, cultivation, harvesting, threshing etc., so that no economic evaluation of the different cropping patterns and land and water management systems is feasible at this time. Much more detailed data collection on variable costs and returns of alternative systems is planned for succeeding years. However, even without this information a number of interesting observations can be made.

Although weather conditions throughout the 1973 monsoon appeared relatively favorable for a good crop, traditional kharif cropping, the presently most widely applied system of farming in the Hyderabad region (simulated in watershed BW2) resulted in hardly any grain production, while the dry fodder produced amounted to 153 and 95 q/ha for sorghum and pearl millet respectively. It must be admitted that one of the reasons for this poor result in terms of production was caused by rain damage due to a shift of the high rainfall period, which normally occurs in September, towards October. However, even when the rainfall distribution had been more favorable, production under the system of farming simulated in watershed BW2 would in all probability have been the lowest observed in all watersheds. It may be recalled that watershed BW2 was characterized by the smallest amount of surface runoff during the past season (table 25).

It must be assumed, that the low input levels in terms of human labor, animal and/or mechanised power, machinery, fertilizers, etc., and the use of the traditional tall varieties are primary reasons for the unsatisfactory result. However, poor drainage conditions due to stagnant water in local depressions and above field bunds, which were observed repeatedly, may have been another factor.

In watershed BW4 a traditional rabi cropping system on black soils was simulated. The late rains provided for relatively good seedbed conditions and reasonable stands were obtained. The final yields (table 27) compared favorably with those reported by farmers located near the experiment station. In a ranking of production figures the rabi cropping system under last season's conditions would certainly seem preferable to a traditional kharif cropping system. During the monsoon season the watershed had to be ploughed four times to control weeds.

The production figures reported for the three black soil watersheds on which a kharif crop as well as a rabi crop was grown are of a different order of magnitude. On watershed BW1 (during the wet season planted to ridges and furrows at a .6% grade) a sorghum production of 33.4 q/ha was obtained while the maximum recorded safflower production in the post monsoon season amounted to 22.6 q/ha.

On watershed BW3 (in the monsoon planted to ridges and furrows at .8 and 1.1% grades) the results obtained were even a little better; a pearl millet grain production of 44.1 q/ha and a maximum safflower yield of 23.0 q/ha were obtained. On watershed BW5 (in the monsoon planted to ridges and furrows at a 1.7% grade), the soils appear to be somewhat inferior to those in watersheds BW1-BW4, particularly in terms of their nutrient status, probably due to somewhat steeper slopes and related past erosion patterns. A soil depth map prepared for watersheds BW1-BW8 also shows somewhat shallower soils in watershed BW5 (fig. 14). It is therefore not surprising that the maximum yields recorded are relatively low, with a monsoon season sorghum yield of 25.3 q/ha and a post-monsoon season chick pea yield of 21.3 q/ha.

In both the BW3 and the BW5 watersheds, runoff water was collected and later reutilized to supplement the residual moisture in the soil after the monsoon season crop. In most cases the response to irrigation has been low (table 27). One reason may have been the fact that the moisture status of the soils at the beginning of the post monsoon season was unusually good (fig. 12). The large quantity of total available moisture in the deep black soils and the relatively cool weather conditions during the period November to February reduce any supplemental demand appreciably. Also, particularly for the sunflower crop, the irrigation water may have been supplied too late to affect yield substantially.

Although no formal replicated date of planting experiments were conducted in the black soil watersheds during the rabi season, a large number of chick pea plantings were made from mid-September to early November, which provide some interesting data. The yield of chick pea (BEG 42) planted on black soils on September 15, October 14 and October 21 was 21.3, 15.1 and 6.8 q/ha, respectively. The grain yield of local chick pea planted on October 14 and November 9 was 17.5 and 8.5 q/ha, respectively. Preliminary observations from these data indicate benefits from earlier plantings. More comprehensive date of planting experiments for different varieties are planned for the next season to investigate this further.

A variety of grasses was planted in waterways on watersheds BW1, BW3 and BW5. The performance of these grasses in terms of stand establishment and erosion control has been discussed earlier. Particularly on watershed BW1 the grasses in

Table 27 - Average yields of crops grown in five black soil watersheds during the monsoon and post monsoon seasons. Yields included are derived either from replicated trials or from replicated random samples (4-8). All yields in q/ha.

Crop	Variety	Grain Straw	Sowing date	Harvest date	BW 1	BW 2	BW 3	BW 4	BW 5	Remarks
MONSOON SEASON:										
Sorghum	CSH-1	Grain	Jun. 8	Oct.12	33.4		37.6		25.3	
		Stalk			58.3		63.2		45.2	
Sorghum	Local	Grain	Jul.16,17	Nov. 2		— 1/				
		Stalk				153.0				
P.Millet	HB-3	Grain	Jun. 8	Sep.20	21.7		37.0		17.0	
		Stalk			32.2		81.1		32.0	
P.Millet	HB-4	Grain	Jun. 8	Sep.20	24.6		44.1		21.4	
		Stalk			39.6		25.7		54.7	
P.Millet	Local	Grain	Jul.18,19	Nov. 9		.2 2/				
		Stalk				95.0				
POST MONSOON SEASON:										
Sorghum	Local	Grain	Nov.10	Mar. 3				12.8		
		Stalk						49.9		
Sorghum	CSH-1	Grain	Oct. 8	Feb.25					19.4	Irrigated
		Stalk							18.6	
Sorghum	CSH-3	Grain	Oct. 8	Feb.25					16.2	Irrigated
		Stalk							19.2	
P.Millet	HB-1	Grain	Sep.15	Dec.27					4.3	
		Stalk							32.8	

1/ No grain yields taken because of severe mold damage due to October rains.

2/ Extremely low yields due to the effect of October rains.

Table 27 (Continued)

Crop	Variety	Grain Straw	Sowing date	Harvest date	BW 1	BW 2	BW 3	BW 4	BW 5	Remarks
POST MONSOON SEASON:										
Chick Pea	BEG482	-	Sep.15	Jan. 1					21.3	
" "	BEG482	-	Oct.14	Feb. 6			15.1			
" "	Local	-	Oct.14	Jan.26			17.5			
" "	Local	-	Oct.19	Feb.24				11.0		
" "	Local	-	Nov.29	Mar.14					8.5	
Setaria	H-1	Grain	Sep.15	Dec.18					18.6	
		Stalk							30.4	
Safflower	S-11	-	Sep.15	Feb.19					10.6	
"	"	-	Oct.13	Mar. 1	20.2		23.0	12.8		
"	"	-	Oct.15	Feb.20					12.5	
"	"	-	Oct.23	Mar. 1	22.6					
"	"	-	Nov. 9	Mar.23	7.6					
"	S-5	-	Oct.13	Mar. 1			17.7			
"	"	-	Nov. 9	Mar.23	7.8					
"	C-431	-	Nov. 9	Mar.22	8.7					
"	C-437	-	Nov. 9	Mar.22	9.5					
"	C-440	-	Nov. 9	Mar.22	11.3					
Sunflower	EC68415	-	Sep.15	Jan. 3					10.7	
"	EC68415	-	Oct.14	Feb. 6			6.1			
"	EC68415	-	Oct.15	Feb. 9					10.4	
"	EC68415	-	Nov. 8	Mar.12			10.0			Irrigated
"	EC68415	-	Nov. 8	Mar.11			7.7			
"	EC68415	-	Nov.10	Feb. 7				4.2		
"	EC68415	-	Nov. 7	Mar.10					8.4	Irrigated
"	EC68415	-	Nov. 7	Mar.10					6.0	
Wheat	Kalyansona	Grain	Nov. 9	Feb.19					13.6	Irrigated
		Straw							6.2	

the drainage way contributed substantially to fodder production. Four cuttings were made while grass seeds were collected from the last cutting. In total fodder (green weight) production Cenchrus Ciliaris ranked first with about 82 q/ha, Cenchrus Cetigerus second with 71 q/ha, Dicanthium Annulatum third with 62 q/ha and Chrysopogon Fulvus fourth with 35 q/ha. Although a number of other grasses were planted, problems with stand establishment and weeds made it impossible to obtain representative production samples.

It is of course easy to find arguments against a comparison between systems of farming superimposed on the black soil watersheds. First of all, one year's data may give a wrong impression of the degree to which the basic natural resources land and water will be able to support more productive and stable systems of farming and only longer term data will give the required information. Also, a relatively substantial development cost was incorporated into the three watersheds on which improved production technology was used. Data will have to be generated first with regard to the question of how much resource development is really essential, secondly with respect to the costs of these improvements under real world conditions, and on the returns on investments made. The inclusion of a large mechanically powered sophisticated machinery component in the development phase as well as in the land preparation, planting, cultivation and harvest phase has resulted in many questions from visitors and colleagues. It will be necessary to adapt the development process, as well as the improved systems of farming which must be generated, to the real world of the Semi-Arid Tropics. Therefore, human labor and animal power will be incorporated into the experimental systems of farming, wherever these resources can be efficiently used. Five pairs of bullocks and an increasing number of improved bullock drawn implements are presently being tried in the Farming Systems Research Program.

The development of better systems of farming will be dependent upon an integration of a number of subject matter areas. The probably most severe problem experienced during the last season's watershed-based activities has been the lack of appropriate power-implement packages to execute required operations satisfactorily. This is true for mechanically powered operations as well as when animals are used. Land preparation for a succeeding monsoon season crop ought to be done immediately after the harvest of the previous crop, when the soil is still having some moisture and when the animals used are physically in an optimum state. In case a single cropping system is transformed into a double cropping system, a number of operations like harvesting, threshing, drying, land preparation and planting has to be executed simultaneously. Where timeliness, particularly on the black soils is extremely important, only a short period is available. The necessary machinery and implements, suited to the labor and power conditions and the soils of the Semi-Arid Tropics are not presently available.

Concluding this section, it can be said that the quality of production research on watershed-based farming systems will have to be substantially improved. The results in terms of production should be regarded with caution because of unusually favorable weather conditions. However, it does appear that even at existing levels of technology (although that technology may not be universally available and applicable), the potential exists, to increase yields several fold over what is presently produced in large regions of the Semi-Arid Tropics. The task of the Farming Systems Program at ICRISAT can be envisaged as an effort to generate the innovations that will provide for substantially more productive and stable systems of farming, which will improve the quality of life for the people of the Semi-Arid Tropics.

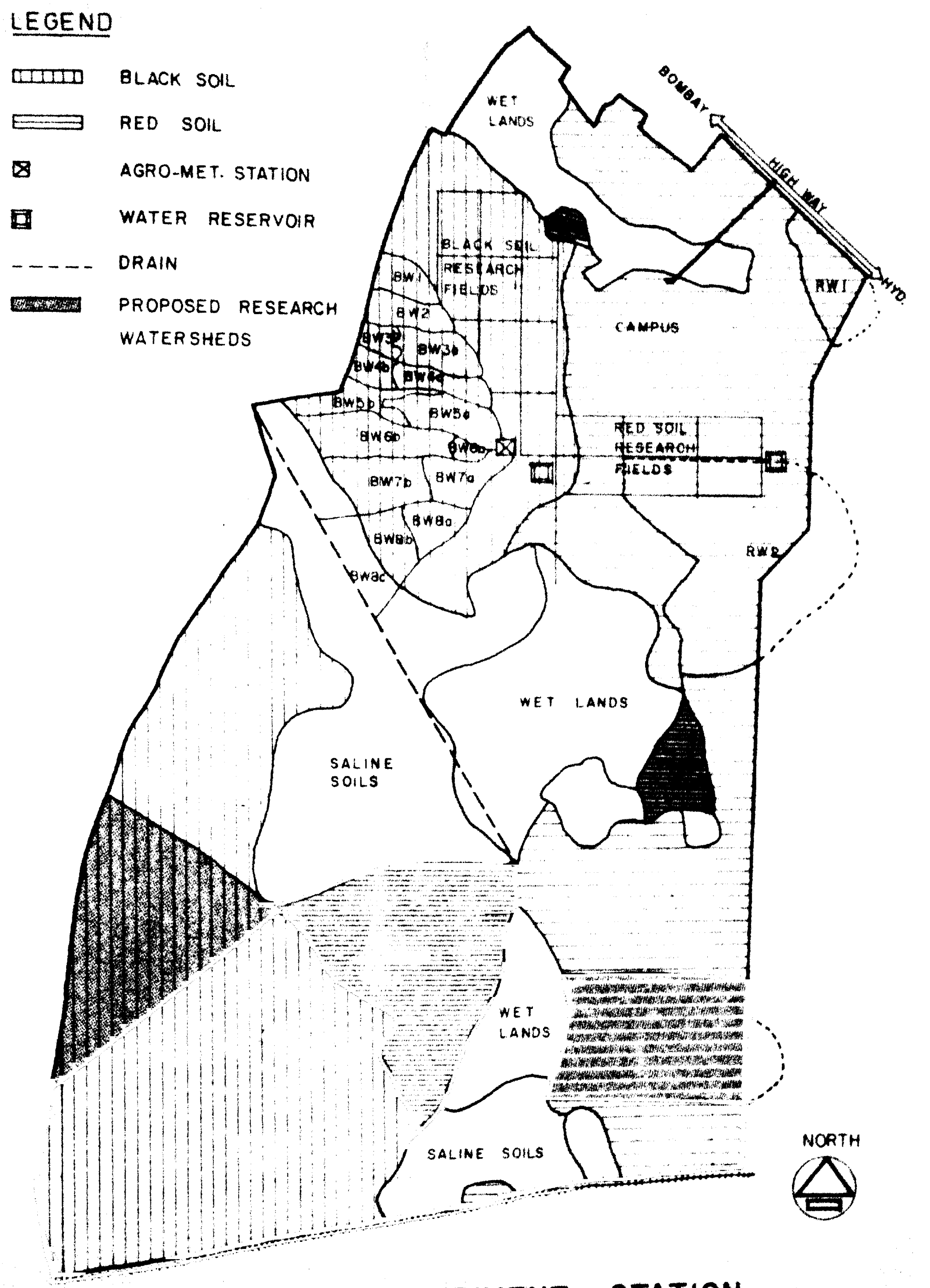


FIG. I THE ICRISAT EXPERIMENT STATION

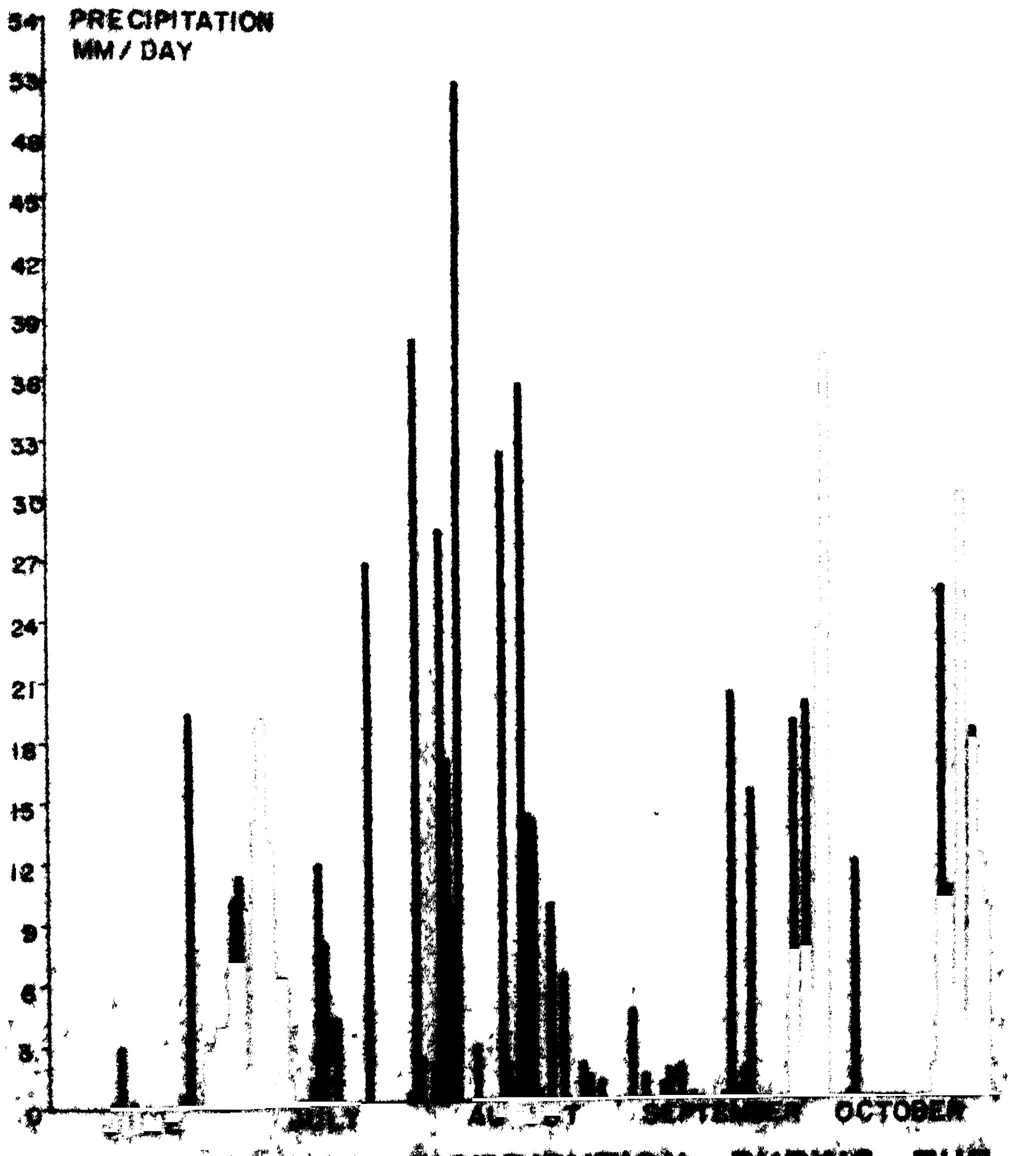


FIG. 2 RAINFALL DISTRIBUTION DURING THE 1973 MONSOON SEASON AT ICRISAT

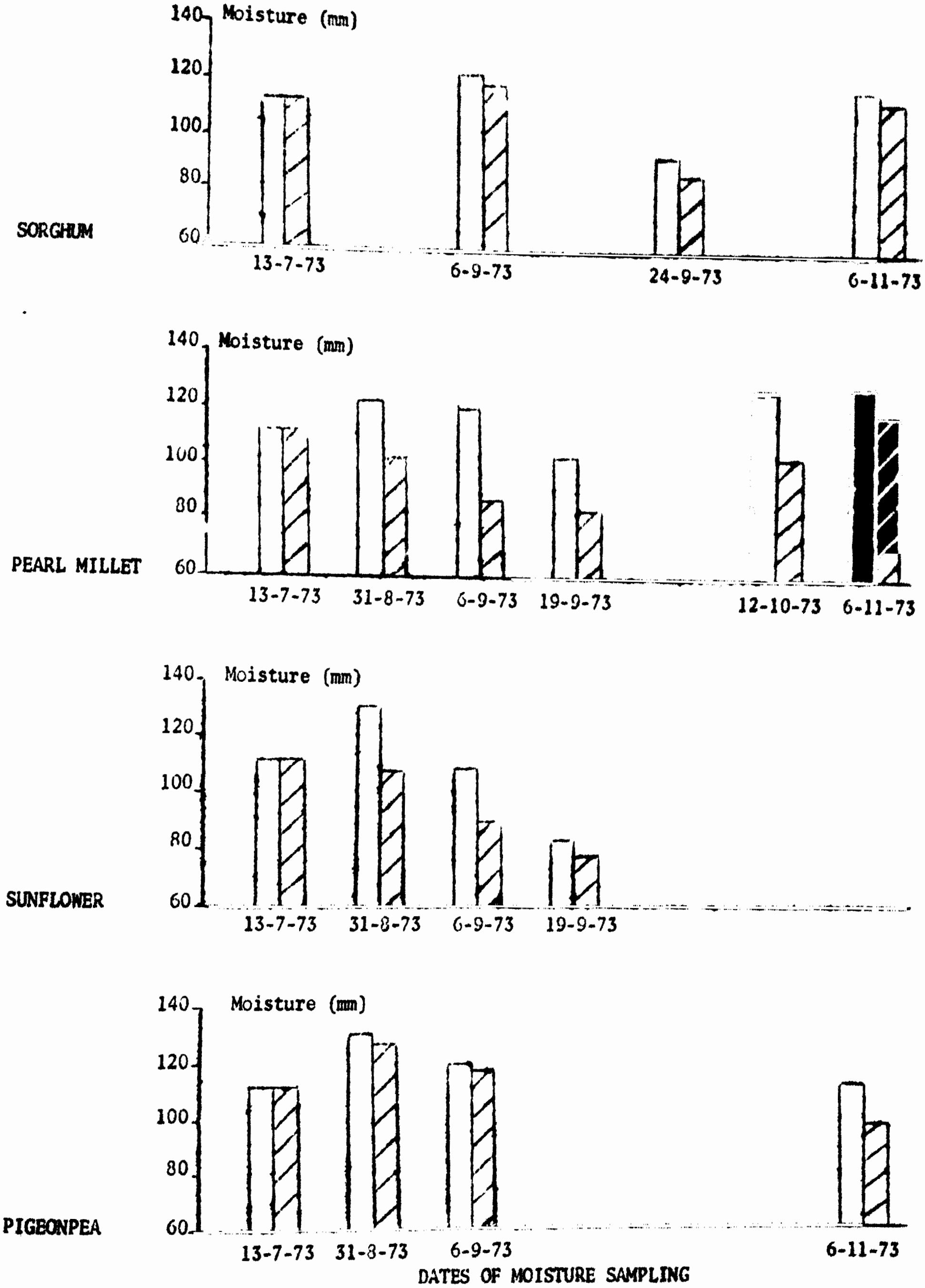


Fig. 3 - The effect of N-Fertilization on the Moisture status in the upper 60 cms of the red soil under 4 different crops; ☐ No Nitrogen, ▨ with 100 N.

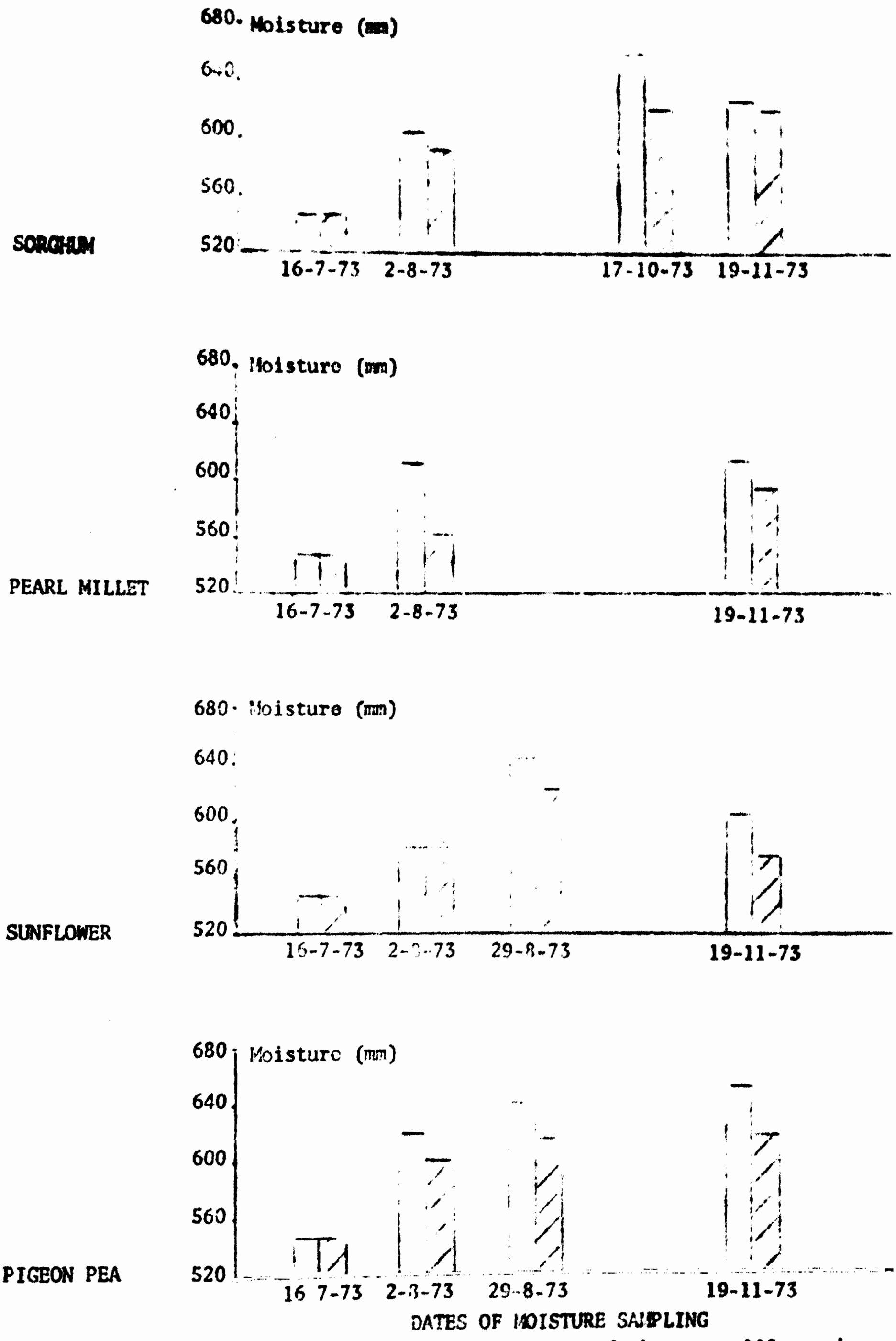
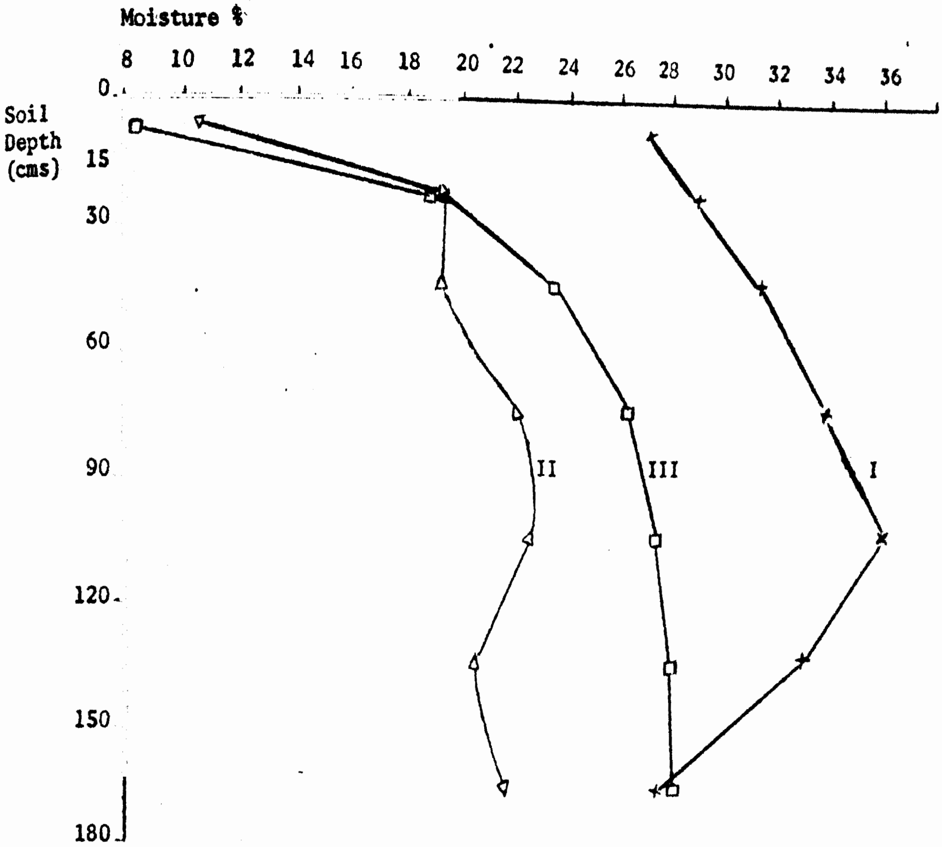


Fig. 4 - Effect of N Fertilization on the Moisture status of the upper 180 cms in the black soil under 4 different crops; ☐ No Nitrogen, ▨ With 100 N.



Legend:

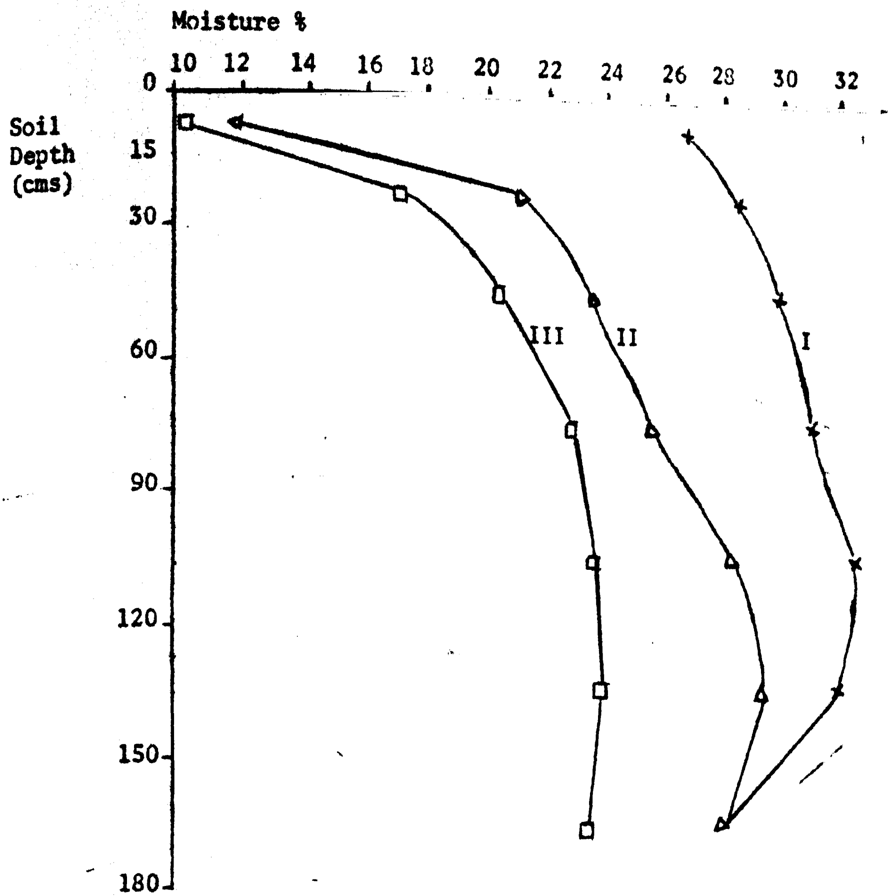
X——X = I = Moisture status November 7 after heavy rains in late October.

△——△ = II = Moisture status March 6, safflower II, planted October 22, harvested March 1

□——□ =III = Moisture status March 23, safflower III, planted Nov. 9, harvested March 22.

I — III = 288 mm; I — II = 183 mm; II — III = 105 mm

Fig. 5 - Moisture status (%) of 180 cms deep profiles on November 7 and at the harvest dates of two bulk plantings of safflower in watershed BW1.



Legend:

X——X = I = Moisture status November 7 after heavy rains in late October.

Δ——Δ = II = Moisture status March 13, sunflower II, planted November 8, harvested March 12

□——□ = III = Moisture status February 7, sunflower III, planted October 14, harvested February 6

I—III = 223 mm; I—II = 133 mm; II — III = 90 mm

Fig. 6 - Moisture status (%) of 180 cms deep profiles on November 7 and at the harvest dates of two bulk plantings of sunflower in watershed BW3A.

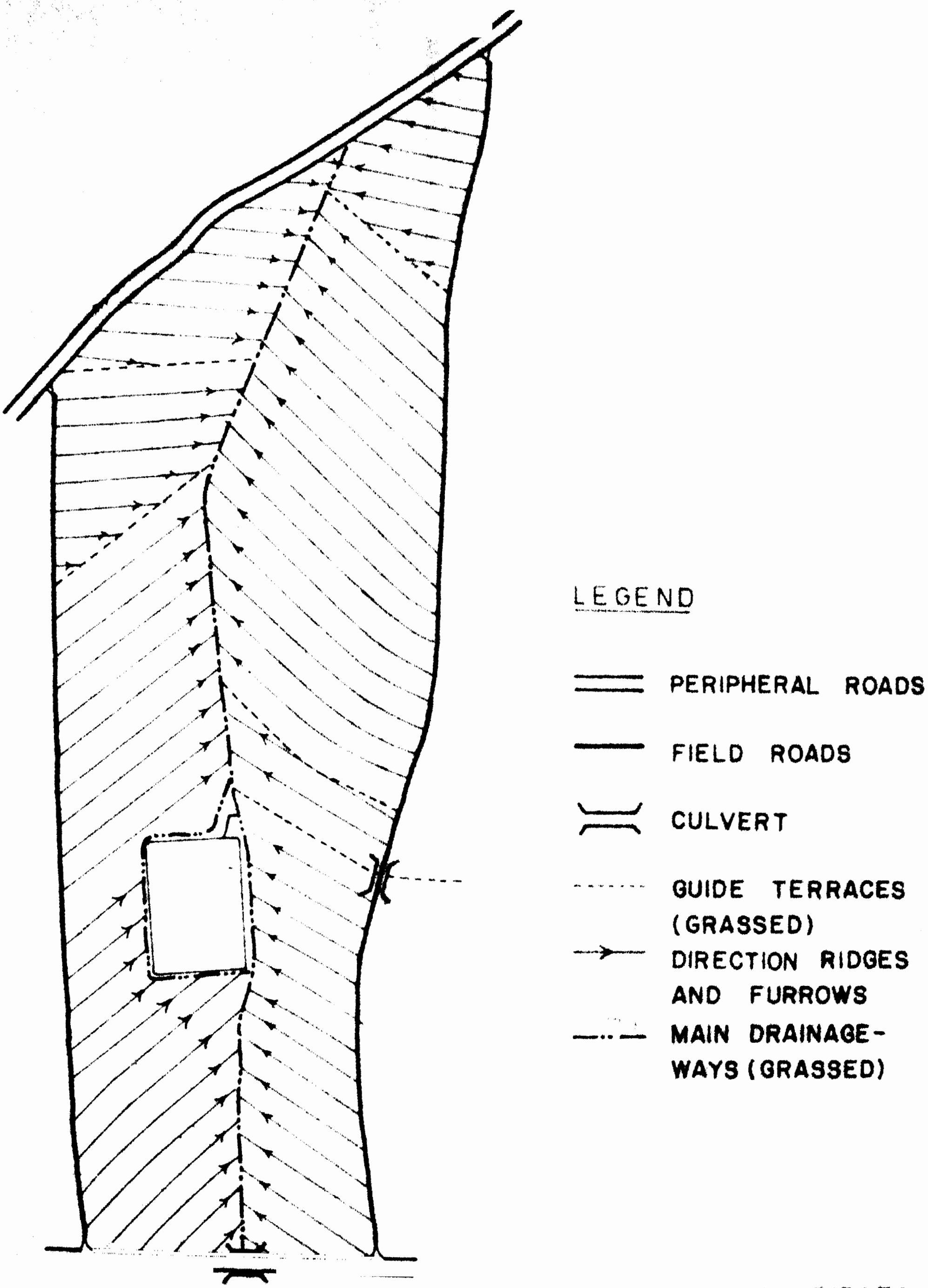


FIG. 7 SCHEMATIC DRAWING OF A WATERSHED IN RIDGES AND FURROWS WITH A RUNOFF STORAGE FACILITY.

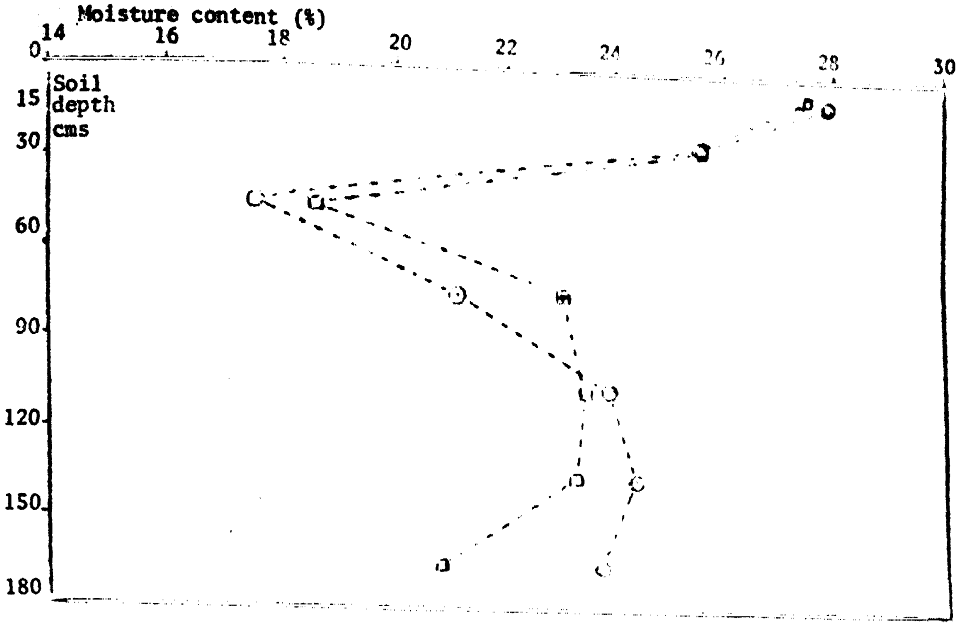


Fig. 8 - Moisture contained in the profile (%) early in the monsoon (July 18) in watershed BW1.

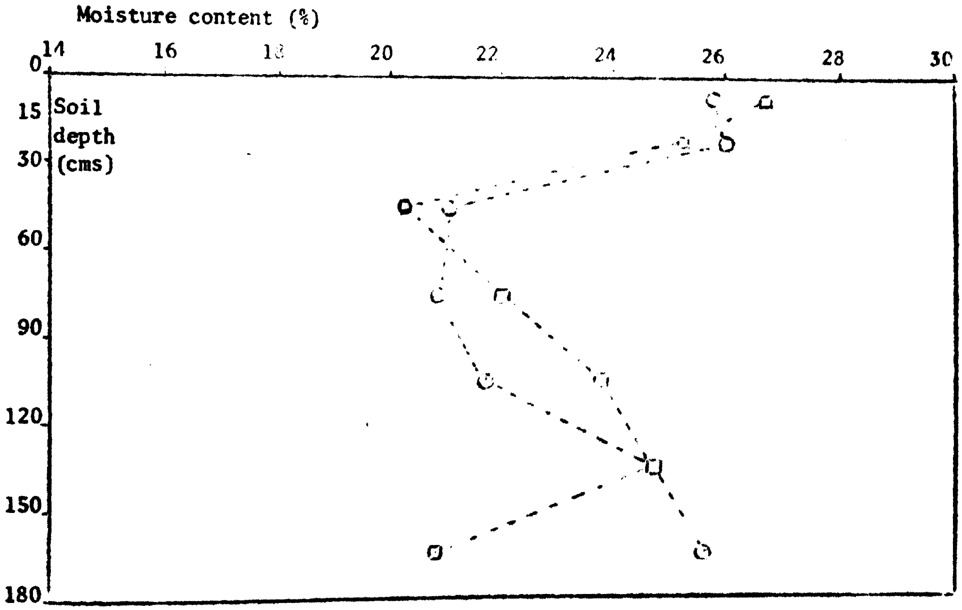


Fig. 10 - Moisture contained in the profile (%) early in the monsoon (July 21) in watershed BW3.

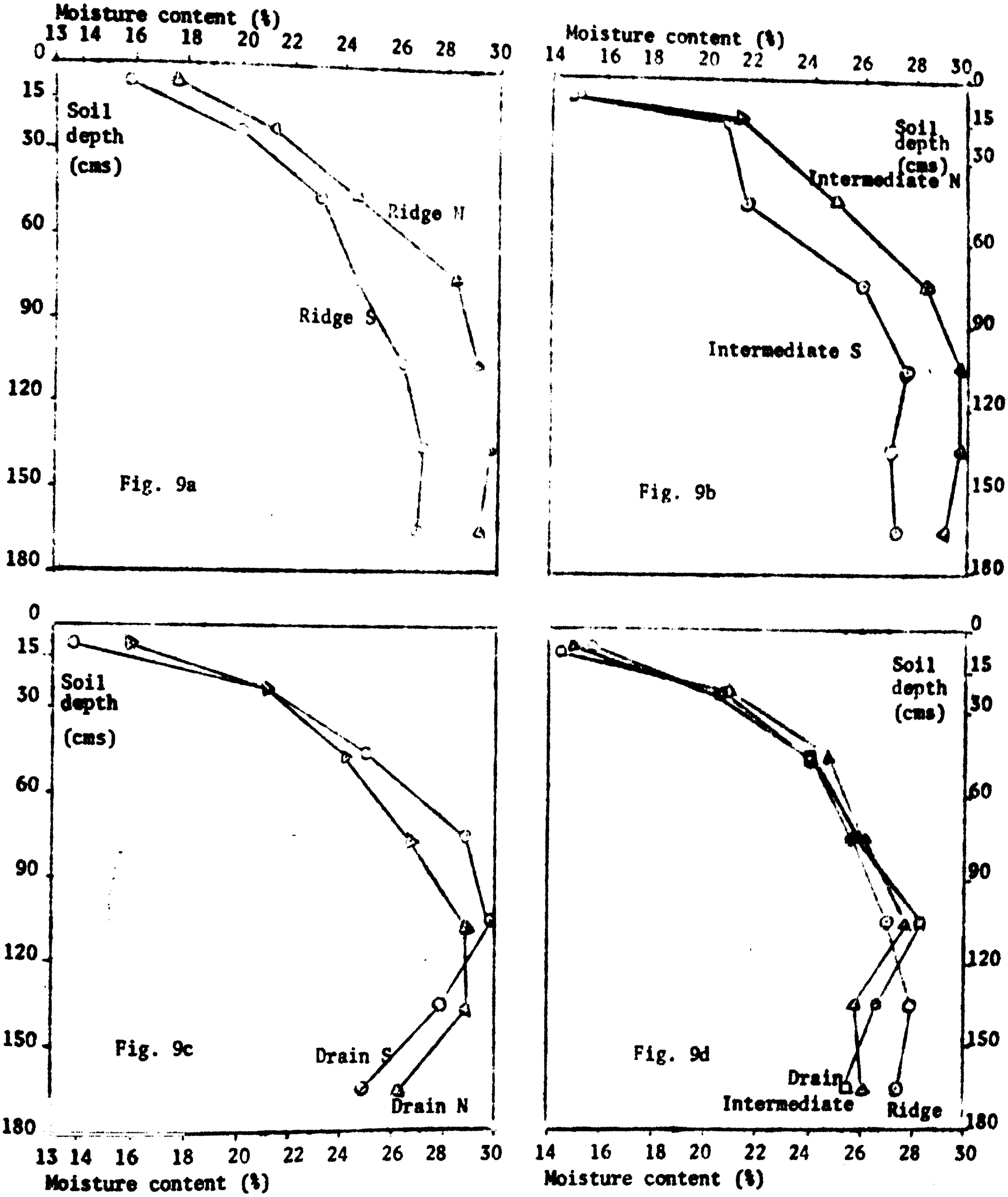


Fig. 9 a-d Moisture contained in the soil profile at 3 locations along the furrows (near boundary ridge, near drain and at an intermediate location) on the Northern and Southern half of watershed BW1 at the end of the post-monsoon season:

a-c Separate moisture determinations near ridge, intermediate and near drain locations

d Comparison of all determinations near ridge, intermediate and near drain locations.

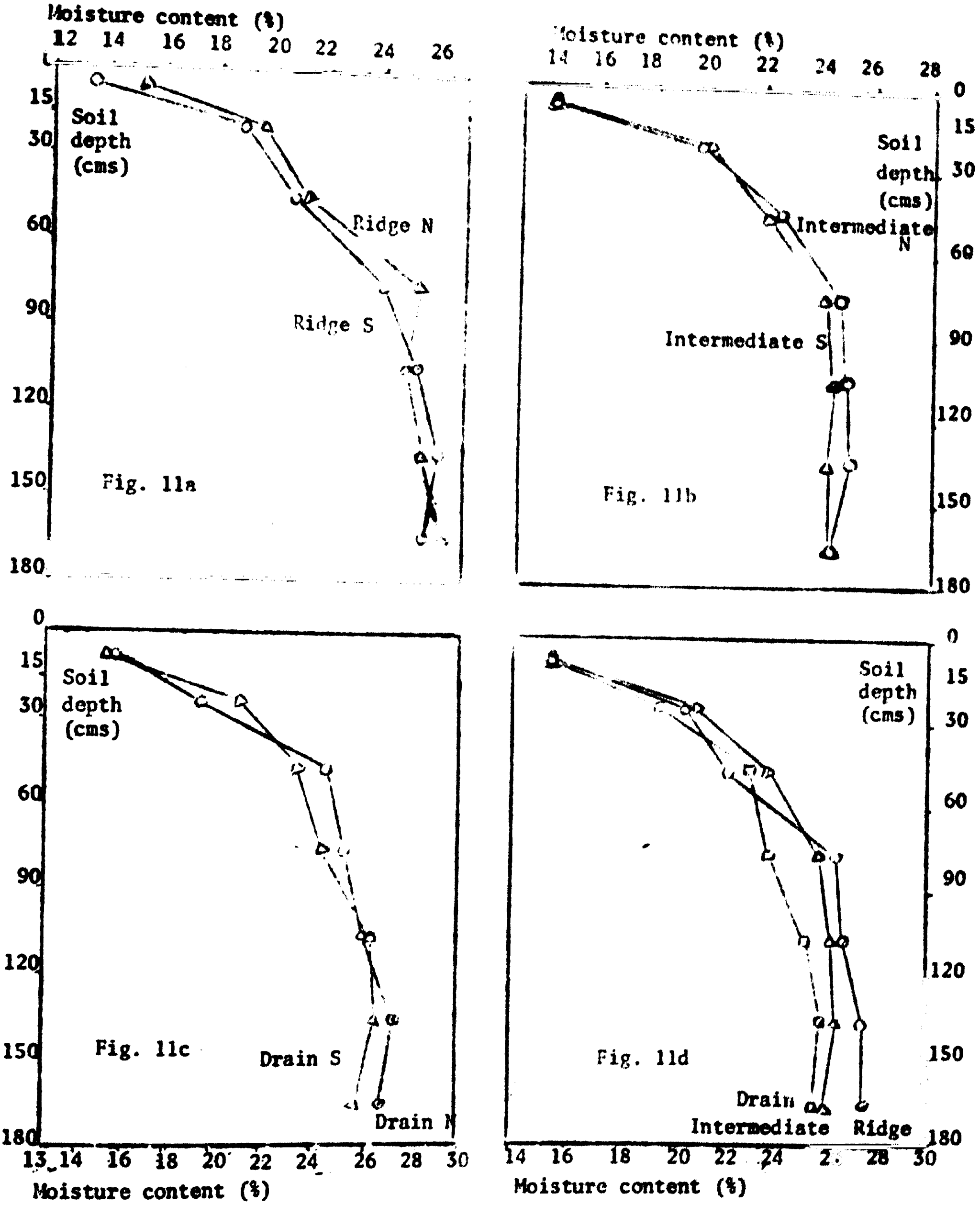


Fig. 11 a-d Moisture contained in the soil profile at 3 locations along the furrows (near boundary ridge, near drain and at an intermediate location) on the Northern and Southern half of watershed BW3 at the end of the post-monsoon season:

a-c Separate moisture determinations near ridge, intermediate and near drain locations.

d Comparison of all determinations near ridge, intermediate and near drain locations.

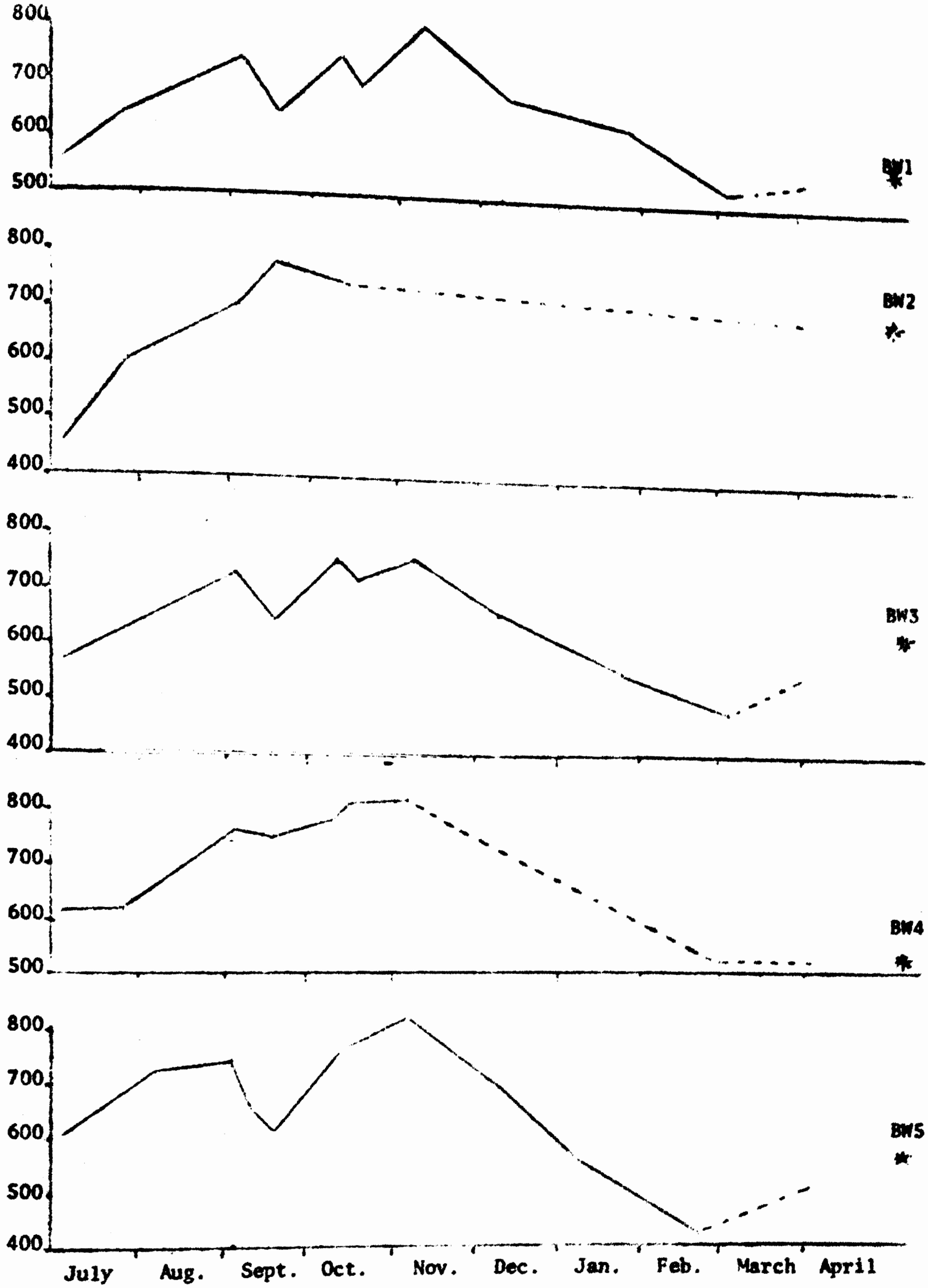


Fig. 12 - Soil moisture (mm) of a 180 cms deep profile in five watersheds at several dates in 1973-74
(*Moisture data from a May 5 replicated sampling)

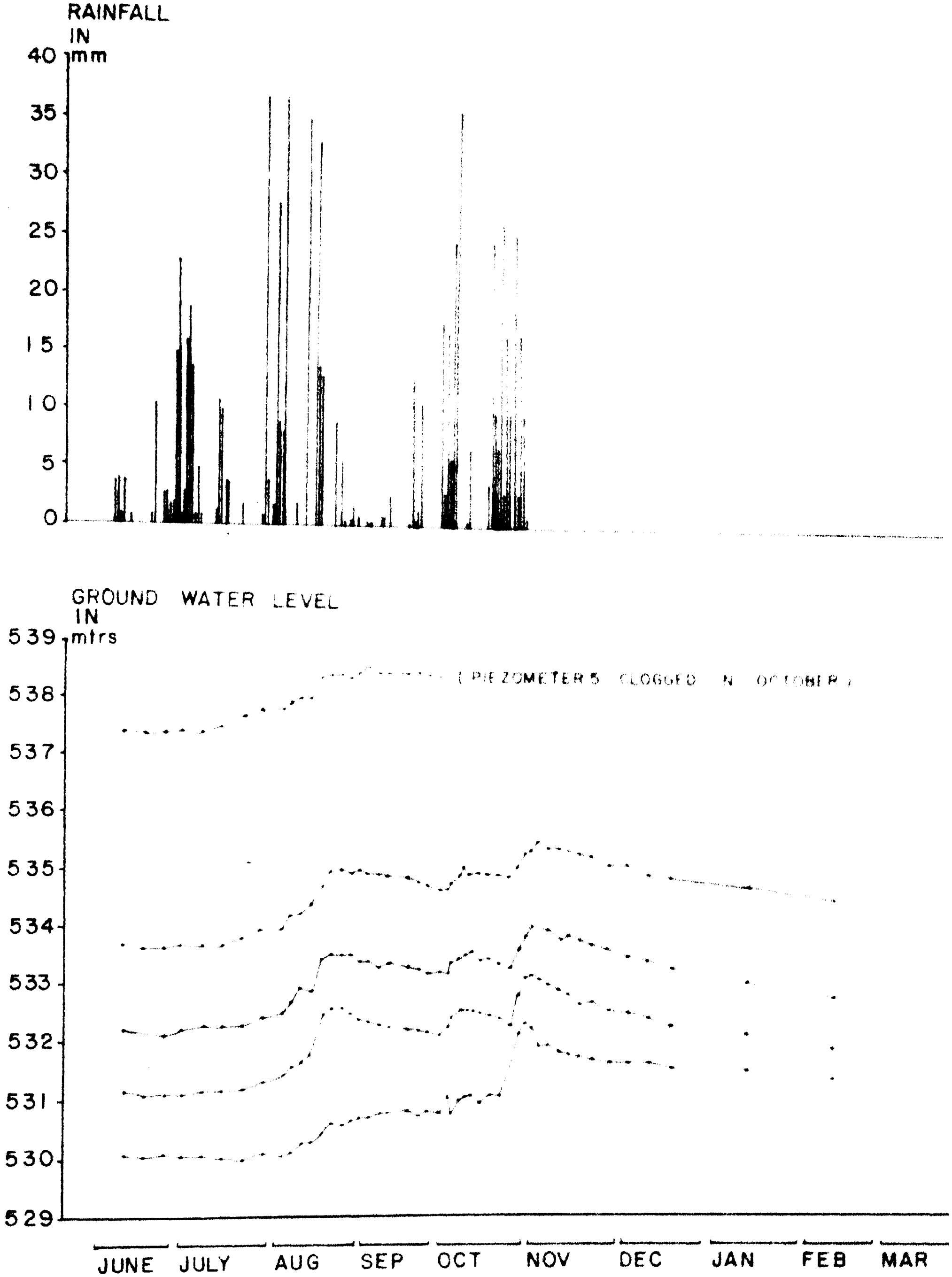


FIG. 13 GROUND WATER LEVELS AT 5 PIEZOMETERS IN THE BLACK SOIL RESEARCH WATERSHEDS

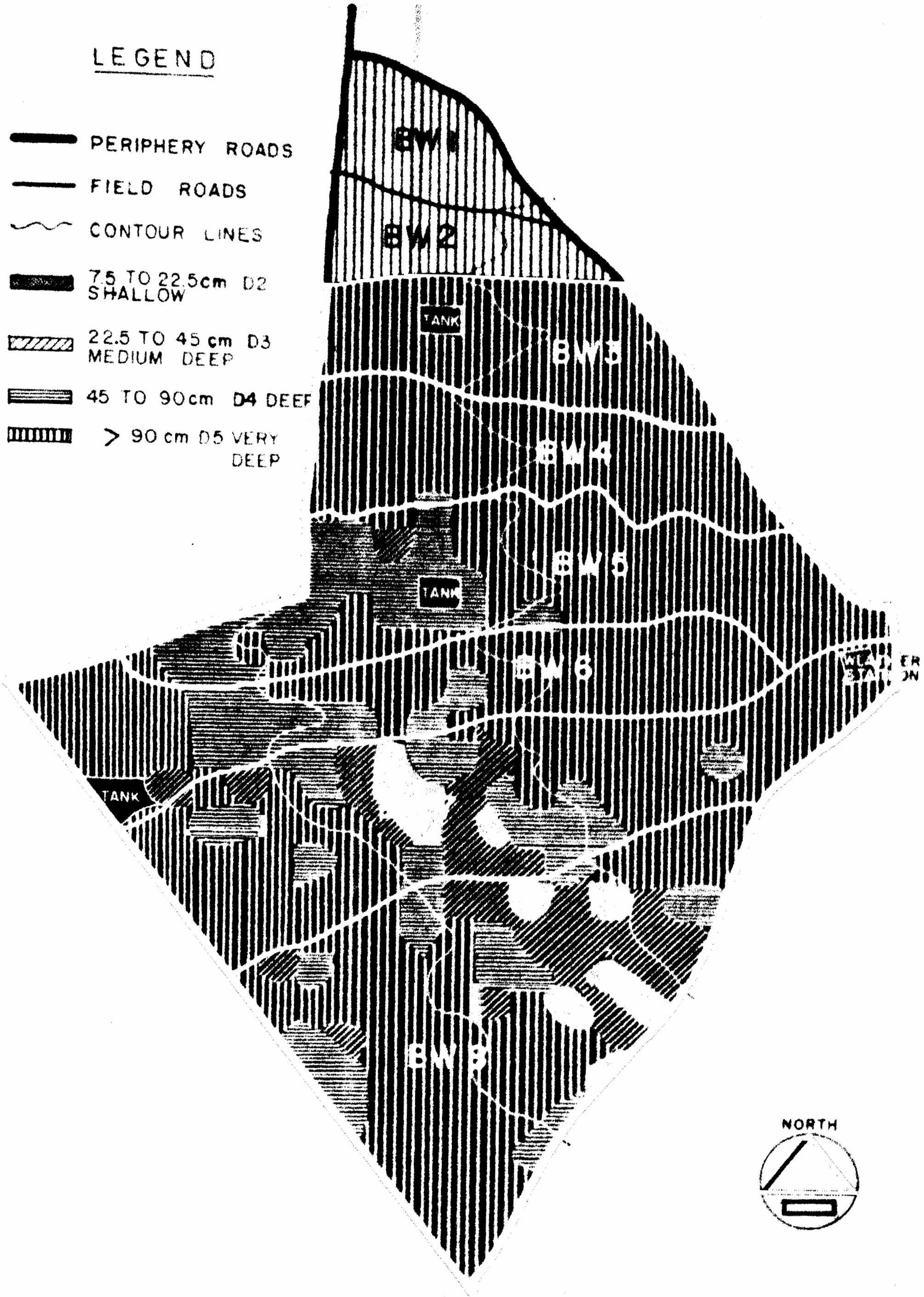


FIG. 14 SOIL DEPTH MAP OF BLACK SOIL WATERSHED BWI TO BW8

MAP OF BLACK SOIL WATERSHEDS BW-1 to BW-8

FIG. 18

LEGEND

- Boundary Bunds
- Boundary of Watershed units
- Natural Drains
- Graded Waterways
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- Outlet Structure
- [illegible]
- [illegible]
- [illegible]
- Recording Rain Gauge

SURFACE AREAS OF WATERSHED UNITS

BW-1	3.52 Ha.	BW-6A	[illegible]
BW-2	3.55 Ha.	BW-6B	[illegible]
BW-3A	4.28 Ha.	BW-6C	[illegible]
BW-3B	2.39 Ha.	BW-7A	[illegible]
BW-4A	5.07 Ha.	BW-7B	[illegible]
BW-4B	3.61 Ha.	BW-8A	[illegible]
BW-5A	6.86 Ha.	BW-8B	[illegible]
BW-5B	6.62 Ha.	BW-8C	[illegible]