TILLAGE PRACTICES, FREQUENCY OF NITROGEN FERTILIZER APPLICATION AND CROP ROTATION AS THEY AFFECT SOIL MOISTURE STORAGE AND YIELDS.

BY

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UNDER THE SUPERVISION OF

PROFFESOR ANWAR BATTIKHI

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ABSTRACT

A study was carried out in Mushaqqar Agricultural Experiment Station, located 30 km South West of Amman. The objectives were; (1) to study the effect of tillage practices on soil moisture storage efficiency and yield of wheat; (2) to compare between the following crop rotations; a) duck foot fallow-wheat-lentil, b) chemical fallow-wheat-lentil, c) wheat-wheat-lentil; and (3) to study the effect of splitting the recommended amounts of nitrogen fertilizer in to one, tow, and three deses. dosages.

Three experiments using the three different rotations were carried out. A split plot in completely randomized design was used with moldboard plow, and chisel plow followed by sweeping as main treatments, and nitrogen fertilizer splitted one, twice, and three times as sub treatments. This design was used for wheat grown during the first season (1987/88) and the second season (1988/89).

A randomized complete block design was used for lentil during the third growing season, using moldboard and chisel followed by sweeping, as treatments.

Results indicated that, the efficiency of the duck foot fallow was higher than that of chemical fallow, (13.4% and 8.7% respectively). Also it was found that, three duck foot or chemical fallow cultivations for weed control were needed before June.

Soil moisture storage during wheat growing season due to

rainfall decreased as the amounts of soil moisture stored at the end of the fallow in in the previous season had increased.

No significant differences were obtained between chisel followed by sweeping and moldboard fall tillage treatments with respect to all the parameters measured. Also wheat yield was the highest after duck foot fallow (3.36 Mg/ha), followed by chemical fallow (2.84 Mg/ha).

Results showed that, applying the required amount of nitrogen fertilizer in one dose at planting time was more useful than splitting it into two or three doses at planting, tillering, and boating stage.

Lentil crop yield was not affected by the crop rotations used before, especially the three crop rotations before planting lentil, which ended with the same amounts of soil moisture content.

1- INTRODUCTION

In Jordan wheat is the basic cereal crop grown under dryland conditions. It covers an area from the desert In the East and South East (about 250 mm annual rainfall), to the western highland where annual rainfall is more than 400 mm. Even, in the western heightlands of Jordan, the amount, frequency, and duration of rainfall are inadequate to meet wheat crop water requirement. Fallow-wheat crop rotation system appears essential for satisfactory long term crop production.

Soil preparation methods are usually carried out by conventional plowing moldboard plow. Recently, the chisel plow and the sweep are being accepted by the farmers as good implements for initial tillage and seedbed preparations and for conserving moisture. Lutfi (1985) found that no differences were detected between the moldboard and chisel plows for seedbed preparation for wheat. He recommended that chisel plow should be used to minimize damage to the soil structure and N status, and reduce power requirements and cost.

Wheat generally responds favorably to applications of nitrogen fertilizers. Several investigators have emphasized the significant role of nitrogen as one of the important factors influencing the growth and yield of wheat, and to its being directly related to soil water conservation and depletion. Time of fertilization during growing season here in Jordan commonly happened at sowing time specially for wheat crop. So such a study was conducted to know the proper time of fertilization for recommended amount of nitrogen.

A study was carried out in Mushaqqar Agricultural Experiment Station with the following objectives :

1- To study the effect of some tillage practices on soil water storage efficiency and yield of wheat.

2- To study and compare the following crop rotations :

(a) Duckfoot fallow-wheat-lentil;

(b) Chemical fallow-wheat-lentil;

(c) Wheat-wheat-lentil;

on soil moisture storage and yield.

3- To study the effect of applying the recommended amount of nitrogen fertilizers, at seeding or at seeding and tillering stage or at seeding, tillering and boating stage on wheat yield.

2- LITERATURE REVIEW

2-1. Tillage practices and seedbed preparation :

Karlen and Gooden (1987) evaluated tillage systems and N fertilizer rates in Southeastern Coastal Plains (USA) on wheat production. The results of eight field studies and one greenhouse study showed that moldboard or chisel plowing were the optimum tillage systems for wheat production. Average grain yield with moldboard plowing was significantly higher (0.4 Mg/ha) than with disking, in four of five studies, but it was significantly higher than chisel plowing (3.09 vs. 2.48 Mg/ha) only once. They reported that disruption of compacted tillage/traffic pans and improved aeration were probably the most important reasons for higher wheat yield with chisel or moldboard plowing (250 mm deep) than disking (100 mm deep) or planting no-till wheat.

Lutfi (1985) studied that the effects of using moldboard or chisel plows for seedbed preparation for wheat cultivar Maxipak on subsequent grain and wheat seed yields. No differences were detected between the two treatments, but it was recommended that chisel plow should be used in irrigated areas in central Iraq to minimize damage to the soil structure and to preserve N status, and reduce power requirements and costs.

Qusous (1989) found that preparing the field with chisel and sweep produced a higher potential yield of wheat as compared to the no-tillage and moldboard plows.

The potential yields were 2608 kg/ha, 2021 kg/ha for chisel and moldboard plows, respectively.

Saimeh and Battikhi (1985) studied the replenishment and depletion of soil moisture as affected by crop rotation. Their study was conducted in the Irbid area during 1979/80 and 1980/81 growing seasons. The average rainfall during these two seasons were 742 and 427 mm respectively. On gentile slopes (0-3 %) fallow land stored 43 mm more water than land planted to summer crop, and 97 mm more water than land planted to wheat. For slopes of 3-8 %, 53 mm more water were stored in fallow land than in land planted to wheat. One land left fallow for two consecutive years, for 93 cm soil depth the moisture content at the end of the first season (1979/80), was 276 mm, and at the end of second season (1980/81), was 331 mm. Moisture depletion in the fallow treatments were 93, 29, and 21 mm, in the first season, from the first (0-32.5 cm), second (32.5-62.5 cm), and third (62.5-92.5 cm), layers of soil, respectively. In the second season it was 35, 15, and 5 mm from the first, second, and third layers of soil respectively. The depletion from wheat planted area was 103, 58, and 38 mm fro the first, second, and third layers of soil, respectively. Saimeh and Battikhi concluded that the moisture depletion decreased as the rainfall quantity decreased, and in wheat the depletion from the second layer was higher than that in fallow due to extraction by wheat roots which reached the second layer.

Snobar (1986) found that the chisel plow and sweep for tillage and seedbed preparation, grain drill for sowing, herbicides for weed control in addition to fertilizer application increase the yield significantly as compared with the traditional practices used for wheat production.

Kharouf (1989) found no significant differences in soil moisture storage during the growing season between chisel and moldboard fall tillage treatments (376 and 387 mm, respectively). Chisel and moldboard plows had resulted in the same amount of soil moisture depletion during the growing season (378 and 377 mm), respectively, and also similar yields.

Blevins et al. (1971) found that no tillage treatments had higher volumetric moisture contents to a depth of 60 cm during most of the growing season, in comparison with conventional tillage. The greatest differences occurred in the upper 0 to 8 cm depth. Beyond a depth of 60 cm, systems of tillage had little influence on soil moisture during the growing seasons. This can often carry the crop through periods of detrimental moisture stresses in the plant. The more efficient use of soil moisture by no-tillage was reflected in higher corn yields.

Masse and Siddoway (1969) in a study carried out in the state of Idaho from 1955 until 1965 stated that when in zero tillage was used, the average yield of wheat was 837 kg/ha whereas preparing the land with chisel plows increased the yield significantly to an average of 1094 kg/ha. The results of a research conducted for a period of seven year (1968-1974) in Jordan by a team from the Ministry of Agriculture of Jordan and Oregon State University in the United States, showed that the average wheat yield for five seasons in Amman Governate was 2010 kg/ha obtained from using the technology package as compared to 1250 kg/ha when traditional method of production was used. The technology package included the use of chisel plow, grain drill, fertilizers, and chemical weed controls.

Al-Darby and Lowery (1987) studied the effect of conservation tillage on corn emergence and early growth in the Northern Corn Belt. Corn was grown using three conservation tillage systems: Till-plant, Chisel, and No-till Conventional moldboard plow on a Griswold silt loam soil (Tipic Agriudoll) during the 1982 to 1984 growing seasons. They found that soil temperature at the 5-cm depth ranked as follows: Conventional moldboard plow greater than till-plant greater than chisel greater than no-till. Time to 100% emergence, was delayed by 8, 2 to 3, and 2 day for no-till compared to conventional moldboard plow in 1982, 1983, and 1984, respectively. During the first 5 weeks after emergence, corn growth parameters (plant height, leaf area, dry matter) of no-till were consistently lower, and in some cases significantly lower than conventional moldboard plow. Thus, the lower soil temperature associated with conservation tillage systems, especially no-till, is one of the main factors affecting emergence and seedling growth and development.

2-2. Effect of nitrogen fertilization rate on wheat production:

Dimitrov (1976) showed that nitrogen increased grain yields by increasing the number of grain per spike and 100-grain weight. Similar results were obtained by Hussain et al. (1976). They found that the increase in yield resulted from nitrogen application was due to increases in number of tillers per plant, length of spikes, number of grains per spike and 1000-grain weight.

Shekhawat and Mathure (1976) showed that grain yields of rainfed wheat variety Kalyan were increased from 1.12 tons/ha without nitrogen to 2.23 tons/ha with 60 kg N/ha. Yields were similar when nitrogen was broadcasted before seeding in two split dressing before seeding, or to a foliar spray at the late jointing stage.

Randhama et al. (1977) showed that in trails from 1973-1975, that delaying wheat seeding from 10 November to 20 December, grain yields decreased from 3.0 to 2.4, and 2.0 tons/ha, respectively. Grain yields were increased from 1.6 tons/ha without nitrogen to 2.9 tons/ha with 80 kg/ha. Further increases in nitrogen decreased yields.

Mundy and Owers (1974) found that wheat response to nitrogen fertilizers was variable. In one year after a wet autumn and winter, the crop responded to the highest rate of nitrogen applied which was 150 kg N/ha. While in the other two years 75 kg N/ha was adequate. Under rainfed conditions, Singh and Singh (1976) reported that application of 30 kg N/ha increased grain yields from 0.87 ton/ha without nitrogen to 1.17 tons/ha in 1971/72, and from 1.66 to 2.41 tons/ha in 1972/73. Further yield increases with 60-90 kg N/ha were not significant. Water use efficiency increased appreciably with 30 kg N/ha. Similar results were obtained by Scheneider et al. (1987). They reported water use efficiency (WUE) ranged from 45 to 72 kg/ha/cm as rate of nitrogen increased from 0 to 80 kg N/ha.

Sanford and Hairston (1984) found that soil moisture used by wheat was closely related to N rates applied. They also found that depletion of water was related to N uptake and yield. Kumar (1986) found that grain yields of late-sown wheat had increased as N rates increased from 0 to 160 kg N/ha and when N was applied in 2-4 split dressings than when applied in a single dressing.

Comfort et al. (1988) found that root density was significantly increased in the top 30 cm by applying 67 kg N/ha but remained the same as compared to no nitrogen fertilization, or decreased when 134 kg N/ha was applied. Below the 30 cm depth, 134 kg N/ha generally suppressed root growth more than the 0 and 67 kg N/ha rates. Depth of soil water use and root growth were influenced by N fertilization rates. High rates of N fertilization may inhibit deeper root that the ratio of splitting the nitrogen application influenced the shape of the grain yield response. In two of the experiments less nitrogen was required to achieve maximum yield where all the nitrogen was applied at the tillering stage. As the proportion of the total nitrogen applied at sowing was increased, the amount required to achieve the maximum yield also increased. When nitrogen was applied at tillering no variety was responsive, but where all nitrogen was applied at sowing one variety responded positively and the other negatively, (for four experiment conducted).

2-3. Fallow systems and soil moisture conservation :

Smika and Wicks (1968) measured soil water storage during the fallow period of winter wheat-sorghum-fallow and winter wheat-fallow rotations during 1963 to 1966 with average rainfall 49.3 cm. Storage was greater when herbicides rather than conventional tillage practices were used to control weeds. The storage was increased by nearly 4 cm distributed throughout the profile in the three-year rotation. The greatest increase occurred in the upper 60 cm of soil. In the two year rotation, nearly 14-cm of available water was increased in the entire profile, where most of the storage occurred to a depth of 210 cm. Soil water content to a depth of 180 cm was at or near field capacity during the three crop rotations. Soil water storage for the total fallow period for the three year rotation ranged from 18.6 to 22.3 cm, having corresponding storage efficiencies of 35.4 and

42.4 %, for conventional tillage and complete herbicide treatments, respectively. Water storage for the complete fallow period of the two year rotation ranged from 18.6 cm with spring plowing to 23.8 cm with tillage stubble mulch to 32.5 cm with complete use of herbicides, and had fallow storage efficiencies of 25.0, 32.0, and 43.7 % respectively.

Fenster et al. (1969) found that late spring tillage gave the most effective weed control in a winter wheat-fallow rotation. On April 1, plots with October tillage averaged 77 % control of grassy weeds compared with 14 % control for July tillages, and 31 % control on plots which had not yet been tilled. Evaluations were again made before May tillage operations. Tillage with the one-way in October and April gave the best weed control (100 %), followed by the one-way in July and April (93 %), one-way in April (87 %), and disking in April (81 %). The next best treatment on the May evaluation was with the April sweep plow treatment plus October tillage (62 %), followed by one-way in October with 59 % control. With the sweep plow, tillage in April gave 43 % weed control while July and April gave 30 % weed control. The late tillage were ineffective. Results of a study at Alliance, Nebraska, showed that two tillage operations before May 15 during the fallow year were essential with any type of tillage tool to effectively control downy brome and volunteer wheat. Downy brome must be controlled before May 15, otherwise, it will produce seeds which will provide a weed problem for subsequent years.

Smika (1970) compared fallow-wheat with continuous wheat under semiarid conditions. He found that fallow-wheat average yields to be over three times greater than average continuous wheat yields. The fallow-wheat system provides stable production with no crop failures when compared with continuous wheat, which failed more than 30 % of the time. Average water-use efficiency for fallow-wheat was 80 % greater than that for continuous wheat when annual precipitation was between 24.6 and 43 cm. This showed that fallow-wheat was the most efficient means of producing winter wheat when average annual precipitation was less than 43 cm. In all aspects, the fallow winter wheat cropping system was much superior to continuous winter wheat and produced necessary for stable winter wheat production under semiarid conditions in the Great Plains.

Wicks and Smika (1973) found that during the 14-month fallow period from winter wheat harvest until wheat planting, plots receiving no tillage (Weeds were controlled by herbicides) had the least weed growth, the highest soil water storage, and highest amount of surface mulch maintained. Also, the plots receiving only herbicides had the highest grain yields of all treatments. However, an average of 3.8 herbicide applications were needed to control weeds during the last 5.5 months of the fallow period. Greatest weed growth during the fallow period was on plots that received only tillage and occurred during the first 3 months after harvest.

Lindstorm et al. (1974) compared fall chiseling (25 cm deep) and disking (13 cm deep) with no tillage with respect to the effect on over-winter water storage in the low precipitation (24 cm annually) region of eastern Washington. Also, these tillages were compared with a chemical fallow treatment with no tillage. They found that, fall chiseling increased water storage markedly, and disking to a lesser extent as compared with no tillage (8.7 cm increase with chiseling, 2.3 cm with disking), the increase in water storage by chiseling was attributed to improved infiltration properties of the frozen layer associated with this tillage.

Over summer (May to September) soil water loss was not influenced by type of spring tillage; amounts lost ranged from 4 to 9 % of the total profile water stored until May. Seed zone water at the end of fallow was generally increased with increase in total profile water content, and was higher where spring tillage was used as compared with chemical fallow.

Lavake and Wiese (1979) evaluated five sweep tillage intervals for 7 years during the two 11-month fallow periods in a winter wheat-sorghum cropping sequence. The tillage intervals ranged from very short or once every 2 weeks to as long as 24 days after weed emergence. He found that delaying tillage for 17 and 24 days after weed emergence reduced

3- MATERIALS AND METHODS

3-1. Study location :

The experiment was carried out in Mushaqqar Agricultural Station, located approximately 30 km Southwest of Amman. The location has a mean annual rainfall of about 350 mm. The Station lies at 31.5° North latitude and 850 m above sea level altitude.

3-2. Soil :

Spenser and Rihani, (1982) classified the soil in Mushaqqar Agricultural Experiment Station as fine, montmorillonitic thermic, entic chromoxerert, with the following profile description :

Ap 0-12cm : Brown to dark brown (7.5 YR 4/4) clay; strong fine to medium subangular blocky structure; firm, very sticky and very plastic; common very fine roots; many fine interstitial pores; strongly effervescent; abrupt smooth boundary. About 3% fine pebbles throughout pedon.

A1 12-37 cm : Brown to dark brown (7.5 YR 4/4) clay; strong fine to medium subangular blocky structure; firm, very sticky and very plastic; common very fine and a few roots; few fine tubular and many fine interstitial pores; strongly effervescent; clear wavy boundary. About 3% fine pebbles throughout pedon.

AB 37-60 cm : Brown to dark brown (7.5 YR 4/4) clay; strong medium angular blocky structure; firm, very sticky and very plastic; a few very fine roots; few fine tubular and many fine interstitial pores; strongly effervescent; clear wavy boundary. Common weakly expressed slickensides. About 3% fine pebbles throughout pedon.

BW 60-90 : Brown to dark brown (7.5 YR 4/4) clay; strong medium angular blocky structure; firm, very sticky and very plastic; a few very fine roots; few fine tubular pores; gradual wavy boundary. Many moderately expressed slickenside. About 3% fine pebbles throughout pedon.

BK1 93-125 : Brown to dark brown (7.5 YR 4/4) clay; strongly medium angular blocky structure; firm, very sticky and very plastic; a few very fine roots; a few fine tubular pores; strongly effervescent; gradual wavy boundary. Many strongly expressed slickenside. Common fine and medium lime masses. About 3% fine pebbles throughout pedon.

BK2 125-150 cm : Brown to dark brown (7.5 YR 4/4) clay; strong medium angular blocky structure; very sticky and very plastic; a few very fine roots; a few fine tubular pores; strongly effervescent. Many strongly expressed slickenside. Common fine and medium lime masses. About 3% fine pebbles throughout pedon.

3-3. First season (1987/88).

3-3-1. Planting wheat :

The purpose of this study in the first season was to study the effect of two fall tillage treatments and three nitrogen fertilizer dosages on soil moisture conservation, wheat yield.

A split plot using randomized complete block design was used with three replications. It consisted of two types of fall tillage treatments as main treatments, three nitrogen dosages as sub treatments. Total amounts of nitrogen applied in three dosages were equal 60 kg N/ha as ammonium sulfate) (Fig. 1A).

The two main treatments were as follows : (1) conventional tillage by moldboard plow on late September, 1987, and (2) tillage by chisel plow on late September, 1987, followed by sweeping for seedbed preparation just before planting. The moldboard and chisel plows had a depth of about 25 cm each, and sweep had a depth of about 10 cm. The dimension of each main plot was 36 x 5 m.

The three sub treatments were; (1) 60 nitrogen applied once at planting (N_2), total amount applied equal (60 kg/ha), (2) Nitrogen applied two times (N_1), at planting and tillering stage. Total nitrogen applied at each dosage was equal to 30 kg/ha, (3) Nitrogen applied three times (N_0) at planting, tillering, and boating stage. Total nitrogen applied at each dosage was equal to 20 kg/ha. Nitrogen was applied by hand broadcasting without incorporation. The dimension of each sub plot was 18 x 5 m. All plots in the three experiments were fertilized with 50 kg P/ha (250 kg/ha triple super phosphate), applied by band drilling at time of sowing.

Spring wheat (Horani) was planted on January 19,1988 by

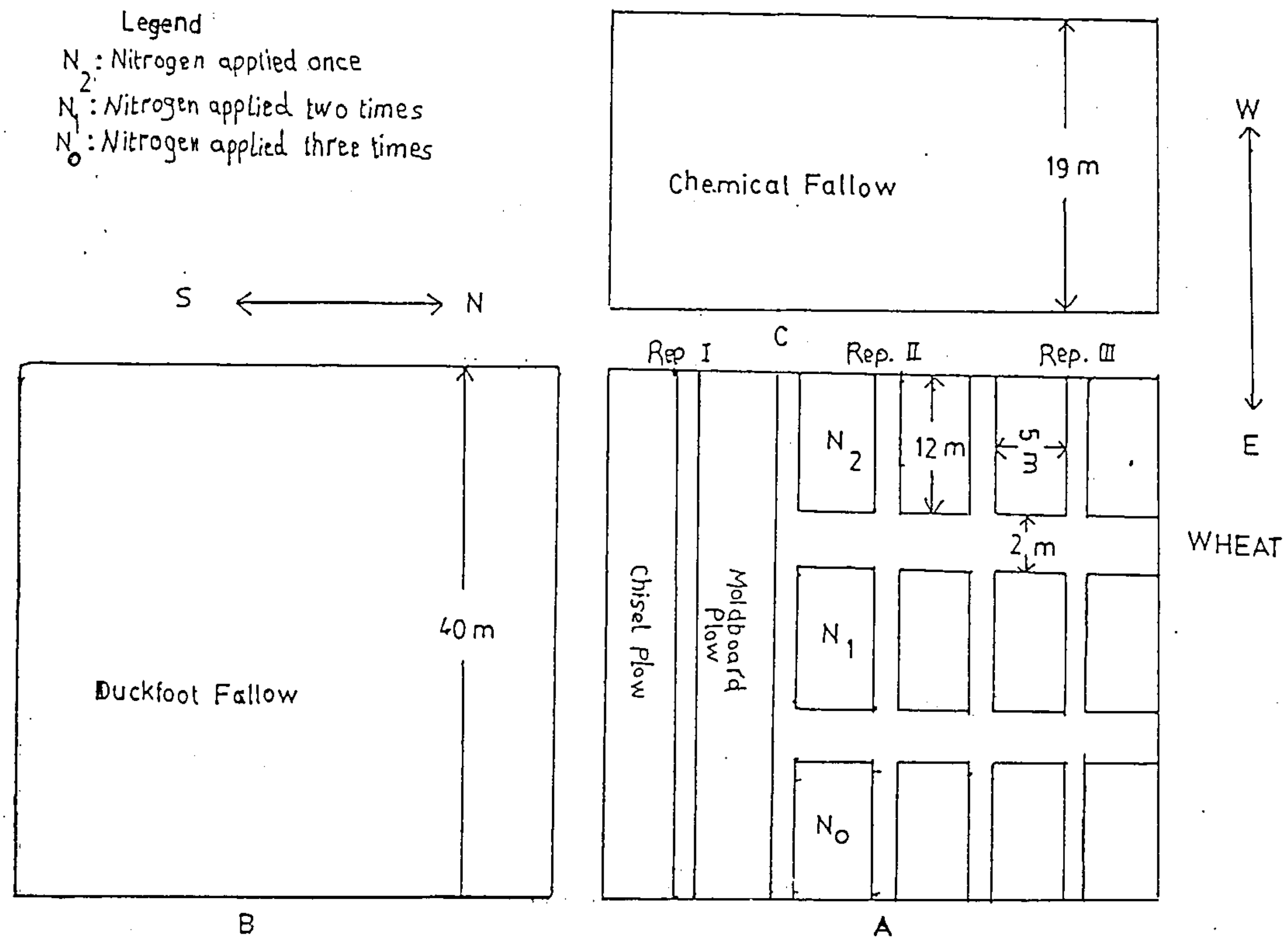


Fig. 1 : Experiment layout at Mushaqqar Agricultural Experiment Station, during 1987/88 grouing season .

grain drill at a rate of 100 kg/ha. Seed depth was about 8 cm with 20 cm spacing between rows. Weed control during wheat growing season was done by spraying the whole field area with 2, 4-D (24% 2, 4-D acid esters with 36-37% content in 2, 4-D acid) at a rate of 800 cm^3 of solution per hectare.

3-3-2. Duckfoot fallow :

Beside the area planted with wheat, an area was left to study the duckfoot fallow using duckfoot plow for weed control as needed during Spring and Summer fallow period.

The dimension of the area left fallow using duckfoot fallow was 40 x 40 m. Duckfoot plowing was done on March 25, 1988, and May 15, 1988, during the fallow period, (Fig. 1B). This area was left fallow to be planted by wheat during the second season 1988/89.

3-3-3. Chemical fallow :

Also an area was left to study the chemical fallow using chemicals (Gramaxon 60 ml/20 L). Gramaxon was applied as needed during the fallow period. It was applied twice during the fallow period, on April 12, 1988, and April 27, 1988 followed by hand weeding. The dimensions of the area left for chemical fallow was 40 x 19 m. This area was left fallow to be planted by wheat in the second season 1988/89, Fig. 1C).

3-4. Second season (1988/89).

The experimental area was planted by wheat (Horani) on December 1, 1988 by grain drill at a rate of 100 kg/ha. The same design was used during the growing season 1987/88, with the same treatments in which the main treatments were as follows: (1) conventional tillage by moldboard plow on late September, 1988, and (2) tillage by chisel plow on late September, 1988, followed by sweeping for seedbed preparation just before planting. the moldboard and chisel plows had a depth of about 25 cm each, and sweep had a depth of about 10 cm. The dimensions of each main plot was 36 x 5 m for wheat planted after wheat and wheat planted after duckfoot fallow, while for wheat planted after chemical fallow the dimension were 15 x 5 m.

The three sub treatments were; (1) Nitrogen applied once at planting (N_2), where the total amount of applied nitrogen was equal to 60 kg N/ha, (2) Nitrogen applied two times (N_1) at planting and tillering stage,where for each time total nitrogen applied was equal to 30 kg N/ha, (3) Nitrogen applied three times (N_0) at planting, tillering, and boating stage, for each time total nitrogen applied was equal to 20 kg/ha. Methods of nitrogen application were hand broadcasting without incorporation.

The dimension of each sub plot for wheat planted after wheat and wheat planted after duckfoot fallow was equal to 12 x 5 m, while for wheat after chemical fallow was equal 5 x 5 m, (Fig. 2 A,B,C). By the end of 1988/89 growing season, three crop rotations were completed. They were; continuous wheat (wheat-wheat); duckfoot fallow-wheat; and chemical fallow-wheat.

3-5. Third season (1989/90).

To complete the three crop rotations, for three years each, the experimental area was planted by lentil (Jordan 1) on November 20, 1989 by grain drill at a rate of 120 kg/ha, seed depth was about 5 cm with 20 cm spacing between rows. Weed control during lentil growing season was done by spraying the whole experimental area with Nabo (Sethoxydim 186 g ai/L), at a rate of 40 cm^3/20 leters.

A randomized complete block design was used, it consisted of two types of fall tillage as main treatments, (1) Conventional tillage by moldboard plow on late September , 1989, and (2) Tillage by chisel plow on late September, 1989, followed by sweeping for seedbed preparation just before planting. The moldboard and chisel plows had a depth of about 25 cm each, and sweep had a depth of about 10 cm. The dimensions of each main plot was 40 x 5 m, (Fig. 3, A,B,C).

By the end of growing season 1989/90, the three crop rotations were completed, wheat-wheat-lentil, duckfoot fallow-wheat-lentil, and chemical fallow-wheat-lentil.

3-6. Soil fertility status .

Soil samples for the upper 30 cm soil layer were taken from 20 locations in the experiment site before planting (1988/89) in order to determine the initial fertility status

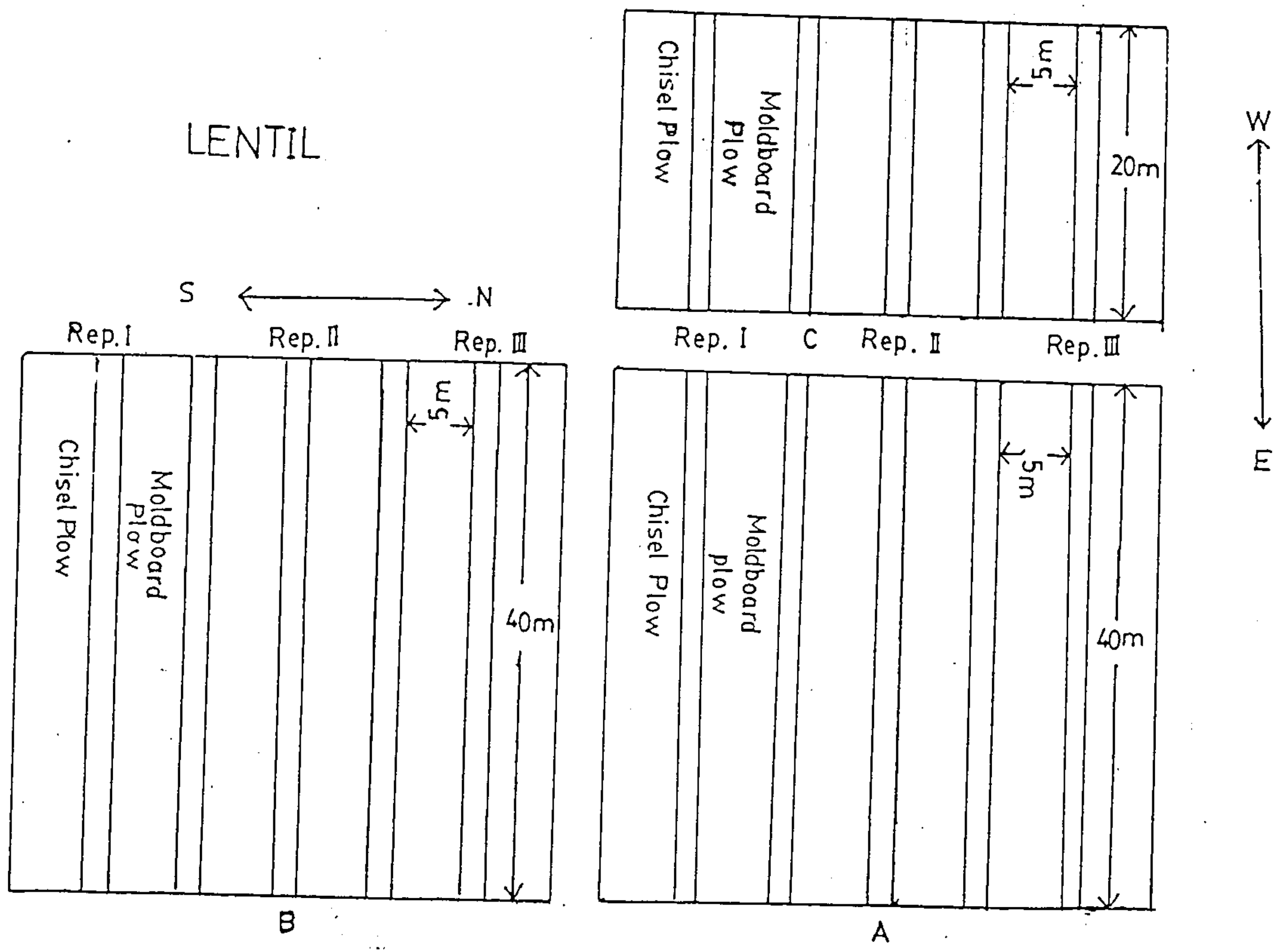


Fig. 3 : Experiment layout at Mushaqqar Agricultural Experiment Station, during 1989/90 growing season .

of the soil. Total Nitrogen was determined using Kjeldhal method (Bremner, 1965). Available Phosphorus was determined using $NaHCO_3$ extraction method (Olsen, et al. 1965). Available Potassium was determined using Ammonium acetate (CH_3,$COONH_4$) extraction method (Pratt, 1965). Electrical Conductivity (EC) was determined using the conductivity bridge in 1:2.5 soil water extract (Bower and Wilcox, 1965). Soil reaction (pH) was measured using the pH-meter in 1:1 soil water suspensions (Peech, 1965). The analyses were done on ten samples as replications, (Table 1). Some physical properties (bulk density, field capacity, permanent wilting point) were taken from (Karouf M. 1989), and were used in the calculation of this study.

Table (1): Some chemical soil properties and fertility status of the experiment site.

Layer Depth cm	EC dS/m	pH	Total Nitrogen %	Available Phosphorus ppm	Available Potassium ppm	Textural class
0-30	0.22*	7.80*	0.02*	4.5*	400*	Clay

* values are averages of 10 replications.

3-7. Soil moisture measurements .

The neutron probe (CPN 503DR Hydro Probe) was used to measure the moisture content in the soil at 7.5, 22.5, 45, 75, and 105 cm soil depth to represent the whole 120 cm soil layer.

Fifty four access tubes were installed in the field

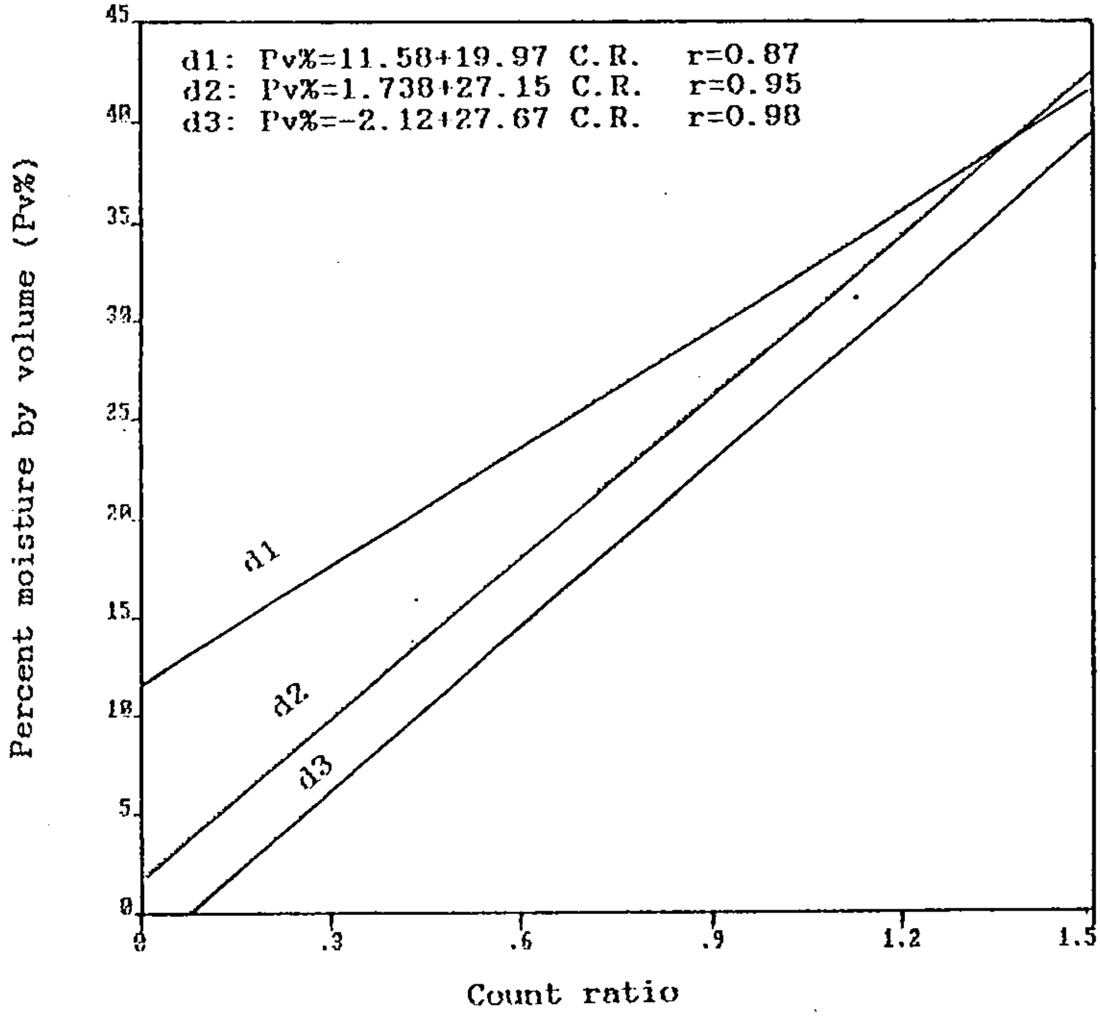


Fig. 4a : Neutron probe calibration curve for soil depth 0-15 cm (d1), 16-30 cm (d2), 31-60 cm (d3), for the experiment site at Mushaqqar Agricultural Station.

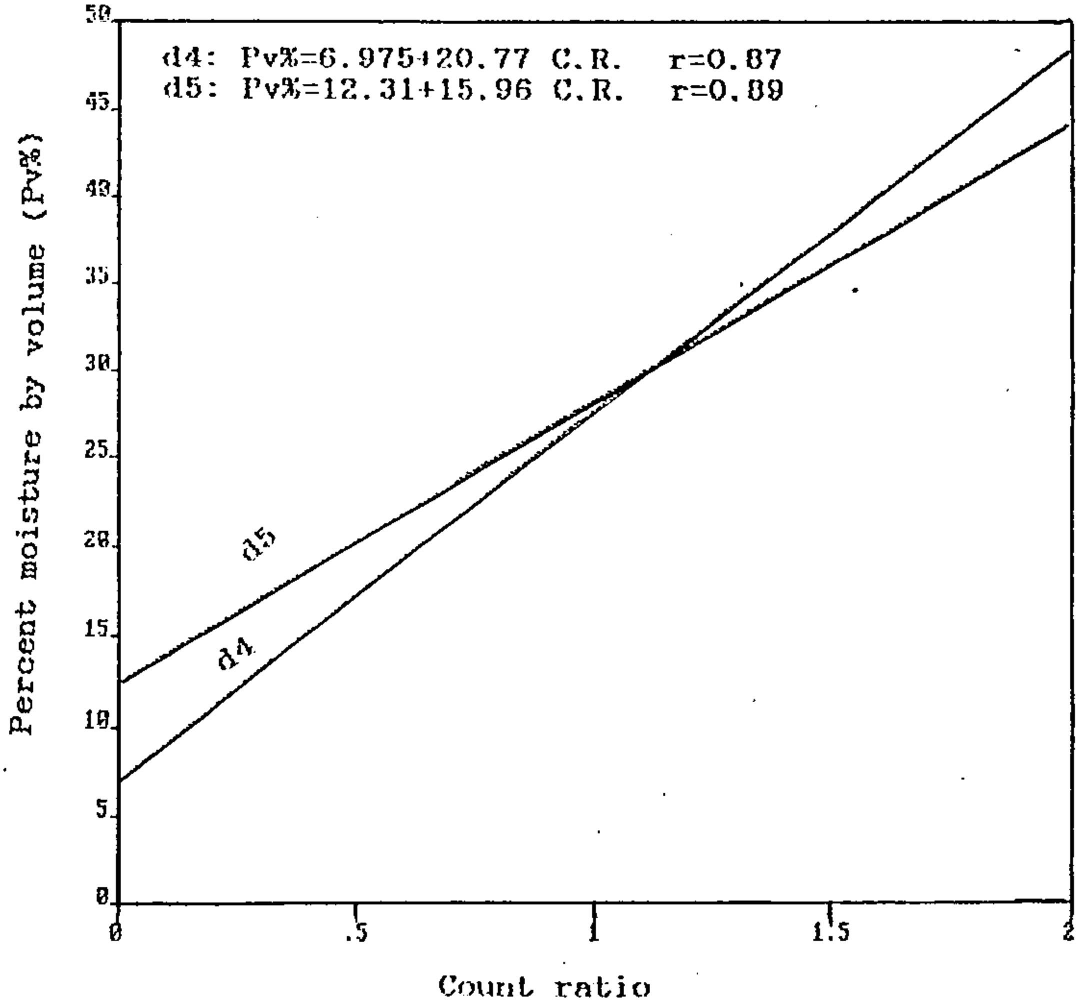


Fig. 4b : Neutron probe calibration curve for soil depth 61-90 cm (d4), 91-120 cm (d5), for the experiment site at Mushaqqar Agricultural Station.

wheat (1987/88 and 1988/89) and for lentil growing season (1989/90) was calculated as the difference between the highest point in the curve nine to fourteen (Soil moisture content above the field capacity point was removed), and the initial soil moisture just before the rainy season, plus soil moisture stored or depleted during the heavy rainfall period, which was estimated from class A pan evaporation readings, using the following formula:

$$ETc = Ep \times Kp \times Kc$$

Where : Etc = Actual crop evaporation in (mm).

Ep = Class A pan evaporation

Kp = Pan coefficient (FAO, 1975).

Kc = Crop coefficient (Fig, 5 and 6).

The actual amount of water used by wheat crop and lentil crop, is the difference between the maximum soil moisture content during the growing season and the soil moisture content at crop harvest time, (plus the amount of soil moisture stored and used by the crop during the heavy rainfall period.

Soil moisture depletion during the fallow period through evaporation is the difference between the highest point in the curve and the lowest point at the end of the fallow period before the rainfall event.

For example: to calculate the amount of soil moisture stored and used by lentil crop during the heavy rainfall period 1989/90.

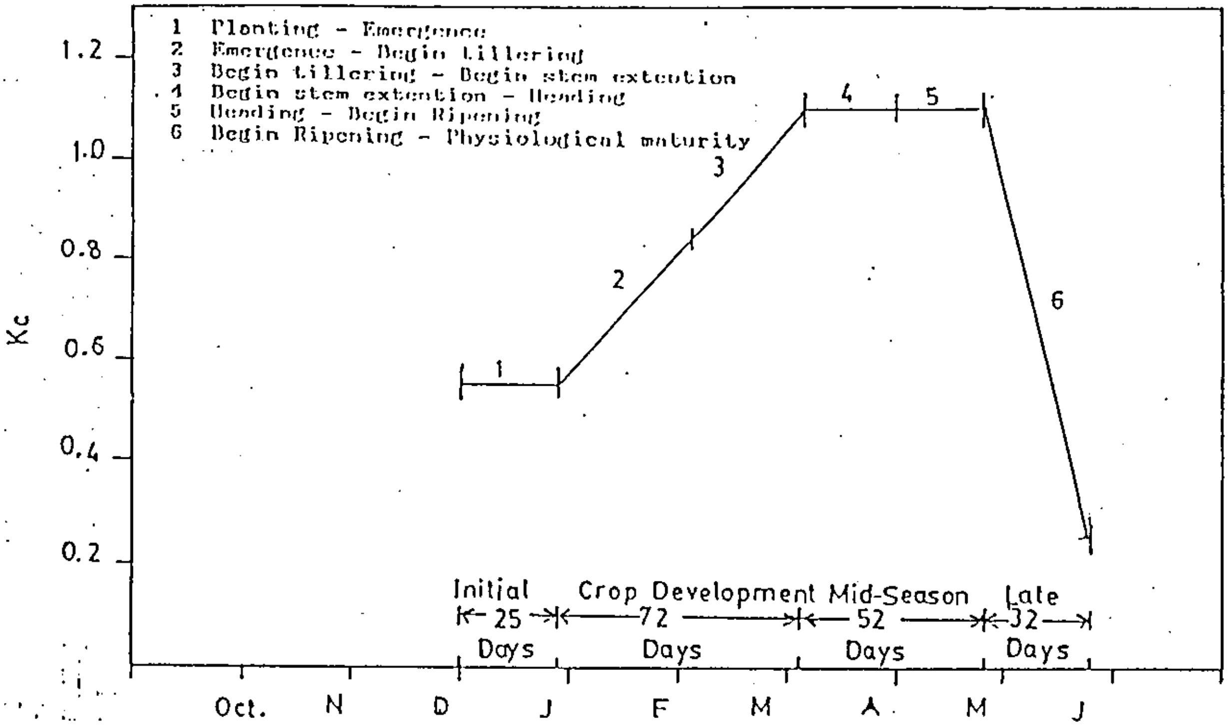


Fig. 5 : Crop coefficient curve, for wheat planted at Mushaqqar Agricultural Station, 1988/89.

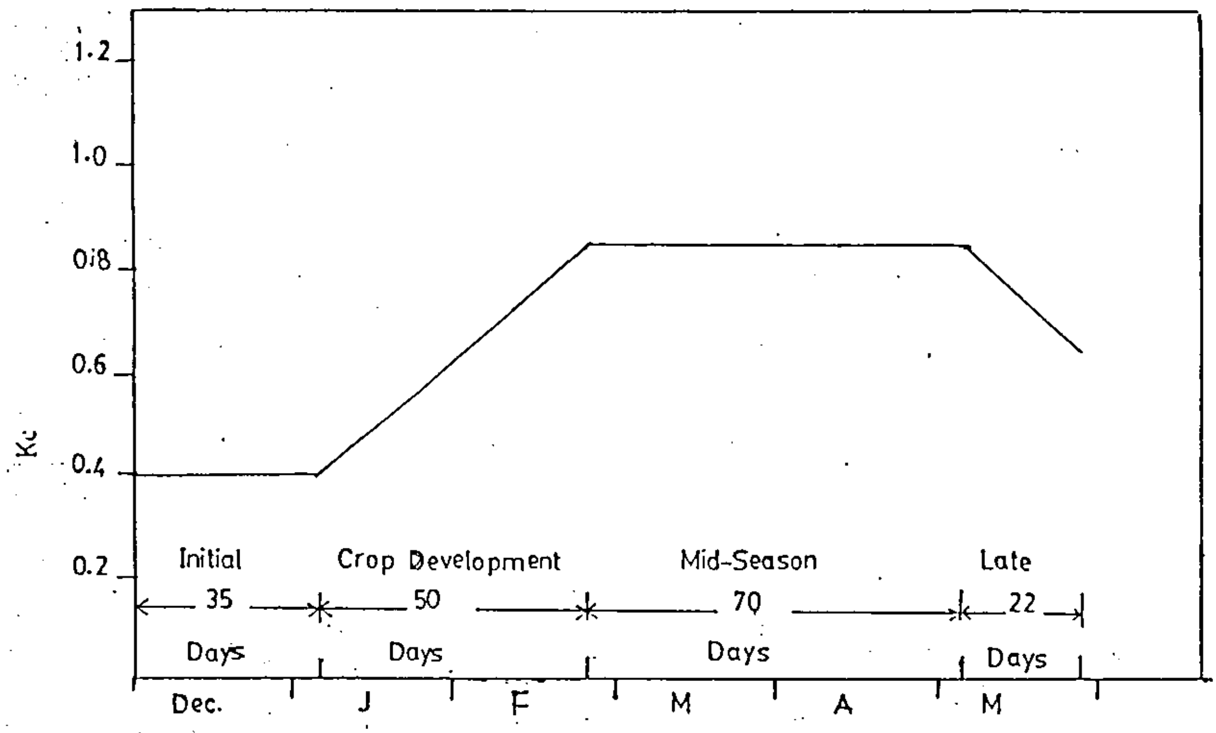


Fig. 6 : Crop coefficient curve, for lentil planted at Mushaqqar Agricultural Station, 1989/90.

Crop stage	Ep mm/day	Kp	Kc	ETc (mm)
Planting to emergence				
(35 days)	2.34	0.8	0.40	26.18
Crop development				
(50 days)	1.18	0.8	0.70	33.16
Mid season				
(35 days)	3.40	0.70	0.85	70.80
			Total =	130.14

3-10. Wheat and lentil yield components .

Five random plant samples of one square meter were collected from each plot during the three growing seasons, 1987/88, 1988/89, and 1989/90, then weighed and threshed to determine the potential biological yield, grain yield, straw yield, and plant height for both wheat and lentil, also number of heads per meter square, and number of heads per plant were determined only for wheat crop.

3-11. Climatic data .

Rainfall, class A pan evaporation, and average monthly temperature were taken from the Mushaqqar Agrometerological Station located about 200 m from the experiment site. Rainfall in millimeters, mean monthly temperature in °C, and 10 days mean of class A pan evaporation are shown in Fig.7a, 7b, and 7c. The total rainfall amounts during 1987/88, 1988/89, and 1989/90 were 462, 332, and 307 mm respectively.

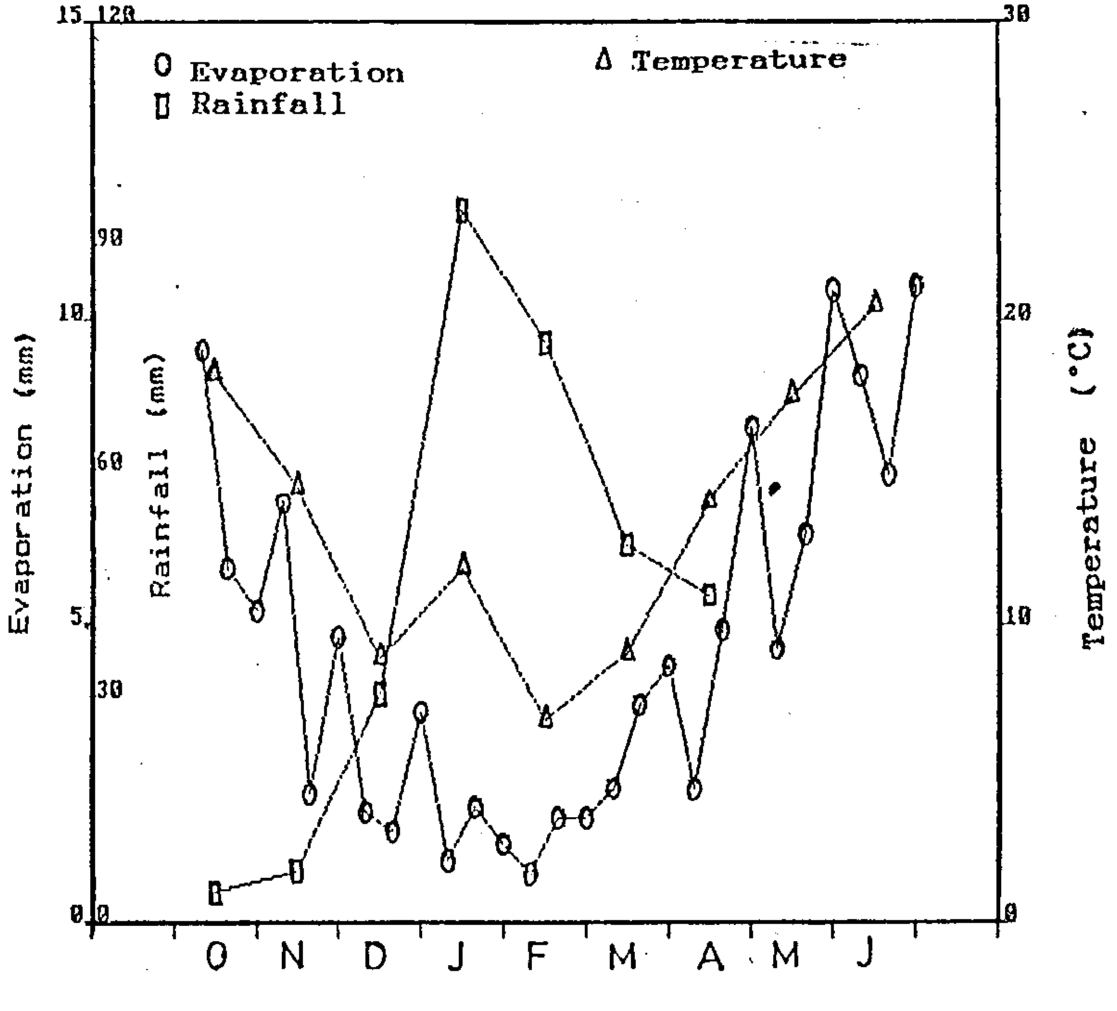


Fig. 7c : Rainfall, mean monthly temperature, and 10 days mean class A pan evaporation during the growing season (1989/90).

4- RESULTS AND DISCUSSIION

4-1. First Season 1987/88.

4-1-1. Fallow techniques.

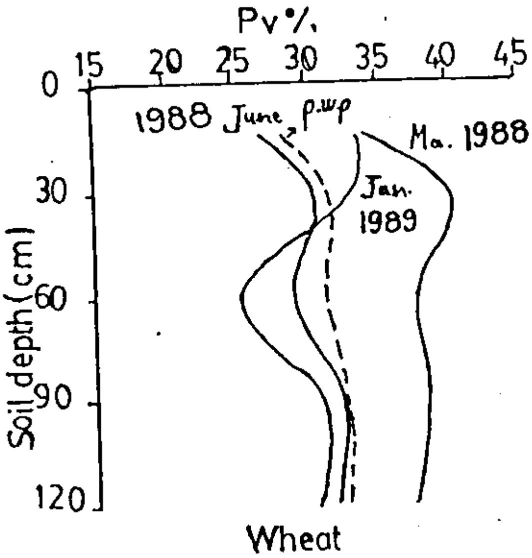
Two fallow cultivation operations either by duck foot or by chemical fallow were needed to control weeds during the fallow period. They were used once in mid March and once in late April. Fenester et. al., obtained similar findings in 1969.

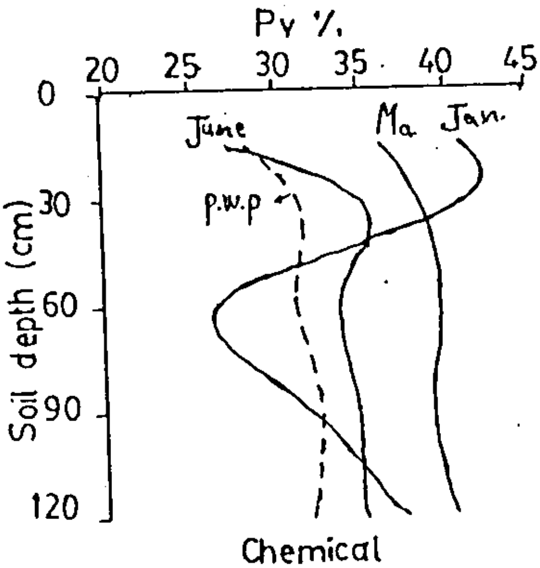
4-1-2. Soil moisture availability.

Fig. 8 shows the soil moisture profile under the different fallow treatments and continuous wheat for the three selected dates during Spring and Summer fallow periods, and at the begining of the following growth season Jan. 1989.

It can be noticed that at the beginning of the fallow period March 1988, the soil of all fallow treatments and wheat contained available water down to 120 cm soil depth. No measurements were taken on soil below 120 cm, Kharouf M. A. (1989) found that there was available water down to 150 cm soil depth.

By June 1988 there was no soil moisture available in the wheat grown area down to 90 cm soil depth, while at that time there was available soil moisture under duck-foot and chemical fallow treatments down to 120 cm soil depth. This variation in soil moisture availability between wheat and fallow systems was due to moisture consumption by wheat crop. It could be noticed that on June 1988 soil moisture





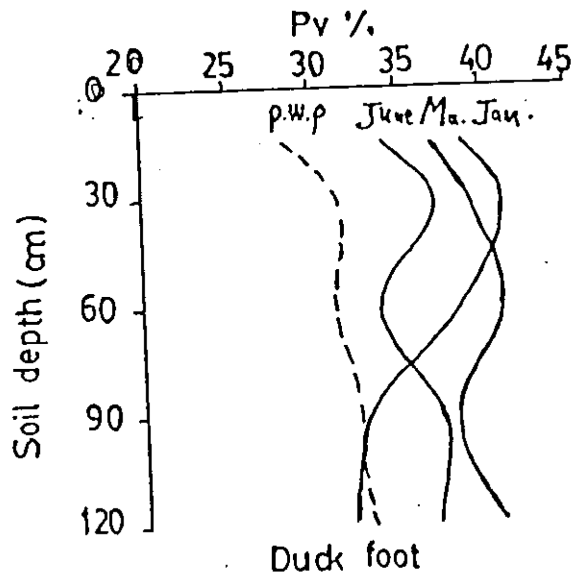


Fig. 8 : Soil moisture profiles by volume at Permenant wilting point, March, and June 1988, and Jan. 1989, for continuous wheat, chemical fallow followed by wheat, and duck foot fallow followed by wheat during 1988 and 1989 growing season.

availability for duck foot treatment extended from soil surface down to 120 cm soil depth, which was more than chemical fallow which was below Permanent Wilting Point to a depth of 20 cm then increased to become above Permanent Wilting Point (PWP) below 20 cm down to 120 cm soil depth. These variations in soil moisture availability between fallow treatments were attributed mainly to the differential ability of each fallow system to control weeds.

One can conclude from the above results that cultivation during fallow period should be done by the end of May and before June to conserve moisture.

At the beginning of the following growth season, Jan. 89 the amount of rainfall (Table 2 and 3) was enough to raise the moisture in soil cultivated by duck foot above PWP down to 90 cm soil depth, while in chemical fallow, moisture rose above PWP down to 60 cm soil depth only. These amounts of water were enough for successful wheat emergence and stand establishment. In continuous wheat the amount of rainfall replenished soil moisture to near PWP down to 30 cm soil depth only. Below 30 cm soil depth moisture was still below PWP. This amount of soil moisture in continuous wheat treatment is inadequate for successful wheat emergence and stand establishment.

Table 2 shows the available soil moisture (mm) in 120 cm soil profile under the different fallow treatments followed by moldboard fall tillage, and nitrogen fertilizer

Table (2) : Available soil moisture (mm) in 120 cm soil profile under different fallow treatments and cultivation practices and nitrogen fertilizer doses for the moldboard fall-tillage treatment 1987/1988 and 1988/1989, growing seasons.

Date	Treatments								
	Duck foot fallow			Chemical fallow			Continuous wheat		
Jan. 19,88	89.70			89.70			89.70		
March 29,88	95.60			93.10			77.60		
April 12,88	72.40			46.40			47.70		
May 12,88	68.60			28.70			- 7.60		
June 2,88	53.50			27.00			- 13.80		
Sept. 18,88	-----			-----			- 41.80		
Nov. 16,88	-----			-----			- 57.70		
	Nitrogen Doses			Nitrogen Doses			Nitrogen Doses		
	one dose	two doses	three doses	one dose	two doses	three doses	one dose	two doses	Three doses
Jan. 1,89	57.30	57.30	57.30	35.50	35.50	35.50	- 24.80	17.90	- 24.80
Feb. 15,89	90.80	86.40	79.80	46.00	51.00	39.20	47.40	46.30	13.40
March 25,89	60.30	59.80	65.00	41.10	48.60	46.20	46.40	46.10	21.90
May 27,89	- 75.10	- 83.10	- 65.80	- 80.20	- 91.60	- 110.40	- 83.90	- 78.80	- 80.40

doses during 1988/89 growing season. It can be noticed that at the beginning of the fallow period (Jan. 19,88), available soil water was the same for the fallow and wheat treatments, 89.7 mm.

On April 12,88 the available water for duck foot treatment was the highest (72.4 mm), compaired with chemical fallow (46.4 mm), and wheat (47.7 mm). Also, at the time of wheat harvest (June 2, 1988), soil moisture availability for wheat was below the PWP (-13.8 mm), while for duck foot and chemical fallow available moisture was 53.5 mm and 27.0 mm, respectively.

This soil moisture availability variation between duck foot and chemical fallow was attributed to weed density, which was more under chemical fallow than duck foot fallow.

By the end of the fallow period or at the beginning of second growing season (Nov. 16, 1988), available soil moisture for the area planted by wheat was -57.7 mm, while at that time soil moisture readings for fallow treatments were not monitored because of technical problems. About one and half month after planting wheat (Jan. 1, 1989) soil moisture availability under continuous wheat were still below PWP (-24.8 mm), (17.9 mm), and (-24.8 mm) for one dose, two doses, and three doses nitrogen fertilizer treatments, respectively. This means that after one and half month of planting wheat there was no available water for the plants, while for wheat planted after duck foot and chemical fallow

fallow, and fertilized, one, two, and three doses of nitrogen, respectively; and -62.1, -91.4, and -89.3 mm for wheat grown after wheat, and fertilized in one, two, and three doses of nitrogen respectively. Soil moisture availability at the end of growing season (May 27, 1989) for chisel followed by sweeping were lower than moldboard fall tillage for most nitrogen fertilizer doses treatments, because soil moisture extraction under chisel plow was more uniform to some extend (Fig. 9 to 14) than soil moisture extraction under moldboard plow, and that chisel plow broke the hard pan layer and allowed roots to penetrate deeper down to soil profile more than moldboard plow.

<u>4-1-3.</u> <u>Fallow efficiency.</u>

Soil moisture content for continuous wheat at the begining of growing season (Jan. 1989), was 37.2 cm (Average for moldboard and chisel followed by sweeping), while at that time soil moisture content for duck foot fallow and chemical fallow were 43.5 and 41.3 cm, respectively, (Table 4). This mean that duck foot fallow and chemical fallow had stored 6.3 and 4.1 cm water, respectively, more than continuous wheat. Rainfall amount during 1988 was 47. 1 cm water. Calculated fallow efficiency for duck foot and chemical fallow were equal to 13.4 % and 8.7 %, respectively. Duck foot fallow efficiency (13.4 %) was more than chemical fallow efficiency (8.7 %), due to the effictivness of each fallow treatment to control weeds. It could be concluded that, duck foot fallow doses during 1988/89 growing season. It can be noticed that at the beginning of the fallow period (Jan. 19,88), available soil water was the same for the fallow and wheat treatments, 89.7 mm.

On April 12,88 the available water for duck foot treatment was the highest (72.4 mm), compaired with chemical fallow (46.4 mm), and wheat (47.7 mm). Also, at the time of wheat harvest (June 2, 1988), soil moisture availability for wheat was below the PWP (-13.8 mm), while for duck foot and chemical fallow available moisture was 53.5 mm and 27.0 mm, respectively.

This soil moisture availability variation between duck foot and chemical fallow was attributed to weed density, which was more under chemical fallow than duck foot fallow.

By the end of the fallow period or at the beginning of second growing season (Nov. 16, 1988), available soil moisture for the area planted by wheat was -57.7 mm, while at that time soil moisture readings for fallow treatments were not monitored because of technical problems. About one and half month after planting wheat (Jan. 1, 1989) soil moisture availability under continuous wheat were still below PWP (-24.8 mm), (17.9 mm), and (-24.8 mm) for one dose, two doses, and three doses nitrogen fertilizer treatments, respectively. This means that after one and half month of planting wheat there was no available water for the plants, while for wheat planted after duck foot and chemical fallow

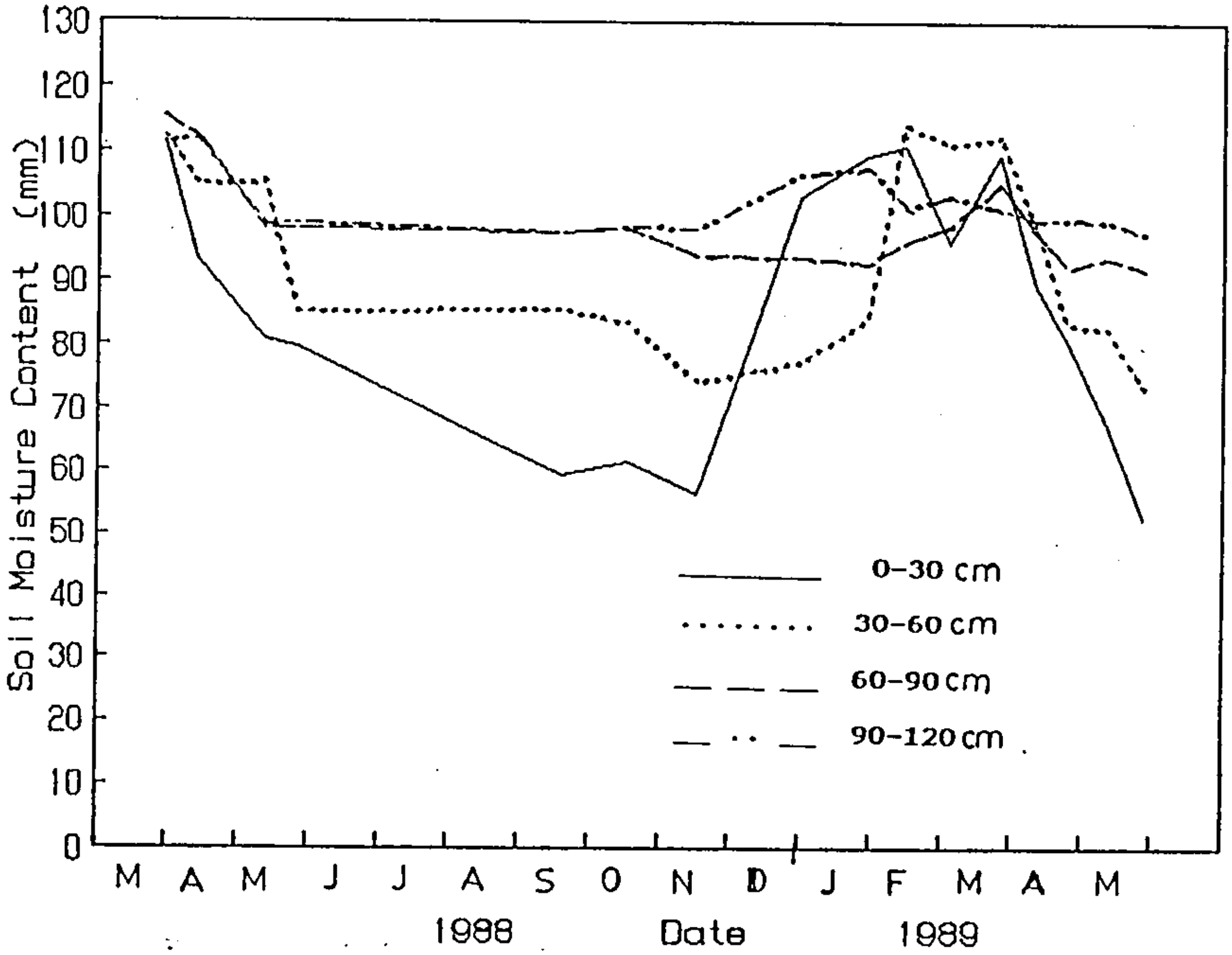


Fig. 9 : Soil moisture depletion and storage (mm) for wheat planted after wheat, chisel plow followed by sweeping for fall tillage, fertilized by nitrogen one dose, during the growing seasons 1988 and 1989.

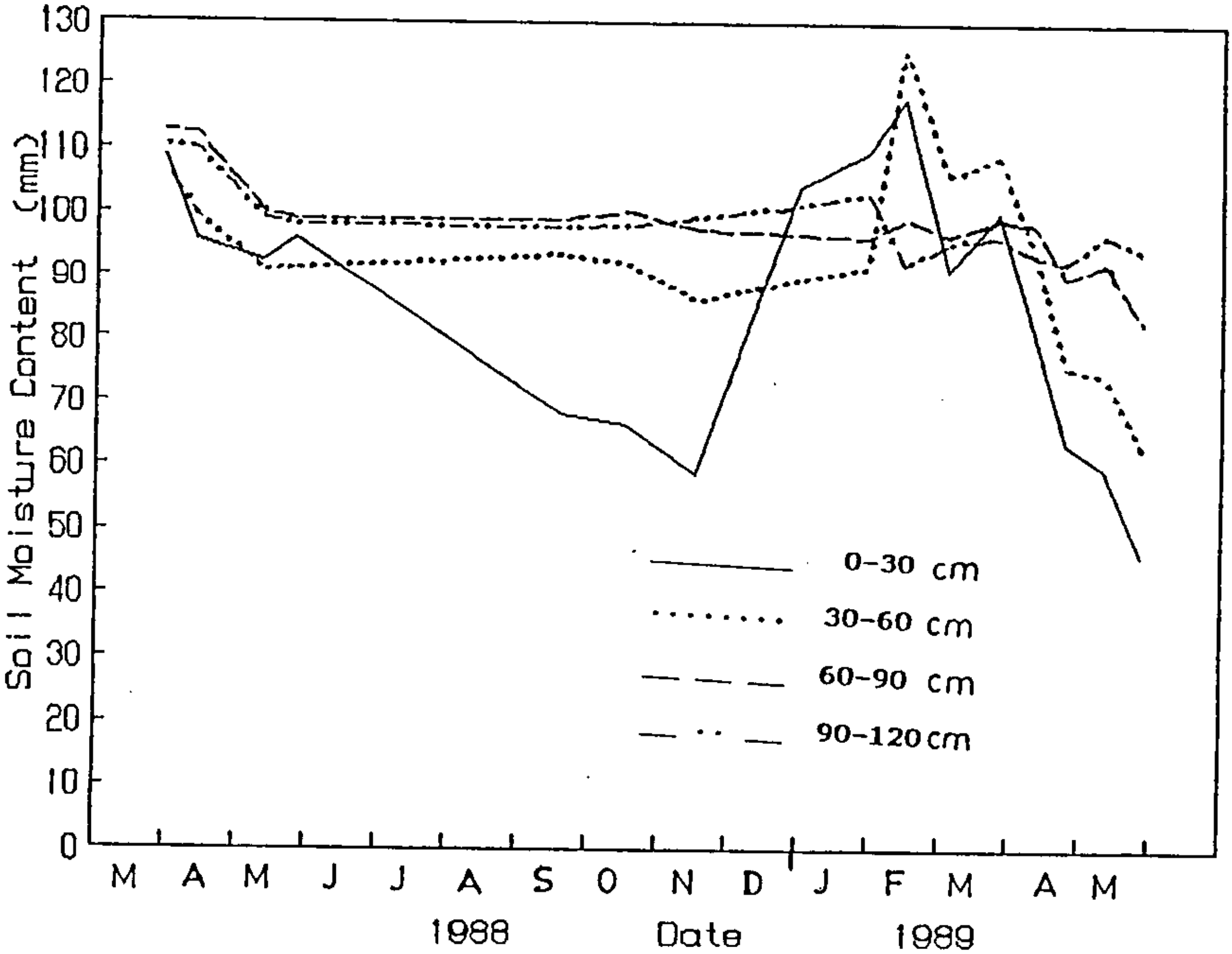


Fig. 10 : Soil moisture depletion and storage (mm) for wheat planted after wheat, chisel plow followed by sweeping for fall tillage, fertilized by nitrogen two doses, during the growing seasons 1988 and 1989.

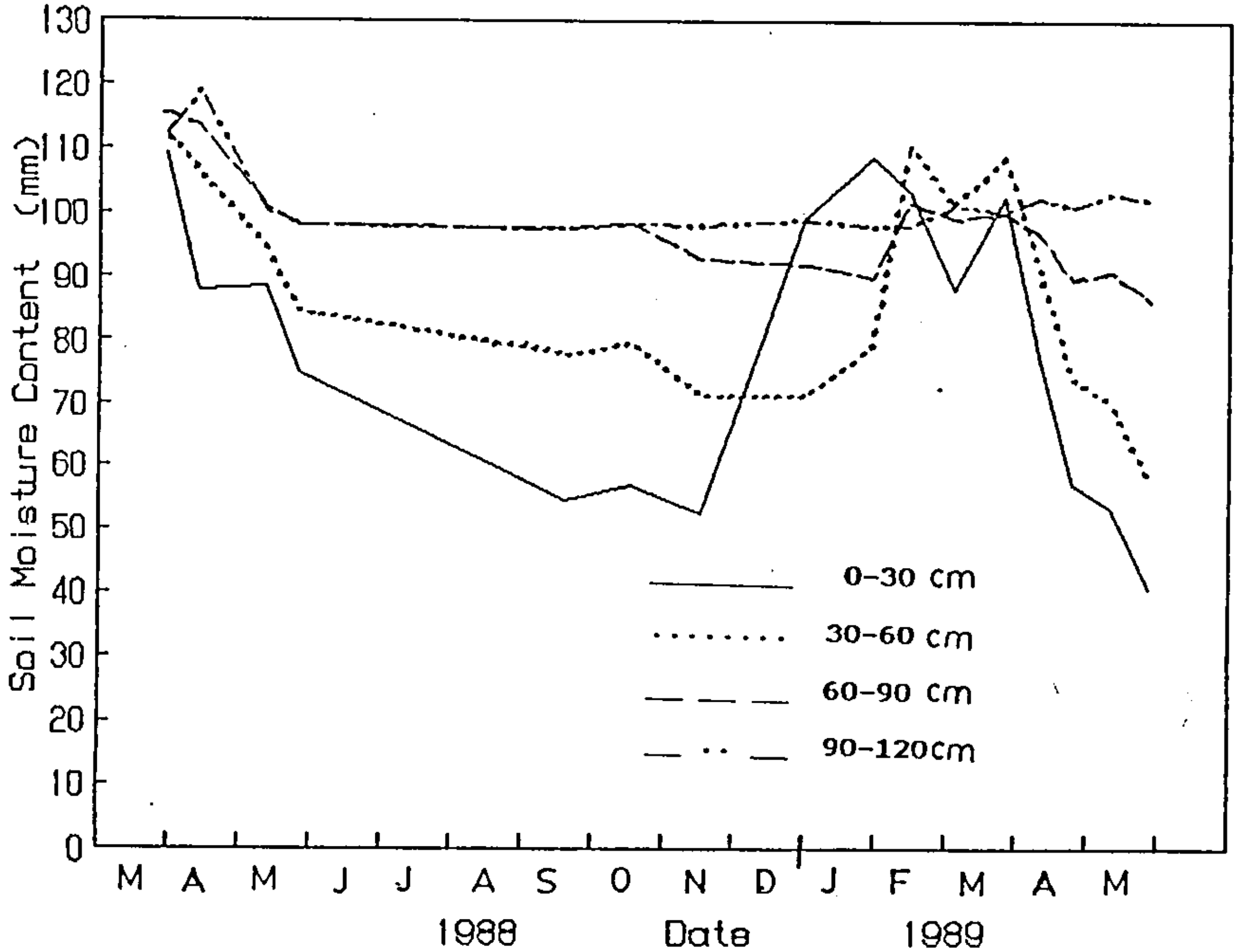


Fig. 11 : Soil moisture depletion and storage (mm) for wheat planted after wheat, chisel plow followed by sweeping for fall tillage, fertilized by nitrogen three doses, during the growing seasons 1988 and 1989.

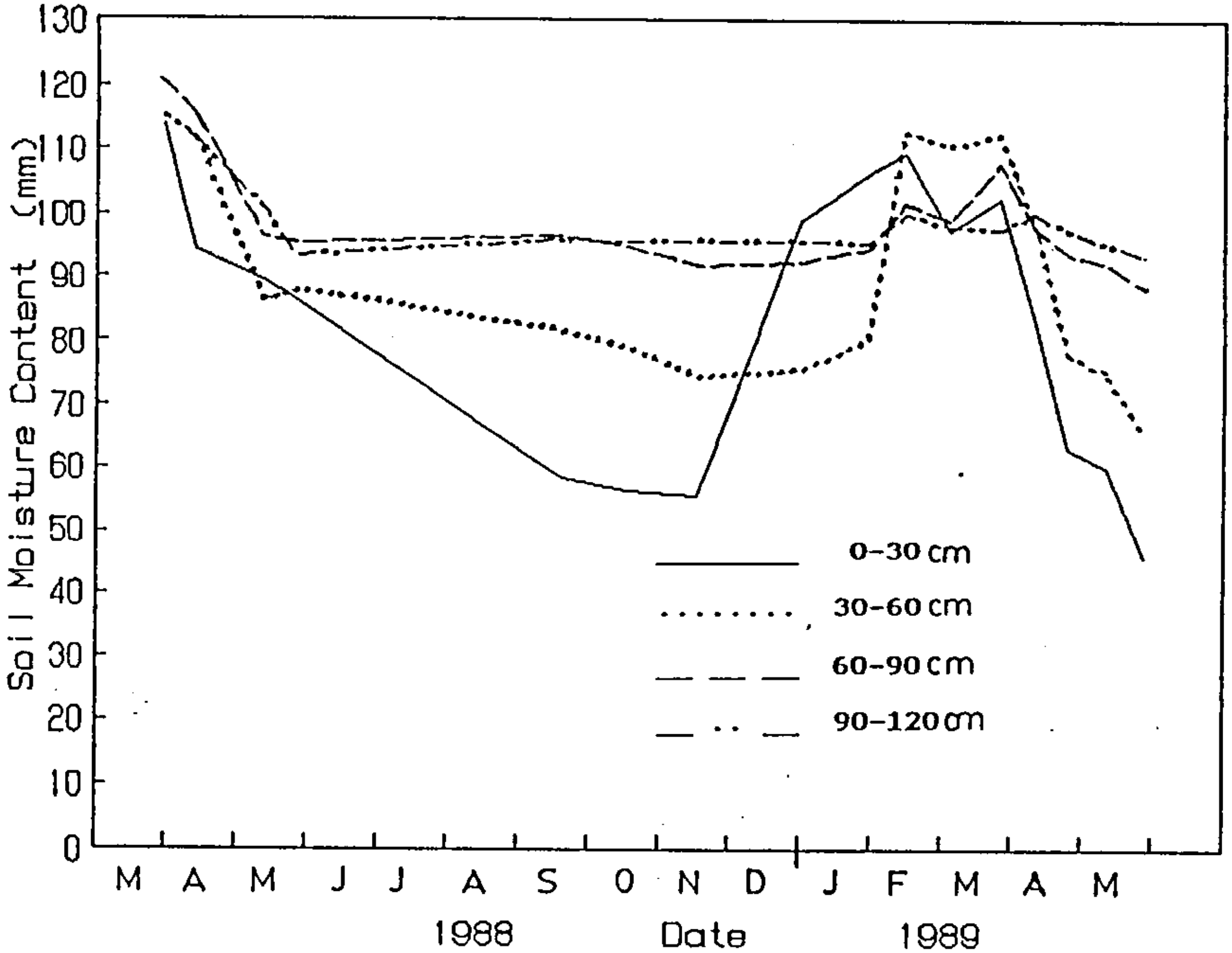


Fig. 12 : Soil moisture depletion and storage (mm) for wheat planted after wheat, moldboard plow for fall tillage, fertilized by nitrogen one dose, during the growing seasons 1988 and 1989.

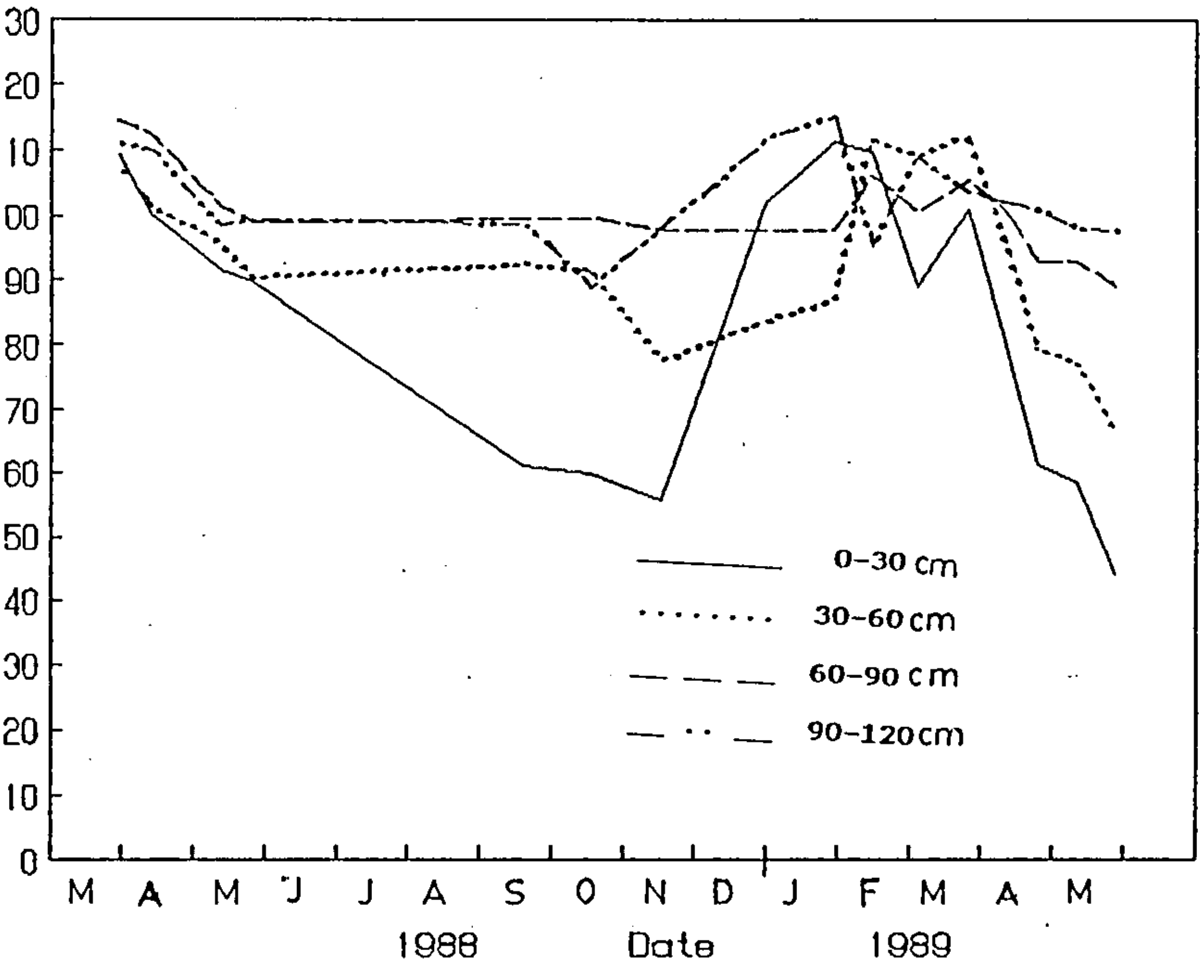


Fig. 13 : Soil moisture depletion and storage (mm) for wheat planted after wheat, moldboard plow for fall tillage, fertilized by nitrogen two doses, during the growing seasons 1988 and 1989.

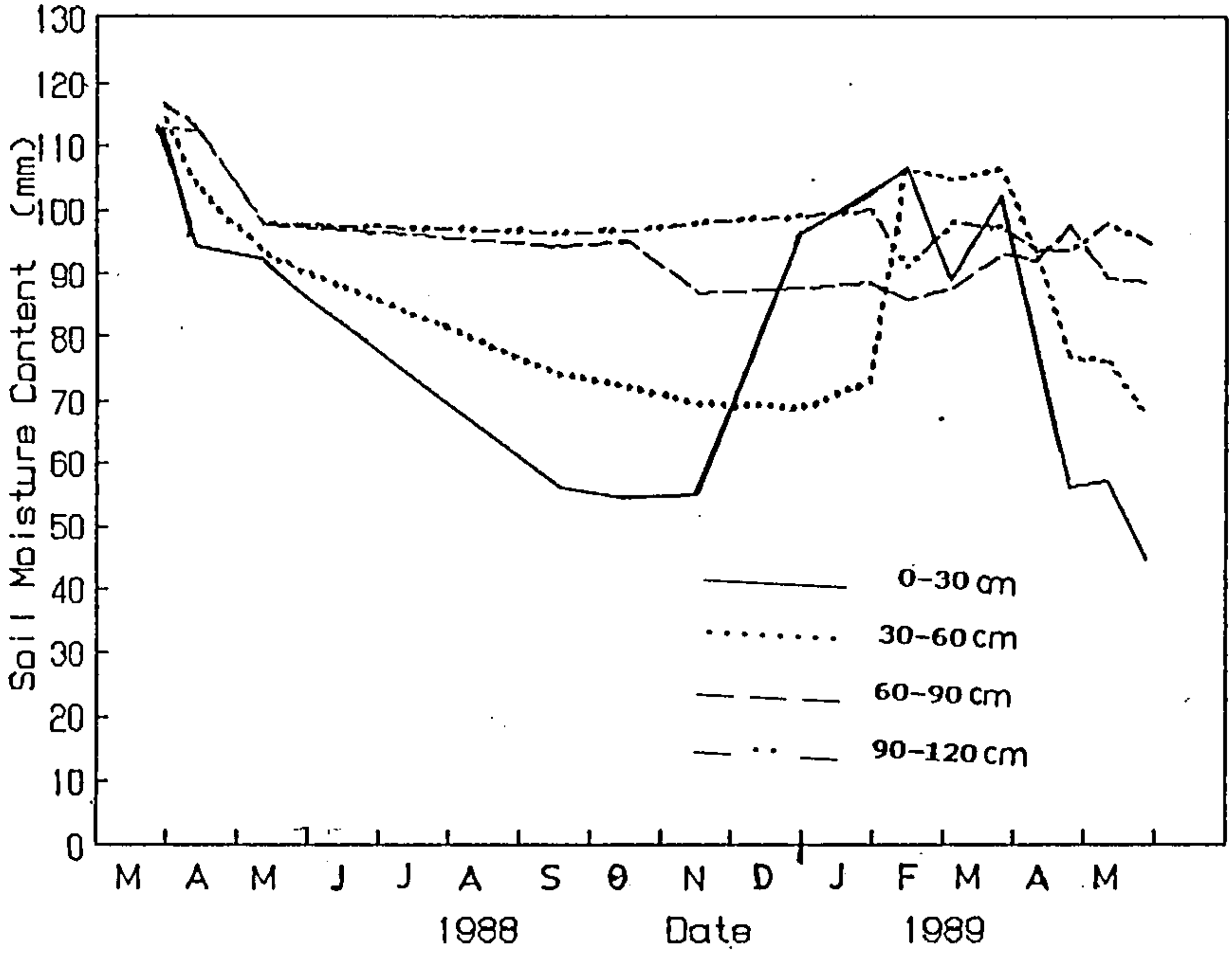


Fig. 14 : Soil moisture depletion and storage (mm) for wheat planted after wheat, moldboard plow for fall tillage, fertilized by nitrogen three doses, during the growing seasons 1988 and 1989.

Table (4) : Soil moisture content (cm/120 cm soil) on different dates, under different tillage practices, during the growing seasons 1987/1988 and 1988/1989.

Treatments		1988					1989		
	Date	12/2	29/3	25/5	2/6	6/11	1/1	15/2	27/5
Duck foot fallow	M*	-	47.3	-	43.1	-	43.5	46.3	30.3
	C	-	47.3	-	43.1	-	43.5	45.7	27.8
Chemical fallow	M	-	47.1	-	40.4	-	41.3	43.9	28.3
	C	-	47.1	-	40.4	-	41.3	44.0	28.8
Wheat-Wheat	M	50.0	45.4	37.6	-	32.0	36.7	38.5	29.4
	C	48.0	44.6	36.6	-	32.3	37.7	39.1	29.6

* M = Moldmord plow ; C = Chisel + sweep.
Rainfall during 1987/88 growing season = 47.1 cm.

Table (6) : Average wheat grain yield, yield components, soil moisture depletion, W.U.E, under chisel+sweep, and moldboard fall-tillage treatments in Mushaqqar, during (1987/1988) growing season.

Parameters	Chisel + sweep		Moldboard		F-test 0.05
1. Grain yield (Mg/ha)	3.12	a	3.48	a	ns
2. Straw yield (Mg/ha)	7.67	a	8.15	a	ns
3. Biological yield (Mg/ha)	10.78	a	11.63	a	ns
4. Grain yield / straw Yield	0.42	a	0.44	a	ns
5. Grain yield / biolo. yield	0.30	a	0.30	a	ns
6. Soil moisture depletion (mm)	237.50	a	246.00	a	ns
7. W.U.E based on grain yield (Kg/mm/du)	1.34	a	1.42	a	ns
8. W.U.E based on biol. yield (Kg/mm/du)	4.61	a	4.74	a	ns

ns : not significant.
W.U.E based on grain yield = grain yield (kg/du) / soil moisture depletion (mm).
W.U.E based on biol. yield = biol. yield (kg/du) / S.M depletion (mm).

Table (7) : Average wheat grain yield, straw yield, biological yield, grain yield / straw yield, grain yield / biological yield, soil moisture depletion, W.U.E, under different nitrogen fertilizer doses for wheat in Mushaqqar (1987/1988), growing season.

Parameters	Treatments: Nitrogen Doses — One dose	Two doses	Three doses	F-test
1. Grain yield (Mg/ha)	3.56 a	3.03 a	3.31 a	ns
2. Straw yield (Mg/ha)	84.52 a	73.00 a	79.78 a	ns
3. Biological yield (Mg/ha)	12.02 a	10.32 a	11.29 a	ns
4. Grain yield / straw Yield	0.44 a	0.42 a	0.42 a	ns
5. Grain yield / biolo. yield	0.30 a	0.29 a	0.30 a	ns
6. Soil moisture depletion (mm)	251.80 ab	216.20 b	257.30 a	*
7. W.U.E based on grain yield (kg/mm/du)	1.43 a	1.41 a	1.30 a	ns
8. W.U.E based on biol. yield (kg/mm/du)	4.82 a	4.78 a	4.43 a	ns

* : significant difference at 0.05 level, according DMRT.

** : along each raw, values followed by the same letter are not significantly different an 5% level, according DMRT.

ns : not significant.

W.U.E based on grain yield = grain yield (kg/du) / soil moisture depletion (mm).

W.U.E based on biol. yield = biol. yield (kg/du) / soil moisture depletion (mm).

Table (8) : Average wheat grain yield, straw yield, biological yield, grain yield/straw yield, grain yield/biological yield, soil moisture depletion, W.U.E under different fall-tillage practices and different nitrogen fertilizer doses in Mushaqqar (1987/1988), growing season.

Parameters	Chisel + sweep			Moldboard			F-test 0.05
	Nitrogen applied one dose	Nitrogen applied two doses	Nitrogen applied three doses	Nitrogen applied one dose	Nitrogen applied two doses	Nitrogen applied three doses	
1. Grain yield (Mg/ha)	3.08 b	3.20 b	3.07 b	4.04 a	2.85 b	3.55 ab	*
2. Straw yield (Mg/ha)	8.12 a	7.06 a	7.82 a	8.79 a	7.52 a	8.14 a	ns
3. Biological yield (Mg/ha)	11.20 a	10.30 a	10.90 a	12.80 a	10.40 a	11.70 a	ns
4. Grain yield / straw Yield	0.40 a	0.46 a	0.40 a	0.49 a	0.39 a	0.44 a	ns
5. Grain yield / biolo. yield	0.28 a	0.32 a	0.28 a	0.32 a	0.26 a	0.31 a	ns
6. Soil moisture depletion (mm)	250.50 a	212.50 a	250.00 a	253.20 a	220.00 a	265.00 a	ns
7. W.U.E based on grain yield (kg/mm/du)	1.25 a	1.51 a	1.24 a	1.60 a	1.30 a	1.35 a	ns
8. W.U.E based on biol. yield (kg/mm/du)	4.58 a	4.85 a	4.41 a	5.06 a	4.71 a	4.45 a	ns

* : significant difference at 0.05 level, according DMRT.

** : Along each raw, values followed by the same letter are not significantly difference at 5% level, according DMRT.

ns : not significant.

W.U.E based on grain yield = grain yield (kg/du) / soil moisture depletion (mm).

W.U.E based on biol. yield = biol. yield (kg/du) / soil moisture depletion (mm).

significantly higher (4.04 Mg/ha), than the other treatments.

4-2. Second Season 1988/89.

4-2-1. Wheat planted after wheat.

Fig. 9 shows soil moisture variations for the different layers of 120 cm soil depth. The soil was tilled by chisel followed by sweeping for fall tillage on late September, then planted by wheat in 1989, then fertilized by one dose of nitrogen at planting.

The initial moisture content found in the soil at the begining of second season after wheat was 315.5 mm, distributed as 56.4, 67.24, 93.8, and 98.56 mm for the first, second, third, and fourth layers of soil, respectively.

The depletion during the continuous wheat growing season 1988/89, until wheat harvest, (May 1989), was 283.3 mm, distributed as 99.2, 81.6, 55.8, and 46.3 mm for the four respective layers.

The total soil moisture storage during the continuous wheat growing season from Nov. 1988 to March 1989 was 265.3 mm, distributed as 82.6, 80.8, 53.8, and 45.8 mm for the four respective layers.

Fig. 10 shows soil moisture variations for the different layers of 120 cm soil depth. The soil was tilled by chisel followed by sweeping for fall tillage on late September, then planted by wheat 1989, then fertilized by two doses of nitrogen.

The initial soil moisture of soil before planting wheat was 341.4 mm, distributed as 58.93, 86.0, 97.3, and 99.2 mm, for the first, second, third, and fourth soil layers, respectively.

The depletion during the the growing season was 287.8 mm, distributed as 96.0, 88.3, 58.8, and 44.7 mm, for the four respective soil layers, respectively.

Total soil moisture storage was 232.4 mm, distributed as 83.3, 65.2, 44.4, and 37.5 mm, respectively for the four respective soil layers.

Fig. 11 shows soil moisture variations for the different layers of 120 cm soil depth. The soil was tilled by chisel followed by sweeping for fall tillage on late September, then planted by wheat in 1989, then fertilized by three doses of nitrogen.

The initial soil moisture content before planting wheat was 312.5 mm, distributed as 52.9, 71.11, 93.2, and 98.2 mm, for the first, second, third, and fourth layers, respectively.

The depletion during the continuous wheat growing, was 283.0 mm distributed as 93.0, 83.5, 55.5, and 40.2 mm for the four respective layers.

The total soil storage during that growing season was 285.8 mm distributed as 92.2, 101.6, 49.0, and 43.0 mm for the four respective layers.

Fig. 12 shows soil moisture variations for the different layers of 120 cm soil depth. The soil was tilled by moldboard for fall tillage on late September, then planted by wheat in 1989, then fertilized by one dose of nitrogen at planting.

The initial moisture content found in the soil at the beginning of second season after wheat was 310.3 mm, distributed as 55.73, 65.21, 91.76, and 97.6 mm, for the first, second, third, and fourth layers of soil respectively.

The depletion during the continuous wheat growing season 1989. was 271.5 mm, distributed as 84.95, 75.15, 62.0, and 49.4 mm for the four respective layers.

The total soil storage was 285.2 mm, distributed as 95.0, 86.4, 58.6, and 45.2 mm for the four respective layers.

Fig. 13 shows soil moisture variations for the different layers of 120 cm soil depth. The soil was tilled by moldboard for fall tillage, then planted by wheat in 1989, then fertilized by two doses of nitrogen.

The initial soil moisture content found was 329.3 mm, distributed as 55.93, 77.5, 97.7, and 98.16 mm for the first, second, third, and fourth layers of soil, respectively.

The depletion during growing season, was 292.4 mm, distributed as 93.0, 87.7, 57.0, and 51.9 mm, for the four respective layers.

The total soil moisture storage was 263.4 mm, distributed as 87.7, 77,1, 50.4, and 48.2 mm, for the four respective layers.

Fig. 14 shows soil moisture variations for the different layers of 120 cm soil depth. The soil was tilled by moldboard fall tillage, then planted by wheat in 1989, then fertilized by three doses of nitrogen.

The initial soil moisture content was 319.4 mm, distributed as 55.78, 70.02, 87.07, and 98.3 mm for the first, second, third, and fourth layers of soil, respectively.

The depletion during that growing season was 299.4 mm, distributed as 106.6, 94.25, 53.8, and 44.7 mm for the four respective soil layers.

The total soil moisture storage was 272.4 mm, distributed as 96.4, 86.1, 48.6, and 41.3 mm for the four respective soil layers.

Most of soil moisture depletion was from the first two depths, while at the beginning of growing season, soil moisture content down 60 cm soil depth was more than above. Also soil moisture storage was more at the soil surface depths than down.

Table 9 shows a comparison between the different treatments for fall tillage, and different nitrogen doses treatments, during the wheat growing season 1989, after wheat.

The amounts of water stored during that growing season, were consistent with the amounts of moisture content at the beginning of that season 1988/89.It could be concluded that the amount of soil moisture storage during the growing season due to rainfall increased as the amount of soil moisture content at the beginning of that season decreased.

Table (9) : Comparison of the d.màx, d.harvest, storage, depletion between different treatments under chisel plus sweep and moldboard fall-tillage treatments and nitrogen fertilizer doses, under continuous wheat, during 1988/1989 growing season.

Tillage Treatment	Fertilizer doses	d.min (mm)	d.max (mm)	d.harv (mm)	storage (mm)	depletion (mm)
Chisel	One dose	315.5	411.6	297.4	265.3	283.3
+	Two doses	341.4	404.6	286.0	232.4	287.8
sweep	Three doses	312.5	429.1	315.3	285.8	283.0
	One dose	310.3	400.0	297.0	285.2	271.5
Moldboard	Two doses	329.3	423.5	298.6	263.4	292.4
	Three doses	319.4	423.8	293.5	272.4	299.4

d-min : Minimum soil moisture content before the rainy season after wheat, upto 120 cm soil depth.

d-max : Maximum soil moisture content, excluding the moisture content above the F.C for each layer.

d-harv : Soil moisture content at harvest time.

storage = (d.max - d.min) + 169 mm

depletion = (d.max - d.harv) + 169 mm

155.2 mm water was calculated from pan evaporation readings.

169.0 mm water stored and depleted during rainfall.

Rainfall equal 332.0 mm.

The depletion (d.max - d. harv) for chisel followed by sweeping and moldboard were not so much different. Also there were no differences between the nitrogen fertilizer doses treatments.

Table 10 shows the grand average wheat grain yield, yield components, soil moisture storage, soil moisture depletion, W.U.E, and water storage efficiency under chisel followed by sweeping and moldboard fall tillage treatments, during 1989 wheat growing season after wheat.

Table 10 shows no significant differences at 5% level concerning all the parameters measured except grain yield. Grain yield under chisel followed by sweeping was significantly higher (1.16 Mg/ha) than grain yield under moldboard plow (1.0 Mg/ha).

Table 11 shows the grand average wheat grain yield, yield components, soil moisture storage, soil moisture depletion, W.U.E, and water storage efficiency, under the three nitrogen fertilizer doses.

Results indicate that was were no significant differences at 5% level between all parameters measured except number of heads/m^2, and wheat plant heights. The greatest number of heads/m^2 (152.7), and plant height (50.8 cm) were for the nitrogen fertilizer treatment applied in two doses at planting and tillering stages.

Table 12 shows the grand average wheat grain yield, yield components, soil moisture storage, soil moisture

Table (10) : Average wheat grain yield, yield components, soil moisture storage, soil moisture depletion, W.U.E, and water storage efficiency under chisel +sweep, and moldboard fall-tillage treatments under continuous wheat in Mushaqqar, during (1988/1989) growing season.

Parameters	Chisel + sweep	Moldboard	F-test 0.05
1. Grain yield (Mg/ha)	1.16 a	1.00 b	*
2. Straw yield (Mg/ha)	3.44 a	3.16 a	ns
3. Biological yield (Mg/ha)	4.58 a	4.03 a	ns
4. Number of tillers/plant	1.57 a	1.22 a	ns
5. Number of heads/m^2	130.00 a	135.00 a	ns
6. Wheat plant hight (cm)	51.10 a	52.80 a	ns
7. Grain yield / straw Yield	0.36 a	0.32 a	ns
8. Grain yield / biolo. yield	0.25 a	0.25 a	ns
9. Soil moisture storage (mm)	264.70 a	261.20 a	ns
10. Soil moisture depletion (mm)	284.70 a	287.80 a	ns
11. W.U.E based on grain yield (kg/mm/du)	0.41 a	0.35 a	ns
12. W.U.E based on biol. yield (kg/mm/du)	1.61 a	1.41 a	ns
13. Water storage efficiency (%)	73.20 a	79.70 a	ns

* : significant difference at 0.05 level, according DMRT.
ns : not significant.
W.U.E based on grain yield = grain yield (kg/du) / soil moisture depletion (mm).
W.U.E based on biol. yield = biol. yield (kg/du) / soil moisture depletion (mm).
Water storage efficiency (%) = Water stored/Rainfall x 100

Table (11) : Average wheat grain yield, yield components, soil moisture storage, soil moisture depletion, W.U.E, and water storage efficiency under different nitrogen fertilizer doses treatments under continuous wheat in Mushaqqar (1988/1989), growing season.

Parameters	Treatments: Nitrogen Doses			F-test
	One dose	Two doses	Three doses	
1. Grain yield (Mg/ha)	1.00 a	1.14 a	1.10 a	ns
2. Straw yield (Mg/ha)	3.25 a	3.40 a	3.25 a	ns
3. Biological yield (Mg/ha)	4.23 a	4.38 a	4.32 a	ns
4. Number of tillers / plant	1.20 a	1.50 a	1.50 a	ns
5. Number of heads/m^2	116.30 b	152.70 a	128.30 ab	*
6. Wheat plant height (cm	48.30 b	50.80 a	50.70 a	*
7. Grain yield / straw Yield	0.30 a	0.34 a	0.34 a	ns
8. Grain yield / biolo. yield	0.24 a	0.26 a	0.25 a	ns
9. Soil moisture storage (mm)	279.10 a	247.90 a	261.80 a	ns
10. Soil moisture depletion (mm)	291.20 a	290.10 a	277.40 a	ns
11. W.U.E based on grain yield (kg/mm/du)	0.35 a	0.40 a	0.40 a	ns
12. W.U.E based on biol. yield (kg/mm/du)	1.45 a	1.51 a	1.57 a	ns
13. Water storage efficiency (%)	83.90 a	75.10 a	70.50 a	ns

* : significant difference at 0.05 level, according DMRT.

** : along each raw, values followed by the same letter are not significantly different an 5% level, according DMRT.

ns : not significant.

W.U.E based on grain yield = grain yield (kg/du) / soil moisture depletion (mm).

W.U.E based on biol. yield = biol. yield (kg/du) / soil moisture depletion (mm).

Water storage efficiency (%) = Water stored/Rainfall x 100

Table (12) : Average wheat grain yield, yield components, soil moisture storage, soil moisture depletion, W.U.E, and water storage efficiency under different fall-tillage practices and different nitrogen fertilizer doses, under continuous wheat in Mushaqqar (1988/1989), growin season.

Parameters	Chisel + sweep			Moldboard			
	Nitrogen applied one dose	Nitrogen applied two doses	Nitrogen applied three doses	Nitrogen applied one dose	Nitrogen applied two doses	Nitrogen applied three doses	F-test 0.05
1. Grain yield (Mg/ha)	1.03 ab	1.26 a	1.18 a	0.98 b	1.02 ab	1.02 ab	*
2. Straw yield (Mg/ha)	3.30 a	3.59 a	3.42 a	3.19 a	3.21 a	3.08 a	ns
3. Biological yield (Mg/ha)	4.30 ab	4.85 a	4.60 ab	4.17 ab	3.90 b	4.03 b	*
4. Number of tillers / plant	1.00 a	1.70 a	2.00 a	1.30 a	1.30 a	1.00 a	ns
5. Number of heads/m^2	110.00 b	148.00 ab	132.00 ab	122.70 ab	157.30 a	124.70 ab	*
6. Wheat plant hight (cm)	45.00 b	51.70 ab	56.70 a	51.70 ab	50.00 ab	56.70 a	*
7. Grain yield / straw Yield	0.30 a	0.35 a	0.35 a	0.30 a	0.32 a	0.33 a	ns
8. Grain yield / biolo. yield	0.24 a	0.26 a	0.26 a	0.23 a	0.26 a	0.24 a	ns
9. Soil moisture storage (mm)	286.80 a	232.40 a	265.30 a	272.40 a	263.40 a	258.20 a	ns
10. Soil moisture depletion (mm)	283.00 a	288.00 a	283.30 a	300.00 a	292.40 a	271.50 a	ns
11. W.U.E based on grain yield (kg/mm/du)	0.36 ab	0.44 a	0.42 ab	0.33 b	0.35 ab	0.38 ab	*
12. W.U.E based on biol. yield (kg/mm/du)	1.51 abc	1.70 a	1.62 ab	1.39 bc	1.33 c	1.51 abc	*
13. Water storage efficiency (%)	85.70 a	77.07 a	63.20 a	82.10 a	79.40 a	77.80 a	ns

* : significant difference at 0.05 level, according DMRT.
ns : not significant.
W.U.E based on grain yield = grain yield (kg/du) / soil moisture depletion (mm).
W.U.E based on biol. yield = biol. yield (kg/du) / soil moisture depletion (mm).
Water storage efficiency (%) = Water stored/Rainfall x 100

depletion, W.U.E, and water storage efficiency, for the different fall tillage and nitrogen fertilizer doses treatments.

Grain yield under chisel followed by sweeping for fall tillage and seed bed preparation and by applying nitrogen at two doses, (Table 12) was the highest (1.26 Mg/ha), followed by (1.18 Mg/ha), for the chisel followed by sweeping and by applying nitrogen fertilizer three times. There were no significant differences among grain yield under chisel plow followed by sweeping and the three different nitrogen fertilizer doses. Also biological yield (4.85 Mg/ha), W.U.E based on grain yield (0.44 kg/mm/du), W.U.E based on biological (1.70 kg/mm/du) were greatest for chisel followed by sweeping and applying nitrogen fertilizer two doses. While there were no significant differences with respect to the other parameters measured.

Interaction were detected only with respect to grain yield, biological yield, number of heads/m^2, plant heights, W.U.E based on grain yield, and W.U.E based on biological yield.

4-2-2. Wheat planted after duck foot fallow.

Table 13 shows a comparison among d.max, d.harv, and depletion for wheat planted after duck foot fallow, for the different fall tillage treatments and nitrogen fertilizer doses, during 1989 growing season.

Results in Table 13 indicated that highest depletion

Table (13) : Comparison of the d.max, d.harvest, depletion, in mm for 120 cm soil depth between different treatments under chisel plus sweep and moldboard fall-tillage treatments and nitrogen fertilizer doses under wheat planted after duck foot fallow during (1988/1989) growing season.

Tillage Treatment	Fertilizer doses	d.max (mm)	d.harv (mm)	depletion (mm)
Chisel + sweep	One dose	437.9	266.2	341.0
	Two doses	427.8	286.0	311.1
	Three doses	435.1	284.1	320.2
Moldboard	One dose	442.4	311.6	324.7
	Two doses	437.2	294.3	212.2
	Three doses	437.7	302.3	304.6

d-max : Maximum soil moisture content, excluding the moisture content above the field capacity for each layer.

d-harv : Soil moisture content at harvest time.

depletion = (d.max - d.harv) + 169.2 mm
169.2 mm water was calculated from pan evaporation readings, and Kc curves.

Rainfall equal 332.0 mm.

was detected under chisel plow followed by sweeping and applying nitrogen fertilizer one dose (341.0 mm). This treatment ended with the lowest soil moisture content (d.harv was 266.2 mm). The second highest depletion was under moldboard fall tillage and applying nitrogen fertilizer one dose (324.7 mm).

Table 14 shows grand average wheat grain yield, yield components, soil moisture depletion, and W.U.E under chisel plow followed by sweeping and moldboard plow, during 1989 growing season, for wheat planted after duck foot fallow.

Results indicated that there were no significant differences among all parameters measured, at 5% level. Most of the parameters measured in that table shows that, chisel plow followed by sweeping was more effective than moldboard fall tillage.

Table 15 shows the grand average wheat grain yield, yield components, soil moisture depletion, and W.U.E under different nitrogen fertilizer doses, under wheat grown after duck foot fallow, during 1989 growing season.

There were no significant differences among all parameters measured except the number of heads/m^2. Applying one dose of nitrogen fertilizer had resulted in the highest heads/m^2 (396.3). Applying nitrogen fertilizer in two doses had resulted in the second highest heads/m^2 (374.8). Both one and two doses were significantly higher than applying nitrogen fertilizer in three doses (354.2).

Table (14) : Average wheat grain yield, yield components, soil moisture depletion, W.U.E, under chisel +sweep, and moldboard fall-tillage treatments under wheat planted after duck foot fallow in Mushaqqar, during (1988/1989) growing season.

Parameters	Chisel + sweep	Moldboard	F-test 0.05
1. Grain yield (Mg/ha)	3.50 a	3.21 a	ns
2. Straw yield (Mg/ha)	8.12 a	7.50 a	ns
3. Biological yield (Mg/ha)	11.62 a	10.70 a	ns
4. Number of tillers/plant	3.30 a	3.20 a	ns
5. Number of heads/m^2	369.70 a	380.60 a	ns
6. Wheat plant hight (cm)	98.30 a	97.60 a	ns
7. Grain yield / straw Yield	0.42 a	0.43 a	ns
8. Grain yield / biolo. yield	0.30 a	0.30 a	ns
9. Soil moisture depletion (mm)	324.00 a	313.80 a	ns
10. W.U.E based on grain yield (kg/mm/du)	1.11 a	1.04 a	ns
11. W.U.E based on biol. yield (kg/mm/du)	3.64 a	3.44 a	ns

* : significant difference at 0.05 level, according DMRT.
ns : not significant.
W.U.E based on grain yield = grain yield (kg/du) / soil moisture depletion (mm).
W.U.E based on biol. yield = biol. yield (kg/du) / soil moisture depletion (mm).

Table (15) : Average wheat grain yield, yield components, soil moisture depletion, W.U.E, under different nitrogen fertilizer doses treatments under wheat planted after duck foot fallow in Mushaqqar (1988/1989), growing season.

Parameters	Treatments: Nitrogen Doses — One dose	Two doses	Three doses	F-test
1. Grain yield (Mg/ha)	3.50 a	3.30 a	3.28 a	ns
2. Straw yield (Mg/ha)	8.00 a	7.75 a	7.70 a	ns
3. Biological yield (Mg/ha)	11.50 a	11.04 a	10.93 a	ns
4. Number of tillers / plant	3.20 a	3.20 a	3.50 a	ns
5. Number of heads/m^2	396.30 a	374.80 ab	354.20 b	*
6. Wheat plant hight (cm)	100.50 a	97.50 a	95.80 a	ns
7. Grain yield / straw Yield	0.42 a	0.43 a	0.43 a	ns
8. Grain yield / biolo. yield	0.30 a	0.30 a	0.30 a	ns
9. Soil moisture depletion (mm)	312.40 a	311.60 a	332.80 a	ns
10. W.U.E based on grain yield (kg/mm/du)	1.14 a	1.07 a	1.00 a	ns
11. W.U.E based on biol. yield (kg/mm/du)	3.74 a	3.56 a	3.32 a	ns

* : significant difference at 0.05 level, according DMRT.
** : along each raw, values followed by the same letter are not significantly different an 5% level, according DMRT.
ns : not significant.
W.U.E based on grain yield = grain yield (kg/du) / soil moisture depletion (mm).
W.U.E based on biol. yield = biol. yield (kg/du) / soil moisture depletion (mm).

Table 16 shows grand average wheat grain yield, yield components, soil moisture depletion, and W.U.E under different fall tillage treatments and nitrogen fertilizer doses treatments, for wheat planted after duck foot fallow during 1989 growing season.

The grain yield, number of tillers/m^2, biological yield under chisel plow followed by seeping for fall tillage and seed-bed preparation, and applying nitrogen fertilizer one dose, produced significantly higher (3.64 Mg/ha, 3.3, and 11.95 Mg/ha, respectively), than the other treatments (Table 16).

4-2-3. Wheat planted after chemical fallow.

Table 17 shows a comparison among d.max, d.harv, and depletion for different fall tillage treatments and nitrogen fertilizer doses treatments, for wheat planted after chemical fallow, during 1989 growing season.

Results in (Table 17) indicate that depletion under chisel followed by sweeping, depletion was the highest (331.0 mm). Also depletions under applying nitrogen fertilizer in one dose for both chisel followed by sweeping and moldboard (331.0 mm) and (325.8 mm) respectively, than two or three doses.

Table 18 shows grand average grain yield, yield components, soil moisture depletion, and W.U.E under chisel followed by sweeping and moldboard fall tillage, during 1989 growing season.

Table (16): Average wheat grain yield, yield components, soil moisture depletion, W.U.E, under different fall-tillage practices and different nitrogen fertilizer doses, under wheat planted after duck foot fallow in Mushaqqar (1988/1989), growin season.

Parameters	Chisel + sweep			Moldboard			F-test 0.05
	Nitrogen applied one dose	Nitrogen applied two doses	Nitrogen applied three doses	Nitrogen applied one dose	Nitrogen applied two doses	Nitrogen applied three doses	
1. Grain yield (Mg/ha)	3.64 a	3.50 ab	3.40 ab	3.32 b	3.12 b	3.20 ab	*
2. Straw yield (Mg/ha)	8.37 a	8.07 a	8.00 a	7.71 a	7.42 a	7.37 a	ns
3. Biological yield (Mg/ha)	11.95 a	11.55 ab	11.35 ab	11.03 ab	10.53 b	10.51 b	*
4. Number of tillers / plant	3.30 a	3.30 a	3.30 a	3.00 a	3.00 a	3.70 a	ns
5. Number of heads/m^2	390.70 ab	360.70 ab	357.60 ab	402.00 a	389.00 ab	350.70 b	*
6. Wheat plant hight (cm)	100.00 a	98.30 a	96.70 a	101.00 a	96.70 a	95.00 a	ns
7. Grain yield / straw Yield	0.41 a	0.43 a	0.42 a	0.43 a	0.42 a	0.43 a	ns
8. Grain yield / biolo. yield	0.30 a	0.30 a	0.30 a	0.30 a	0.30 a	0.31 a	ns
9. Soil moisture depletion (mm)	320.20 a	311.10 a	340.90 a	304.60 a	312.20 a	324.70 a	ns
10. W.U.E based on grain yield (kg/mm/du)	1.18 a	1.12 a	1.02 a	1.10 a	1.02 a	1.00 a	ns
11. W.U.E based on biol. yield (kg/mm/du)	3.83 a	3.73 a	3.37 a	3.66 a	3.40 a	3.27 a	ns

* : significant difference at 0.05 level, according DMRT.

** : Along each raw, values followed by the same letter are not significantly difference at 5% level, according DMRT.

ns : not significant.

W.U.E based on grain yield = grain yield (kg/du) / soil moistur depletion (mm).

W.U.E based on biol. yield = biol. yield (kg/du) / soil moisture depletion (mm).

Table (19) : Average wheat grain yield, yield components, soil moisture depletion, W.U.E, under different nitrogen fertilizer doses treatments under wheat planted after chemical fallow in Mushaqqar (1988/1989), growing season.

Parameters	Treatments: Nitrogen Doses			F-test
	One dose	Two doses	Three doses	
1. Grain yield (Mg/ha)	2.81 a	2.72 a	2.73 a	ns
2. Straw yield (Mg/ha)	5.71 a	5.90 a	5.90 a	ns
3. Biological yield (Mg/ha)	8.52 a	8.62 a	8.58 a	ns
4. Number of tillers / plant	1.50 b	2.20 a	2.20 a	*
5. Number of heads/m^2	215.70 a	200.00 a	227.30 a	ns
6. Wheat plant hight (cm)	80.00 a	81.70 a	77.50 a	ns
7. Grain yield / straw Yield	0.50 a	0.46 a	0.47 a	ns
8. Grain yield / biolo. yield	0.33 a	0.32 a	0.32 a	ns
9. Soil moisture depletion (mm)	295.30 a	308.40 a	328.40 a	ns
10. W.U.E based on grain yield (kg/mm/du)	1.01 a	0.90 a	0.84 a	ns
11. W.U.E based on biol. yield (kg/mm/du)	2.90 a	2.83 a	2.64 a	ns

* : significant difference at 0.05 level, according DMRT.

** : along each raw, values followed by the same letter are not significantly different an 5% level, according DMRT.

ns : not significant.

W.U.E based on grain yield = grain yield (kg/du) / soil moisture depletion (mm).

W.U.E based on biol. yield = biol. yield (kg/du) / soil moisture depletion (mm).

Table (20): Average wheat grain yield, yield components, soil moisture depletion, W.U.E, under different fall-tillage practices and different nitrogen fertilizer doses, under wheat planted after chemical fallow in Mushaqqar (1988/1989), growin season.

Parameters	Chisel + sweep			Moldboard			F-test 0.05
	Nitrogen applied one dose	Nitrogen applied two doses	Nitrogen applied three doses	Nitrogen applied one dose	Nitrogen applied two doses	Nitrogen applied three doses	
1. Grain yield (Mg/ha)	2.39 a	2.63 a	2.68 a	3.32 b	2.79 a	2.77 a	ns
2. Straw yield (Mg/ha)	5.10 a	6.65 a	6.23 a	6.33 a	5.16 a	5.56 a	ns
3. Biological yield (Mg/ha)	7.48 a	9.28 a	8.82 a	9.55 a	7.95 a	8.33 a	ns
4. Number of tillers / plant	1.70 ab	2.00 ab	2.30 a	1.30 b	2.30 a	2.00 ab	*
5. Number of heads/m^2	204.00 a	166.30 a	216.70 a	227.30 a	233.30 a	238.00 a	ns
6. Wheat plant height (cm	81.70 a	78.30 a	78.30 a	78.30 a	85.00 a	76.70 a	ns
7. Grain yield / straw Yield	0.47 a	0.40 a	0.43 a	0.52 a	0.53 a	0.51 a	ns
8. Grain yield / biolo. yield	0.32 a	0.28 a	0.30 a	0.34 a	0.35 a	0.33 a	ns
9. Soil moisture depletion (mm)	300.10 a	307.40 a	331.00 a	290.50 a	309.50 a	325.80 a	ns
10. W.U.E based on grain yield (kg/mm/du)	0.81 a	0.88 a	0.82 a	1.21 a	0.92 a	0.86 a	ns
11. W.U.E based on biol. yield (kg/mm/du)	2.53 a	3.05 a	2.67 a	3.27 a	2.62 a	2.63 a	ns

* : significant difference at 0.05 level, according DMRT.

** : Along each raw, values followed by the same letter are not significantly difference at 5% level, according DMRT.

ns : not significant.

W.U.E based on grain yield = grain yield (kg/du) / soil moisture depletion (mm).

W.U.E based on biol. yield = biol. yield (kg/du) / soil moisture depletion (mm).

Table (21) : Average wheat grain yield, yield components, soil moisture depletion, W.U.E, under the three crop rotations for wheat grown in Mushaqqar (1988/1989), growing season.

Parameters	Treatments		
	Continuous wheat	Duck foot fallow-wheat	Chemical fallow-wheat
1. Grain yield (Mg/ha)	1.08	3.36	2.84
2. Straw yield (Mg/ha)	3.30	7.81	5.84
3. Biological yield (Mg/ha)	4.30	11.16	7.07
4. Number of tillers / plant	1.40	3.25	2.00
5. Number of heads/m^2	132.50	375.15	214.30
6. Wheat plant hight (cm)	51.95	97.95	88.70
7. Grain yield / straw Yield	0.34	0.43	0.48
8. Grain yield / biolo. yield	0.25	0.30	0.32
9. Soil moisture depletion (mm)	286.30	318.90	310.70
10. W.U.E based on grain yield (kg/mm/du)	0.38	1.08	0.92
11. W.U.E based on biol. yield (kg/mm/du)	1.51	3.54	2.79

W.U.E based on grain yield = grain yield (kg/du) / soil moisture depletion (mm).

W.U.E based on biol. yield = biol. yield (kg/du) / soil moisture depletion (mm).

foot fallow (3.36 Mg/ha), was greater than wheat yield after wheat "Continuous wheat", (1.08 Mg/ha) by 3.0 times, while wheat grain yield after chemical fallow, (2.84 Mg/ha) was greater by 2.60 times. Same trends were detected for all parameters measured, because soil moisture availability at the beginning of 1988/89 under duck foot fallow was more higher than chemical fallow and continuous wheat (Table 2 and 3).

One can see that wheat grain yield after duck foot fallow was greater than wheat grain yield after chemical fallow by 1.2 times. The same trends were detected with respect to all parameters measured, because soil moisture availability at the beginning of growing season 1988/89 for duck foot fallow was greater than chemical fallow and continuous wheat (Table 1 and 2).

To discuss the effect of splitting nitrogen fertilizer. Nitrogen was applied by broadcasting without incorporation. Also rainfall distribution during 1988/89 growing season according to wheat crop stages were as follows; after time of seeding about 146.0 mm; at time of tillering stage about 60.0 mm; while at boating stage there was no rainfall events. Soil moisture depletion under chisel followed by sweep and applying nitrogen one dose equal 341.0 mm. Also soil moisture depletion under moldboard plow and applying nitrogen one dose equal 324.7 mm, which was more than two and three doses. This may be due to rainfall distribution at each stage. Were applying nitrogen fertilizer at sowing with presence of adequate rainfall resulted in much more growth than splitting it in to more than one dose. Also, the used fertilizer was $(NH_4)_2SO_4$, which is the common nitrogen fertilizer in Jordan. The soil to which it was applied has a high pH (over 8) and a high amount of free $CaCO_3$ and lack of rainfall specially at tillering and boating stages. So, conditions for for NH_4 volatilization were very likely to happened. The fertilizer was broadcasted without incorporation. Surface application of ammonium sulfate on alkaline (dry) soil also resulted to NH_4 loss, which gave a low utilization of nitrogen at tillering and boating stage.

4-3. Third Season 1989/90.

4-3-1. Lentil grown after continuous wheat.

Fig. 15 shows soil moisture depletion and storage for chisel plow followed by sweeping for fall tillage and seed bed-preparation, for lentil grown after continuous wheat during 1989/90 growing season.

The initial soil moisture content found in the soil at the beginning of the growing season was 312.46 mm, distributed as 56.73, 66.73, 90.80, and 98.20 mm for the first, second, third, and fourth layers of soil, respectively.

The depletion during that growing season was 231.0 mm, distributed as 76.0, 67.7, 46.7, and 40.6 mm, for the four respective soil layers.

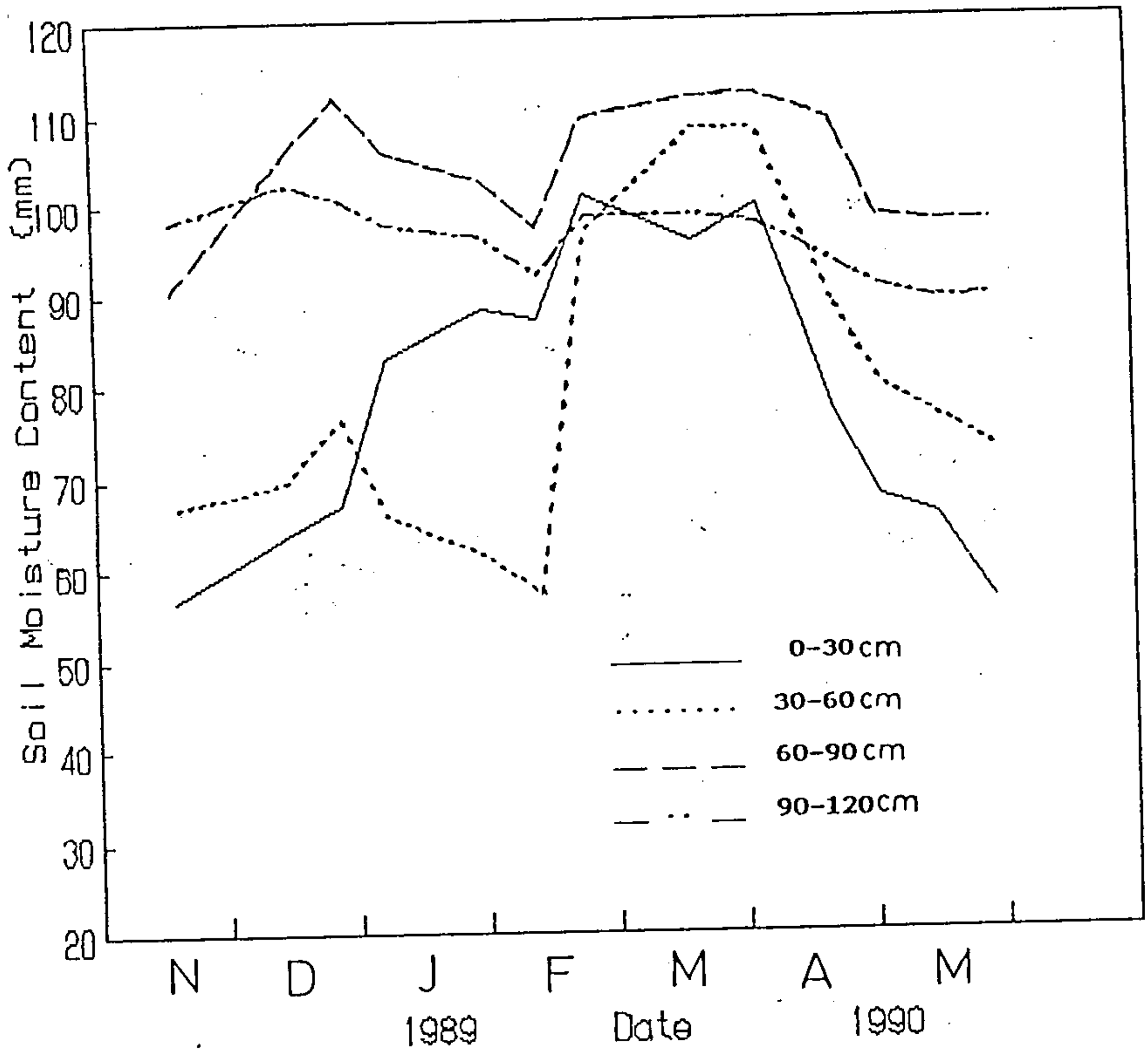


Fig. 15 : Soil depletion and storage (mm) for the chisel followed by sweeping plow, for lentil planted after wheat-wheat crop rotation, during 1989/90 growing season.

The total storage was 236.18 mm, distributed as 75.75, 73.0, 54.0, and 33.43 mm for the four respective soil layers.

Fig. 16 shows soil moisture depletion and storage for moldboard plow for fall tillage, for lentil grown after continuous wheat during (1989/90) growing season.

The initial soil moisture content found in the soil at the beginning of growing season was 321.23 mm, distributed as 58.43, 72.30, 92.50, and 48.00 mm for the first, second, third, and fourth layers, respectively.

The depletion during that growing season was 211.14 mm, distributed as 74.8, 59.3, 43.37, and 33.67 mm, respectively for the four respective soil layers.

The total storage was 216.71 mm, distributed as 74.2, 49.4, 50.7, and 32.41 mm, for the four respective soil layers.

Figure 17, 18, 19, and 20 shows soil moisture depletion and storage for lentil grown under different fall tillage, after duck foot fallow-wheat and chemical fallow-wheat, crop rotations, during 1989/90 growing season.

Results indicate that, same trends were detected with respect to initial soil moisture content, depletion, and storage, when compared with lentil grown after continuous wheat, (Fig. 15 and Fig. 16).

<u>4-3-2. Soil moisture and lentil yield.</u>

Table 22 shows the average soil moisture availability down to 120 cm soil depth, under the three crop rotations,

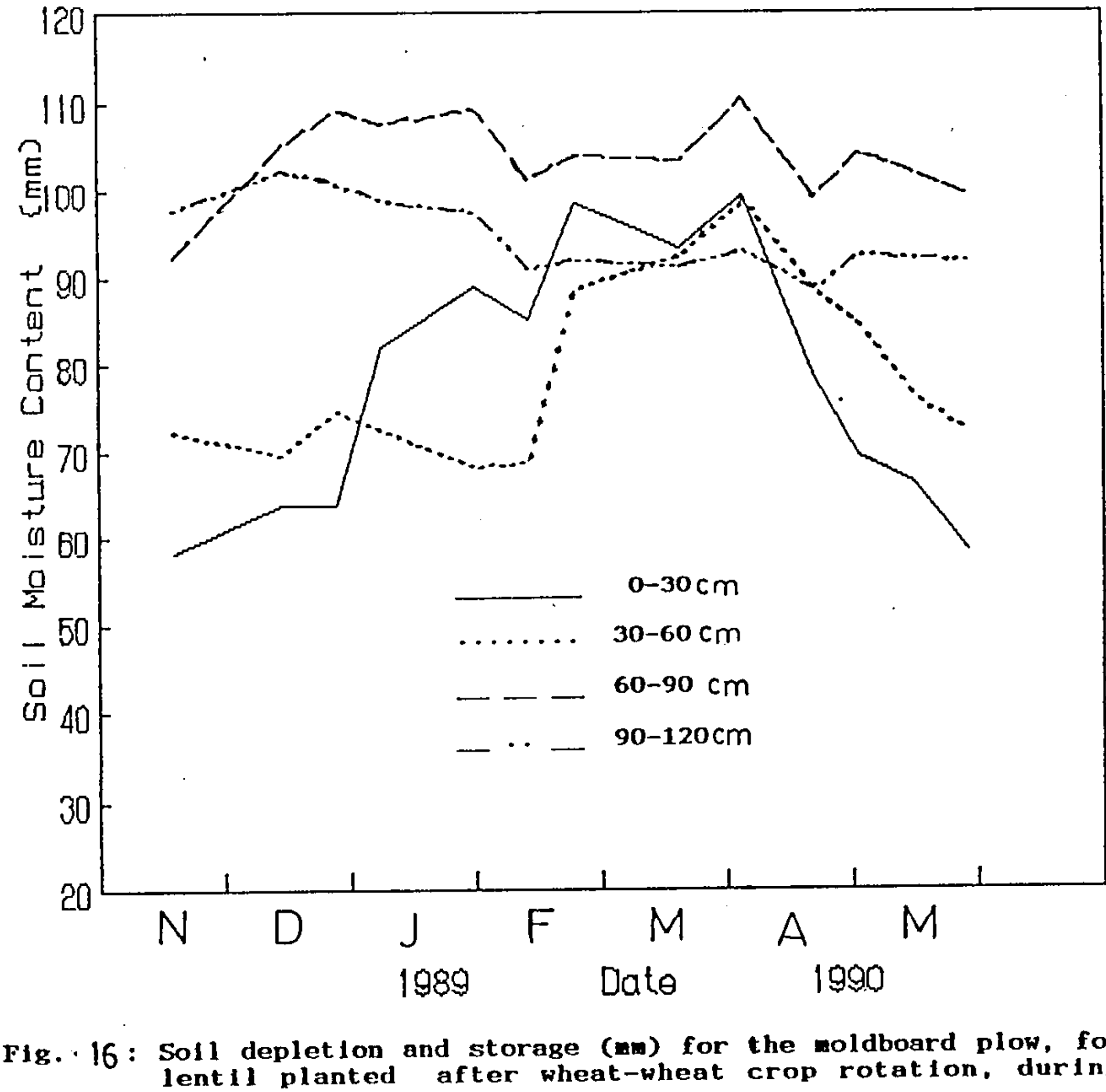


Fig. 16 : Soil depletion and storage (mm) for the moldboard plow, for lentil planted after wheat-wheat crop rotation, during 1989/90 growing season.

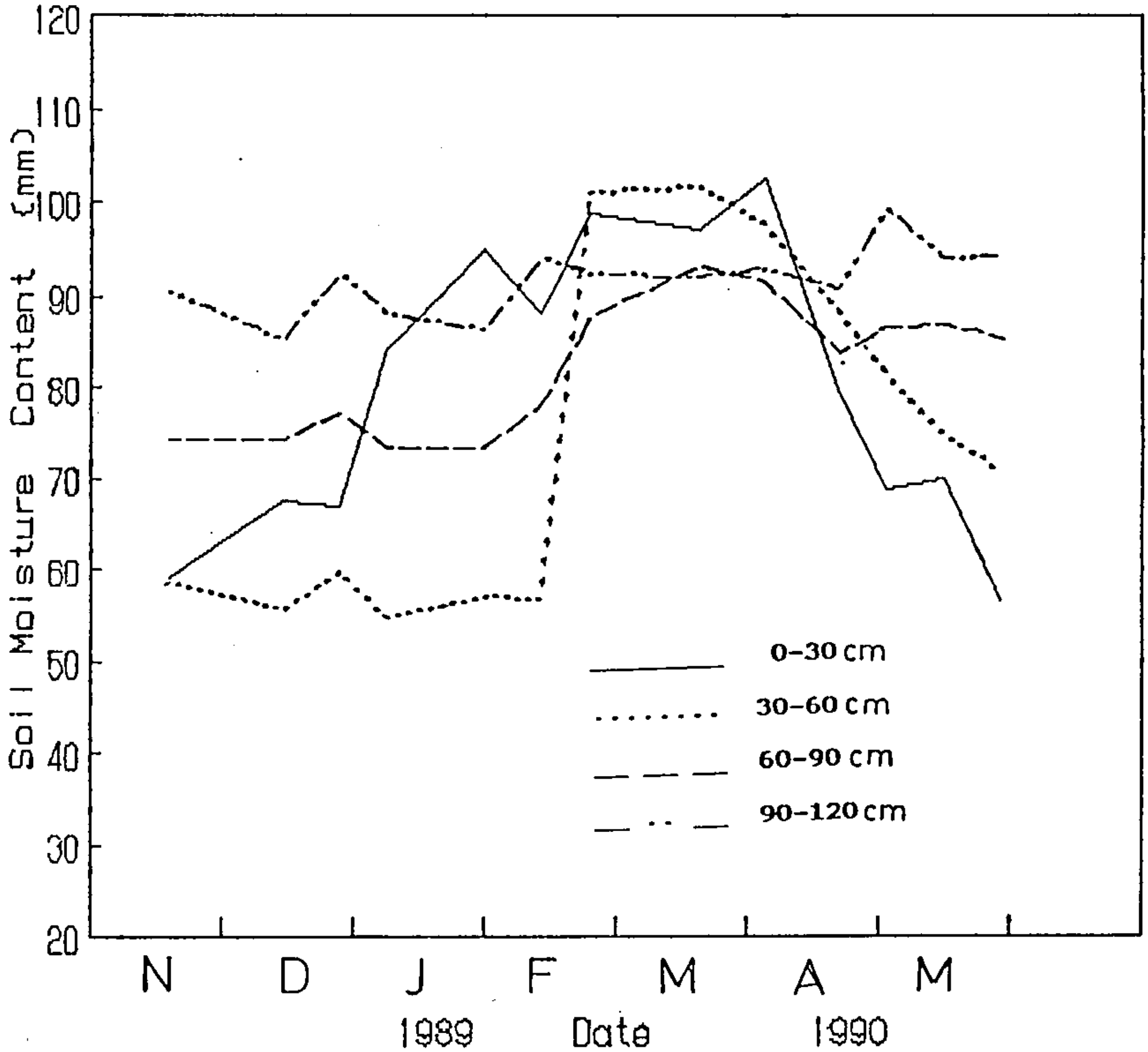


Fig. 17 : Soil depletion and storage (mm) for the chisel followed by sweep plow, for lentil planted after duck foot fallow-wheat crop rotation, during 1989/90 growing season.

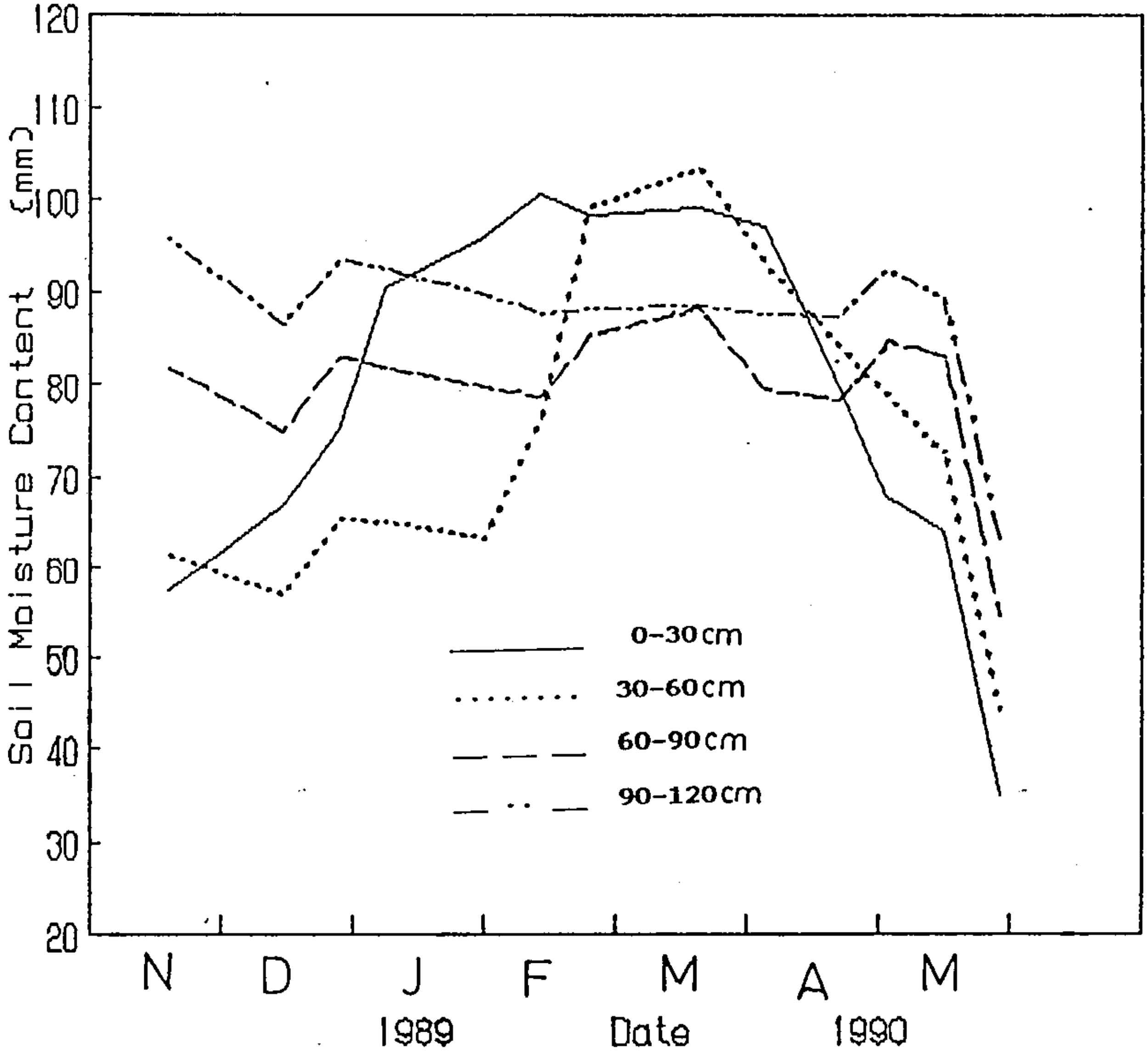


Fig. 18 : Soil depletion and storage (mm) for the moldboard plow, for lentil planted after duck foot fallow-wheat crop rotation, during 1989/90 growing season.

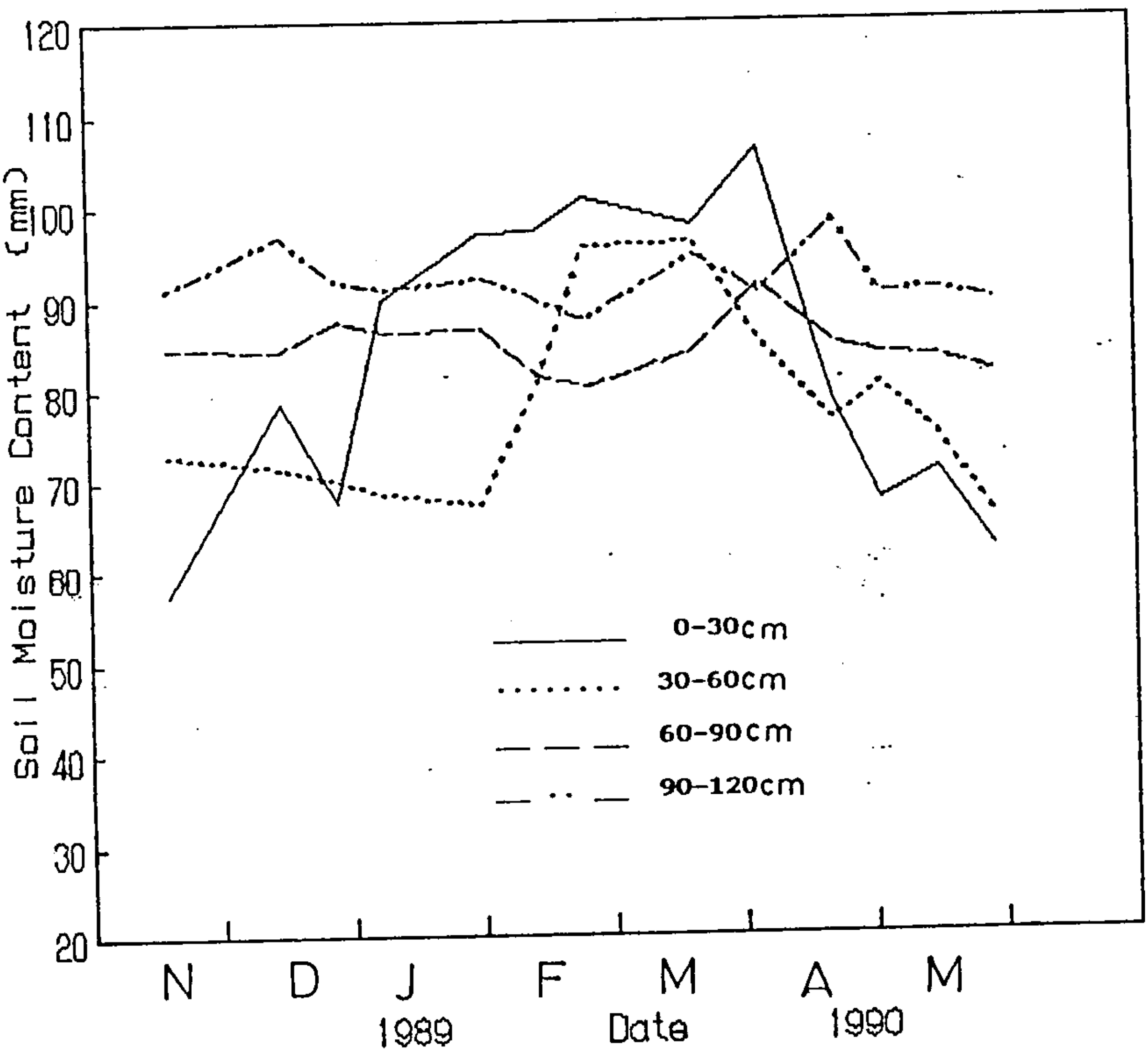


Fig. 19 : Soil depletion and storage (mm) for the chisel followed by sweepi... plow, for lentil planted after chemical fallow-wheat crop rotation, during 1989/90 growing season.

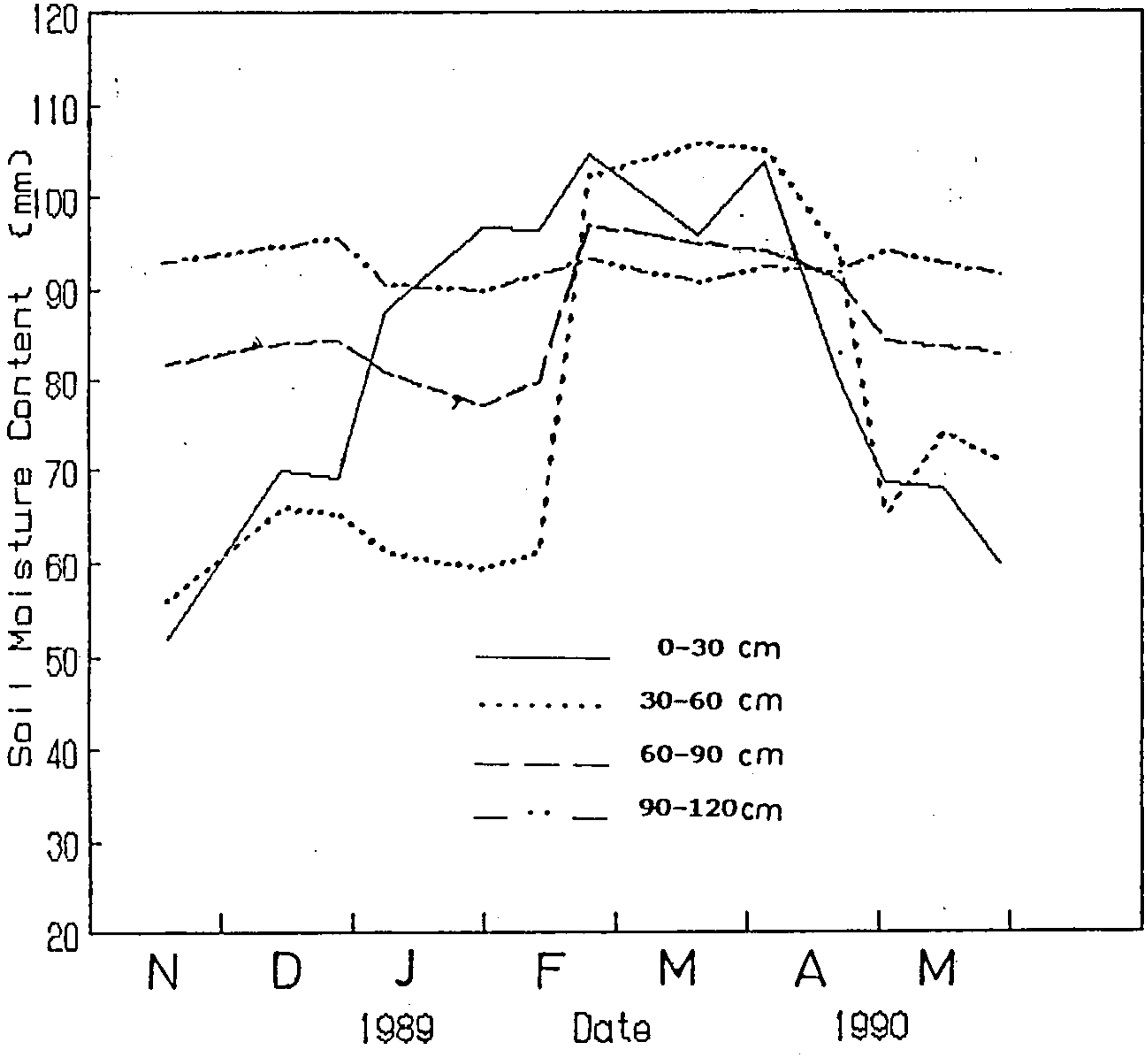


Fig. 20 : Soil depletion and storage (mm) for the moldboard plow, for lentil planted after chemical fallow-wheat crop rotation, during 1989/90 growing season.

Table (22) : Soil moisture availability for lentil under different fall tillage during 1989/90 growing season, in 120 cm soil depth.

Date	Chisel + sweep	Moldboard
Nov. 11, 89	-80.3	-51.1
Dec. 14, 89	-35.5	-11.07
Jan. 7 , 90	-35.7	-4.0
Feb. 24, 90	28.1	58.0
March 19,90	24.7	61.2
April 21,90	-7.0	11.8
May 27,90	-47.4	-34.6

Total rainfall during 1989/90 was 307 mm.

for lentil grown under different fall tillage treatments.

Results indicate that, at the time of planting (Nov. 1989), soil moisture availability for moldboard plow (-51.1 mm), was more than chisel plow followed by sweep (-80.3 mm), but both were below PWP. After planting and rainfall events, replenishment occurred but soil moisture availability under moldboard plow was still more than chisel followed by sweep.

One can conclude that, the shortages of water under both fall tillage treatments, for lentil were extended until Jan. 1990, which affected directly plant growth and yield.

Table 23 shows grand average lentil yield, straw yield, biological yield, W.U.E, storage, depletion, and storage efficiency, for lentil grown under different fall tillage treatments, after continuous wheat, during 1989/90 growing season.

Results indicate that, there were no significant differences at 5% level with respect to all parameters measured. Also, the same trends were detected for lentil planted after duck foot fallow-wheat and chemical fallow-wheat (Tables 24 and 25). One can conclude from tables 22, 23, 24, and 25 that lentil growth was not affected by the three crop rotations, namely; continuous wheat, duck foot fallow-wheat, and chemical fallow-wheat. All the soils under the three crop rotations ended in 1989 before planting lentil, with the same moisture contents, which were below PWP.

Table (23) : Average lentil grain yield, straw yield, biological yield, W.U.E, storage, depletion, and storage efficiency for lentil grown under different fall tillage treatments, after continuous wheat during 1989/90 growing season.

Parameters	Chisel + sweep		Moldboard		F-test 0.05
1. Grain yield (Mg/ha)	0.97	a	0.97	a	ns
2. Straw yield (Mg/ha)	3.36	a	3.38	a	ns
3. Biological yield (Mg/ha)	4.33	a	4.48	a	ns
4. W.U.E based on grain yield (kg/mm/du)	0.42	a	0.46	a	ns
5. Storage (mm)	236.18	a	216.71	a	ns
6. Soil moisture depletion (mm)	231.00	a	211.40	a	ns
7. Storage efficiency (%)	77.0	a	70.6	a	ns

ns : not significant.
** along each column, values followed by the same letter are not significantly different at the 5% level, according to DMRT.
W.U.E based on grain yield = grain yield (kg/du) / soil moisture depletion (mm).
W.U.E based on biol. yield = biol. yield (kg/du) / soil moisture depletion (mm).
Storage efficiency (%) = Water stored/Rainfall x 100

Rainfall equal 307.0 mm.

Table (25) : Average lentil grain yield, straw yield, biological yield, W.U.E, storage, depletion, and storage efficiency for lentil grown under different fall tillage treatments, after chemical fallow-wheat during 1989/90 growing season.

Parameters	Chisel + sweep	Moldboard	F-test 0.05
1. Grain yield (Mg/ha)	0.72 a	0.83 a	ns
2. Straw yield (Mg/ha)	2.70 a	3.35 a	ns
3. Biological yield (Mg/ha)	3.41 a	4.18 a	ns
4. W.U.E based on grain yield (kg/mm/du)	0.34 a	0.39 a	ns
5. Storage (mm)	225.81 a	242.66 a	ns
6. Soil moisture depletion (mm)	210.20 a	214.90 a	ns
7. Storage efficiency (%)	73.60 a	79.00 a	ns

ns : not significant.
** along each column, values followed by the same letter are not significantly different at the 5% level, according to DMRT.
W.U.E based on grain yield = grain yield (kg/du) / soil moisture depletion (mm).
W.U.E based on biol. yield = biol. yield (kg/du) / soil moisture depletion (mm).

Rainfall equal 307.0 mm.

Also, soil moisture availability for lentil under the three crop rotations were below PWP during most of the growing season. This had probably reduced lentil yield and other yield components.

5- SUMMARY, CONCLUSION, AND RECOMMENDATION

A study was carried out in Mushaqqar Agricultural Experimental Station, located approximately 30 km South West of Amman, on fine, montmorillonitic, thermic, entic, chromoxerert.

The total area of the experiment was 6,000 m^2, during the first season 1987/88. This area was divided into three parts: 1) to study the effects of duck foot fallow-wheat-lentil crop rotation; 2) to study the effects of chemical fallow-wheat-lentil crop rotation; 3) to study the effects of continuous wheat-lentil crop rotation on soil moisture storage, depletion, and crop yields under two tillage operations namely moldboard and chisel followed by sweep, and using three nitrogen fertilizer dosages.

A split plot in randomized complete plot design with three replications was used. Fall tillage by moldboard and by chisel followed by sweep were the main treatments. Nitrogen doses; one, two, and three, were the sub treatments. Total nitrogen applied for each treatment was equal to 60 kg/ha Also all the treatments were fertilized by 50 kg/ha phosphorus, as triple super phosphate.

During the second season the whole area of the experiment was planted to wheat using the same main and sub main treatments.

During the third season whole the area of the experiment was planted to lentil, to study the effect of fall tillage moldboard and chisel followed by sweep as main treatments using randomized complete block design.

The results obtained from the three seasons can be summarized as follows:-

1. Two to three duck foot or chemical fallow cultivation operations for weed control should be done by the end of May before June.
2. At the beginning of the second season after fallow, soil moisture availability was extended down to 90 cm for duck foot fallow, and down to 60 cm for chemical fallow, while for continuous wheat, soil moisture availability was close to PWP down to 30 cm soil depth, whereas below 30 cm soil moisture availability was below PWP.
3. Duck foot fallow was more efficient to control weeds and conserve moisture than chemical fallow, duck foot fallow efficiency was 13.4%, which was more than chemical fallow efficiency which was 8.7%.
4. The amount of soil moisture storage during wheat growing season due to rainfall were decreased as the amounts of soil moisture content at the end of the fallow season had decreased.
5. Soil moisture content by the end of the second growing season May 27, 1989 under chisel followed by sweep was lower than soil moisture content under moldboard plow.
6. No significant differences were obtained among chisel followed by sweep and moldboard fall tillage treatments

with respect to all the parameters measured, namely: grain yield, yield components, soil moisture storage, soil moisture depletion, W.U.E, and water storage efficiency.

7. No significant differences were obtained among the three nitrogen fertilizer doses, one dose, two doses, and three doses with respect to all parameters measured, namely: grain yield, yield components, soil moisture storage, soil moisture depletion, W.U.E, and water storage efficiency.

8. Wheat crop which was grown after duck foot fallow cultivation treatment had resulted in highest values of grain yield (3.36 Mg/ha), straw yield (7.81 Mg/ha), biological yield (11.16 Mg/ha), number of tillers/plant (3.25), number of heads/m^2 (375), wheat plant height (97.95 cm), W.U.E based on grain yield (1.08 kg/mm/du), W.U.E based on biological yield (3.54 kg/mm/du), and soil moisture depletion (318.9 mm).

9. Wheat crop which was grown after chemical fallow cultivation treatment had resulted in the second highest values after duck foot fallow for all parameters measures grain yield (2.82 Mg/ha), straw yield (5.84 Mg/ha), biological yield (7.07 Mg/ha), number of tillers/plant (2.00), number of heads/m^2 (214.0), wheat plant height (88.7 cm), W.U.E based on grain yield (1.08 kg/mm/du), W.U.E based on biological yield (2.79 kg/mm/du), and soil

moisture depletion.

10. Wheat crop which was grown after wheat "continuous wheat", had resulted in the lowest values of grain yield (1.08 Mg/ha), straw yield (3.3 Mg/ha), biological yield (4.3 Mg/ha), number of tillers/plant (1.4), number of heads/m^2 (132.5), wheat plant height (51.95 cm), W.U.E based on grain yield (0.38 kg/mm/du), W.U.E based on biological yield (1.51 kg/mm/ha), and soil moisture depletion (286.3 mm).

11. Soil moisture content after the three crop rotations before planting lentil ended with same amounts.

12. Lentil crop was not affected by the crop rotations used before, namely: continuous wheat, duck foot fallow-wheat, chemical fallow-wheat.

13. No significant differences were obtained among chisel followed by sweep, and moldboard plow fall tillage, with respect to all parameters measured for lentil.

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Appendix 1 :

Analysis of variance for the experiment design (Split-plot using randomized complete block design), In 1987/88 and 1988/89 growing season.

Source of variation	df
Sub plots	18
Main plots	5
Blocks	2
Fall tillage (Fall)	1
Main plot error, BF	2
Nitrogen doses	2
FxN	2
Subplot error, BN+B(FxN)	8

Analysis of variation for the experiment design (Randomized complete block design), in 1989/90 growing season

Source of variation	df
Total	5
Block	2
Treatments	1
Error (BT)	2

Appendix 2 : Wheat grain yield, yield components, soil moisture depletion, W.U.E, for the different treatments and replicates of the experiment in 1987/88 growing season.

1- Wheat grain yields (Mg/ha).

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
Moldboard plow	Three doses*	2.96	3.70	4.00
	Two doses	2.92	3.00	2.62
	One dose	3.98	4.00	4.15
Chisel plow followed by sweep	Three doses	3.51	2.92	2.77
	Two doses	2.62	3.74	3.25
	One dose	2.92	3.36	2.97

* Nitrogen treatments.

2- Wheat straw yields (Mg/ha).

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
Moldboard plow	Three doses*	6.20	8.96	9.26
	Two doses	6.25	7.25	9.06
	One dose	8.32	11.60	6.44
Chisel plow followed by sweep	Three doses	8.56	6.48	8.41
	Two doses	5.30	7.74	8.15
	One dose	6.98	7.34	10.03

* Nitrogen treatments.

3- Wheat biological yields (Mg/ha).

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
Moldboard plow	Three doses*	9.16	12.66	13.26
	Two doses	9.17	10.25	11.68
	One dose	12.30	15.60	10.59
Chisel plow followed by sweep	Three doses	12.07	9.40	11.18
	Two doses	7.92	11.48	11.40
	One dose	9.90	10.70	13.00

* Nitrogen treatments.

4- Soil Moisture depletion (mm).

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
Moldboard plow	Three doses*	238.6	235.1	321.2
	Two doses	213.3	207.0	239.2
	One dose	236.4	267.2	255.9
Chisel plow followed by sweep	Three doses	224.9	261.7	262.4
	Two doses	217.9	212.2	207.4
	One dose	293.5	235.0	222.9

* Nitrogen treatments.

5- W.U.E based on grain yield, in (kg/mm/du).

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
	Three doses*	1.24	1.57	1.25
Moldboard plow	Two doses	1.37	1.45	1.10
	One dose	1.68	1.50	1.62
Chisel plow followed by sweep	Three doses	1.56	1.12	1.05
	Two doses	1.20	1.76	1.57
	One dose	1.00	1.43	1.33

* Nitrogen treatments.

6- W.U.E based on biological yield, in (kg/mm/du).

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
	Three doses*	3.84	5.38	4.13
Moldboard plow	Two doses	4.30	4.95	4.88
	One dose	5.20	5.84	4.14
Chisel plow followed by weep	Three doses	5.37	3.59	4.26
	Two doses	3.64	5.40	5.50
	One dose	3.37	4.55	5.83

* Nitrogen treatments.

4- Soil moisture depletion (mm)

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
	Three doses*	275.4	260.7	278.4
Moldboard plow	Two doses	312.6	292.4	272.2
	One dose	313.9	288.5	295.9
Chisel plow followed by sweep	Three doses	279.9	296.3	273.8
	Two doses	287.7	267.8	307.8
	One dose	303.3	264.7	280.9

* Nitrogen treatments.

5- Soil moisture storage (mm).

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
	Three doses*	271.3	238.0	265.3
Moldboard plow	Two doses	303.3	227.6	259.3
	One dose	274.0	277.8	265.3
Chisel plow followed by sweep	Three doses	241.1	263.8	291.0
	Two doses	193.3	244.0	260.0
	One dose	336.1	254.1	267.2

* Nitrogen treatments.

6- W.U.E based on grain yield, (kg/mm/du).

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
Moldboard plow	Three doses*	0.42	0.42	0.30
	Two doses	0.36	0.33	0.36
	One dose	0.35	0.32	0.31
Chisel plow followed by sweep	Three doses	0.42	0.42	0.41
	Two doses	0.47	0.45	0.40
	One dose	0.42	0.42	0.25

* Nitrogen treatments.

7- W.U.E based on biological yield, (kg/mm/du).

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
Moldboard plow	Three doses*	1.65	1.61	1.27
	Two doses	1.34	1.35	1.30
	One dose	1.46	1.42	1.28
Chisel plow followed by sweep	Three doses	1.52	1.72	1.62
	Two doses	1.72	1.89	1.48
	One dose	1.66	1.62	1.26

* Nitrogen treatments.

8- Wheat plant heights (cm).

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
Moldboard plow	Three doses*	60	60	50
	Two doses	50	50	50
	One dose	50	50	55
Chisel plow followed by sweep	Three doses	55	55	60
	Two doses	50	50	55
	One dose	45	40	50

* Nitrogen treatments.

9- Heads/m^2

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
Moldboard plow	Three doses*	160	96	118
	Two doses	190	122	160
	One dose	128	140	100
Chisel plow followed by sweep	Three doses	120	126	150
	Two doses	160	144	144
	One dose	100	130	100

* Nitrogen treatments.

10- Tillers/plant

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
Moldboard plow	Three doses*	1	1	1
	Two doses	1	1	2
	One dose	2	1	1
Chisel plow followed by sweep	Three doses	3	1	2
	Two doses	2	1	2
	One dose	1	1	1

* Nitrogen treatments.

Appendix 4 : Wheat grain yield, yield components, soil moisture depletion, and W.U.E , for the different treatments and replicates of the wheat grown after duck foot fallow during 1988/89 growing season.

1- Wheat grain yield (Mg/ha).

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
Moldboard plow	Three doses*	2.88	3.50	3.20
	Two doses	2.89	3.41	3.05
	One dose	3.10	3.20	3.67
Chisel plow followed by sweep	Three doses	3.20	3.58	3.34
	Two doses	3.25	3.92	3.26
	One dose	3.28	4.28	3.37

* Nitrogen treatments.

2- Wheat straw yield (Mg/ha).

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
Moldboard plow	Three doses*	6.87	7.50	7.75
	Two doses	7.01	8.24	7.00
	One dose	7.05	8.10	7.98
Chisel plow followed by sweep	Three doses	7.70	8.52	7.71
	Two doses	8.40	8.88	6.94
	One dose	7.77	9.72	7.43

* Nitrogen treatments.

3- Wheat biological yield (Mg/ha).

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
Moldboard plow	Three doses*	9.75	11.00	10.95
	Two doses	9.90	11.65	10.05
	One dose	11.15	11.30	11.65
Chisel plow followed by sweep	Three doses	10.90	12.10	11.05
	Two doses	11.65	12.80	10.20
	One dose	11.05	14.00	10.80

* Nitrogen treatments.

4- Soil moisture depletion (mm).

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
Moldboard plow	Three doses*	343.1	307.6	323.3
	Two doses	328.4	290.1	318.0
	One dose	276.6	278.9	358.2
Chisel plow followed by sweep	Three doses	376.9	302.1	343.7
	Two doses	283.0	352.0	298.2
	One dose	333.9	276.4	350.3

* Nitrogen treatments.

5- W.U.E based on grain yield.

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
Moldboard plow	Three doses*	0.84	1.14	1.00
	Two doses	0.88	1.17	1.00
	One dose	1.12	1.15	1.03
Chisel plow followed by sweep	Three doses	0.85	1.20	1.00
	Two doses	1.15	1.12	1.10
	One dose	1.00	1.55	1.00

* Nitrogen treatments.

6- W.U.E based on biological yield.

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
Moldboard plow	Three doses*	2.84	3.57	3.40
	Two doses	3.01	4.01	3.16
	One dose	3.67	4.05	3.25
Chisel plow followed by sweep	Three doses	2.90	4.00	3.22
	Two doses	4.12	3.64	3.42
	One dose	3.31	5.07	3.10

* Nitrogen treatments.

7- Wheat plant heights (cm).

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
Moldboard plow	Three doses*	100	100	65
	Two doses	100	90	100
	One dose	110	88	105
Chisel plow followed by sweep	Three doses	95	100	95
	Two doses	105	100	90
	One dose	110	100	90

* Nitrogen treatments.

8- Heads/m^2

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
	Three doses*	312	370	370
Moldboard plow	Two doses	401	360	406
	One dose	402	401	403
Chisel plow followed by sweep	Three doses	403	350	320
	Two doses	400	332	350
	One dose	402	410	360

* Nitrogen treatments.

9- Tillers/plant

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
	Three doses*	4	4	3
Moldboard plow	Two doses	3	3	3
	One dose	3	3	3
Chisel plow followed by sweep	Three doses	3	4	3
	Two doses	3	3	4
	One dose	3	3	3

* Nitrogen treatments.

Appendix 5 : Wheat grain yield, yield components, soil moisture depletion, and W.U.E , for the different treatments and replicates of the wheat grown after chemical fallow during 1988/89 growing season.

1- Wheat grain yield (Mg/ha).

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
Moldboard plow	Three doses*	3.43	2.22	2.67
	Two doses	2.96	1.71	3.70
	One dose	3.82	3.02	2.82
Chisel plow followed by sweep	Three doses	2.45	2.44	3.16
	Two doses	3.87	2.16	1.87
	One dose	2.72	2.40	2.06

* Nitrogen treatments.

2- Wheat straw yield (Mg/ha).

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
Moldboard plow	Three doses*	5.67	6.03	4.98
	Two doses	5.24	4.09	6.15
	One dose	7.38	6.88	4.73
Chisel plow followed by sweep	Three doses	6.35	5.99	6.34
	Two doses	7.28	4.99	7.68
	One dose	5.33	5.35	4.59

* Nitrogen treatments.

3- Wheat biological yield (Mg/ha).

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
Moldboard plow	Three doses*	9.10	8.25	7.65
	Two doses	9.20	5.80	9.85
	One dose	11.20	9.90	7.55
Chisel plow followed by sweep	Three doses	8.80	8.15	9.50
	Two doses	11.15	7.15	9.55
	One dose	8.05	7.75	6.65

* Nitrogen treatments.

4- Soil moisture depletion (mm).

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
	Three doses*	323.4	278.6	375.5
Moldboard plow	Two doses	264.3	340.7	323.4
	One dose	303.2	305.2	263.2
Chisel plow followed by sweep	Three doses	357.4	290.0	345.7
	Two doses	282.2	286.4	353.6
	One dose	260.7	339.6	299.9

* Nitrogen treatments.

5- W.U.E based on grain yield.

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
	Three doses*	1.06	0.80	0.71
Moldboard plow	Two doses	1.12	0.51	1.14
	One dose	1.56	1.00	1.07
Chisel plow followed by sweep	Three doses	0.70	0.84	0.91
	Two doses	1.37	0.75	0.53
	One dose	1.04	0.71	0.69

* Nitrogen treatments.

6- W.U.E based on biological yield.

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
Moldboard plow	Three doses*	2.81	2.96	2.04
	Two doses	3.10	1.70	3.05
	One dose	3.70	3.24	2.87
Chisel plow followed by sweep	Three doses	2.46	2.81	2.75
	Two doses	3.95	2.50	2.70
	One dose	3.10	2.28	2.22

* Nitrogen treatments.

7- Wheat plant heights (cm).

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
Moldboard plow	Three doses*	80	70	80
	Two doses	85	70	100
	One dose	75	80	80
Chisel plow followed by sweep	Three doses	90	65	80
	Two doses	70	80	85
	One dose	80	85	80

* Nitrogen treatments.

8- Heads/m^2

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
	Three doses*	332	132	250
Moldboard plow	Two doses	260	180	260
	One dose	180	250	252
Chisel plow followed by sweep	Three doses	230	208	212
	Two doses	135	152	212
	One dose	168	152	292

* Nitrogen treatments.

9- Tillers/plant

Main plot	Sub-plot	Rep.1	Rep.2	Rep.3
	Three doses*	2	1	3
Moldboard plow	Two doses	2	2	3
	One dose	1	1	2
Chisel plow followed by sweep	Three doses	2	2	3
	Two doses	2	2	2
	One dose	1	2	2

* Nitrogen treatments.

Appendix 6 : Lentil grain yield, straw yield, and biological yield, for lentil grown after continuous wheat crop rotation during 1989/90 growing season.

1- Grain yield (Mg/ha)

Treatment	Rep.1	Rep.2	Rep.3
Moldboard plow	0.62	0.72	0.82
Chisel plow followed by sweep	0.55	0.80	0.79

2- Straw yield (Mg/ha).

Treatment	Rep.1	Rep.2	Rep.3
Moldboard plow	3.53	3.78	4.21
Chisel plow followed by sweep	3.60	3.80	3.59

3- Biological yield (Mg/ha)

Treatment	Rep.1	Rep.2	Rep.3
Moldboard plow	4.15	4.50	5.03
Chisel plow followed by sweep	4.14	4.60	4.38

Appendix 7 : Lentil grain yield, straw yield, and biological yield, for lentil grown after duck foot fallow wheat crop rotation during 1989/90 growing season.

1- Grain yield (Mg/ha)

Treatment	Rep.1	Rep.2	Rep.3
Moldboard plow	0.74	0.78	0.97
Chisel plow followed by sweep	0.55	0.83	0.77

3- Biological yield (Mg/ha)

Treatment	Rep.1	Rep.2	Rep.3
Moldboard plow	4.04	5.35	4.14
Chisel plow followed by sweep	4.04	4.80	4.14