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INFLUENCE OF THE MANAGEMENT OF NITROGEN FERTILIZERS AND MOISTURE DEPLETION ON WHEAT PRODUCTION IN A RAINFED AREA OF JORDAN.

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Dedicated to

My Mother , Father , Sisters , Brothers , Wife ,
And Friends .

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ABSTRACT

INFLUENCE OF THE MANAGEMENT OF NITROGEN FERTILIZERS AND MOISTURE DEPLETION ON WHEAT PRODUCTION IN A RAINFED AREA OF JORDAN.

Ali Husni Ahmed Ankeer

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Dr. Butros Hatter.

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Two studies were carried out at Mushaqqar Agricultural Experimental Station, located approximately 28 km South West Amman. Its annual rainfall is about 350 mm. The soil was classified as fine, montmorillonitic, thermic, entic chromoxerert. The objectives were to study the effect of different tillage-nitrogen management practices on soil moisture storage and depletion, and crop yield.

A randomized complete block design was carried out, in three replications. The first experiment included two application methods of fertilizers broadcasting, (B), and incorporation, (I) were assigned as the main treatments, whereas, the three nitrogen fertilizer sources urea, (F1), ammonium sulfate, (F2), and potassium nitrate, (F3) were used as submain treatments. The second experiment chisel plow, (T1), and moldboard plow, (T2) were assigned as the main treatments and nitrogen fertilizer splitted once, (N1), twice, (N2), and three times (N3) as submain treatments. These experiments were run in 1990/91 and 1991/92 growing seasons.

The results indicated that in 1990/91 growing season, there was no effect of the method of nitrogen fertilizers application, while in 1991/92 season broadcasting of urea as nitrogen fertilizer affected the soil moisture parameters studied, and produced the highest yield and soil residual mineral nitrogen forms. Under duck-foot fallow-wheat rotation the highest grain yield was obtained compared to chemical fallow, while the lowest yield was found under continuous wheat rotation. In all rotations, moldboard plow treatment produced the highest yield and the total depth of water stored compared to chisel plow during 1991/92 growing season.

1. Introduction

Wheat is one of the most important cereal crops grown under dryland conditions in Jordan. About 70% of the total cultivated area is used for field crops. The cultivated area extends within the desert in the East and South East (annual rainfall is about 250 mm), and the Western High-lands (annual rainfall is more than 400 mm). The fluctuation in the rainfall amounts, intensity, and distribution between the regions, and even between the successive years for the same region, results in differences in total area cultivated, and in yield.

Nitrogen fertilizer as well as soil moisture level influence the growth and yield of wheat crops markedly. Nitrogen application to wheat is not a common practice by most Jordanian farmers.

Two separate experiments were conducted in Mushaqqar Agricultural Experiment Station to achieve the following objectives:

1. To study the effect of using different nitrogen fertilizers forms, namely: nitrate; and ammonium, on wheat yield components.
2. To evaluate two methods of N-fertilizers applications, namely: broadcasting followed by seeding or broadcasting the fertilizers followed by incorporating them in the soil then seeding the field.
3. To study the effects of different methods of nitrogen fertilizers application on water consumptive use of wheat crop, soil moisture content, and their relation with wheat yield.
4. To study the effects of the rate of N-fertilizer and time of addition on wheat growth, and its relations with the yield and yield components, under two tillage practices, namely: chisel and moldboard, and wheat-fallow crop rotations, in the Mushaqqar area.

2- Literature Review

2-1 Effect of nitrogen fertilization on wheat production:

The application of nitrogen fertilizers to wheat crop was found to increase the nitrogen concentration in grain and straw and had resulted in increasing uptake of nitrogen and phosphorus. Irrigation at 75% available soil moisture gave the highest nitrogen and phosphorus uptake(1).

Application of N - fertilizer increased vegetative growth of crops and soil water extraction prior to heading stage. The applied nitrogen did not increase depth of soil water extraction(2).

Comfort *et al.* (3) found that applying 67 kg N ha^{-1}, increased the wheat root density significantly in the upper 30 cm compared to the control. While, the density decreased by applying 134 kg N ha^{-1}. The root growth was much less below the 30 cm depth, when 134 kg N ha^{-1} were applied, compared to the 0 and 67 kg N ha^{-1} treatments. Root growth and depth of soil at which is consumed moisture were found to be highly influenced by N fertilization. Wheat yield was not significantly increased when more than 134 kg N ha^{-1} were applied. The total nitrogen uptake by wheat crop exceeded the amount of N applied showing that N mineralization during crop growth was an important factor in the N uptake by the crop (4). Korentajer and Berliner (5) in studying the effect of soil moisture on nitrogen response for two seasons indicated that grain yield response significantly to N- fertilization. The mean yield values obtained were 3.18 Mg ha^{-1} grain yield at 389 mm seasonal rainfall, and 1.7 Mg ha^{-1} grain yield at 136 mm seasonal rainfall. A better correlation was obtained (R2 = 0.63) between the predicted and the observed yields.

The fallowed plots contained significantly more moisture at seeding time than the continuously cropped plots. Grain yields usually varied with available soil moisture at the seeding time. Stubble mulch plots usually had less nitrate than the control plots because residues remained longer on the surface than when incorporated into the soil. Mineralization was so slow when residues were left (6). Stanford and Epstein (7) reported that the highest N mineralization rates occurred at soil matric suctions of 1/3 to 1/10 bar. A linear relationship had generally existed between amounts of mineral N accumulated and soil water contents, but increasing the dryness reduced, N mineralization.

2-2- Effect of application methods and forms of nitrogen fertilizers on wheat production:

Different nitrogen sources have different effects on wheat production due to the different N- losses after application, during the growing season. El-Khattari (8) reported that the dry weight of straw and grain had increased significantly as the rate of nitrogen applied increased. He found that ammonium sulfate produced more dry weight of both straw and grain than did urea or ammonium nitrate.

Brown (9) studied the effect of three rates (0, 67, and 268 kg N ha^{-1}) fall-applied (NH_4NO_3) on evapotranspiration, ET, and water use by winter wheat. The results indicated that ET for the spring-summer growth period was 22.1, 27.2, and 31.5 cm for the respective N treatments. The amount soil moisture consumed by wheat were 6.1, 11.2, and 15.5 cm for the respective three N treatments. Grain yields were 1.61, 3.09, and 3.63 Mg ha^{-1}. In addition to increasing ET, nitrogen fertilization was found to increase both, evapotranspiration, and water use efficiency.

In a greenhouse experiment, Huang and Broadbent (10), applied potassium nitrate and urea to rice at different placements. The results indicated that substantial losses of potassium nitrate - N occured, and the plant uptake of N was very low, except the split-broadcast application. Banded and incorporated applications of urea were more efficient than broadcasted ones. The highest uptake of N was 50%.

El-Khattari and Kharabsheh (11) studied the transformation of urea and ammonium sulfate fertilizers in five soils of Jordan using two rates of 80 and 160 ppm N applied to the soil as solution. The results indicated that nitrification of the high and low rates of ammonium sulfate and urea was affected by type of the soil and climate. The order of soils were Ramtha > Al-Jerm> Hisban> Karak, and it was very low in the Azraq soil. Although the time required for urea hydrolysis to NH4-N form varied from 8 to 16 days, hydrolysis started 2- days after incubation for both urea and ammonium sulfate. El- Khattari and Kharabsheh (12) studied volatilization of NH_3 from ammonium sulfate and urea in the laboratory. Both were surface applied to soils at rates of 160 and 320 kg N ha^{-1} from Hisban region, Al-Jerm (Jordan valley), and Azraq region. The volatilized NH_3 was determined after 6, 18, 42, 66, 114, 162, and 210 hours of application. After 210 hours the total loss of nitrogen as NH_3 from ammonium sulfate was 10.4, 24.1, and 12.5% of 160 kg N, while was 17.7, 51.2, and 20.5% of 320 kg N for Hisban, Al-Jerm, Azraq soils, respectively. Corresponding losses from urea were 6.3, 35.7, and 0.0% at 160 kg N, and 4.9, 52.9, and 0.0% at 320 kg N for these soils. Reynolds and Wolf (13) found that ammonia volatilization from soils was characterized by a period of linear ammonia loss after that the volatilization becomes negligible with time. The ammonia volatilization rate ranged from 0.101 to 0.416% hr^{-1} and was negatively correlated with the percentage of clay, total nitrogen, CEC, organic carbon, and urease activity.

Khafagi et al., (14) reported that nitrate diffusion coefficient increased as the soil moisture content had increased. It ranged between 0.6×10^{-6} cm^2 sec^{-1} to 6.0×10^{-6} cm^2 sec^{-1}. It was also found that there was a negative relationship between the diffusion values of nitrate and the bulk density of the studied soils. They found that the diffusion coefficient of ammonium had ranged between 3.0×10^{-9} cm^2 sec^{-1} at the lowest level of moisture content, and 3.4×10^{-7} cm^2 sec^{-1} at the highest level of moisture content. It was found that the charged clay surface affects the diffusion coefficient of ammonium, especially at the lowest level of moisture content.

Reynolds and Wolf (15) in a laboratory study at a constant soil water potential of -0.033 MPa and relative humidity of 35%, found that the volatilized ammonia was 46.4% of the total nitrogen applied after 257 hr. At initial soil water potential of -0.033 PMa without replenishing soil water, the ammonia loss was reduced to 10.8% and this reduction was due to the inhibition of urea hydrolysis as the soil had dried out.

McInnes et al. (16) studied the broadcast application of urea-ammonium nitrate solution at a rate of 200 kg N ha^{-1} to soil with wheat straw residue cover. The results indicated that cumulative NH_3-N loss was 16.6% of the N applied. Simulated rainfall with 2.5 mm sprinkler irrigation was found to increase the NH_3 loss. Peak volatilization rates occured in the first day following the irrigation. The maximum measured rate of NH_3 loss was 51 Mg m^{-2} Sec^{-1} (1.5 kg N ha^{-1} h^{-1}).

O'Deen (17) employed N^{15} enriched fertilizer to measure the NH_3 volatilization directly from the plants. He insulated the upper part of the wheat crop in chambers to measure NH_3 volatilization. The volatilized nitrogen was 3% of the harvested wheat nitrogen fertilized with NO_3^-, while it was 4% of the harvested wheat nitrogen fertilized with ammonium form.

Abu Awad et al. (18) indicated that increasing the concentration of the applied nitrate-N and its movement in a soil of Jordan Valley, has taken place upon increasing cumulative total amounts of irrigation water applied and total amounts of urea fertilizer used.

Olson and Swallow (19) in a 5-years experiment on winter wheat, found that the spring applications of ammonium sulfate fertilizer at a rate of 100 kg N ha^{-1} gave better fertilizer use efficiency than fall applications at a rate of 50 kg N ha^{-1}. This was probably due to the greater immobilization of fall-applied N. After 5 years, 27 to 33% of the applied fertilizer N had been recovered by the grain. The results also showed, that 71 to 77% of the surface-applied N remained in the profiles was in the 0 to 0.1 m soil layers.

Response of wheat to source of nitrogen was studied in a calcareous soil (20). Ayoub found that urea, calcium nitrate and nitrophoska were equally good N sources for wheat grain yield. However urea, being richer in N, may be preferred to the other two sources. The N content of grain increased significantly upon application of N-fertilizer.

Nitrogen application increased grain N by about 24%. Whereas, N source did not affect grain N yield significantly. Nitrogen recovery was highest from the nitrate fertilizer followed by urea, and was the lowest smallest from the ammonium forms. Time and source of applied N had no significant effects on grain and there was no correlation between grain weight and grain yield.

Gharaibah (21) studied the effect of different types of tillage, phosphate rates, and nitrogen fertilizers on wheat production in rainfed areas of Jordan. The results indicated that phosphorus and nitrogen application had increased the yield and had improved the crop components of wheat significantly.

2-3 Effect of tillage practices as related to moisture conservation on wheat production:

Turshan and Battikhi (22) studied the effect of different fallow-wheat rotations of wheat-wheat rotation at Mushaqqar Agricultural Experiment Station. They found that, the fallow-wheat rotation had stored 92.3% of the total received rainfall during the winter season following the fallow season. While wheat-wheat rotation only 79% of rainfall were stored during the first wheat growing season. Fallow-wheat rotation resulted in higher wheat yield when compared to continuous wheat. This increase in yield for fallow-wheat rotation was due to higher moisture storage, (72 and 45.3 mm, more available water, respectively).

Power et al. (23) found that nitrogen uptake by wheat crop was not affected by fallowing. Total nitrogen was decreased by 50% from October to April of the fallow year for N-fertilized wheat, and by 35% for unfertilized wheat, when compared to the plowed and subtilled. Non-tilled fallow enhanced retention of N in the several crop residue, and increased N uptake by the two wheat crops.

Tanka and Aase (24) reported that soil moisture storage was similar in the period elongated after harvesting of crop to spring as compared to that of chemical fallow or stubble-mulch fallow. The soil moisture storage efficiency from the rainfall in winter period time to spring time, was similar under chemical and stubble-mulch fallow treatments. There was higher soil moisture storage during summer fallow for winter wheat-fallow rotation than that during the second over winter for spring-wheat-fallow rotations.

Fredrickson et al. (25) in a field study, wheat was grown in microplots under conventional tillage and no-till seeding to compare availability of nitrogen fertilizer for crops uptake. The spring wheat crop utilized 25 to 40% of N fertilizer, with the highest uptake occuring on no-till when ammonium sulfate was surface applied. There was no differences in dry matter production between tillage methods. In a study of effect of tillage practices on root development of winter wheat, Wilhelm et al. (26) reported that the root weight was greatest for the chemical treatment (45 mg/dm^3) and least for the sub tillage treatment (26 mg/dm^3). The root density was the highest in the upper 30 cm of the soil surface for all treatments. Nitrogen fertilization did not significantly change the rooting pattern. On other hand, Fester et al. (27) found that the yields of winter wheat were highest in the mold-board plow treatment followed by one way and sweep plow tilled in July and again in April. During the fallow year, weed control in June was best on mold-board plowed treatment followed by May tillage with the sweep plow.

Izaurrade et al. (28) indicated that no-tillage wheat yield was higher than the conventional tillage treatment (2.37 and 2.01 Mg ha^{-1}, respectively) under relatively dry environmental conditions. It was found that the total soil water content in the upper 84 cm was higher on no-tillage than on conventionally tilled plots.

Lutfi (29) in a field study at the University of Baghdad used two types of plows (moldboard and chisel) for preparation the seedbed for wheat. The results indicated that there was no effect of the type of plow on the yield of wheat, and density of weed population.

Blevins et al. (30) indicated the no-tillage treatment had higher moisture contents to a depth of 60 cm during most of the growing season. The decrease in evaporation and the greater ability to store moisture under no-tillage produces a greater water reserve and prevents the detrimental moisture stresses in the plant.

Aase and Tanka (31) tested the soil water evaporation under four tillage practices namely; bare fallow, stubble-mulch fallow, chemical fallow-mixed standing and flat residue, and chemical fallow-flat residue. The results showed that soil water evaporation during the summer months is about the same from all tillage treatments tested.

Tollner et al. (32) reported that the temperature near the soil surface for the conventional and no-till plow were > 40 and 33-35°C, respectively. Soil moisture under no-till always exceeded that under conventional tillage. Roots in no-till tended to be concentrated near the soil surface and they were larger and less numerous than roots under the conventional tillage. The cumulative infiltration in the no-till treatments was substantially greater than under conventional tillage.

Wilfried (33) found that in both tillage treatments (zero-tilled and conventional) water was absorbed mainly in the soil top layers. Also in tilled soil, roots absorbed less water from the 20-30 cm layer with a small porosity as compared to adjacent layers with higher porosity.

Saad et al. (34) indicated that in calcareous soils, wheat straw and grain yield had increased four times with increasing phosphorus applications form 0 to 240 P_2O_5 kg ha^{-1}. Wheat yield response was highest when soil phosphorus content reached an average value of about 13 ppm.

Cox et al. (35) studied the effect of conventional tillage, no-till, and ridge tillage on some soil physical properties. They found that the soil temperature at 0.1 m depth under no-tillage averaged lower values, than those for conventional and ridge tillage. When the water stress was not a factor, the lower soil temperature under no-till resulted in decrease leaf, stem, and total phytomass throughout the vegetative period.

Unger and Wiese (36) reported that no-tillage, sweep, and disk methods stored soil moisture during the fallow period at an average of 35, 23, and 15% of total rainfall. Available soil water contents down to a depth of 1.8 m had averaged 21.7, 17.0, and 15.2 cm. Water-use efficiencies (W.U.E) for sorghum grain had averaged 89, 77, and 66 kg ha^{-1}-cm for the respective treatments.

Lindstrom et al. (37) conducted a study to evaluate the effect of tillage systems (moldboard, chisel, an no-till) in clay loam soil on interrow runoff and infiltration. They reported that the conservation and conventional non wheat tracked interrows had a greater infiltration rate after runoff started than the wheel tracked interrows and the no till system. This study indicated, that the no-till system may resulted in a consolidated soil surface with a low infiltration capacity, that is persistent with time, and susceptible to high volumes of runoff during severe rainstorm events.

Power et al. (38) found that the plant growth, grain yields, and nutrient uptake were proportional to available moisture and were increased with phosphorus fertilization. Phosphorus fertilization had no effect upon total moisture use at any stage of growth. At soft dough and harvest stages, P fertilization had increased the plant material produced per unit of moisture used.

Knapp and Knapp (39) found in silty loam soil that the wheat planted in mid to late September had greater winter survival and produced significantly more grain with a higher test weight than did later planted wheat. Nitrogen alone had little effect on yields when compared to unfertilized wheat, and when N was applied with P the results were similar to those from P alone.

Shatanawi et al. (40) measured the water use of wheat and barley in the Jordan Valley by using drainage type lysimeters. The results indicated that wheat production was 4.2 tons ha^{-1} for 326 mm seasonal evapotranspiration calculated from the water budget equation.

Goos et al. (41) reported that data of stored available water at seeding, precipitation, and grain yield from 53 spring wheat experiments were analyzed to make a decision to use fallow or recrop the field. The results indicated that to get a minimum acceptable recrop wheat yield of 1350 kg ha^{-1}, they defined the following critical level: if stored available soil water at seeding is less than 6.4 cm, crop failure is likely and summer fallow is advised; whereas, stored available soil moisture > 9.4 cm, crop success is likely and recropping is advised.

Aase and Siddoway (42), studied the evaporative flux from wheat and fallow practices using a lysimeter method. They found that cropped and fallowed lysimeters lost almost identical amounts of water up to the time that tillering was completed. Thereafter, evapotranspiration from cropped surfaces was much higher than evaporation from non cropped surfaces. The fallowed lysimeter gained 12 cm of water in 1978 and lost 7 and 2.5 cm in 1979 and 1980, respectively, whereas the cropped lysimeter lost 20 cm in 1978, 42 cm in 1979, and 14 cm in 1980. Also the results indicated that rates of water use by the wheat were highest during the heading growth stage and flowering stage.

Radke et al. (43) studied the effect of different tillages on soil temperature, soil water, and wheat growth in south Australia. They found that wheat grown on rotary cultivator (rotovator) was significantly taller and gave more yield than using scarified (tine digger) (3300, and 1500 kg ha^{-1}, respectively). While soil moisture in the first 10 cm depth was greater for scarifier than rotovator.

Saimeh and Battikhi (44) indicated that on gentle slopes 0-3% fallow land stored 97 mm more water as compared to wheat planted land of the same slope. For slopes 3-8%, 53 mm more water were stored in fallow land as compared to wheat planted land of the same slope. They indicated also that the moisture depletion had decreased as the rainfall quantity decreased, and for wheat the depletion from the second layer was higher than that in fallow due to extraction by wheat roots which reached the second layer. The moisture storage efficiency of ranged from 18% to 34% of the total rainfall.

Kharouf and Battikhi (45), in a study of the effect of fall tillage plows on soil moisture storage, depletion, and wheat yields at Mushaqqar Agricultural Experiment Station, found that there were no significant differences in soil moisture storage and depletion between moldboard and chisel plow (387 and 376 mm for storage; 377 and 378 mm for depletion, respectively).

3- Materials and Methods:

3-1 Study Location:

The study was conducted at Mushaqqar Agricultural Experiment Station, located approximately 28 km south west 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 The Soil:

The soil in Mushaqqar Agricultural Station was classified by Spenser and Rihani, as fine, montmorillonitic, thermic, entic chromoxerert, with the following profile description.:

Ap 0-12 cm: Brown to dark brown (7.5YR4/4) clay; strong fine to medium subangular blocky structure; firm, very sticky and very plastic; common very fine root; many fine interstitial pores; strongly effervescent; abrupt smooth boundary. About 3% fine pebbles throughout the pedon.

Al 12-37 cm: Brown to dark brown (7.5YR4/4) 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 the pedon.

A_b 37-60: Brown to dark brown (7.5YR4/4) 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 the pedon.

Bw 60-90 cm: Brown to dark brown (7.5YR4/4) 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 slickensides. About 3% fine pebbles throughout the pedon.

Bk1 93-125 cm: Brown to dark brown (7.5YR4/4) 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 the pedon.

BK2 125-150 cm: Brown to dark brown (7.5YR4/4) 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 slickensides. Common fine and medium lime masses. About 3% fine pebbles throughout the pedon.

3-3 First Experiment:

The objectives of this experiment were to study the effects of three nitrogen fertilizers sources, two methods of fertilizers applications, and soil moisture storage, depletion on wheat production.

A split plot in randomized complete block design of three replications was used. The application methods assigned as main treatments whereas the three nitrogen fertilizers were the sub main treatments. The nitrogen rate (60 kg N ha^{-1}) was used for all N-fertilizers forms.

The two main treatments were as follows:

Broadcasting (B) the nitrogen fertilizer on the soil surface by hand.

Applying the nitrogen fertilizer on the soil surface, then incorporated (I) with the soil surface down to 10 cm depth.

The three sub-treatments (N-sources) were: F1, urea $[CO(NH_2)_2]$; F2, ammonium sulfate $[(NH_4)_2SO_4]$; and F3, potassium nitrate (KNO3).

The dimension of each plot was 20 x 10 m and each sub plot was 10 ×10 m. The recommended nitrogen rate (60 kg N ha^{-1}) was applied at one dosage at sowing date. All plots of the experiment were fertilized with 50 kg P_2O_5 ha^{-1}, applied at time of sowing.

For the subtreatments, potassium (singral, 0-0-50) was added in amounts equal to the amounts present in the third sub treatment (KNO_3) (Fig. 1). Wheat (Horani) was planted on December 15, 1990 by seed driller at a rate of 100 kg ha^{-1} to 8 cm depth and 20 cm spacing between rows.

Weed control during growing season was done by spraying the whole field area with Round-up (60 ml/120 L water).

3-3-1 Soil Moisture Measurements:

Access tubes, two inch diameter galvanized steel pipes 150 cm long, were installed in each plot of each experiment to measure moisture for soil depths at: 7.5; 22.5; 45; 75; and 105 cm using neutron probe (CPN 503 DR Hydro Probe).

3-3-2 Soil moisture calculation:

Soil moisture depths (mm) were calculated from the volumetric moisture content by using calibration curves prepared for each layer.

Calculations of crop evapotranspiration (ETc), and soil moisture storage during the season were dependent upon the change in soil moisture content for the whole soil profile at different times of the season. Meteorological data was used to calculate the amount of moisture stored

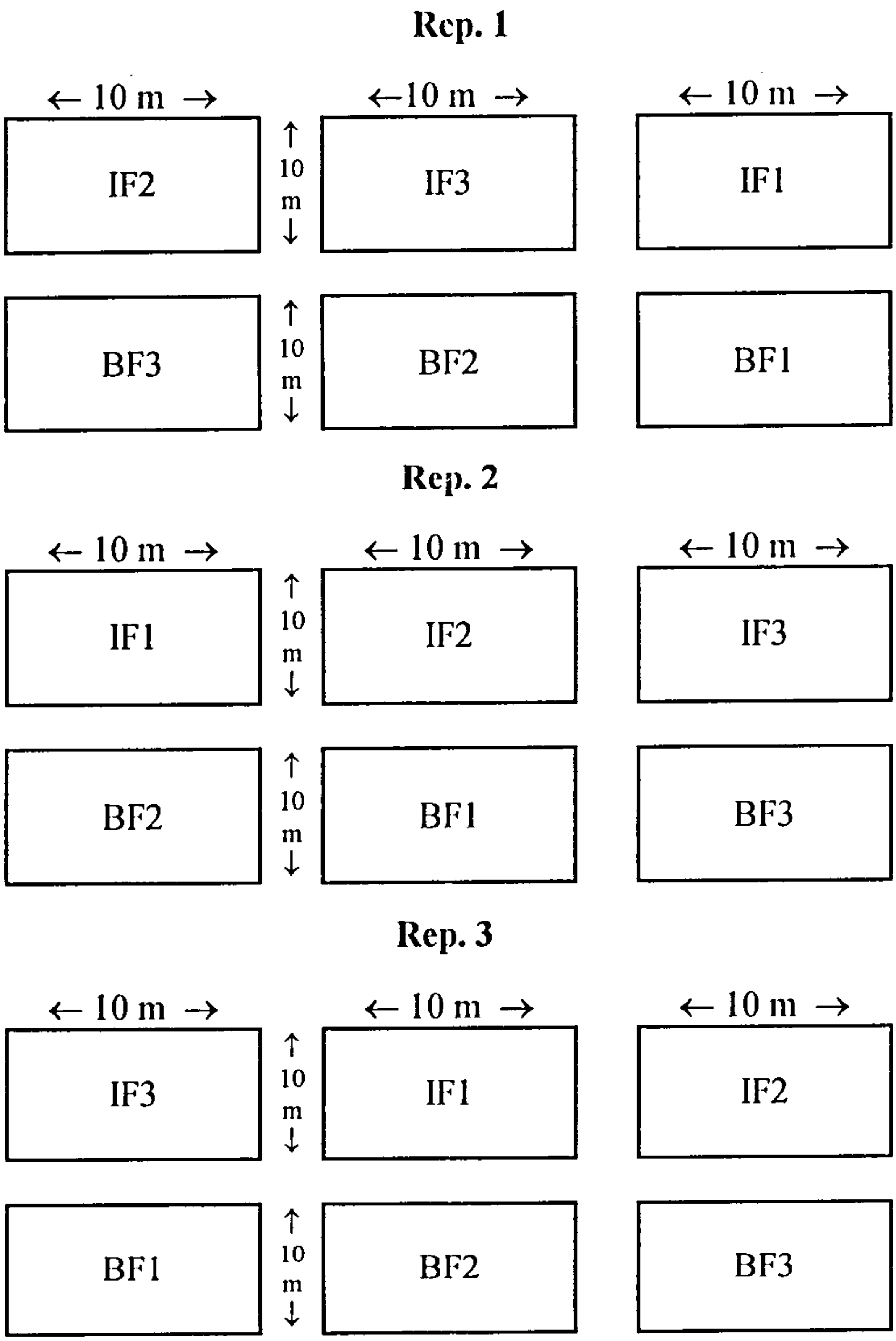


Fig. 1. Experimental layout of the first experiment at Mushaqqar Agricultural Station, during 1990/91 and 1991/92 growing seasons.

during the rainy days. Crop evapotranspiration and soil moisutre storage were calculated using the following equations:

$$ETc = ET + ETc^* \text{..................................} (1)$$

where:

ETc: total actual evapotranspiration.

ET: Soil moisture depletion for the periods between neutron probe readings during the growing season which is due to crop consumtive use during those periods.

ETc*: total sum of actual crop water requirments during rainy days (when it was difficult to determine by depletion using neutron probe readings because of inconveneince to work in the field during those days.

$$ETc^* = Ep \times Kp \times Kc \text{..................................} (2)$$

Where: ETc* = crop evapotranspiration (mm)

Ep = class A pan evaporation (mm)

Kp = pan coefficient (FAO, 1974 (46))

Kc = crop coefficient (Fig. 2 and 3)

Different soil moisture and crop yield components were calculated as the following:

Crop evapotranspiration (ETc) = Σ [decrease in soil moisture (-ΔS)] + ΣSoil moisture stored + depleted during rainy days (from planting to harvest)............(3)

Soil moisture depletion (mm) = Σ [decrease in soil moisture (-ΔS) + ΣSoil moisture stored + depleted during rainy days (from beginning to end of season)..(4)

Soil moisture storage (mm) = Σ[increase in soil moisture (+ΔS) + Σ soil moisture stored + depleted during rainy days (From first rainfall event to last rainfall event during the winter season)..(5)

Total seasonal soil moisture storage, SMS = ΣΔS + ETc*......................(6)

ΔS: soil moisture storage from rainfall for the periods between neutron probe readings.

Water storage efficiency (W.S.E) =

$$\frac{\text{Soil moisture storage}}{\text{Total rainfall}} \times 100 \text{..................(7)}$$

Water use efficiency (W.U.E) (kg/du/mm) =

$$\frac{\text{Grain or biological yield (kg / du)}}{\text{ETc(mm)}} \text{............(8)}$$

Fertilizer use efficiency (F.U.E) (Kg/Kg) =

$$\frac{\text{Grain or biological yield (kg / du)}}{\text{Fertilizer added (kgN / du)}} \text{................(9)}$$

Runoff(mm) = Total rainfall- Soil moisture storage ....(10)

Same treatments were used for both seasons.

3-3-3 Fertility Status:

Soil samples were taken from the surface layer (0-30 cm) and subsurface layer (30-60 cm) from the 18 locations in the experiment to determine the fertility status of the soil during the growing season. Plant samples from $0.5m^2$ were taken from the 18 plots at the following growth stages tillering, boating and harvesting to measure the concentration of total nitrogen and phosphorus in wheat. At the harvesting stage planting height was measured and three random plant samples of one meter square were collected from each plot, then weighed and threshed to determine grain and straw yields and number of spikes.

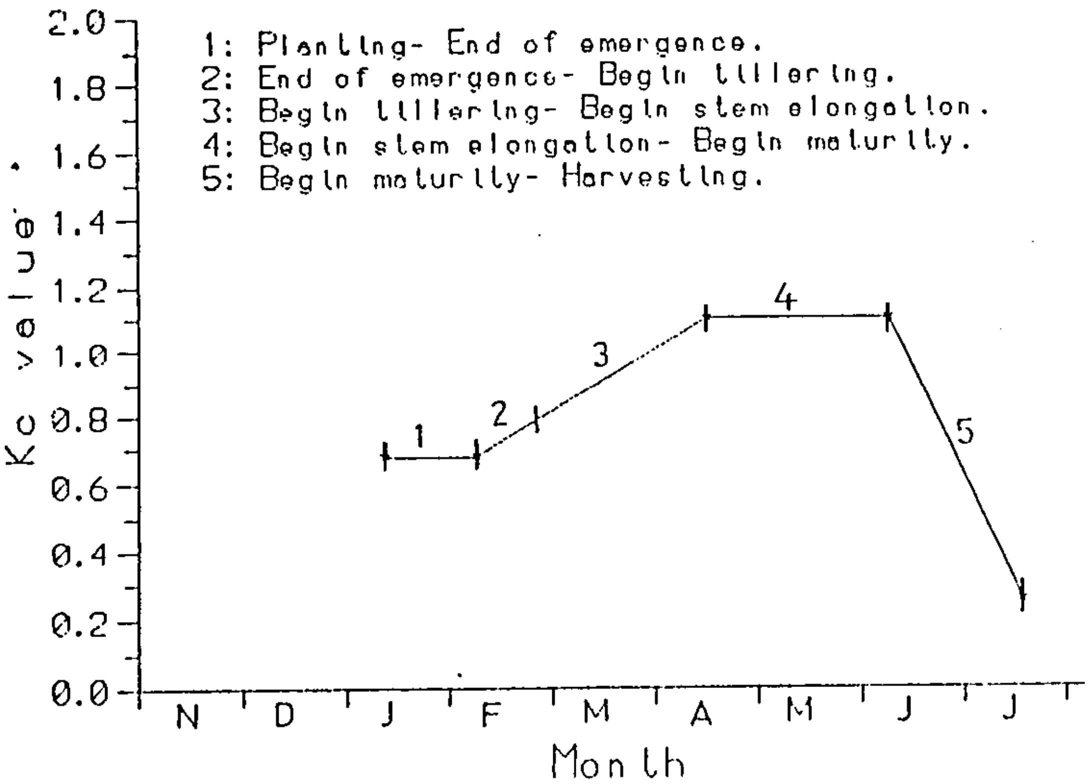


Fig. 2: Crop coefficient curve for wheat crop planted at Mushaqqar Station for (1990-91) season.

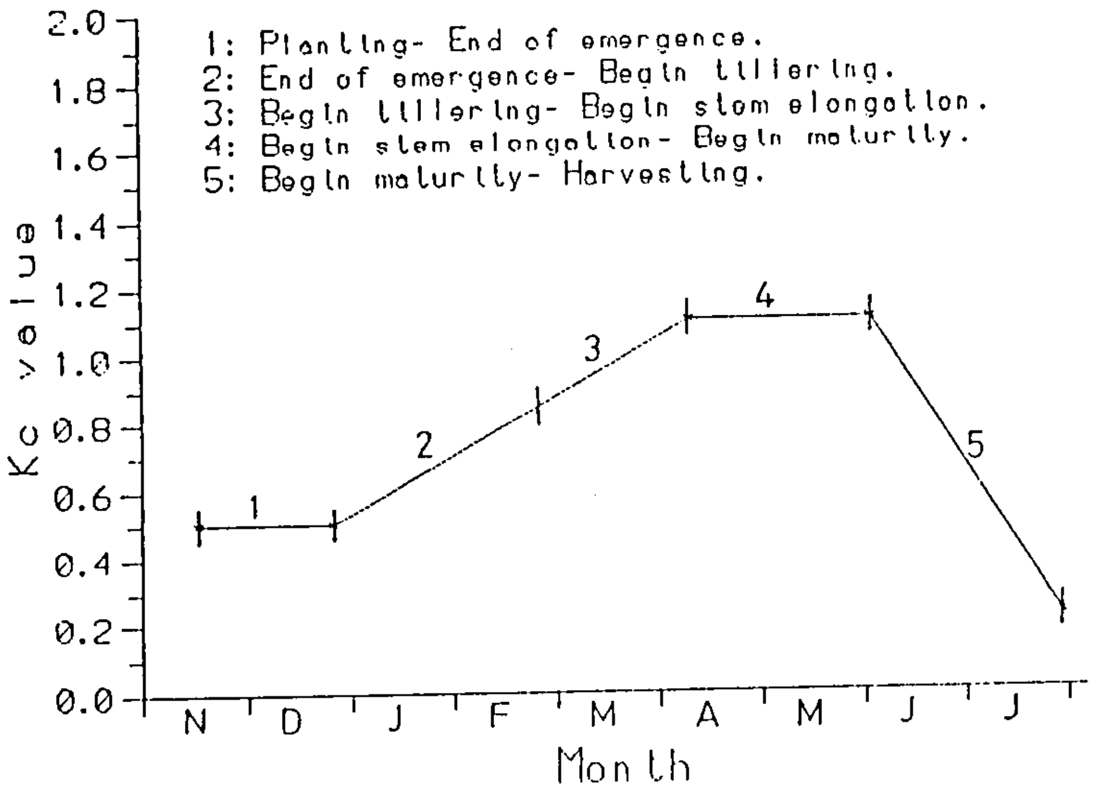


Fig. 3: Crop coefficient curve for wheat crop planted at Mushaqqar Station for (1991-92) season.

Soil mineral nitrogen (ammonia, nitrate, and total mineral nitrogen) was determined using micro Kjeldhal method (47). Total nitrogen of plant was determined using Kjeldhal method (48). Soil available phosphorus was determined using $NaHCO_3$ extraction method (Olsen, et al., 49). The whole experiment was repeated in the next year (1991/92) with the same main and sub main treatments.

3-4 Second Experiment:

This experiment was carried out in the two seasons 1990-91 and 1991-92 in order to follow up a previous crop rotation experiment. Figure 4 shows the layout of the three different rotations used.

3-4-1 Continuous wheat:

The objective of this part during the first season was to study the effect of tillage practices treatment and nitrogen fertilizer dosages on wheat production and soil moisture conservation.

The main treatments were as follows:

(1) Moldboard plowing in October, 1990. (T2).

(2) Chisel plowing in October, 1990, then followed by sweep before planting for seed bed preparation(T1).

Each main treatment plot has a dimension of 36 × 5m.

Recommended total amount of nitrogen (60 kg ha^{-1}) using ammonium sulfate fertilizer was used as sub main treatment, as follows:

1. Nitrogen fertilizer (60 kg ha^{-1}) was applied once at planting (N1).
2. Total amount of nitrogen fertilizer was splited into two doses (N2), one dosage was applied at planting and the second dosage was applied at tillering stage. Total nitrogen applied at each dosage was

Continuous Wheat Rotation

Rep. 1		Rep. 2		Rep. 3	
		N0		↑ 12 m ↓	← 5 m →
Chisel plow	Moldboard plow	N1			
		N2			

Duck-foot Fallow- Wheat Rotation

Rep. 1		Rep. 2		Rep. 3	
		N1		↑ 12 m ↓	← 5 m →
Chisel plow	Moldboard plow	N2			
		N0			

Chemical Fallow Wheat Rotation

Rep. 1		Rep. 2		Rep. 3	
		N1		↑ 5 m ↓	← 5 m →
Chisel plow	Moldboard plow	N0			
		N2			

Fig. 4. Experimental layout of the second experiment at Mushaqqar Agricultural Station during 1990/91 and 1991/92 growing seasons.

submain treatments, while it was left fallow during the first season (1990/91).

Access tubes were installed in each submain treatment, and soil moisture content readings were taken using neutron probe device after each rainfall event, and every two weeks when no rainfall had occurred.

Three samples of wheat from each sub plot were taken randomly. They were weighed and threshed to determine wheat yield and other yield components.

3-5 Climatic data:

Rainfall (mm), minimum and maximum temperature (°C), for the two seasons 1990-91, and 1991-92, were obtained for Mushaqqar from the Agrometeorological Departments. The data is presented in Figures 5 and 6.

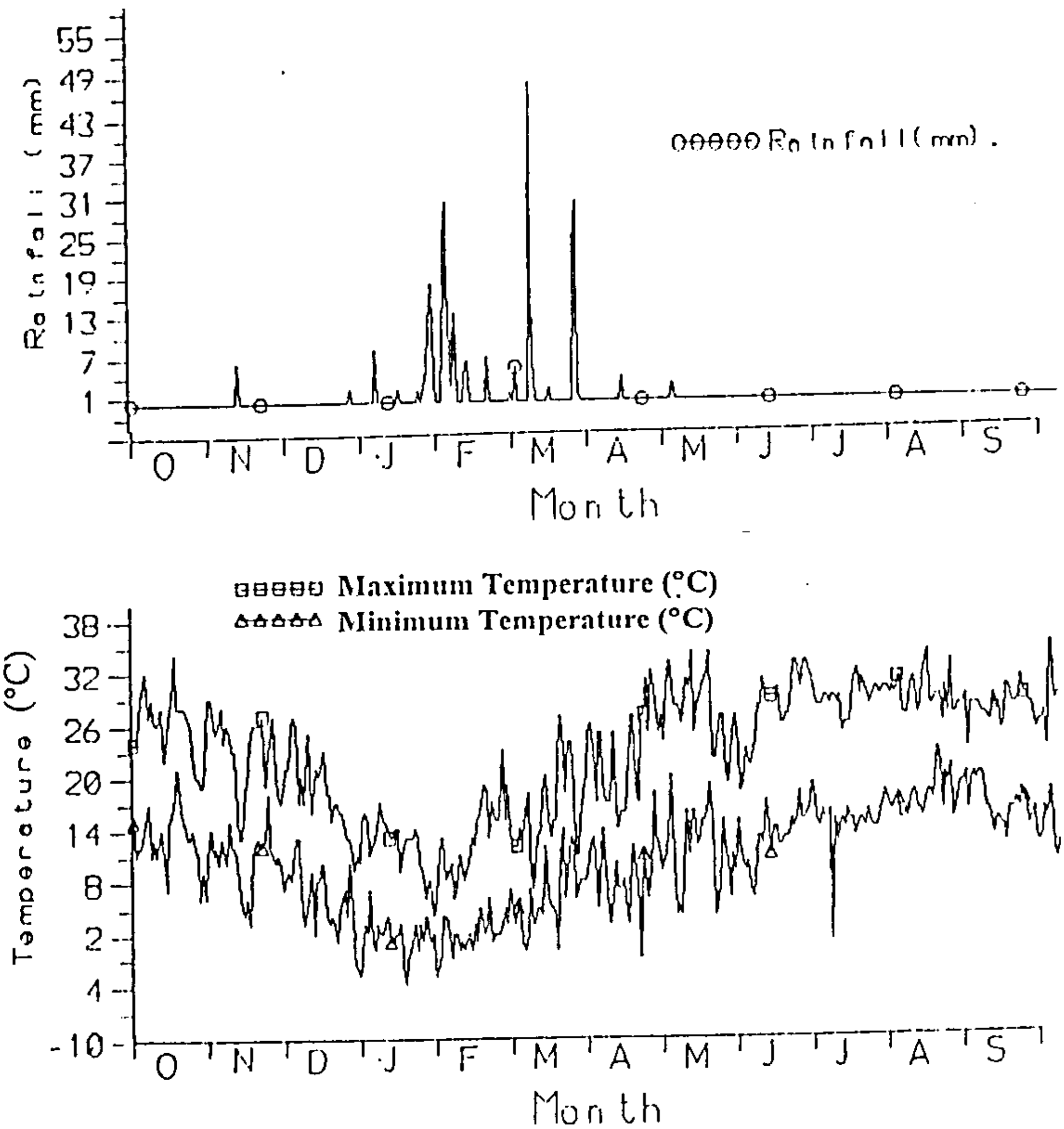


Fig. 5: Daily rainfall, Maximum, and Minimum Temperature for Mushaqqar Station during (1990-91) season.

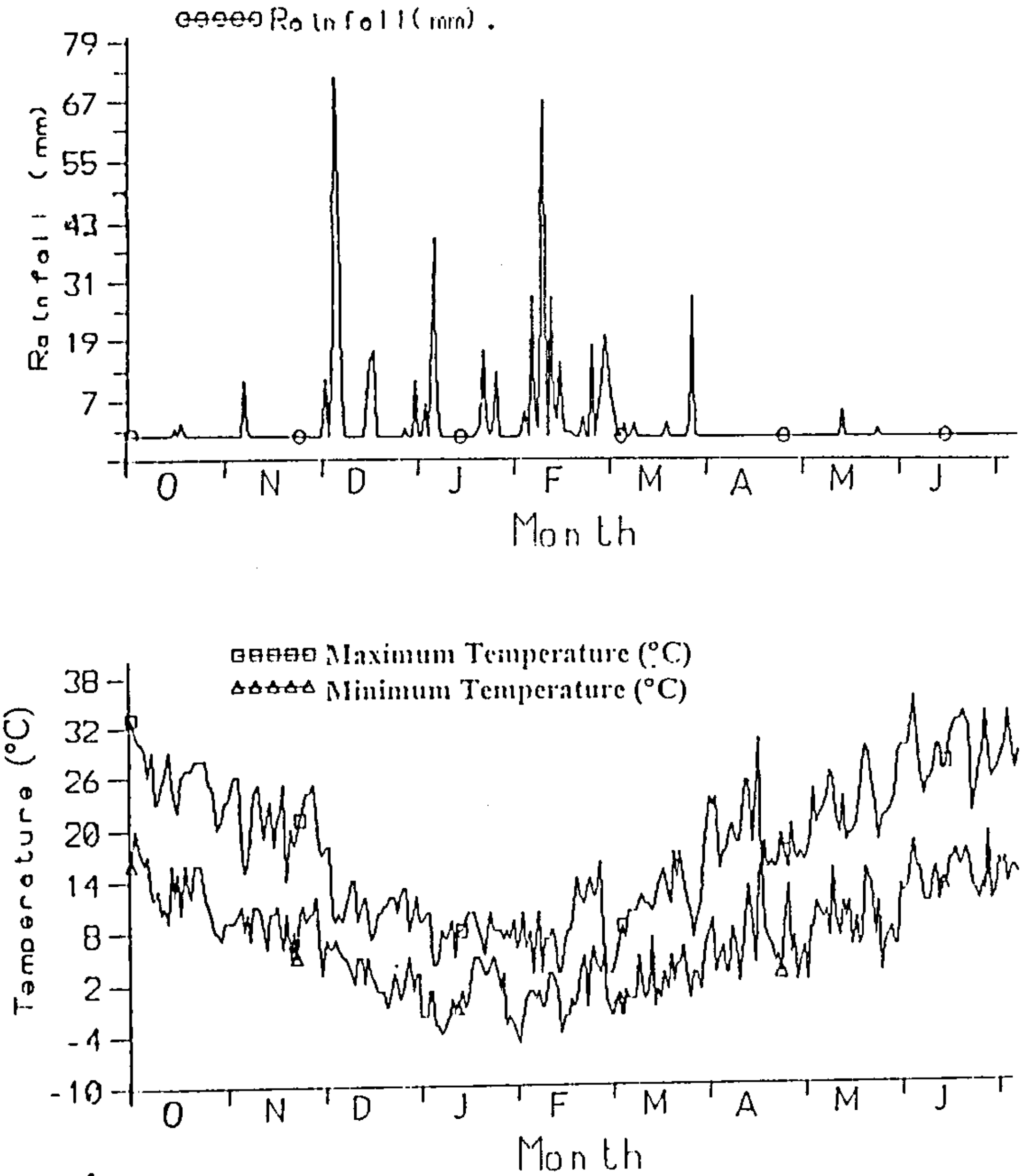


Fig. 6: Daily rainfall, Maximum, and Minimum Temperature for Mushaqqar Station during (1991-92) season.

4- Results and Discussion

4-1 First Experiment:

4-1-1 Effect of application methods-nitrogen forms treatment on soil moisture parameters:

Tables 1 and 2 show the grand average for crop actual evapotranspiration, soil moisture depletion and storage, rainfall, rainfall storage efficiency, grain yield, water use efficiency based on grain yield and biological yield, fertilizer use efficiency and runoff amounts in Mushaqqar Station during the growing season 1990/91 and 1991/92, for the two methods of application and the three nitrogen fertilizer forms.

The results indicated that the two methods of nitrogen fertilizer application were not significantly different with respect to all the crop and soil moisture parameters measured except for grain yield, storage, water storage and fertilizer use efficiency in the 1991/92 growing season, in which, broadcasting of nitrogen fertilizer on the soil surface had resulted in higher vegetative growth which resulted in higher grain yield and so higher water use and fertlizer use efficiency. The higher vegetative growth resulted in higher storage through the decrease of the runoff amounts than the incorporation of the N fertilizer with the soil. This can be explained when we consider the rainfall amount in Mushaqqar in the 1991/92 season which was 600 mm. Under incorporation, the extinsive rainfall may resulted of higher downward movement of nitrogen, thus resulting in a trend where higher values for the hand broadcasting treatment for this year were obtained, for all parameters tested. The opposite can be noticed in the 1990/91 season data, in which the rainfall amount was 350 mm, although there no significant differences between treatments, incorporation the fertilizer into the soil had resulted in higher values than those obtained under

Table 1: Average evapotranspiration, soil moisture depletion, soil moisture storage, water storage efficiency, water use efficiency, fertilizer use efficiency, and runoff under (nitrogen forms confounded) and nitrogen forms (application methods confounded) in Mushaqqar for wheat crop (1990-91).

Parameters	Grain yield (Mg/ha)	ETc (mm)	Depletion (mm)	Storage (mm)	W.S.E (%)	W.U.E.1 (kg/mm)	W.U.E.2 (kg/mm)	F.U.E (kg/kg)	Runoff (mm)
B	1.29 a+	275.3 a	323.1 a	232.7 a	87.2 a	0.49 a	2.44 a	21.5 a	34.6 a
I	1.39 a	273.2 a	333.5 a	240.5 a	90.1 a	0.51 a	2.51 a	23.2 a	26.6 a
F1	1.41 a	266.6 b	318.3 b	232.9 b	87.2 a	0.51 a	2.57 a	23.5 a	34.2 a
F2	1.22 b	278.0 a	318.6 b	268.2 a	89.0 a	0.45 a	2.27 a	20.4 a	28.9 a
F3	1.39 a	284.2 a	348.0 a	238.8 a	89.4 a	0.53 a	2.60 a	23.2 a	28.3 a
F-test:									
A	NS	NS	NS	NS	NS	NS	NS	NS	NS
S	*	*	*	*	NS	NS	NS	NS	NS
Ax S	NS	NS	NS	NS	NS	NS	NS	NS	NS

+ Along each column, values followed by the same letter are not significantly different at the 5% level according to DMRT.
A= method of nitrogen fertilizers application.
S= nitrogen fertilizer forms.
*= significant at the .05 level; NS not signifcant.
1 : Water use effeciency based on grain yield.
2 : Water use effecienty based on biological yield.

Table 2: Average evapotranspiration, soil moisture depletion, soil moisture storage, water storage efficiency, water use efficiency, fertilizer use efficiency, and runoff under different application methods (nitrogen forms confounded) and nitrogen forms (application methods confounded) in Mushaqqar for wheat crop (1991-92).

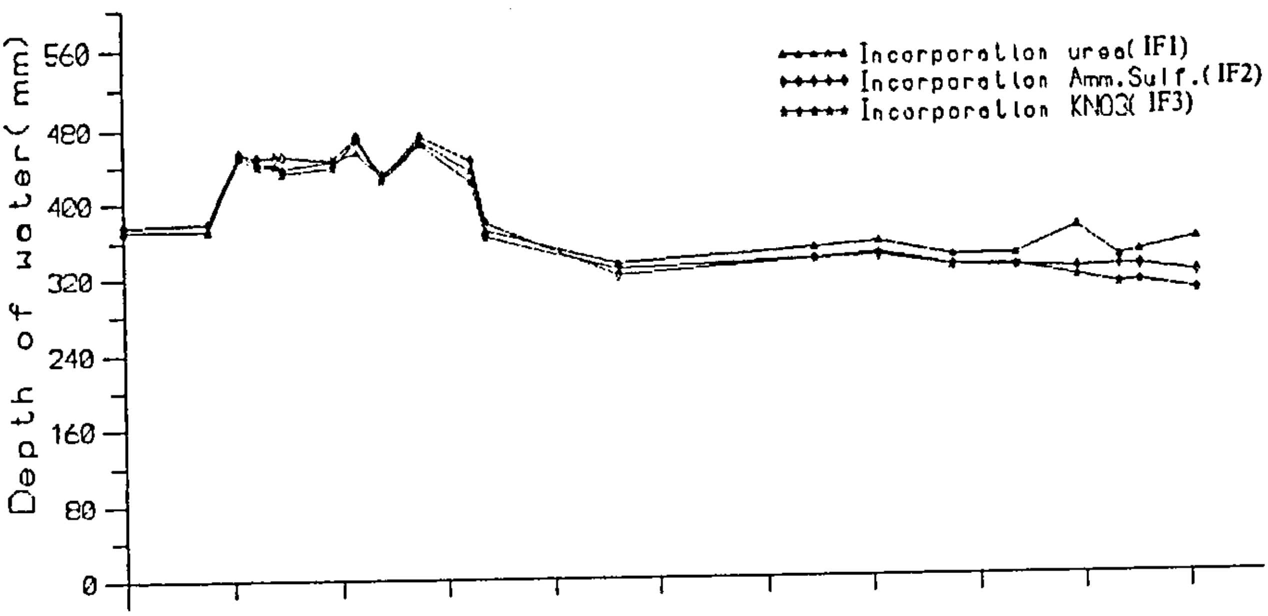
Parameters	Grain yield (Mg/ha)	ETc (mm)	Depletion (mm)	Storage (mm)	W.S.E (%)	W.U.E.1 (kg/mm)	W.U.E.2 (kg/mm)	F.U.E (kg/kg)	Runoff (mm)
B	3.64a+	341.2 a	443.5 a	521.7 a	74.2 a	1.09 a	5.72 a	60.7 b	162.7b
I	3.39 b	334.0 a	433.7 a	507.3 b	74.1 b	1.00 a	5.08 a	56.5 a	177.1a
F1	3.71 a	338.6 a	439.3 a	508.2 a	74.3 a	1.10 a	5.53 a	61.9 a	176.2a
F2	3.45 b	343.7 a	444.4 a	517.3 a	75.6 a	1.00 a	5.23 a	57.4 a	167.1a
F3	3.39 b	330.6 a	432.1 a	518.1 a	75.7 a	1.03 a	5.43 a	56.4 a	166.3a
F-test:									
A	*	NS	NS	*	*	NS	NS	*	*
S	*	NS	NS	NS	NS	NS	NS	NS	NS
A x S	NS	NS	NS	NS	NS	NS	NS	NS	NS

+ Along each column, values followed by the same letter are not significantly different at the 5% level according to DMRT.
A= method of nitrogen fertilizers application.
S= nitrogen fertilizer forms.
*= significant at the .05 level; NS not signifcant.
1 : Water use effeciency based on grain yield.
2 : Water use effecienty based on biological yield.

broadcasting for wheat yield components and soil moisture parameters. In 1990/91 growing season, under potassium nitrate treatment, the higher vegetative growth may resulted in higher crop evapotranspiration (ETc) and soil moisture depletion as compared to urea and ammonium sulfate treatments. This may resulted of the hot conditions in 1991/92 growing season, which affected the use of different nitrogen forms because both urea and ammonium sulfate are hydrolysed first to NH4-N, which can be easily lost through volatilization at the high temperature and low rainfall conditions, so reducing the effect of using urea and ammonium sulfate fertlizers. As urea fertilizer needs more time to be hydrolyzed so the effect of volatilization on urea is less than on ammonium sulfate, and that can be noticed in the higher grain yield which resulted from the application of urea, followed by potassium nitrate as a nitrogen source. No significant differences found for wheat yield components and soil moisture measurments under the interaction between the method of nitrogen application and using different nitrogen forms in 1990/91 and 1991/92 growing seasons.

Figures 7 and 8 shows the monthly moisture stored in the soil profile for the interactions of methods of application (incorporation (I) and broadcasting (B)), with the forms of fertilizer (urea (F1), ammonia sulfate (F2), and potassium nitrate (F3)).

In 1990/91 growing season, the lower wheat canopy and higher evapotranspiration due to dry conditions did not affect the monthly stored soil moisture for the interactions of incorporation and broadcasting with urea, ammonium sulfate, and potassium nitrate. Whereas, in 1991/92 growing season, the lower temperatures and higher wheat canopy under incorporation with ammonium sulfate fertilizer and broadcasting with urea fertilizer resulted in higher monthly stored soil moisture over the season as



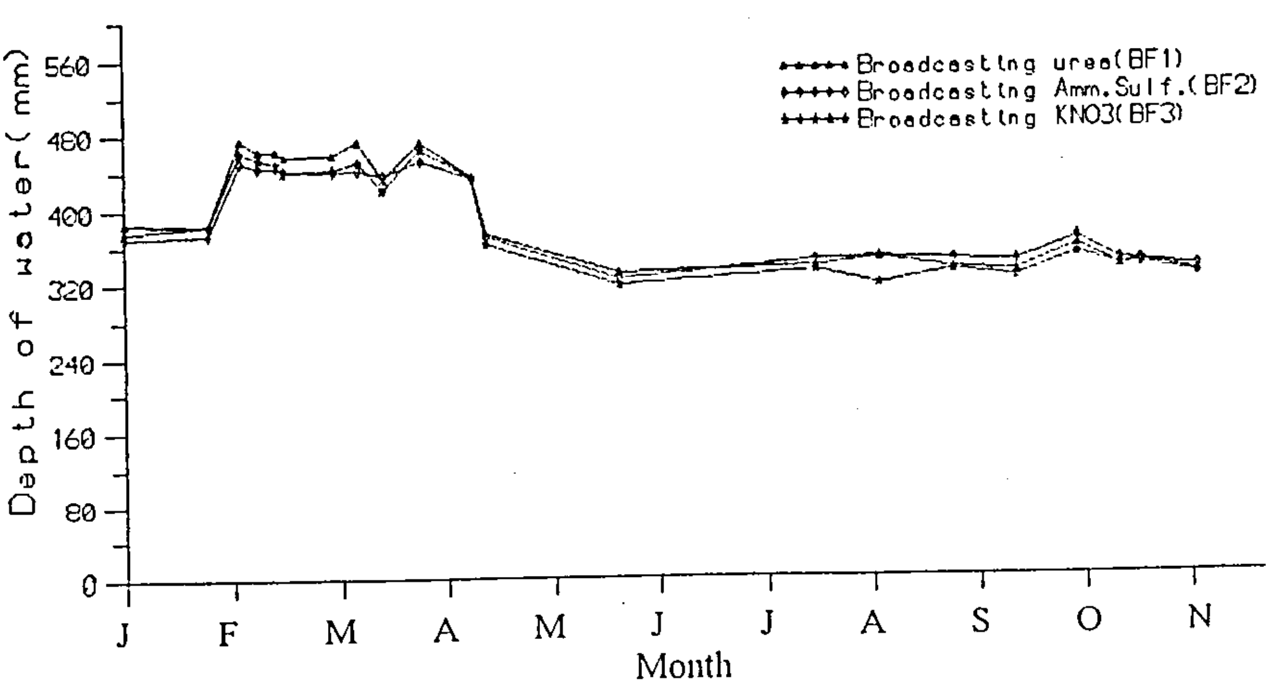


Fig. 7: Total depth of soil moisture content /120 cm soil depth for the different nitrogen forms during the (1990-91) season.

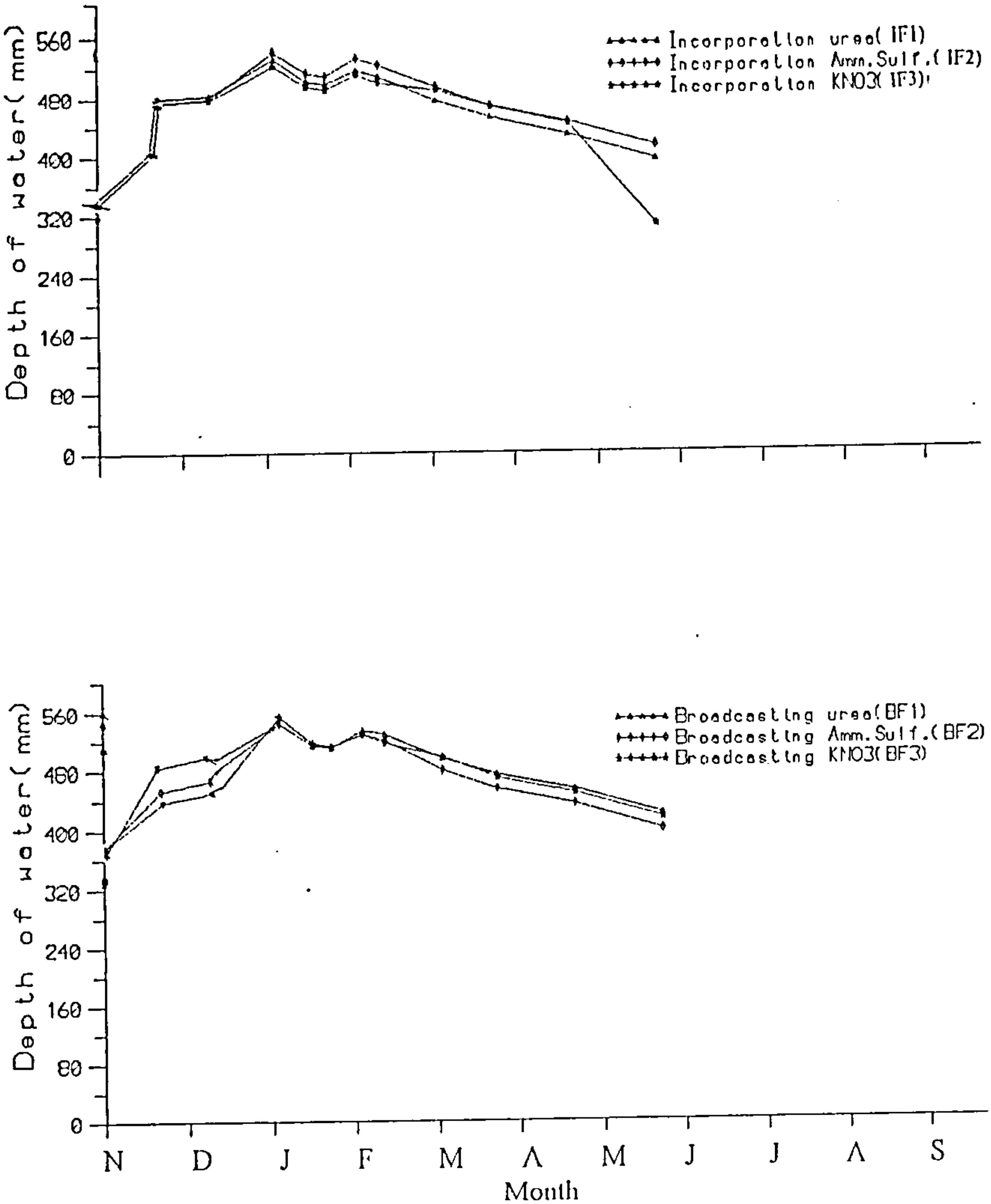


Fig. 8: Total depth of soil moisture content /120 cm soil depth for the different nitrogen forms during the (1991-92) season.

compared to other interactions. Under these two interactions the higher vegetative growth decreased runoff and so increased the amount of stored soil moisture. (Figures 7 and 8).

4-1-2 Yield and yield component :

Tables 3 and 4 show the means of the crop parameters in different methods of application and forms of nitrogen fertilizer in 1990/91 and 1991/92 growing seasons. Table 3 showed that straw and spike numbers were significantly higher under the incorporation treatment during 1990/91 growing season. Whereas in 1991/92, only plant height was significant and higher under the incorporation treatment. This may have resulted due to the higher availability of nitrogen for wheat uptake in earliear stages which cause higher plant height under the incorporation treatment. Also under urea fertilizer higher plant height was resulted in 1991/92 growing season. While the interaction of method of application with the nitrogen forms did not affect wheat yield and yield components.

4-1-3 Soil residual phosphorus and mineral nitrogen:

Table 5 shows the mean of soil residual phosphorus and mineral nitrogen after wheat in relation to different nitrogen application methods and different forms of nitrogen fertilizer, in 1991/92 growing season.

No significant effect for incorporation method on residual P. However, under the broadcasting treatment higher soil residual phosphorus was found in subsurface samples, whereas, NO3-N and TMN were higher in surface samples. Under the incorporation treatment higher soil residual phosphorus and NH4-N were found in surface samples, whereas, NO3-N, and TMN were higher in subsurface samples. This may have been due to the fact of the slow release of fertilizer form in the broadcasting method, whereas in subsurface samples the lowest values of NH4-N, NO3-N, and

Table 3 : Means of different variables for each application method (nitrogen forms confounded) and each source (application methods confounded) in (1990/91) growing season.

Parameters	Grain yield (Mg/ha)	Straw yield (Mg/ha)	Plant height (cm)	Spike No. $/0.5m^2$
I	1.39a+	5.48a	85.6a	100.9a
B	1.29a	5.28b	77.4a	93.6b
F1	1.41a	5.43a	78.7a	89.2a
F2	1.22a	4.98a	75.3a	84.5a
F3	1.39a	4.12a	90.5a	118.0a
F-test:				
A	NS	*	NS	*
S	NS	NS	NS	NS
A x S	NS	NS	NS	NS

+ Along each column, values followed by the same letter are not significantly different at the 5% level according to DMRT.
A= method of nitrogen fertilizers application.
S= nitrogen fertilizer forms.
*= significant at the .05 level; NS not signifcant.

Table 4 : Means of different variables for each application method (source confounded) and each source (application method confounded) in (1991/92) growing season.

Parameters	Grain yield (Mg/ha)	Straw yield (Mg/ha)	Plant height (cm)	Spike No. /0.5m^2
I	3.39a+	1.46a	99.4a	143.1a
B	3.64a	1.57a	95.7b	170.9a
F1	3.71a	1.60a	100.5a	153.7a
F2	3.45a	1.38a	100.0b	173.3a
F3	3.39a	1.35a	92.2b	144.0a
F-test:				
A	NS	NS	*	NS
S	NS	NS	*	NS
A x S	NS	NS	NS	NS

+ Along each column, values followed by the same letter are not significantly different at the 5% level according to DMRT.
A= method of nitrogen fertilizers application.
S= nitrogen fertilizer forms.
*= significant at the .05 level; NS not signifcant.

Table 5: Means of soil residual phosphorus and mineral nitrrogen after wheat in relation to application methods (sources confounded) and each sources (application methods confounded) in 1991/92 growing season.

Parameters	P (ppm)		Mineral nitrogen components (ppm)					
	surface	subsarface	surface			subsurface		
			NH4-N	NO3-N	TMN	NH4-N	NO3-N	TMN
I	2.65a+	1.73a	18a	5a	23a	17a	4a	21a
B	2.43a	2.97a	17a	7a	24a	17a	3a	20a
F1	2.00a	1.89a	18a	8a	26a	18a	2a	20a
F2	2.23a	1.73a	17a	6a	23a	16a	4a	20a
F3	2.39a	3.42a	17a	4a	21a	16a	5a	21a
F-test								
A	NS	NS	NS	NS	NS	NS	NS	NS
S	NS	NS	NS	NS	NS	NS	NS	NS
A x S	NS	NS	NS	NS	NS	NS	NS	NS

+ Along each column, values followed by the same letter are not significantly different at the 5% level according to DMRT.
A= method of nitrogen fertilizers application.
S= nitrogen fertilizer forms.
NS= not signifcant.

TMN existed under the broadcasting methods. This explains the slow movement of nitrogen down and which is resulted of the slow release of nitrogen fertilizer under the broadcasting method. On the other hand, under potassium nitrate treatment the highest soil residual phosphorus in surface and subsurface samples and NO3-N and TMN in subsurface samples were found. Whereas, under urea treatment NH4-N, NO3-N, and TMN in surface samples and NH4-N in subsurface samples the highest soil residuals were found.

Generally, Table 5 shows that there was a deficiency in the available phosphorus in soil but on the other hand, there is high amount of soil residual nitrogen, NO3-N and TMN. The reason of the deficiency of phosphorus is not known.

4-1-4 Nitrogen and phosphorus concentration in wheat at different grwoth stages:

Table 6 shows the nitrogen and phosphorus content at different stages of wheat growth in relation to different nitrogen application methods and different forms of nitrogen fertilizers in 1990/91 and 1991/92 growing seasons.

Under incorporation treatment, higher nitrogen content of seed and straw were existed due to the higher availability of nitrogen for wheat. This higher available nitrogen uptake by wheat under the incorporation, was used by wheat for seed formation, so the amount of N found in seed was higher under the incorporation method.

4-2 Second Experiment:

4-2-1 Fallow efficiency:

Three crop rotations were used to examine the fallow efficiency and to control weeds during the growing season.

Table 6: Nitrogen and phosphorus concentration in wheat plant at different growth stages as affected by nitrogen sources (application methods confounded) and application methods (sources confounded) in 1990/91 and 1991/92 seasons.

Parameter	1991/92												1990/91			
	Tillering		Boating		at 11-5-92		at 21-5-92		Straw		Seed		Straw		Seed	
	%															
	N	P	N	P	N	P	N	P	N	P	N	P	N	P	N	P
I	4.59a+	0.15a	2.69a	0.15a	2.19a	0.15a	2.05a	0.09a	0.66a	0.006a	1.91a	0.07a	1.04a	0.07a	2.56a	0.099a
B	4.33a	0.19a	2.71a	0.15a	2.51a	0.13a	2.33a	0.12a	0.59a	0.007a	1.74a	0.08a	1.14a	0.06a	2.30a	0.098a
F1	4.37a	0.16a	2.55a	0.16a	2.39a	0.13a	2.22a	0.10a	0.62a	0.005a	1.79a	0.06a	1.00a	0.06a	2.26a	0.092a
F2	4.91a	0.15a	2.42a	0.13a	2.36a	0.15a	2.17a	0.12a	0.49a	0.009a	1.86a	0.07a	1.21a	0.07a	2.44a	0.098a
F3	4.09a	0.20a	3.12a	0.16a	2.30a	0.13a	2.17a	0.10a	0.75a	0.006a	1.83a	0.08a	1.03a	0.07a	2.60a	0.104a
F-test:																
A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
A x S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

+ Along each column, values followed by the same letter are not significantly different at the 5% level according to DMRT.
A= method of nitrogen fertilizers application.
S= nitrogen fertilizer forms.
NS= not signifcant.

There was no difference between duck-foot fallow and chemical fallow with respect to the total depth of moisture stored in soil profile during the two fallow processes. Total depth of water stored by the end of October-1990 was 361 to 364 mm for duck foot fallow, whereas in chemical fallow it was 348 to 361 mm. These results may have been due to the drought season (Total depth of water stored 267.2 mm) and the little increment in amount of water in duck-foot fallow treatment was due to weeds density which was more under chemical fallow than duck-foot fallow.

4-2-2 Continuous wheat rotation:

4-2-2-1 Soil moisture and crop yield:

Tables 7 and 8 represent a comparison between different tillage-nitrogen treatments for wheat during 1990/91 and 1991/92 growing seasons on the effect of the ETc, soil moisture depletion, soil moisture storage, W.S.E, W.U.E, runoff, and grain yield .

During 1990/91 season, no significant differences between chisel and moldboard plows, splitiing of nitrogen fertilizer into doses, and the interactions were found according to Duncan's Multiple Range Test (DMRT), with regard to the different parameters tested (Table 7). This may have resulted of the dry climate in 1990/91 season, which reduced the effect of tillage treatments. The lack of soil moisture cause decreased the effectivness of nitrogen fertilizer spliting.

In table 8, splitting of nitrogen fertilizer doses have similarly no effect on all the parameters being determined. While significancy is shown for the soil moisture storage, water storage efficiency, and runoff with respect to tillage treatments during 1991/92. From the above results, one can find that moldboard plowing showed more water storage, W.S.E, and less

Table 7: Average evapotranspiration, soil moisture depletion, soil moisture storage, water storage efficiency, water use efficiency, fertilizer use efficiency, and runoff under different tillage treatments (nitrogen doses confounded) and nitrogen doses (different tillage treatments confounded) in continuous wheat in Mushaqqar for wheat crop (1990-91).

Parameters	Grain yield (Mg/ha)	ETc (mm)	Depletion (mm)	Storage (mm)	W.S.E (%)	W.U.E.1 (kg/mm)	W.U.E.2 (kg/mm)	F.U.E (kg/kg)	Runoff (mm)
Chisel	0.69a+	265.1a	312.9a	244.2a	91.4a	0.27a	2.61a	11.5a	22.9a
Moldboard	0.78a	263.3a	297.7a	251.1a	94.0a	0.30a	2.27a	12.8a	16.0a
N1	0.81a	260.7a	314.0a	248.2a	92.9a	0.32a	2.65a	13.5a	18.9a
N2	0.91a	260.7a	307.3a	146.0a	92.1a	0.37a	2.53a	15.2a	21.1a
N3	0.47a	271.3a	294.6a	248.7a	93.1a	0.17a	2.13a	7.9a	18.4a
F-test:									
T	NS	NS	NS	NS	NS	NS	NS	NS	NS
N	NS	NS	NS	NS	NS	NS	NS	NS	NS
T x N	NS	NS	NS	NS	NS	NS	NS	NS	NS

1 : Water use effeciency based on grain yield.
2 : Water use effecienty based on biological yield.
+ Along each column, values followed by the same letter are not significantly different at the 5% level according to DMRT.
T= tillage practices.
N= nitrogen fertilizer splitung.
NS= not significant.

Table 8: Average evapotranspiration, soil moisture depletion, soil moisture storage, water storage efficiency, water use efficiency, fertilizer use efficiency, and runoff under different tillage treatments (nitrogen doses confounded) and nitrogen doses (different tillage treatments confounded) in continuous wheat in Mushaqqar for wheat crop (1991-92).

Parameters	Grain yield (Mg/ha)	ETc (mm)	Depletion (mm)	Storage (mm)	W.S.E (%)	W.U.E.1 (kg/mm)	W.U.E.2 (kg/mm)	F.U.E (kg/kg)	Runoff (mm)
Chisel	2.75a+	319.4a	417.1a	457.3b	66.8b	1.09a	4.93a	57.7a	227.1a
Moldboard	2.61a	326.3a	426.4a	473.6a	69.2a	1.02a	4.67a	54.3a	210.8b
N1	2.38a	320.5a	423.1a	466.3a	68.1a	0.95a	4.38a	49.8a	218.1a
N2	2.58a	324.8a	418.8a	464.4a	67.9a	1.06a	4.82a	57.3a	220.1a
N3	3.10a	323.2a	423.5a	465.7a	68.0a	1.15a	5.20a	60.9a	218.8a
F-test:									
T	NS	NS	NS	*	*	NS	NS	NS	*
N	NS	NS	NS	NS	NS	NS	NS	NS	NS
T x N	NS	NS	NS	NS	NS	NS	NS	NS	NS

1 : Water use effeciency based on grain yield.
2 : Water use effecienty based on biological yield.
+ Along each column, values followed by the same letter are not significantly different at the 5% level according to DMRT.
T= tillage practices.
N= nitrogen fertilizer splitung.
*= significant at the .05 level; NS not signifcant.

runoff than chisel plow. These results may have been attributed to deeper plow under moldboard compared to chisel plow which increased soil macropores, soil infiltration rate, and decreased the runoff. Interactions between tillage and nitrogen fertilizer were also not significant for wheat in 1991/92 growing season.

Through the 1991/92 growing season grain yield, water storage, W.U.E and F.U.E were more than those during 1990/91 growing season. These results may have occurred due to the more rainfall amount and distribution during 1991/92 growing season. For that, the highest yield obtained in 1991/92 growing season was due to effective use of nitrogen fertilizer dosages applied resulted specially the enough soil moisture at the time of the third dose application.

Figures 9 and 10 present the total depths of seasonal soil moisture content (mm)/120 cm soil depth for the continuous wheat treatments during the 1990/91 and 1991/92 growing seasons, for the three nitrogen dosages subtreatments. With respect to monthly depth of water there were no differences between moldboard plow and chisel plow treatments. Also by splitting the nitrogen fertilizers there were no effects on total depths of water stored per 120 cm soil depth from January to November for the 1990/91 growing season (Figure 9). Whereas, for the 1991/92 growing season, monthly depth of moisture in the soil profile was the highest under moldboard-(N1) interaction compared to other interactions. While for chisel interactions treatments, there were no significant differences with respect to moisture depths (Fig. 10).

In general, monthly soil moisture depth stored during 1991/92 growing season for all interactions were higher than those during the 1990/91 growing season.

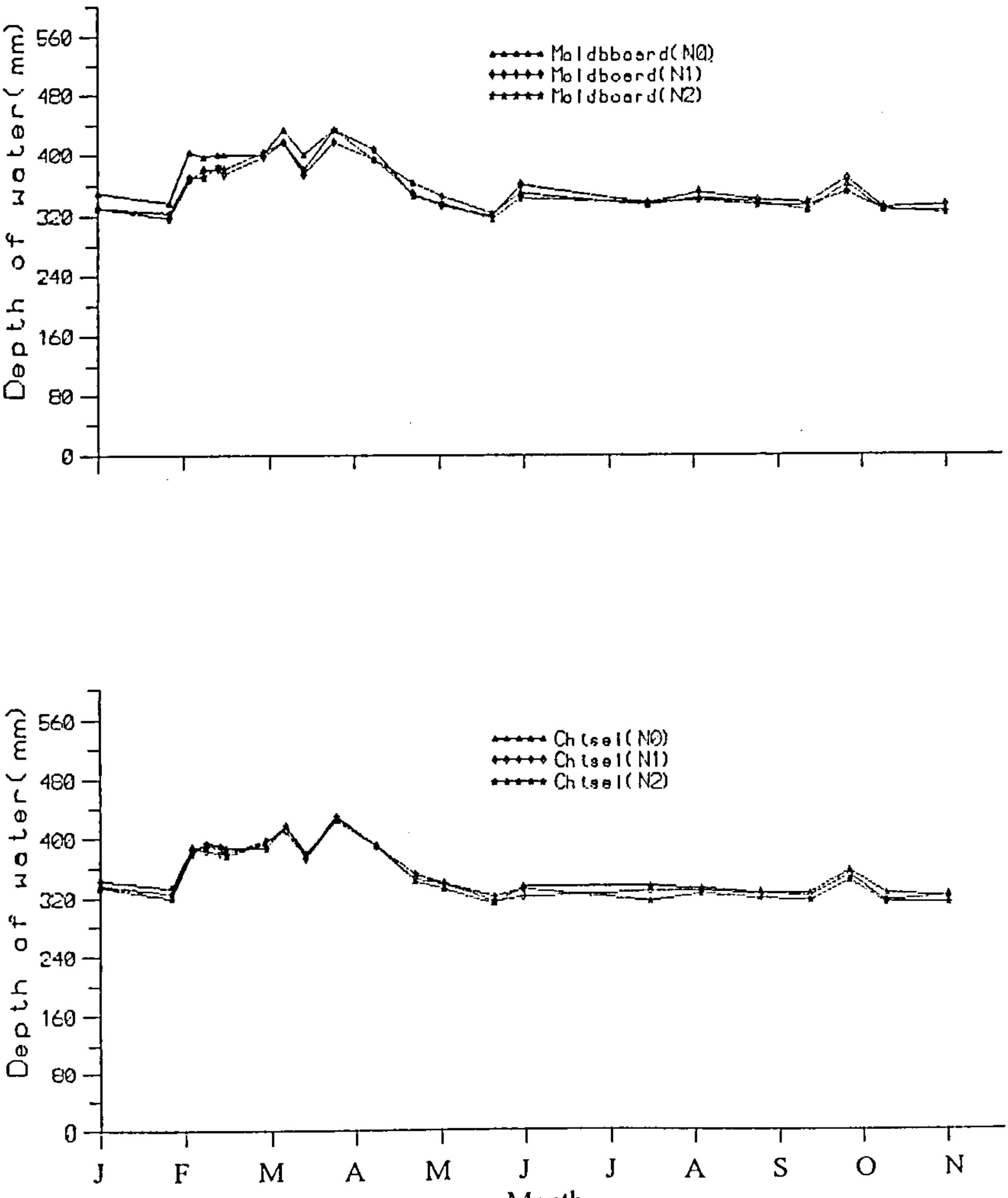


Fig. 9: Total depth of soil moisture content /120 cm soil depth for the continuous wheat experiment during the (1990-91) season.

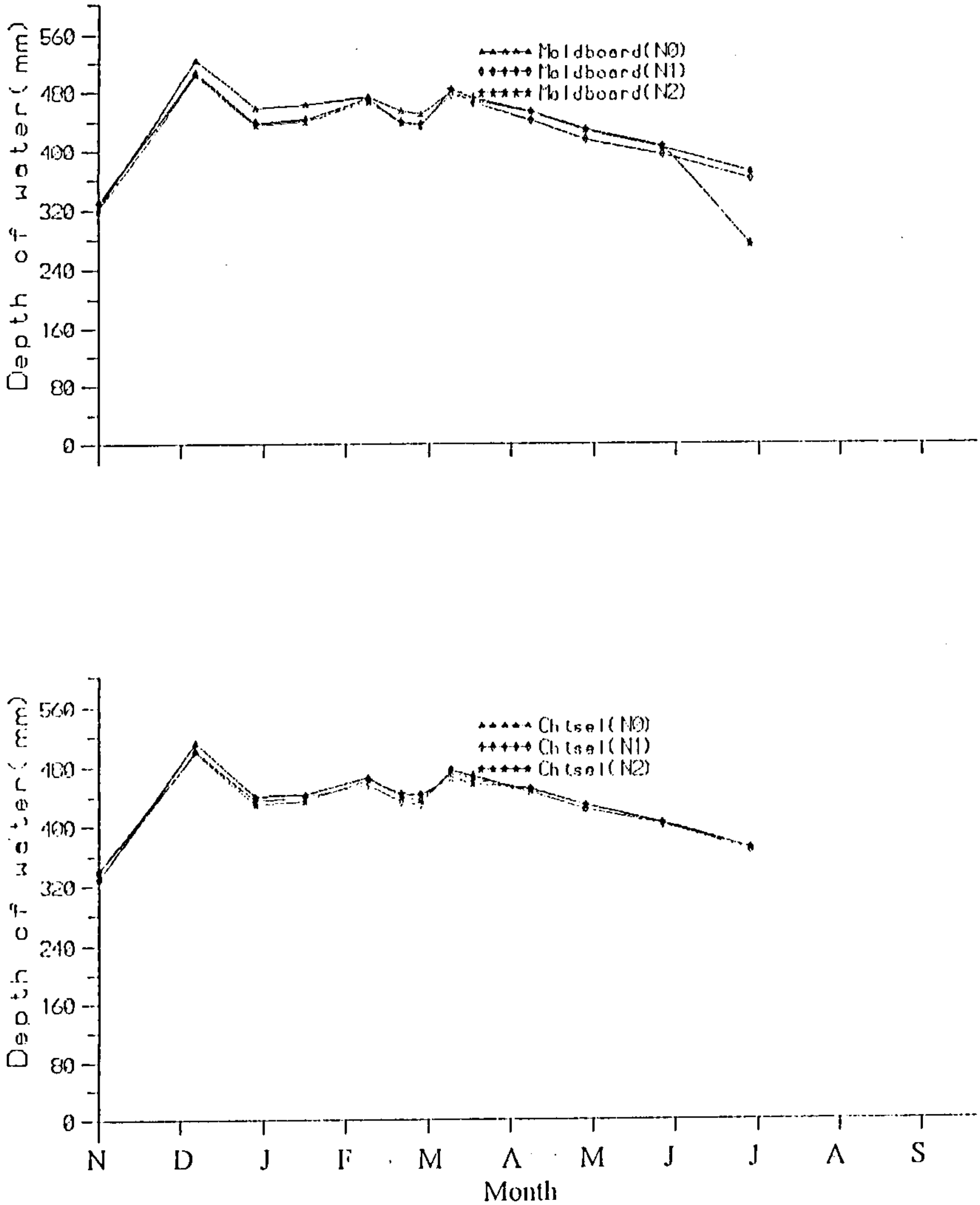


Fig. 10: Total depth of soil moisture content /120 cm soil depth for the continuous wheat experiment during the (1991-92) season.

4-2-2-2 Yield and Yield Components:

Tables 9 and 10 represent means of crop parameters for the different tillage-nitrogen treatments, for the continuous wheat rotation during 1990/91 and 1991/92. The results show that tillage and nitrogen doses treatments had a significant effect on spike numbers only, in 1990/91 and 1991/92 growing seasons. However, during 1990/91, grain yield and spike number, under moldboard plow, were higher than those under chisel plow. Whereas straw yield and plant height were higher under chisel plow than under moldboard plow. N2 treatment showed the highest grain yield and plant height when compared to N1 and N3 treatments. Highest grain yield was highest under moldboard (T2) plow interacted with N2 sub-treatment, while chisel plow interacted with N3 gave highest straw yield and plant height.

Whereas, during 1991/92 growing season, grain yield, straw yield, and plant height were found to be higher under the chisel plow (T1) when compared to the moldboard plow, (T2). This result may have occurred due to the more residues under chisel plow followed by sweep, than under moldboard, which resulted in high permeability and low evapotranspiration, under chisel plow. The interaction of the different tillage and nitrogen dosages were not significant with respect to all crop parameters in 1990/91 and 1991/92 growing season.

4-2-3 Duck-foot fallow-wheat rotation:

4-2-3-1 Soil moisture and crop yield:

Tables 11 and 12 represent a comparison between ETc, depletion, W.S.E, W.U.E, runoff, and grain yield under different tillage-nitrogen

Table 9 : Means of different variables for each tillage method (nitrogen doses confounded) and each nitrogen doses (tillage method confounded) for continuous wheat in 1990/91 growing season.

Parameters	Grain yield (Mg/ha)	Straw yield (Mg/ha)	Plant height (cm)	Spike No. /0.5m^2
Chisel	0.69a+	6.27a	66.9a	82.0b
Moldboard	0.77a	4.71a	56.0a	94.9a
N1	0.81a	6.04a	59.3a	77.2c
N2	0.91a	5.23a	62.8a	87.3b
N3	0.47a	5.19a	62.2a	100.8a
F-test:				
T	NS	NS	NS	*
N	NS	NS	NS	*
T x N	NS	NS	NS	NS

+ Along each column, values followed by the same letter are not significantly different at the 5% level according to DMRT.
T= tillage practices.
N= nitrogen fertilizer splitung.
*= significant at the .05 level; NS not signifcant.

Table 10: Means of different variables for each tillage method (nitrogen doses confounded) and each nitrogen doses (tillage method confounded) for continuous wheat in 1991/92 growing season.

Parameters	Grain yield (Mg/ha)	Straw yield (Mg/ha)	Plant height (cm)	Spike No. /0.5m^2
Chisel	2.75a+	10.33a	82.2a	120.9b
Moldboard	2.61a	10.25a	71.1a	135.0a
N1	2.38a	8.96a	72.8a	98.3c
N2	2.58a	10.52a	74.8a	125.7b
N3	3.09a	11.38a	82.3a	159.7a
F-test:				
T	NS	NS	NS	*
N	NS	NS	NS	**
T x N	NS	NS	NS	NS

+ Along each column, values followed by the same letter are not significantly different at the 5% level according to DMRT.
T= tillage practices.
N= nitrogen fertilizer splitung.
*, **= significant at .05 and .01 levels respectively; NS not signifcant.

Table 11: Soil moisture depletion, soil moisture storage, water storage efficiency, and runoff under different tillage treatments in duck-foot fallow in Mushagar (1990/91).

Parameters	Depletion (mm)	Storage (mm)	W.S.E.(%)	Runoff (mm)
Chisel	338.3 ns	266.0 ns	99.6 ns	1.1 ns
Moldboard	254.0 ns	266.9 ns	99.9 ns	0.2 ns

ns= not significant.

Table 12: Average evapotranspiration, soil moisture depletion, soil moisture storage, water storage efficiency, water use efficiency, fertilizer use efficiency, and runoff under different tillage treatments (nitrogen doses confounded) and nitrogen doses (different tillage treatments confounded) in duck-foot fallow-wheat in Mushaqqar for wheat crop (1991-92).

Parameters	Grain yield (Mg/ha)	ETc (mm)	Depletion (mm)	Storage (mm)	W.S.E (%)	W.U.E.1 (kg/mm)	W.U.E.2 (kg/mm)	F.U.E (kg/kg)	Runoff (mm)
Chisel	3.85a+	326.4a	435.2a	458.6a	65.0a	1.19a	5.46a	64.1a	235.8a
Moldboard	3.40a	338.0a	447.5a	459.1a	67.1a	1.00a	4.57a	56.6a	225.3a
N1	3.26a	327.5a	437.3a	453.7a	66.3a	1.00a	4.50a	54.3a	230.7a
N2	3.71a	338.6a	445.6a	454.4a	66.4a	1.10a	5.15a	61.8a	230.0a
N3	3.90a	330.4a	441.2a	453.5a	66.3a	1.18a	5.38a	65.0a	230.9a
F-test:									
T	NS	NS	NS	NS	NS	NS	NS	NS	NS
N	NS	NS	NS	NS	NS	NS	NS	NS	NS
T x N	NS	NS	NS	NS	NS	NS	NS	NS	NS

1 : Water use effeciency based on grain yield.
2 : Water use effecienty based on biological yield.
+ Along each column, values followed by the same letter are not significantly different at the 5% level according to DMRT.
T= tillage practices.
N= nitrogen fertilizer splitung.
NS= not signifcant.

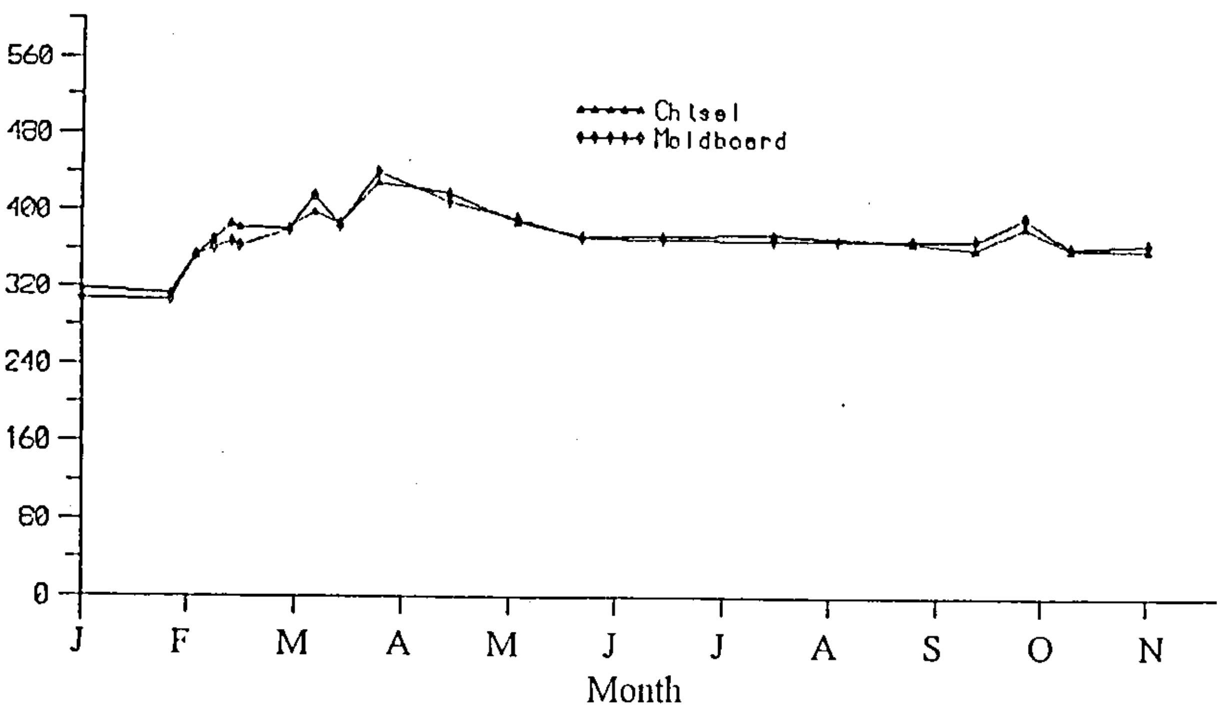


Fig. 11: Total depth of soil moisture content /120 cm soil depth for the duck-foot fallow experiment during the (1990-91) season.

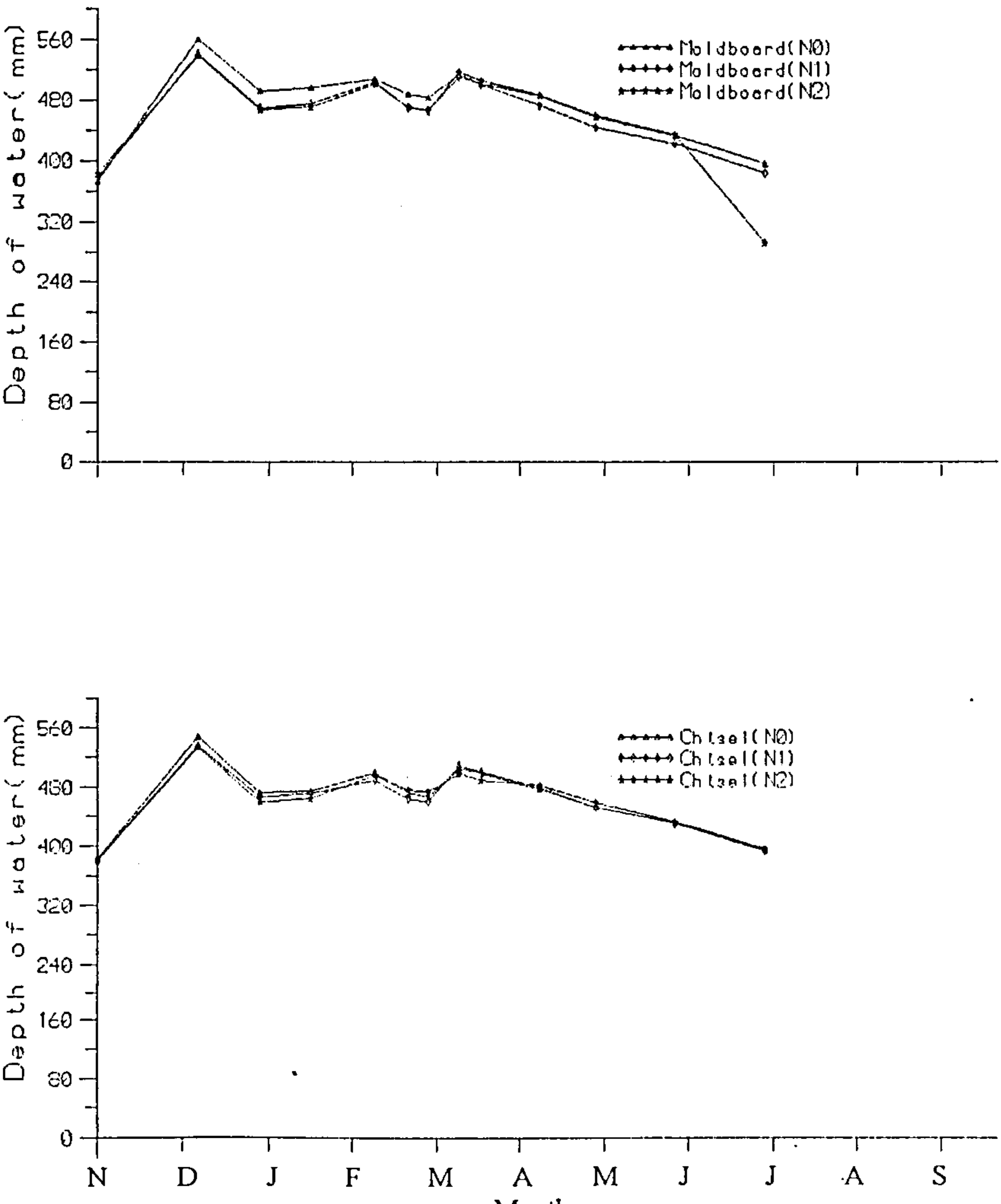


Fig. 12: Total depth of soil moisture content /120 cm soil depth for the duck-foot fallow experiment during the (1991-92) season.

4-2-3-2 Yield and yield components:

Table 13 presents means for crop parameters under different tillage-nitrogen treatments for duck-foot fallow-wheat rotation.

During 1991/92 season, grain yield, straw yield, and spike number were higher under T1 than for T2. Similar trend was obtained for the N3 treatment compared to N1 and N2. Also similar trend was obtained under the T1N3 interaction compared to other interactions.

Similar trend was found under wheat in continuous wheat rotation, where T1N3 interaction represent the highest grain yield, straw yield, plant height, and spike numbers when compared with other interactions. The availability of soil moisture reduced the effect of the tillage treatments and increased the efficiency of the third dose uptake by wheat crop.

4-2-4 Chemical fallow-wheat rotation :

4-2-4-1 Soil moisture and crop yield:

Tables 14 and 15 show ETc, soil moisture depletion, W.S.E, W.U.E, runoff and grain yield values under different tillage-nitrogen treatments for wheat during 1990/91 and 1991/92 growing seasons. No significant differences were found due to either main and submain treatments in 1990/91 season. This is because there was no practices applied except controling weeds chemically and left as fallow.

During 1991/92 growing season although there were no significant differences between treatments, the highest ETc, soil moisture depletion and storage, W.S.E., and grain yield were found under moldboard plow. Also ETc, soil moisture depletion and storage, W.S.E, grain yield and F.U.E found to be the highest for T2N3 interaction when compared with other

Table 13: Means of different variables for each tillage method (nitrogen doses confounded) and each nitrogen doses (tillage methods confounded) for duck-foot fallow-wheat in 1991/92 growing season.

Parameters	Grain yield (Mg/ha)	Straw yield (Mg/ha)	Plant height (cm)	Spike No. /0.5m^2
Chisel	3.85a+	12.83a	93.3b	151.4a
Moldboard	3.40a	11.87a	101.8a	150.7a
N1	3.26a	11.33a	101.0a	140.0a
N2	3.71a	11.98a	93.5a	141.8a
N3	3.90a	13.75a	98.2a	171.3a
F-test:				
T	NS	NS	*	NS
N	NS	NS	NS	NS
T x N	NS	NS	NS	NS

+ Along each column, values followed by the same letter are not significantly different at the 5% level according to DMRT.
T= tillage practices.
N= nitrogen fertilizer splitung.
*= significant at the .05 level; NS not signifcant.

Table 14: Soil moisture depletion, soil moisture storage, water storage efficiency, and runoff under different tillage treatments in chemical fallow in Mushaqqar (1990/91).

Parameters	Depletion (mm)	Storage (mm)	W.S.E.(%)	Runoff (mm)
Chisel	295.7 ns	259.3 ns	97.1 ns	7.8 ns
Moldboard	304.0 ns	266.8 ns	99.9 ns	0.3 ns

ns= not significant

Table 15: Average evapotranspiration, soil moisture depletion, soil moisture storage, water storage efficiency, water use efficiency, fertilizer use efficiency, and runoff under different tillage treatments (nitrogen doses confounded) and nitrogen doses (different tillage treatments confounded) in chemical fallow-wheat in Mushaqqar for wheat crop (1991-92).

Parameters	Grain yield (Mg/ha)	ETc (mm)	Depletion (mm)	Storage (mm)	W.S.E (%)	W.U.E.1 (kg/mm)	W.U.E.2 (kg/mm)	F.U.E (kg/kg)	Runoff (mm)
Chisel	3.08a+	344.7a	418.0a	398.5a	58.2a	1.01a	4.56a	57.5a	285.9a
Moldboard	3.25a	378.3a	445.4a	409.4a	59.8a	0.86b	4.02a	54.3a	275.0a
N1	2.42a	358.4a	431.2a	405.9a	59.3a	0.83a	3.88a	49.8a	278.5a
N2	3.44a	362.6a	431.5a	401.7a	58.7a	0.93a	4.33a	57.3a	282.7a
N3	3.65a	363.5a	432.4a	404.2a	59.1a	1.03a	4.65a	60.9a	280.2a
F-test:									
T	NS	NS	NS	NS	NS	*	NS	NS	NS
N	NS	NS	NS	NS	NS	NS	NS	NS	NS
T x N	NS	NS	NS	NS	NS	NS	NS	NS	NS

1 : Water use effeciency based on grain yield.
2 : Water use effecienty based on biological yield.
+ Along each column, values followed by the same letter are not significantly different at the 5% level according to DMRT.
T= tillage practices.
N= nitrogen fertilizer splitung.
*= significant at the .05 level; NS not signifcant.

interactions.This may be due to more available moisture, and so the nitrogen utilization was better due to deeper plow by moldboard plow.

Figures 13 and 14 present the total depth of soil moisture /120 cm soil depth for chemical fallow-wheat rotation during 1990/91 and 1991/92 growing seasons. Figure 13 shows no differences in total depth of moisture stored, during the 1990/91 between treatments and their interactions. This was because there were no practices applied except the application of herbicide and left as fallow, which caused water losses through evaporation, because there was no planting in first season. Similar results were found during 1991/92 growing season. Whereas, during the 1991/92 season, the total depth of moisture stored was higher than that for 1990/91 growing seasons. The higher availability of moisture in 1991/92 due to the higher rainfall minimized the effect of the plowing treatments.

4-2-4-2 Yield and yield components:

Table 16 presents means for crop parameters in different tillage-nitrogen

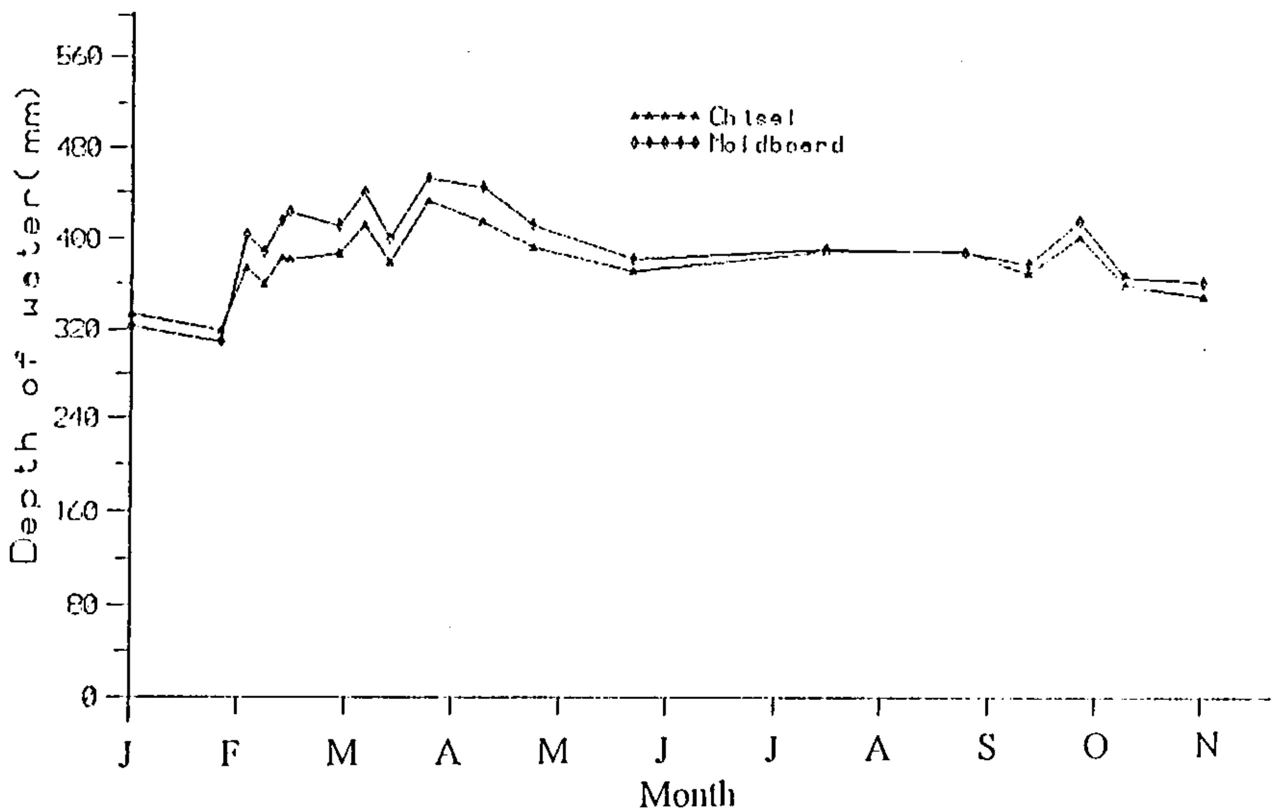


Fig. 13: Total depth of soil moisture content /120 cm soil depth for the chemical fallow experiment during the (1990-91) season.

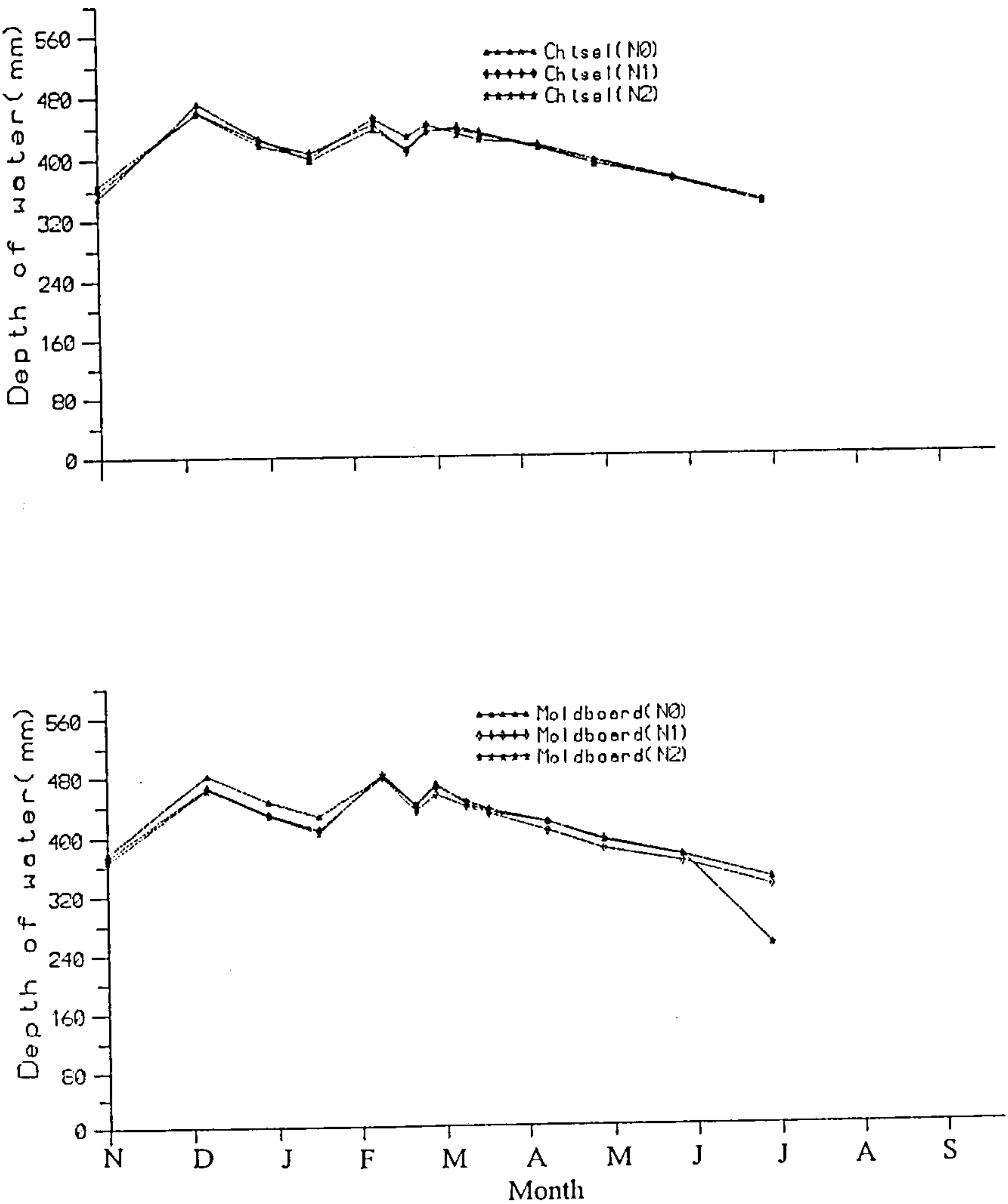


Fig. 14: Total depth of soil moisture content /120 cm soil depth for the chemical fallow experiment during the (1991-92) season.

Table 16: Means of different variables for each tillage method (nitrogen doses confounded) and each nitrogen doses (tillage method confounded) for chemical fallow- wheat in 1991/92 growing season.

Parameters	Grain yield (Mg/ha)	Straw yield (Mg/ha)	Plant height (cm)	Spike No. /0.5m^2
Chisel	3.46a+	12.22a	88.0a	121.2a
Moldboard	3.26a	11.83a	86.9a	118.2a
N1	2.99a	10.92a	85.2a	98.3a
N2	3.44a	12.14a	88.3a	111.7a
N3	3.65a	13.01a	88.8a	149.1a
F-test:				
T	NS	NS	NS	NS
N	NS	NS	NS	NS
T x N	NS	NS	NS	NS

+ Along each column, values followed by the same letter are not significantly different at the 5% level according to DMRT.
T= tillage practices.
N= nitrogen fertilizer splitung.
NS= not signifcant.

4-3 Effect of crop rotations on soil moisture content :

Figures 15, 16, and 17 present comparisons between chisel plow and moldboard plow under different rotations, namely: continuous wheat; duck-foot fallow-wheat; and chemical fallow-wheat, with respect to total depths of moisture stored during the 1990/91 and 1991/92 growing seasons. Both chisel and moldboard plows under chemical fallow, gave highest total depth of moisture stored as compared to duck-foot fallow which was higher than continuous wheat rotation by the end of 1990/91 growing season.

These results may have occured due to the complete removal of wheats by chemical fallow. While in duck-foot fall there were still weeds which caused water depletion and higher evaporation out of soil profile. Besides, more water was depleted by continous wheat crop which resulted in lowest water stored in the soil profile.

In 1991/92 growing season the monthly stored water was the highest for chisel plow and moldboard at duck-foot fallow rotation followed by chisel and moldboard at continuous wheat rotation, and then the lowest stored water was obtained under chemical fallow rotation for both chisel and moldboard plows (Fig. 18).

These results may have been due to the fact that under duck-foot fallow-wheat rotation during 1991/92 season, more storage of water was recorded due probably to the high permeability in the soil profile, when compared to chemical fallow-wheat rotation where there was higher runoff due to compaction of soil through the previous season producing the lowest storage of water.

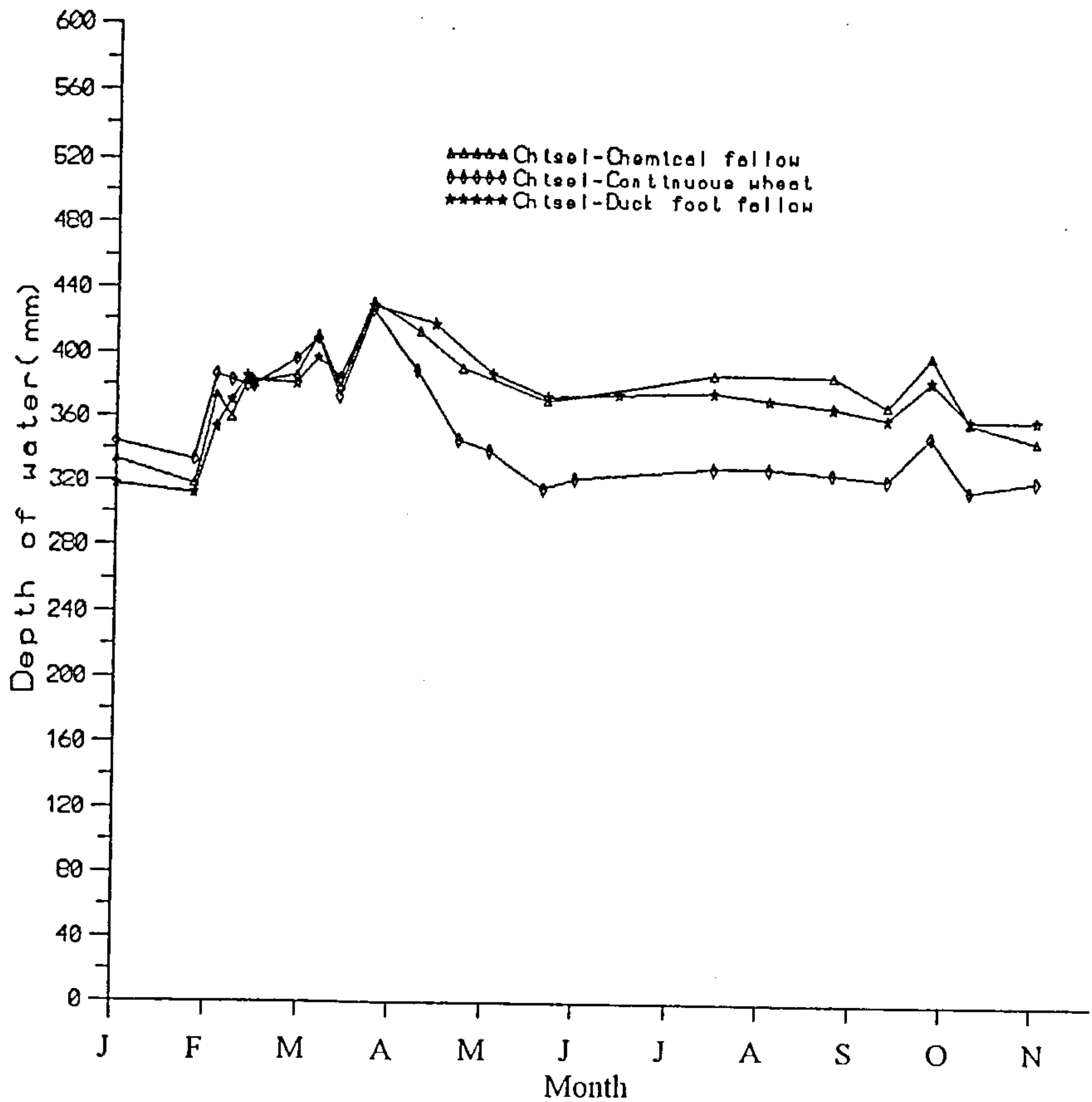


Fig. 15: Total depth of soil moisture content /120 cm soil depth for the interactions of chisel plow with the three rotations during the (1990-91) season.

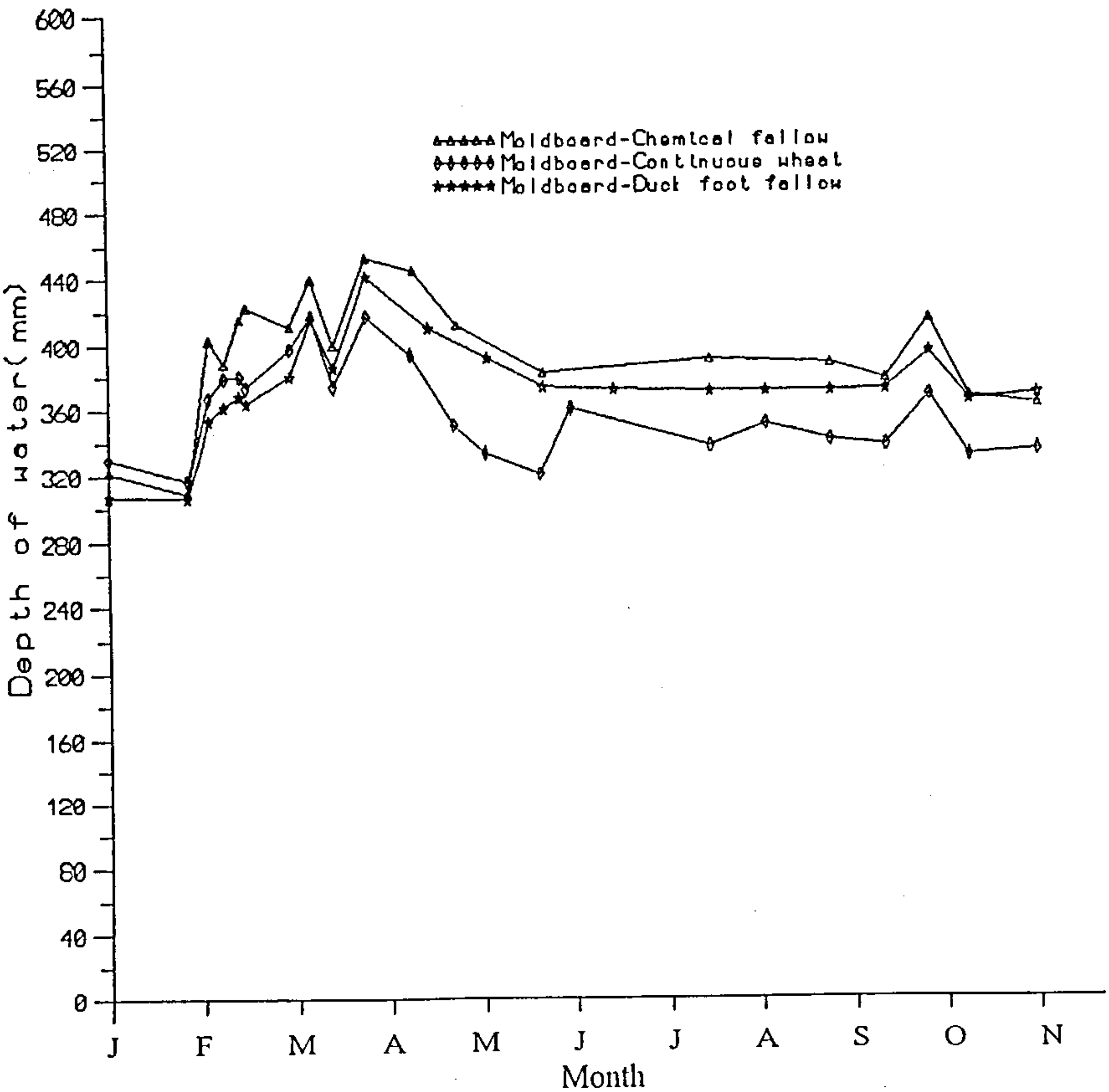


Fig. 16: Total depth of soil moisture content /120 cm soil depth for the interactions of moldboard plow with the three rotations during the (1990-91) season.

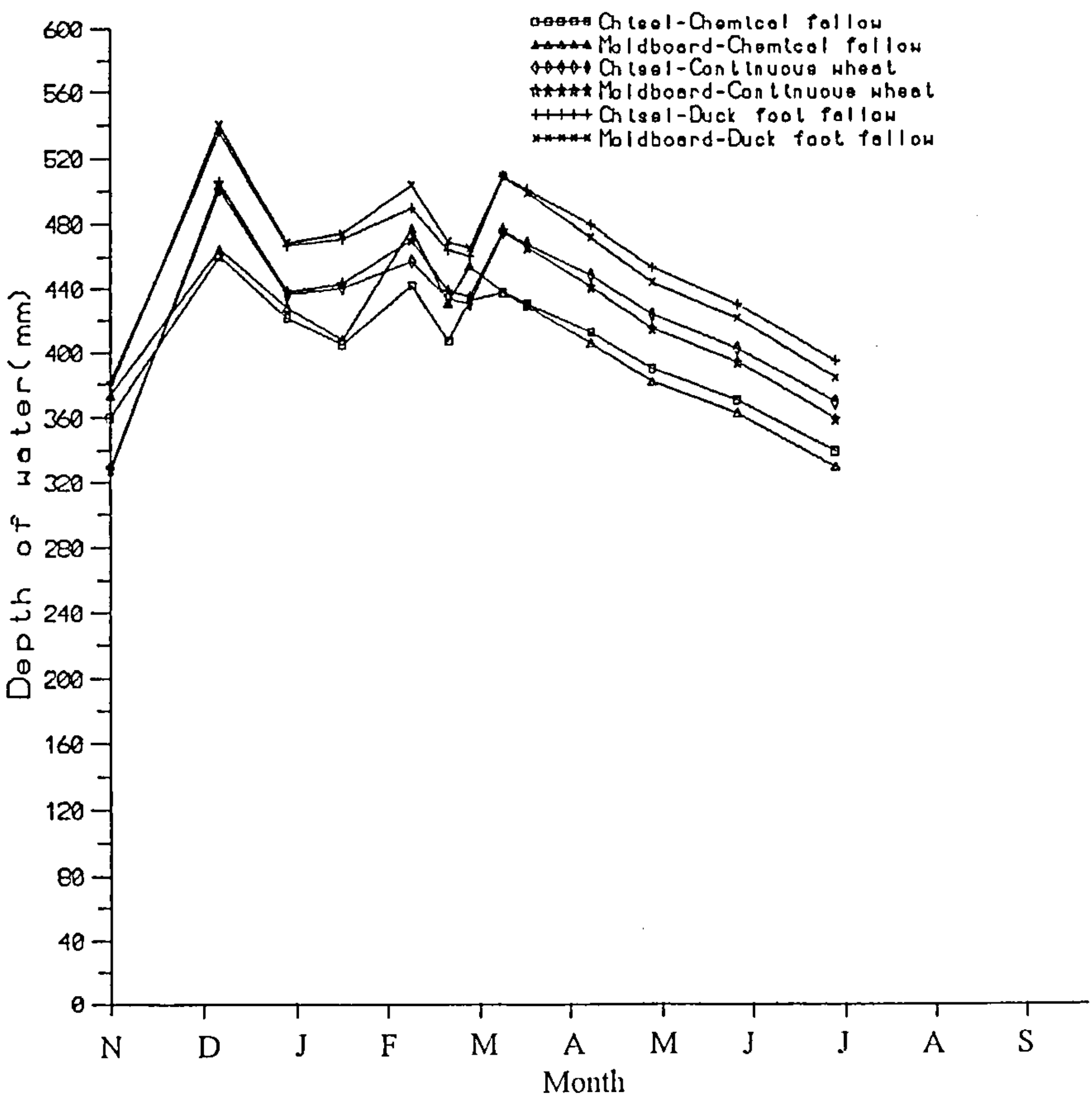


Fig. 18: Total depth of soil moisture content /120 cm soil depth for the interactions of chisel and moldboard plow with the three rotations during the (1991-92) season.

5 - Summary , Findings, and Conclusions

Two studies were carried out in Mushaqqar Agricultural Experimental Station, located approximately 28 km South West Amman, on fine, montmorillonitic, thermic, entic chromoxerert soil. The rainfall amounts were 267.1 and 584.4 mm for 1990/91 and 1991/92 seasons, respectively.

The objectives of this study were 1. To study the effect of using different nitrogen fertilizers forms, namely: nitrate; and ammonium, on wheat yield components. 2. To evaluate two methods of N-fertilizers applications, namely: broadcasting followed by seeding or broadcasting the fertilizers followed by incorporating them in the soil then seeding the field. 3. To study the effects of different methods of nitrogen fertilizers application on water consumptive use of wheat crop, soil moisture content, and their relation with wheat yield. 4. To study the effects of the rate of N-fertilizer and timing of addition on wheat growth, and its relations with the yield and yield components, under two tillage practices, namely: chisel and moldboard, and wheat-fallow crop rotations, in the Mushaqqar area.

In both experiments a split plot in randomized complete block design was used with three replications. In the first experiment the application methods assigned as main treatments, whereas the nitrogen fertilizer forms were used as submain treatments. While in experiment two a moldboard plow and chisel plow were assigned as main treatments and nitrogen fertilizer splitted once, twice, and three times, as submain treatments. This design was used in 1990/91 and 1991/92 growing seasons.

The results obtained from both experiments can be summarized as follows :-

1. The two methods of nitrogen fertilizers application were not significantly different with respect to all the crop and soil moisture parameters measured during 1990/91 growing season. Whereas, during 1991/92 growing season, soil moisure storage from rainfall, water storage efficiency and fertilizer use efficiency showed significance, where, broadcasting of nitrogen fertilizers on the soil surface had resulted in higher values than its incorporation within the soil.

2. Urea fertilizer (F1) resulted in lowest values with respect to crop evapotranspiration, and soil moisture depletion. Whereas, potassium nitrate resulted in higher crop ETc and soil moisture depletion. Ammonium sulfate resulted in higher soil moisture storage from rainfall and lower grain yield.

3. Under broadcasting treatments higher soil residual phosphorus was found in surface than subsurface samples, and a higher NH4-N, NO3-N and TMN residual in subsurface samples. Under urea fertilizer highest NH4-N, NO3-N and TMN residuals were found as compared to the other nitrogen fertilizers forms in surface samples.

4. Results of soil residual phosphorus indicates that there was a phosphorus deficiency under all treatments due to the higher nitrogen uptake.

5. Incorporation of urea nitrogen fertilizer resulted in higher nitrogen content of wheat, compared to KNO_3, or $(NH_4)_2SO_4$ fertilizers.

6. There is no big difference between duck-foot fallow and chemical fallow practices with respect to total depth of water stored from rainfall.

7. In continuous wheat rotation :

   a. During 1990/91 there was no significancy between chisel and moldboard plows with regard to all soil moisture parameters, while in 1991/92 under moldboard plows more water from rainfall was stored. And more water storage from rainfall and less runoff were found as compared to chisel plow.

   b. During 1990/91 highest grain yield, water use efficieny, W.U.E and fertilizer use efficiency, F.U.E. were found when splitting the nitrogen fertilizer into two dosages at planting and tillering stages. Whereas during 1991/92, splitting the nitrogen into three dosages gave highest grain yield, W.S.E and F.U.E.

8. In duck-foot fallow-wheat rotation :

   There was no significancy for grain yield and for all soil moisture parameters tested between tillage and nitrogen treatments. Under moldboard plow and under splitting the nitrogen fertilizer into two dosage, higher ETc, depletion, soil moisture storage from rainfall, water storage efficiency, and grain yield were found.

9. In chemical fallow-wheat rotation :
   Under moldboard plow and splitting of nitrogen fertilizer into three dosages during 1991/92 growing season, the highest ETc, depletion soil moisture storage from rainfall, W.S.E, and grain yield were found.

10. In 1990/91 growing season, under both chisel and moldboard plows, using chemical fallow technique resulted in highest total depth of water stored compared to duck-foot fallow technique which was higher than continuous wheat rotation.

11. In 1991/92 growing season, the water stored was the highest for chisel and moldboard at duck-foot fallow rotation followed by chisel and moldboard at continuous wheat rotation, whereas the lowest water stored was obtained for both chisel and moldboard plows under chemical fallow rotation. This may have resulted from intensive rainfall during the second growing season which minimized the effect of fallow technique.

Recommendation:

1- As there is no differences between the usage of chisel and moldboard plowing, chisel plowing is recommended because it is cheaper.

2- The application of nitrogen fertilizer in three doses is recommended, specially when there is expected rainfall at the time of application of the third dosage.

3- Fallowing the land is recommended to conserve soil moisture for the next season, and the continuity of wheat planting should be avoided.

4- The application of urea fertilizer is recommended to produce high yield and due to its availability in market.

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٧. ملخص عربي

تأثير ادارة السماد النيتروجيني واستنفاذ الرطوبة على انتاج القمح في منطقة مطرية في الاردن.

456215

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الاشراف

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اجريت تجربتين في محطة المشقر للابحاث الزراعية على بعد ٣٠ كم جنوب غرب عمان. يسقط على منطقة المشقر معدل امطار سنوي ٣٥٠ ملم، وتصنف تربة المشقر كتربة طينية متشققه (Fine, montmorillonatic, thermic, entic chromoxerert) .تهدف هذه التجربة لدراسة تأثير ادارة انواع مختلفة من المحاريث و السماد النيتروجيني على حفظ واستنفاذ رطوبة التربة وانتاج القمح.

أجريت التجربتين باستخدام النظام العشوائي الكامل مع القطع المنشقة في ثلاث مكررات. تضمنت التجربة الاولى طريقتين لاضافة السماد النيتروجيني؛ النثر والخلط، والتي وزعت كمعاملات رئيسية. ووزع انواع السماد النيتروجيني؛ اليوريا وسولفات الامونياك ونيترات البوتاسيوم، على القطع المنشقة. واستخدمت في التجربة الثانية معاملات الحراثة؛ محراث السكك و الازميلي كمعاملات رئيسية، ووزعت معاملات اضافة السماد النيتروجيني على عدة جرعات؛ جرعة واحدة وجرعتين وثلاث جرعات، على القطع المنشقة. وقد اجريت التجربتين في موسمين ١٩٩٠/٩١ و ١٩٩١/٩٢.

أظهرت النتائج انه لم يكن هناك تأثير لطريقة اضافة السماد النيتروجيني على رطوبة التربة. واضافة سماد اليوريا في موسم ١٩٩١/٩٢ أثر على عوامل الرطوبة المقاسة كما اعطى اعلى انتاج للقمح وأعلى مخلفات نيتروجينية معدنية. استخدام حراث رجل البطة خلال فترة الكراب اعطى اعلى انتاج للقمح مقارنة مع استخدام الكيماويات خلال فترة الكراب لمقاومة الاعشاب. تحصل على اقل انتاج للقمح في حالة استمرار زراعة الارض لمحصول القمح. استخدام معاملة محراث السكك في جميع الدورات اعطى اعلى انتاج للقمح او اعلى تخزين لرطوبة التربة مقارنة للمحراث الازميلي خلال موسم ١٩٩١/٩٢.