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Title: NITRATE-NITROGEN ACCUMULATION AND DISTRIBUTION IN THE SOIL PROFILE DURING A FALLOW GRAIN ROTATION AS INFLUENCED BY DIFFERENT LEVELS OF SOIL PROFILE MOISTURE

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The effect of different soil moisture levels on the amount and location of NO_3-N accumulation in the soil profile were studied.

The cultivars used in this study were Mcdermid, a soft white winter wheat, and Hudson, a medium early winter barley.

Moisture treatments simulating dry, normal and wet fallow seasons were created by observing the actual precipitation pattern during the season and adjusting the accumulated averages to equal the calculated averages.

Data were obtained for soil profile NO_3-N, soil profile moisture, grain yield, spike per square meter, and 1000 kernel weight.

The effects of fallow moisture levels on NO_3-N accumulation in the soil profile were found significant. The highest NO_3-N accumulation in the soil profile occurred under normal fallow moisture levels. At dry fallow moisture levels NO_3-N accumulation was lowest. Higher levels of profile moisture adversely affected the NO_3-N accumulation in the wet fallow plots. The 0-30 cm soil depth appeared to be an accumulation zone for NO_3-N for all fallow moisture levels at the end of the fallow period.

The effect of residual nitrate on NO_3-N accumulation was highly significant in the spring of the fallow season. High residual nitrate of more than about 6 ppm in the soil profile suppressed NO_3-N accumulation at each moisture level as compared to the initial levels.

Grain yields were influenced by both nitrogen rate and fallow moisture levels. Increasing nitrogen rate to 56 kg/ha resulted in an increase in the grain yield at all moisture levels. Beyond 56 kg/ha nitrogen, all moisture treatments showed a decrease in grain yield.

Fallow moisture levels did not influence 1000 kernel weight. Increased nitrogen rates significantly decreased 1000 kernel weight at each moisture level, except in the dry fallow plots.

Increasing soil profile moisture resulted in an increase in spike number per square meter. Both cultivars produced more spikes/m^2 while nitrogen rate increased to 112 kg/ha at all moisture levels, except in the wet fallow plots with 112 kg/ha N.

Cultivars showed highly significant difference in Water Use Efficiency. Hudson had higher W. U. E. (11.7 kg/ha-mm) than McDermid (9.9 kg/ha-mm). There were no significant effects of the fallow moisture levels on W. U. E.; however, the W. U. E. was increased significantly as the nitrogen rate increased to 56 kg/ha for both cultivars.

Nitrate Nitrogen Accumulation and Distribution in the Soil Profile during a Fallow Grain Rotation as Influenced by Different Levels of Soil Profile Moisture

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TABLE OF CONTENTS

	Page
Introduction	1
Literature Review	3
Nitrogen for Wheat and Barley in Dryland Farming	3
Effect of Cropping System on Nitrogen Loss	9
Nitrate Nitrogen Production in Soils : Nitrification	11
Immobilization of the Nitrogen in Soils : Denitrification	16
Nitrate Nitrogen Movement Through the Soil Profile	18
Factors Affecting Nitrate Accumulation in Soils	20
Material and Methods	23
Plant Materials	23
Location	23
Experiments	24
Soil Sampling	32
Measurements	34
Results and Discussion	36
Experiment I	36
NO_3-N Movement and Accumulation Under Cultivars	36
Soil Profile Moisture After Harvest	39
Grain Yield	42
1000 Kernel Weight	46
Spikes Per Square Meter	46
Effect of Fallow Moisture on NO_3-N Accumulation	48
Experiment II	61
Effect of Fallow Moisture Level on NO_3-N Accumulation	61
Grain Yield	67
1000 Kernel Weight	76
Spikes Per Square Meter	72
Water Use Efficiency	76
Total Soil Profile NO_3-N After Harvest	80
Summary and Conclusions	85
Bibliography	88

LIST OF TABLES

Table		Page
1 a	Experiment I. Initial soil test values for the Walla Walla silt loam soil sampled at five depths	25
1 b	Experiment II. Initial soil test values for the Walla Walla silt loam soil sampled at five depths	25
2	Monthly average and cumulative amount of rainfall during fallow period with three different precipitation patterns (1912-1974)	26
3	Monthly average and cumulative amount of rainfall during cropping period with three different precipitation patterns (1912-1974)	26
4	Experiment I. Monthly precipitation on experimental plots with three levels of moisture during 1975-76 fallow period	31
5	Experiment II. Monthly precipitation on experimental plots with three levels of moisture during 1974-75 fallow period	33
6	Experiment I. Observed mean squares for soil profile NO_3-N during 1974-75 cropping season	37
7	Experiment I. Mean 1000 Kernel weight, Spikes/m^2, Soil profile moisture and NO_3-N at three nitrogen levels	38
8	Experiment I. NO_3-N distribution in the soil profile under the wheat and barley cultivars during the 1974-75 growing season and after harvest	39
9	Experiment I. Moisture distribution in the soil profile under the wheat and barley cultivars after harvest	42
10	Experiment I. Observed mean squares for three agronomic traits of two cultivars, total soil profile NO_3-N, and average soil profile moisture during the 1974-75 crop season	43

Table		Page
11	Experiment I. Moisture distribution in the soil profile at three fallow moisture levels at two sampling dates during the 1975-76 fallow season	48
12	Experiment I. NO_3-N in the soil profile at three fallow moisture levels and three residual nitrogen rates at two sampling dates from plots grown in winter wheat and barley the previous season (1974-75)	51
13	Experiment I. NO_3-N accumulation in the soil profile as influenced by three levels of soil profile moisture x residual nitrate nitrogen after wheat and barley cultivars in 1975-76 fallow season	56
14	Experiment I. Observed mean squares for NO_3-N in the soil profile on April 22, and July 1, 1976	58
15	Experiment I. Observed mean squares for the total NO_3-N in the soil profile on July 1, 1976	59
16	Experiment I. Mean total NO_3-N in the soil profile at three levels of fallow moisture and three nitrogen rates on July 1, 1976	59
17	Experiment II. Moisture distribution in the soil profile at three levels of fallow moisture at two sampling dates during 1974-75 fallow season	61
18	Experiment II. NO_3-N distribution in the soil profile as influenced by three levels of fallow moisture during the 1974-75 fallow season	63
19	Experiment II. Observed mean squares for soil profile NO_3-N during the 1974-75 fallow season	68
20	Experiment II. Mean soil profile NO_3-N at three levels of fallow moisture during the 1974-75 fallow season	68
21	Experiment II. Mean NO_3-N distribution in the soil profile as influenced by three levels of fallow moisture during the 1974-75 fallow season at two sampling dates	69

Table		Page
22	Experiment II. Effect of three nitrogen levels at three levels of fallow moisture on grain yield, water use (W. U. E.) and nitrogen use (N. U. E.) efficiencies	70
23	Experiment II. Observed mean squares for grain yield, spike/m^2, 1000 kernel weight, water use efficiency (W. U. E.), soil profile total NO_3-N, and average soil profile moisture after harvest during the 1975-76 season	73
24	Experiment II. Mean grain yield, spike/m^2, 1000 kernel weight, W. U. E., soil profile total NO_3-N, and average soil profile moisture after harvest during the 1975-76 season	74
25	Experiment II. Moisture distribution in the soil profile after harvest at three fallow moisture levels as influenced by nitrogen rates during the 1975-76 season	77
26	Experiment II. NO_3-N in the soil profile under the wheat and barley cultivars during the 1975-76 crop season	81

LIST OF FIGURES

Figure		Page
1	Experiment I. Cumulative precipitation on the experimental plots for three levels of fallow moisture during 1974-75 fallow period and long term (1912-1974) precipitation pattersn for wet, normal, and dry fallow seasons	28
2	Experiment II. Cumulative precipitation on the experimental plots for three levels of fallow moisture during 1975-76 fallow period and long term (1912-1974) precipitation patterns for wet, normal, and dry fallow seasons	29
3	Cumulative precipitation during 1974-75 and 1975-76 growing period and three different long term precipitation patterns (1912-1974)	30
4	Experiment I. NO_3-N distribution in the soil profile under the wheat cultivar with three levels of nitrogen at two sampling dates	40
5	Experiment I. NO_3-N distribution in the soil profile under the barley cultivar with three levels of nitrogen at two sampling dates	41
6	Experiment I. Moisture distribution in the soil profile under the barley and wheat cultivars after harvest for the 1974-75 crop season	44
7	Experiment I. Effects of nitrogen rate on yields of barley and wheat for the 1974-75 crop season	45
8	Experiment I. Effect of nitrogen rate on spike/m^2 of barley and wheat for the 1974-75 crop season	45
9	Experiment I. Effect of nitrogen rate on 1000 kernel weight of wheat and barley cultivars for the 1974-75 crop season	47

Figure		Page
10	Experiment I. Soil profile moisture at three fallow moisture levels at two sampling dates during the 1975-76 fallow season	49
11	Experiment I. NO_3-N in the soil profile at three fallow moisture levels and three residual nitrogen rates on April 22, 1976 from plots grown in winter wheat the previous season	52
12	Experiment I. NO_3-N in the soil profile at three fallow moisture levels and three residual nitrogen rates on April 22, 1976 from plots grown in barley the previous season	53
13	Experiment I. NO_3-N in the soil profile at three fallow moisture levels and three residual nitrogen rates on July 1, 1976 from plots grown in winter wheat the previous season (1974-75)	54
14	Experiment I. NO_3-N in the soil profile at three fallow moisture levels and three residual nitrogen rates on July 1, 1976 from plots grown in barley the previous season (1974-75)	55
15	Experiment II. Soil profile moisture at three fallow moisture levels at two sampling dates during the 1974-75 fallow season	62
16	Experiment II. Effect of three levels of fallow moisture on NO_3-N distribution and accumulation in the soil profile of Walla Walla Silt loam soil under fallow with three moisture levels at three sampling dates	64
17	Experiment II. NO_3-N distribution in the soil profile as affected by sampling time x sampling depth at three fallow moisture levels during the 1974-75 fallow season	66
18	Experiment II. Effect of three levels of fallow moisture x three levels of nitrogen on grain yield	71
19	Experiment II. Effect of three levels of fallow moisture x three levels of nitrogen on spike/m^2	75

Figure		Page
20	Experiment II. Effect of three levels of fallow moisture x three levels of nitrogen on 1000 kernel weight	75
21	Experiment II. Moisture distribution in the soil profile after harvest as influenced by the Wheat cultivar x three nitrogen levels and three fallow moisture levels (1975-76)	78
22	Experiment II. Moisture distribution in the soil profile after harvest as influenced by the barley cultivar x three nitrogen levels and three fallow moisture levels (1975-76)	79
23	Experiment II. NO_3-N distribution in the soil profile after barley harvest as influenced by three nitrogen rates x three fallow moisture levels during the 1975-76 season	82
24	Experiment II. NO_3-N distribution in the soil profile after wheat harvest as influenced by three nitrogen rates x three fallow moisture levels during the 1975-76 season	83

NITRATE-NITROGEN ACCUMULATION AND DISTRIBUTION IN THE SOIL PROFILE DURING A FALLOW-GRAIN ROTATION AS INFLUENCED BY DIFFERENT LEVELS OF SOIL PROFILE MOISTURE

INTRODUCTION

The use of nitrogenous fertilizers for cereal production under dryland conditions is a relatively recent practice. A common feature of nitrogen fertilizer trials in dryland cereal production is the variable response recorded from year to year. A significant increase in grain yield due to added nitrogen in one season may not give a significant increase at the same nitrogen level during the following season. This variable response to nitrogen fertilizers is generally attributed to the highly variable moisture conditions from season to season during the growing period.

In a fallow-grain rotation it is generally known that a certain amount of nitrate-nitrogen is accumulated in the soil profile due to the breakdown of the organic fraction in the soil mass. In many instances this nitrogen is accounted for when determining the fertilizer rate for a given crop. However, the amount of nitrate-nitrogen accumulated during the fallow period under varying moisture conditions has not been thoroughly investigated. The lack of consistent response to nitrogen fertilizers applied at the same rate over different seasons may be related to differing amounts of nitrate-nitrogen accumulated in the soil profile under varying moisture conditions.

The present nitrogen fertilizer practice in eastern Oregon is to apply a standard rate of 40 to 60 kg nitrogen per hectare as an hydrous ammonia several months prior to seeding. In some seasons a significant increase in yield is obtained, in other seasons little or no response is recorded. Precipitation received during the cropping period probably accounts for a portion of the variable response to nitrogen but not for all of the variation. It is postulated that nitrate-nitrogen accumulates in the soil profile in varying amounts and at varying depths during the fallow season depending on the amount and distribution of precipitation received during a given period. Long-term precipitation data shows that seasons can usually be separated into dry, normal or wet cycles. If there is, indeed, differing amounts of nitrate-nitrogen accumulated in the soil profile under varying moisture conditions it would be an extremely useful tool to use in predicting total nitrogen needs of a given cereal crop. This would prevent the waste of expensive fertilizer materials in one instance and insure an adequate amount of nitrogen in relation to available moisture in another instance.

Thus, it is the objective of this study to determine the effects of different soil moisture levels on the amount and location of nitrate-nitrogen accumulated in the soil profile during the fallow and crop periods. This information could be used to predict more accurately the total nitrogen needs of cereal crops and make more efficient use of applied nitrogen fertilizers.

LITERATURE REVIEW

Nitrogen for Wheat and Barley in Dryland Farming

After soil moisture, nitrogen is one of the more limiting factors in dryland cereal production. Many studies have been conducted to determine the nitrogen needs of cereals to determine the rate, time and method of application in the dry farming regions of the world.

Most investigators have stated that the need for nitrogen fertilization is reduced by summer fallowing. In the Central Anatolian Plateau of Turkey, Bolton (1974) found that there was little or no response to nitrogen fertilizer when the yield level was less than 2.0 tons per hectare. At yield levels above 2.0 tons per hectare a response to nitrogen was recorded. It was, therefore, concluded that the nitrate-nitrogen accumulated from the breakdown of organic matter during the fallow period was sufficient to supply the crop needs to produce 1.5 to 2.0 tons wheat per hectare.

Ferguson and Gorby (1964) reported that nitrogen mineralization during the growing season would normally be low and cereal crops would be dependent on stored mineral nitrogen or fertilizers for their nitrogen requirement.

In North Dakota, Bauer and Conlon (1974) reported that available nitrogen accumulated to a depth of 60 cm. during the fallow period in three of five years was less than 78.5 kg per hectare. The amounts were 123.4 and 139 kg in the other two years.

Olson and Drier (1969) observed highly variable responses of wheat to nitrogen in the Central Plateau of Turkey and reported that this variation was related to differences in mean annual rainfall.

Brown and Champbell (1966) reported that lack of soil moisture was the greatest limiting factor in crop production in the Northern Great Plains of the U. S. A. where annual precipitation averages 254 to 330 mm. Response to N and NP was found to be inconsistent and variable. 22. 5 kg of N decreased grain yields in 1958, 1959 and 1960. On the other hand 45 kg nitrogen did not decrease grain yields significantly in the same years.

In Nebraska, Olson and Rhoades (1953) showed a net gain of 504, 195, 20 kg per hectare from nitrogen application. They also concluded that nitrate released during fallow greatly reduced the need for supplemental nitrogen.

In western Kansas, Greb and others (1974) reported that wheat on medium textured soils responded to nitrogen 45 percent of the time. There was, however, no evidence of significant nitrogen response in Colorado except on sandy soil. In Kansas, the average grain yield increase for the 45 kg/ha nitrogen rate of fertilization has been 134 kg/ha on Harland soil and 47 kg/ha on Sandyland soil. In Colorado average yield increase at the same rate on Sandyland soil was 336 kg/ha. Increases to 67 and 89 kg of nitrogen per hectare have given little or no increases in grain yield. In Nebraska the average grain yield increase has been 806 kg/ha with 45 kg/ha nitrogen on Sandyland soil.

In North Platte, Nebraska, Smika (1970) reported that to prevent crop failure, 39 cm of precipitation is necessary in the 24 months fallow-crop period with nitrogen fertilizer in the fallow-wheat system. In his studies, a response to nitrogen application (45 kg/ha) was obtained 84 percent of the time. The average yields from 1949-1967 were: 2649 kg/ha with nitrogen and 2493 kg/ha without nitrogen.

According to Choriki and others (1971), nitrogen topdressing studies in Montant showed that significant grain yield increases from

NP application might be expected if stored soil water is sufficient and growing season precipitation exceeds 203 mm.

Working on soil nitrogen in a wheat-summer-fallow rotation on the Columbia Plateau, Oveson (1966) obtained an increasing effect of nitrogen fertilizer on wheat yields. He stated that an average wheat crop of 2688 kg/ha at 8 percent protein will remove from the soil approximately 13.6 kg of nitrogen. If this nitrogen is not supplied in some form, the result is a gradual depletion of soil nitrogen. The data presented showed that 13.6 kg of nitrogen as ammonium sulfate added to the wheat straw gave significantly higher yields than straw alone. The addition of 13.6 kg of nitrogen to the wheat straw resulted in a higher soil nitrogen content than straw alone. The results also indicated that straw without 13.6 kg nitrogen is lost in the decomposition process and has no beneficial effect on the soil nitrogen level.

In eastern Washington receiving less than 330 mm. average annual rainfall, Jackson and others (1952) reported that nitrogen fertilization increased wheat yields in 29 of 35 experiments conducted.

Similar results are reported for the dryland areas of northern Utah by Peterson (1952) and in southeastern Idaho by Schaeffer and Klages (1966).

Working on barley in California, Martin and Mikkelson (1960) evaluated responses to nitrogen fertilizer by barley grown continuously and in a fallow-crop system. Fifteen tests out of 17 with continuous barley showed a significant increase in yield from nitrogen fertilizer application in an area having 400 mm rainfall. Average yield increase was 13 bushels per acre from 50.5 kg of nitrogen. In fallow crop system only 5 tests out of 18 had significant response to applied nitrogen and the average yield increase was 215 kg/ha.

According to the data reported by Luebs and Loag (1969), increased vegetative growth can exhaust the soil water early in the season and result in plant water stress when evaporation is high and the rainfall has ended. In their study on barley, nitrogen applied at the 45 kg/ha rate increased the number of tillers by 330 percent and the number of heads produced per meter of row. The 90 kg/ha rate of nitrogen resulted in a 68 percent reduction in barley grain yield due to greater water stress. Yield was highest with the 45 kg nitrogen rate, which showed a 21 percent increase over the check.

Luebs (1974) attributed the increase and decrease in barley yields to the increased nitrogen availability after fallow where annual rainfall is about 305 mm.

Hojjati and Maleki (1972) reported no effect of 50 or 100 kg per hectare of nitrogen on wheat grain yield. On the other hand, 200 kg nitrogen decreased the yield because of the stimulated vegetative growth.

Nielson and Epps (1960) reported that studies conducted in Utah from 1942 through 1950 showed that nitrogen fertilizer increased wheat yield in less than 50 percent of the plots during a period of below normal precipitation. They suggested that 45 kg of nitrogen is adequate in areas where a yield response can be expected. The 67.3 kg rate was not superior to the 45 kg in any of the tests. In some locations a 22.5 kg rate was equal to the 45 kg. Adverse effects from the use of fertilizer occurred only during extreme spring drought years.

According to Hunter and others (1961), rates of added nitrogen on wheat resulted in a significant yield increase on 75 percent of the sites. Rates of 22.5, 45, 67.3, 90, 112 kg nitrogen per hectare gave increases over the check plot of 382, 636.5, 784, 811 and 837.5 kg/ha, respectively, in the low rainfall areas in eastern Oregon where annual rainfall is less than 381 mm. They reported very little difference in actual yield between fall applied or spring applied nitrogen. Type of the responses, however, to added nitrogen was almost the same for fall applied as for spring applied.

The amount of nitrogen required to increase wheat yield by 67 kg/ha was determined to be 4.1 kg for fall applied, and 4.6 kg for spring applied.

Pumphrey (1961) reported the yield increases of dryland wheat resulting from nitrogen fertilization with 38.7 and 67.3 kg in northwest Oregon was 201 and 268 kg/ha respectively. Higher rates produced slightly less yield.

In eastern Washington, Leggett and others (1959) reported that nitrogen fertilization significantly increased wheat yields in 92 of 112 experiments. Yield decreases occurred at high levels of nitrogen fertilization on shallow soils. In areas with less than 254 mm of rainfall yield increases ranged from 134.4 to 1008 kg/ha. The average yield increase was 403 kg/ha. In the 254 to 381 mm rainfall areas, 670 kg per hectare was the average yield increase from the optimum nitrogen level of 22.5 to 67.3 kg. In the same experiments effects of six different sources of nitrogen (anhydrous ammonia, aqua ammonia, ammonium sulfate, ammonium nitrate and urea) were compared and none of the differences were statistically significant. In four experiments, spring andall applications of nitrogen were equally effective. In the high rainfall area with more than 381 mm rainfall, spring spplications of nitrogen were superior to fall applications. Split applications resulted in lower yields.

Hunter and others (1958) observed highly variable effects of residual nitrogen in the wheat-summer fallow areas of eastern Oregon. The residual response depended upon the response of wheat to the initial nitrogen application. In other words, if the response was low in the year of initial nitrogen application, the residual response would be high. Substantial responses to residual nitrogen is always possible because the total amount of nitrogen added to the soil is not utilized by wheat.

In residual fertilizer studies with wheat in eastern Oregon, Smith (1959) related the magnitude of grain yield increase from residual nitrogen to the amount of response the first year and time of the nitrogen application. Because of unknown reasons, the response to the residual from spring applied nitrogen was larger than from fall.

In studies on the relationship of nitrate accumulation to yield response of wheat in Canada, Cook and others (1957) reported that a response to nitrogen can be expected when the nitrate accumulation value is under 50 ppm nitrogen for soils cropped the previous season and 40 ppm nitrogen for fallowed soils.

The yield-moisture relationships and the yield-nitrogen relationships calculated by Leggett (1959) indicated that 10.1 cm of available water is necessary to grow wheat. Each additional 2.54 cm of water increases the yield approximately 403 kg/ha. 3.4 kg of nitrogen per hectare was required to produce 67 kg of wheat per hectare. Maximum expected yields in relation to moisture (Ym) and resulting from the nitrate nitrogen (Yn) were given as follows:

$$Ym = (SM + R - 4)6$$

$$Yn = \text{Recrop Yield} + NO_3\text{-}N/3$$

It was also noted that when (Ym) is greater than (Yn), additional nitrogen application is required to obtain maximum yield. Therefore, estimated nitrogen fertilizer requirement was calculated as follows:

$$N = 3\ (Ym - Yn) = \text{lbs/A}$$

More recently, Gardner and others (1975) working with winter wheat fertilization in relation to the nitrate-nitrogen soil test values, reported that no grain yield increases from nitrogen fertilization were obtained on the low yield sites (1008-2016 kg/ha) where as yield increases were recorded at 86 percent of the medium (2083-3360 kg/ha) and high yield (over 3360 kg/ha) sites.

The average soil test value for nitrate nitrogen for the medium and high yield sites was 18 ppm. Nitrogen fertilizer failed to give a grain yield increase when this test value was found moderately high (37 ppm). The greatest average yield increase occurred where soil test values were in the low range of 4 to 13 ppm. Thus, they pointed out a more consistent response to nitrogen fertilizer at locations with low nitrate nitrogen soil test values. The relationship between yield potential, nitrate nitrogen soil test value and rate of nitrogen was formulated as follows:

$$F = a\,Y - 4\,S$$

Where F = estimated nitrogen fertilizer requirement in lbs/A

a = constant for each wheat varieties (2-2.5)

Y = estimated yield potential (given by YNo = 2.5 S)

S = nitrate-nitrogen soil test value (total ppm)

Effect of Cropping System on Nitrogen Loss

It was reported by Thatcher (1912) that the loss of total nitrogen is generally greater in a rotation containing fallow than under continuous cropping in the State of Washington.

More recently, Hobbs (1957) reported that cropping system had a marked effect on losses: Nitrogen losses were more rapid immediately after breaking the native sod. Losses gradually decreased with continued cultivation. He noted that small grains, either continuously or alternately with summer fallow, caused much less nitrogen loss than row crops.

Doughty (1954) showed that a rapid loss of organic matter and nitrogen occurred in cultivated soils, particularly during the first few years following the initial cultivation after which the loss proceeded at a slower rate.

Nitrogen can also be lost from the soil by crop removal, leaching, volatilization and by removal of the soil material through wind and water erosion. Haas (1974) stated that crop removal would usually not account for the greater loss of nitrogen under fallow than under continuous cropping, because under the fallow system less crop is removed from a given area than with continuous cropping.

Results of experiments conducted by Lehane (1964) showed that there was little difference in the organic carbon, PH, and nitrogen content in the 120 cm depth between treatments which received additional water and rainfall only. On the other hand he found that there was a very high nitrate nitrogen accumulation amounting to more than 168.3 kg nitrogen per hectare in the lower depths of the soil in the wheat-fallow rotation receiving rainfall only. He also stated that this indicates that nitrate production was greater than the crop requirements and the unused nitrate nitrogen was leached below the depth of root penetration.

Doughty (1954) observed the similar results reporting that in some years nitrate nitrogen was leached below the depth of root penetration.

In Nebraska, Fenster and McCalla (1970) conducted a wheat-fallow rotation using three tillage systems (subtill, one way disk and moldboard plow) for an eight-year period. The mean amount of nitrate nitrogen to a depth of 120 cm for the four-year period without nitrogen application was similar for all systems. When 22.5 and 45 kg per hectare of nitrogen fertilizer was added to each of the three tillage treatments, nitrate nitrogen was higher in the plowed plots, but in the one-way disked and subtilled plots, either remained at the same level or was even lower than when no nitrogen was applied.

The data presented by Stephens (1939), in Oregon, showed the deleterious effects of the wheat-fallow farming system on the nitrogen status of the soil. The nitrogen content of the surface foot of soil decreased from 0. 088 percent to 0. 077 percent. There was a decline of about 12 percent in ten years.

In California, similar observations have been made by Luebs (1974). He reported that total nitrogen decreased from 0. 065 percent to 0. 046 percent in a Romona sandy loam and from 0. 074 percent to 0. 043 percent in a Placentia sandy loam as a result of 70 years in the fallow-crop system.

Nitrate Nitrogen Production in Soil : Nitrification

The formation of nitrate from ammonium nitrogen is carried out by primarily autotrophic nitrifying bacteria (Meiklejohn, 1953) and there is also possibility of the formation of nitrate by heterotrophic microorganisms (Cutler, 1931). Murray (1921) noted that straw stimulates the reproduction of the bacteria in the soil. The numbers of bacteria increased with the amount of straw applied to the soil.

Blair and Prince (1928) pointed out the cause of the depressing effect of straw on germination and growth of barley. In their study it was found that barley straw depleted the available nitrogen. This was attributed to assimilation of the nitrogen by microorganisms which use the added organic matter as a source of energy. Allison (1955) found that added straw resulted in more depletion of nitrate in a soil low in organic matter than in a soil higher in organic matter.

In studies conducted by Ferguson and Gorby (1964) incorporation of straw into the soil did not generally induce a nitrogen deficiency in the succeeding cereal crop. They explained that low temperatures and lack of moisture in the fall and spring reduced the rate of straw decomposition so the level of available nitrogen would not be reduced appreciably by soprophytic microorganisms. They also reported that the nitrate content of the surface 15 cm of summer fallow soil was depressed by straw application. This effect lasted throughout the summer fallow period.

Mineralization of nitrogen and differences in microbial populations were studied by Goring and Clark (1948) in cropped and fallowed soils for 13 weeks. Data presented showed a disappearance of mineral nitrogen under crops that could not be completely explained by the nitrogen uptake of the crop. The average mineralization under all crops at five weeks was slightly greater than that in fallow soil. This difference was attributed to very little stimulation of mineralization by the crops during early stages of growth. At the stage maximum vegatative growth the average mineralization for cropped soil was considerably less than that for the fallowed soil. This result indicated a depressing effect of the crops on nitrogen mineralization. When most of the plants were fully mature at 13 weeks, mineralization under the crops was distinctly less than that in fallow soil and also less than mineralization under crops after nine weeks. There had been an actual decrease in the quantity of mineral nitrogen previously formed in or added to the soil. While mineralization in fallow soil showed approximately a straight line rate curve over a period of 13 weeks, the rate was decreasing slightly with time. It was concluded that less mineral nitrogen accumulates in cropped soil than in fallow soils. For total numbers of bacteria, highly significant differences between cropped and fallowed soils were also reported.

Beaumount (1927) observed that under a mulch of 6-8 tons per acre nitrate accumulation was greater than under cultivation. Nitrates are carried by leaching into the soil and accumulate only after the C : N ratio of the mulch has been narrowed by the process of decay.

Working on the effect of grain crop residues on nitrate production in Nebraska, McCalla and Russell (1943) found evidences that the outstanding influence of surface residues was not so much on production as on translocation of nitrate downward. Rainfall was more effective in washing nitrates through the soil profile kept moist by straw mulch than in dry, unmulched soil.

Brown and Gowda (1924) reported that studies of the effect of fertilizers on nitrification gave results that were highly variable. Some workers found a decrease in nitrification in soils receiving phosphates when others found an increase. In their study on Carrington loam soil, phosphate increased the nitrate content and stimulated the nitrifying power of the soil. They found the same results for sodium nitrate.

Different effects of nitrogen fertilizers on nitrification in three different soils were reported by Halvorson and Calder (1948). Application of nitrogen fertilizers stimulated nitrification in the Rockton silt loam soil with PH of 6.2. In Floyd silt loam with PH of 5.0, nitrogen applied as sodium nitrate did seem to increase nitrification. Ammonium nitrate, however, did not apparently increase nitrification of the soil organic matter. The nitrogen added as ammonium was not changed to nitrate at the end of eight weeks incubation. Therefore, it is concluded that PH might have been the factor limiting nitrate production in Floyd silt loam. The application of $CaCO_3$ at the rate of four tons per acre increased the nitrate production power of this soil. Application of phosphate and potash had no significant effect. They also noted the importance of the relationship between C : N ratio and nitrate producing capacity of the soils. It was concluded that the soils with the lower carbon-nitrogen ratios had the lowest nitrate producing capacity.

The effect of soil PH and previous nitrogen treatments on the rates of ammonification and nitrification was reported by Dancer and others (1973). In their study, similar amounts of inorganic nitrogen were found in all soil cultures after 35 days of incubation showing that soil PH did not affect the rates of ammonification appreciable. Previous nitrogen fertilization had no apparent influence on rate of nitrogen mineralization either. On the other hand soil PH and previous nitrogen treatment effects on nitrification rates were found very significant. An increase in soil PH was associated with a decrease in the length of delay period and an increase in maximum rate of nitrate nitrogen accumulation at high PH.

The relationship between temperature and nitrification rates was determined by Frederick (1956) in four different soils. The formation of nitrate was shown at all temperatures studied between 2 and 35^{o}C. Nitrification rate increased with temperature with the greatest change between 7 and 15^{o}C. Optimum temperature for the nitrification lies between 27 and 35^{o}C.

Another experiment was carried out by Chandra (1962) to study the effect of temperature shift on nitrification in a loam soil. Soil samples were incubated at 5, 16, 27^{o}C for 24-day period and some of them were shifted from one temperature to another. Complete nitrification occurred with the continuous incubation at 27^{o}C. Other nitrification values obtained with 16 and 5^{o}C were 58 and 29 percent respectively. Results also showed that continuous cool temperatures do not completely stop the nitrification and less nitrification occurred when the incubation temperature was shifted from suboptimal to optimal than when the temperature was initially optimal and shifted to lower temperatures.

Parker and Larson (1962) reported that a $2^{\circ}C$ differential in soil temperature had a marked effect on the rate of nitrification in the temperature range of 16° to $20^{\circ}C$. However after $25^{\circ}C$, differences in nitrate nitrogen production resulting from small differences in soil temperature were not observed.

Nitrification of ammonium sulfate in a calcareous soil under different moisture levels and temperature conditions were studied by Justice and Smith (1962). Ammonium sulfate at levels of 0, 150 and 450 ppm nitrogen was incubated in a calcareous soil at 2°, 10° and $22^{\circ}C$ at 10, 1 and 0.3 bars moisture tension using periodic aeration and continuous aerations with 7, 15, 115 and 415 bars moisture tension.

At $2^{\circ}C$ there was a conversion of ammonium to nitrate nitrogen in 10 weeks but no nitrate nitrogen was produced. At $10^{\circ}C$ nitrification took place at 1/3, 1 and 10 bars tension but 10 bars moisture delayed the initiation of nitrification and increased the period of nitrate nitrogen accumulation. At $25^{\circ}C$ and at 15 bars tension 50 percent of the 150 ppm nitrogen was oxidized to nitrate nitrogen in 28 days, while the nitrification was completed at 10, 7 and 1 bars tension in 28, 20 and 12 days.

In general, it was concluded that nitrification was more rapid at $25^{\circ}C$ than at $35^{\circ}C$ and at the more favorable temperature the initiation of nitrification was delayed at moisture tensions of 7, 10 and 15 bars.

The higher additions of ammonium-nitrogen, "lowered temperatures", "lowered moistures" and "increased temperature" above $25^{\circ}C$ were noted unfavorable conditions for nitrification.

Parker and Larson (1962) reported that maximum nitrification occurred in two silt loam soils at moisture tensions of 50 to 100 cm of water depending on the temperature and incubation period. Nitrification was retarded at soil moisture tensions below 50 cm of water indicating

31 percent moisture for Webster silt loam soil. They also noted that a high moisture content of the soil had little effect on nitrification except at near saturation.

The effect of soil moisture tension on nitrification and nitrogen mineralization was demonstrated by Miller and Johnson (1964). After 14 days incubation nitrates were determined and nitrification was maximum in the range of 0. 15 to 0. 5 bars moisture tension. Nitrification, then declined as the soil moisture tension increased or decreased. Nitrification was limited by deficient moisture at higher tensions and by aeration at lower tensions. They also reported that the overall effect of soil moisture on nitrogen mineralization was very similar to the effect on nitrification except at very high or low tensions. Mineralization increased rapidly at zero tension. It was concluded that ammonification took place at a faster rate at both high and low tensions indicating that ammonium nitrogen can accumulate in soil at high tension (up to air-dry and low tensions-near zero bars).

Immobilization of the Nitrogen in the Soil : Denitrification

Some workers have demonstrated that denitrification of added nitrate to the soil was inversely related to the partial pressure of oxygen in the gas stream passed through the soil.

Broadbend (1951), studying denitrification in some California soils under aerobic and anaerobic conditions, concluded that the character of the soil is important in determining whether or not aerobic denitrification takes place. Denitrification may occur even though fresh additions of organic matter have not been made. Low oxygen concentration in the soil atmosphere is not a necessary condition for the process. Denitrification rate is affected more by the amount of nitrate and oxidizable carbon in the soil than by partial pressure of oxygen.

According to the data from the experiments conducted by Skerman and Macrae (1957), no nitrate reduction occurred when free oxygen was continuously present, even at very low concentrations.

Using manometric methods to observe changes in gas consumption during denitrification, Gilmour and others (1957) showed that moisture level has a marked effect on denitrification. This observation was attributed to influence of moisture on aeration.

A lysimeter study utilizing isotopic nitrogen was conducted by Owens (1960) to determine the extent of soil nitrogen losses through denitrification. Ammonium sulfate, labeled with N^{15}, was applied to soils at the rate of 120 lbs. of nitrogen per acre and three moisture rates, 30.5, 45.7, 61 cm, were established on the soil during five months prior to crop seeding. Results obtained from the experiment showed that an average of one-third of the applied nitrogen in the winter time was lost through denitrification. The other important feature of that experiment was that the wide range of spring moisture rates had no significant effect on the quantity of denitrification losses of fertilizer nitrogen. It was explained that appreciable denitrification would occur in the noncapillary pores only when the moisture level rises considerably above that of field capacity. Since this condition did not prevail throughout the entire profile for any prolonged time, the amount of the denitrification in the noncapillary pores may have been smaller than that in the capillary pores. Also it was stated that where the anaerobic volume in the soil profiles was periodically increased by frequent saturation, denitrification may have been limited by low nitrate concentrations which results from excessive leaching.

Nitrate Nitrogen Movement through the Soil Profile

The movement of nitrate nitrogen through the soil profile is closely related to the movement of the soil water. Smith (1928), studying the distribution of nitrates in three layers of fallow soil, reported that nitrates moving downward after leaching rains were often retained in the subsoil layers, and at such times the quantities present were in excess of those remaining in the surface layer. Under the high temperature conditions in August, nitrates leached from the 61 cm of soil had been returned by the upward movement of soil water as the surface soil dried. The final determinations, on November 26, showed a downward movement of nitrates and nitrate accumulation took place at the depth of 38-61 cm.

Movement and behavior of nitrate and ammonium nitrogen in field soils in relation to rainfall distribution and soil moisture movement was studied by Krantz and others (1943). They reported results similar to Smith's (1928). It was reported that nitrates accumulated at the surface after a prolonged dry period by moving upward in the soil. This was due to the net upward movement of soil moisture. The amount of surface nitrate accumulation was lower in the non-fertilizer plots than in the treated plots. Any moderate rainfall, however, moved the nitrates back into the main root zone. It was also noted that the addition of lime, phosphorus and potassium along with plowed-under organic matter and ammonium sulfate, increased biological activity and temporarily tied up more of the applied nitrogen in the organic form.

Bates and Tisdale (1957) found that the mean movement of nitrates was related to the pore space distribution of soil and the quantity of the water added. It was stated that "with the addition of a given quantity of water, nitrate movement would be directly related to the amount of large pore space and inversely related to the amount of small pore space."

Owens (1960) concluded that nitrogen lost by means of leaching was directly proportional to the amount of water passing through the soil profile. In his experiment, nitrogen loss ranged from 5 to 20 percent from the low 30 cm to the high moisture rates 60 cm. The amount of fertilizer nitrogen leached out of the soil per 2.54 cm of moisture ranged from 1.12 kg per hectare per 2.54 cm to 2.13 kg per hectare 2.54 cm. At the end of the two-year experiment, 38 percent of the fertilizer nitrogen was found in the soil and was not affected by moisture treatment. This result indicated that most of the nitrogen immobilization occurred before extensive losses took place.

In Australia, Wetselaar (1961) described that the accumulation of nitrate near the soil surface after a long dry period was due to capillary movement of nitrate. He also reported that in Tippera Clay loam the upward movement of nitrate was restricted to the top 45 cm of the soil. Therefore, it was concluded that any nitrate which has been leached below this depth can not be recovered in the top soil by capillary movement. Wetselaar (1962) also pointed out the high correlation (r = +0.946) between rainfall amount and mean movement of anions in the same type soil and suggested that rainfall is the most important factor affecting the movement of the anion within one soil type. The mean movement of the anion was 2.73 cm for each 25.4 mm of rainfall. After 646 mm rainfall it appeared that nitrate accumulation occurred mostly between 60 and 90 cm.

From a study on the rate and depth movement of nitrogen in undisturbed profiles of two widely different fallow soils, Boswell and Anderson (1964) reported appreciable upward movement of nitrate from depth of 150 to 180 cm during moisture stress. In the same study, most of the applied nitrogen was found in 7.5-15 cm layers after five weeks and 5 cm rainfall. After 68 cm of rainfall and 17 weeks on the loamy sand, applied nitrogen was found in the top 60 to 90 cm of both soils. Even with high accumulated rainfall appreciable amounts of the applied nitrogen at the depths of 36 to 72 cm was reported.

Recent work by Boswell and Anderson (1970) showed that applied nitrogen leached more in cropped plots than in fallowed plots. Thirty-four weeks after nitrogen application the cropped plots had more nitrogen in the 60 to 91 cm depth and less in the 91 to 122 cm depth than the fallowed plots indicating that moisture utilization by the crop may have reduced the leaching effects during the rapid growing season. It was also reported that nitrogen movement in the Marlboro soil containing 40 percent clay was considerably greater than in Davidson soil containing 50-60 percent clay.

Factors Affecting Nitrate Accumulation in the Soil

Gainey (1917) investigating the effects of moisture content and compactness on the nitrate nitrogen accumulation in soil found that with the water content of 15 cc per 100 gm of soil, the nitrate accumulation increased with an increasing compactness and also with an increasing column depth. With a moisture content of 20 cc per 100 gm of soil the medium and compact samples both showed a greater nitrate gain than the uncompacted sample. Compacting the soil has inhibited nitrate accumulation at the moisture contents of 30 and 38 cc per 100 gm of soil. Thus it was concluded that "as the moisture content of a soil decreases, increasing the compactness from a very loose condition will increase the accumulation of nitrate nitrogen." Gainey also reported that the accumulation of nitrate nitrogen increases with increasing depth down to 60 cm and it is more rapid in unbroken soil columns than in pulverized soil.

Albrecht and Uhland (1925) noted that increasing moisture, lowering the temperature and preventing the normal exchange of air induce a poor physical condition and unfavorable environment for nitrate accumulation. They worked on nitrate accumulation in the soil as a result of mulching or removing mulch and applied six tons and two tons straw to a brown silt loam soil. They reported that "reducing the moisture content of the soil under the mulch to that of soil without mulch gave a slight increase in nitrates, while raising the moisture of the unmulched soil to that of the mulched gave a decrease in nitrates." This decrease was prevented by aeration. The mulch exerts some force on depressing nitrate accumulation through lessened aeration as a result of increased soil moisture. Removing the mulch gave a marked increase in nitrate accumulation while its application to a previously unmulched soil brought on a decrease in the same time even though the moisture remained unchanged. Aerating the mulched soil increased the nitrate accumulation. It was also reported that changing the structure of the mulched soil by air-drying and remoistening gave a marked increase in nitrate accumulation.

Moisture content and nitrate status of the soils were studied by Calder (1957) in Uganda. He worked with the soil moisture levels between the roughly defined limits of airdryed (10-15 percent moisture) and waterlogged (45 percent moisture). The accumulation of nitrate in the soil is not specially favored by any stable moisture content between those limits of 15 percent and 45 percent. Change of moisture status during drying was associated with much more nitrate than under steady moisture conditions. He also stated that "if no optimum exists the only possibility is that nitrate production occurs in response to of moisture status." However, fluctuation of moisture status about an optimum average of 22-23 percent seemed likely to provide the most favorable condition to the accumulation of the nitrate nitrogen.

In silt loam soils of the Midwest, Sabey (1969) studied the influence of soil moisture tension on the maximum nitrate nitrogen accumulation rates at a tension range from 0 to 15 bars. He found similar results to the early workers. Maximum nitrate nitrogen accumulation rates were found at 0.1 bar. Maximum rate of nitrate nitrogen accumulation in ppm/day decreased as soil moisture tension increased or decreased.

Under field conditions, very early in the season, when the soil temperature was in the range of 16° to 20°C, mulched soil was 1° to 2°C cooler than bare soil. Parker and Larson (1962) noted that during this period greater accumulation nitrate nitrogen could occur in bare than in mulched soil as a result of the temperature difference.

Soil temperature is recognized as one of the most important environmental factors affecting the oxidation of ammonium to nitrate in soils. Investigating the effect of low temperature on nitrification in acid soils, Anderson and Boswell (1964) reported that the accumulation of nitrates was either completely supressed or delayed for several weeks in the sandy soils at 42°F. In a clay loam, nitrate accumulation was severly retarded at 37°F, but rapid accumulation occurred at 47°F. Increasing the amount of added ammonium nitrate delayed or completely supressed nitrate accumulation at low temperatures. The depressive effect of low temperature and high ammonium nitrate concentration was most apparent in the loamy sand, intermediate in the sandyloam, and least in the clayloam.

MATERIALS AND METHODS

Plant Materials

The crop cultivars used in this study were selected from locally grown wheat and barley varieties having high yield potential and adaptability to adverse environmental conditions.

Hudson (Hordeum vulgare L. emend. Lam.), developed at the Cornell University Agricultural Experiment Station by H. H. Love and W. T. Craig, is a medium early, hardy, high yielding, heavy test weight winter barley. It has a short and vigorous plant type producing short compact six-rowed heads with rough awns on strong straw. Hudson is scald and mildew resistant but moderately susceptible to loose smut.

Mcdermid (Triticum aestivum L.) is a soft white, high yielding winter wheat, developed at O. S. U. Agricultural Experiment Station by Dr. W. E. Kronstad. It is a semidwarf wheat with fair straw strength. Mcdermid is resistant to smut (U. tritici) and moderately resistant to stripe rust (P. striiformis) and mildew (E. graminis tritici).

Location

Field plots were established on the Sherman Experimental Farm at Moro, Oregon in 1974. This study covers both fallow and crop seasons of 1974-75 and 1975-76. The experimental sites were selected for uniformity of soil especially in nitrate nitrogen and topography. The soil type is Walla Walla silt loam, a typic hapoxerolls developed on deep loess. A typical profile of this deep, well drained soil has dark grayish brown silt loam Ap and A1 horizons (0-35 cm), brown silt loam B1 and B2 horizons (35-110 cm), and pale brown silt loam C1ca and

C2ca horizons (110-150 cm). The chemical and physical properties of the soil profile from each experimental site are reported in Tables 1a and 1b. Average monthly precipitation for 1912 through 1974 fallow and crop seasons are shown in Tables 2 and 3. The amount of rainfall for the 1974-75 growing season was 247.5 mm and was 217.9 mm for the 1975-76 growing season.

Experiments

This study consisted of two companion experiments. Experiment I was designed to study the applied nitrate nitrogen movement and distribution in the soil profile under two different cultivars with three different levels of nitrogen applied prior to planting and response to nitrogen for grain yield and some of the yield components. The experiment was planted on October 12, 1974, at the seeding rate of 78.5 kg/ha. Spacing between rows was 35 cm. Nitrogen fertilizer as ammonium nitrate was surface applied by hand at the three levels of 56, 112, 168 kg/ha prior to planting. A modification of a split-split block statistical design with four replications was utilized with cultivars as main plots and moisture levels as sub-plots. The nitrogen treatments were randomized within the sub-plots. Moisture treatments simulating dry, normal and wet fallow conditions were established after harvest in the 1975-76 fallow season to study the moisture effects of NO_3-N accumulation and distribution in the soil profile.

Moisture treatments, based on the average rainfall distribution of dry, normal and wet fallow seasons were determined by analyzing 63 years (1912-1974) precipitation data from the Sherman Experiment Station records at Moro, Oregon. The following procedure was used to construct accumulated precipitation curves that would reflect the

Table 1a. Experiment I. Initial soil test values for the Walla Walla silt loam soil sampled at five depths.

Soil Properties	Soil Depth, cm 0-30	30-60	60-90	90-120	120-150
Total Nitrogen %	0.06	0.05	0.04	0.03	0.02
Organic Matter %	1.12	0.70	0.65	0.38	
SO_4-S ppm	0.90	0.60	0.70	1.20	1.80
P ppm	22.00	12.00	15.00	11.00	7.00
Extractable Cations					
K ppm	404	320	244	222	170
Ca meq/100g	8.3	7.5	38.0	30.0	35.0
Mg meq/100g	3.2	3.7	7.6	6.7	6.9
Salts mmhos/cm	0.5	0.24	0.26	0.51	0.6
PH(1:2 soil to H_2O	6.6	7.2	7.7	8.2	8.7
Particle Size Distribution					
Sand %	24.95	23.17	21.20	25.32	35.9
Silt %	60.97	62.99	65.88	64.04	56.9
Clay %	14.08	13.84	12.92	10.64	7.2

Table 1b. Experiment II. Initial soil test values for the Walla Walla silt loam soil sampled at five depths.

Soil Properties	Soil Depth, cm 0-30	30-60	60-90	90-120	120-150
Total Nitrogen %	0.06	0.05	0.04	0.04	0.04
Organic Matter %	0.90	1.04	0.90	0.80	0.80
SO_4-S ppm	1.00	1.30	2.70	1.60	2.00
P ppm	25.00	16.00	17.00	16.00	11.00
Extractable Cations					
K ppm	412	364	330	330	310
Ca meq/100g	6.8	6.9	6.6	6.6	10.4
Mg/meq/100g	2.8	3.2	3.7	4.1	4.9
Salts mmhos/cm	0.2	0.24	0.31	0.25	0.61
Particle Size Distribution					
Sand %	21.72	21.01	19.69	20.78	28.15
Silt %	64.42	64.92	67.1	67.75	62.5
Clay %	13.86	14.07	13.21	11.47	9.35

Table 2. Monthly average and cumulative amount of rainfall during fallow period with three different precipitation patterns (1912-1974).

	63-Seasons		"Dry" Seasons		"Wet" Seasons	
	Average	Cumulative	Average	Cumulative	Average	Cumulative
Months	mm	mm	mm	mm	mm	mm
August	5.8	5.8	8.1	8.1	8.3	8.3
September	15.7	21.5	12.4	20.5	24.9	33.2
October	24.1	45.7	17.0	37.5	33.7	66.9
November	42.9	88.6	28.9	66.4	52.7	119.6
December	42.7	130.8	32.0	98.4	47.9	167.5
January	42.7	173.4	33.0	131.4	62.0	229.5
February	29.5	208.9	19.2	150.6	41.7	271.2
March	23.9	226.8	19.7	170.3	25.3	296.5
April	18.8	245.6	9.9	180.2	22.4	318.9
May	20.1	265.6	9.7	189.9	28.4	347.3
June	18.3	283.9	11.2	201.1	26.5	373.8
July	4.6	288.5	6.5	207.6	8.8	382.6
August	5.8	294.3	4.5	212.1	8.1	390.7
September	15.7	310.1	11.0	223.1	16.0	406.7

Table 3. Monthly average and cumulative amount of rainfall during cropping period with three different precipitation patterns (1912-1974).

	63-Seasons		"Dry" Seasons		"Wet" Seasons	
	Average	Cumulative	Average	Cumulative	Average	Cumulative
Months	mm	mm	mm	mm	mm	mm
October	24.1	24.1	19.8	19.8	32.5	32.5
November	43.2	67.3	27.8	47.6	66.4	98.9
December	43.5	110.8	37.2	84.8	55.1	154.0
January	42.9	153.7	28.4	113.2	60.1	214.1
February	29.8	183.5	23.4	136.6	50.2	264.3
March	24.2	207.7	16.8	154.3	30.3	294.6
April	19.1	226.8	14.2	167.6	19.5	314.1
May	19.8	246.6	13.3	180.9	27.5	341.6
June	17.9	264.5	8.8	189.7	27.6	369.2
July	4.8	269.3	4.0	193.7	6.6	375.8

different levels of moisture that would occur over time. First, the fallow seasons' total precipitation and the average of fallow totals were calculated. Secondly, the fallow seasons were divided into two groups: the fallow seasons having total precipitation above and below the long term average. For each group, again, the average precipitation was calculated. The mean values of these groups gave the upper and lower limits of the normal fallow season. For example, 38 fallow seasons out of 63 in this range, in terms of their total amount of rainfall, are considered as having a normal range of precipitation. The 13 seasons above that range were wet seasons. The remaining 12 seasons represent the dry periods (Table 2). Plotting the monthly averages of these three groups gives the wet, normal and dry fallow seasons' accumulated rainfall distribution (Figures 1, 2, and 3).

The soil profile moisture differences were created by observing the actual precipitation pattern during the season and adjusting the accumulated averages to equal the calculated averages. The "dry" fallow treatment was covered by a plastic sheet during the periods October 20 to November 24, 1975 and February 11 to February 29, 1976. During the first period 26 mm rainfall occurred and during the latter period 17 mm rainfall was recorded, making a total of 43 mm of water captured and removed from the "dry" plots. During approximately the same periods a total of 80 mm water was applied by sprinkler irrigation on the "wet" plots. The "normal" treatment was reasonably close to the actual rainfall pattern until about the latter part of February, 1976, then about 25 mm water was added by sprinkler irrigation to adjust these plots to the "normal" range (Table 4; Figure 1).

The second experiment was established in the 1974-75 fallow period to evaluate the soil NO_3-N distribution and accumulation patterns under three different moisture levels. A somewhat different procedure was used to set up moisture treatments. "Wet" and "normal"

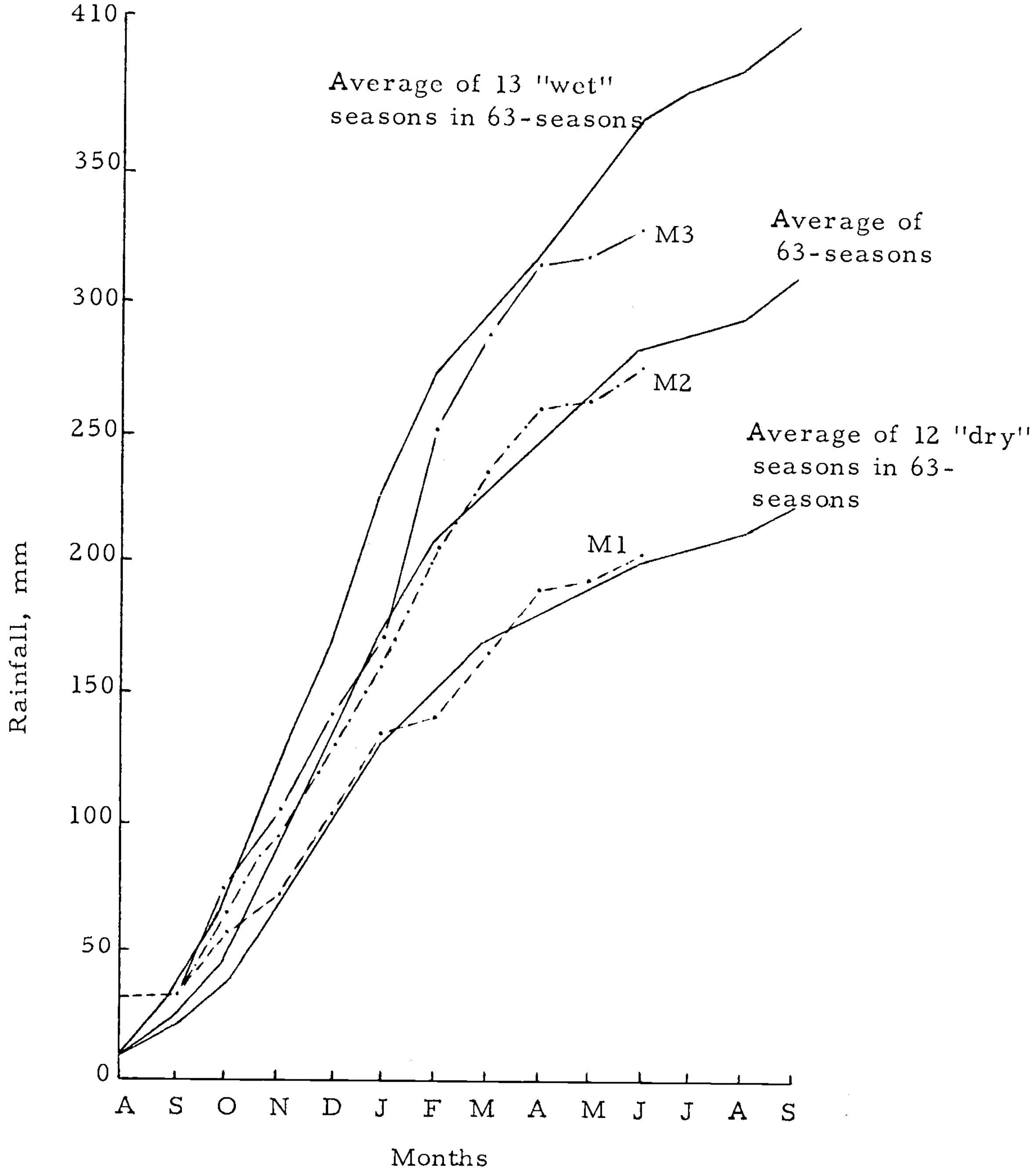

Figure 1. Experiment I. Cumulative precipitation on the experimental plots for three levels of fallow moisture during 1975-76 fallow period and long term (1912-1974) precipitation patterns for wet, normal and dry fallow seasons.

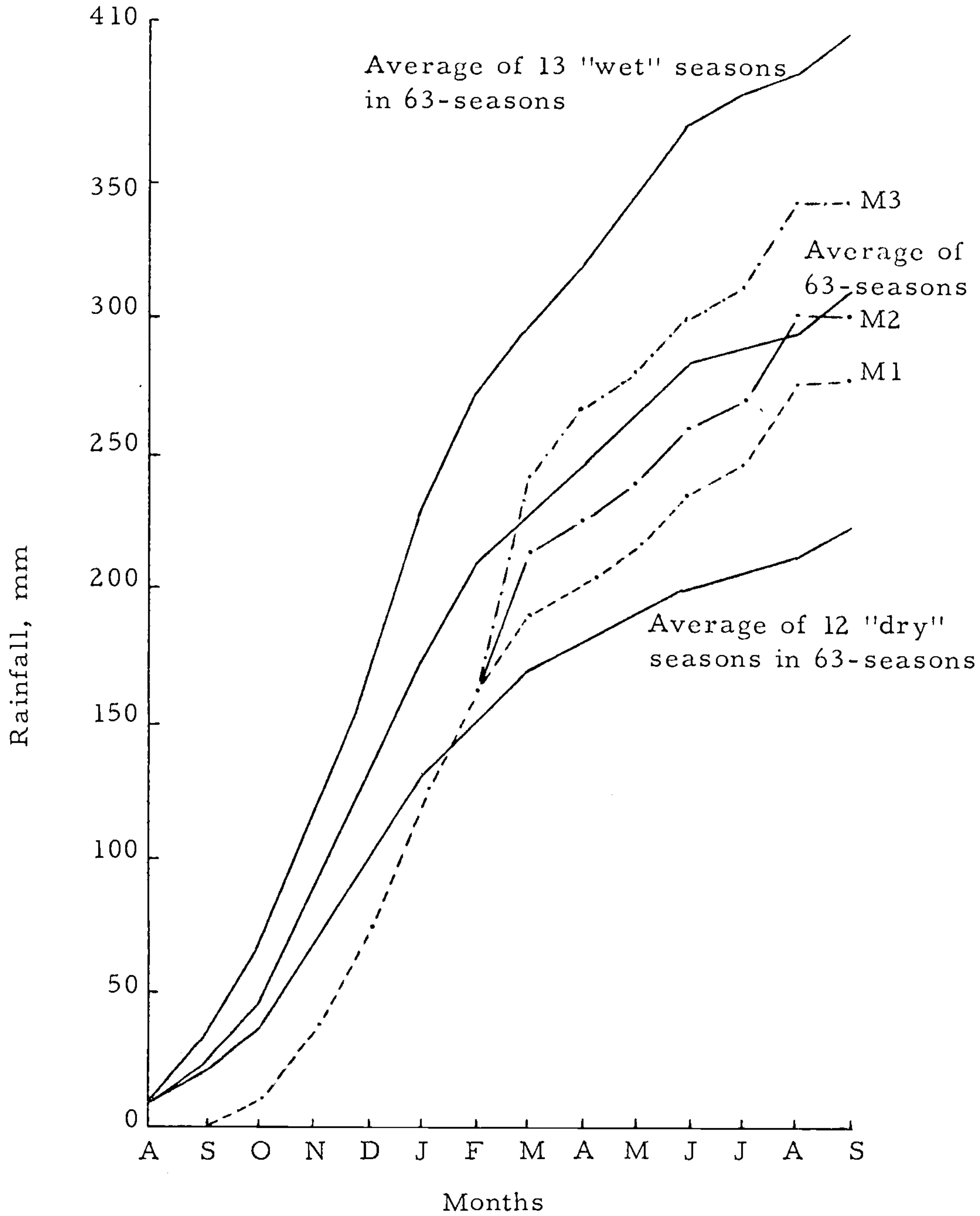

Figure 2. Experiment II. Cumulative precipitation on the experimental plots for three levels of fallow moisture during 1974-75 fallow period and long term (1912-1974) precipitation patterns for wet, normal and dry fallow seasons.

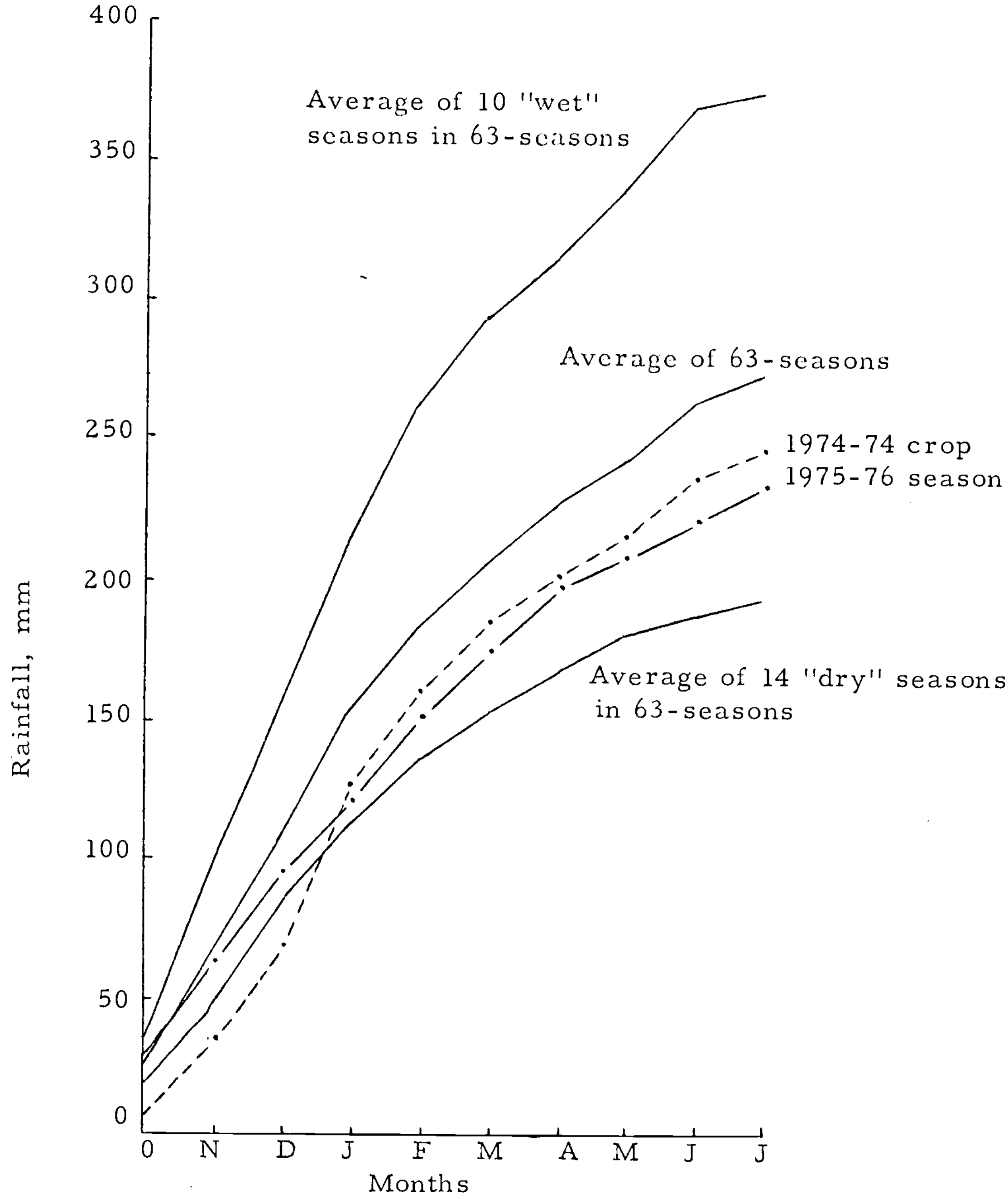

Figure 3. Cumulative precipitation during 1974-75 and 1975-76 growing period and three different long term precipitation patterns (1912-1974).

Table 4. Experiment I. Monthly precipitation on experimental plots with three levels of moisture during the 1975-76 fallow period.

Months	Moisture Level 1 (Dry Season) Monthly Total mm	Cumulative mm	Moisture Level 2 (Normal Season) Monthly Total	Cumulative mm	Moisture Level 3 (Wet Season) Monthly Total mm	Cumulative mm
August	32.0	32.0	32.0	32.0	32.0	32.0
September	-	32.0	-	32.0	-	32.0
October	23.6 1/	55.6	29.7	61.7	39.7*	71.7
November	14.0 2/	69.6	34.0	95.7	34.0	105.7
December	32.0	101.6	32.0	127.8	32.0	137.8
January	31.8	133.3	31.8	159.7	31.8	169.5
February	6.6 3/	140.0	48.6**	208.3	78.6***	248.1
March	24.1	164.1	24.1	232.4	39.1****	287.2
April	26.9	190.1	26.9	259.3	26.9	314.1
May	3.6	193.7	3.6	262.9	3.6	317.7
June	12.2	205.9	12.2	275.1	12.2	329.9

1/ Removal of 6.12 mm rainfall from dry fallow plots

2/ Removal of 20.07 mm rainfall from dry fallow plots

3/ Removal of 17.03 mm rainfall from dry fallow plots

* Addition of 10 mm water to wet fallow plots

** Addition of 25 mm water to normal fallow plots

*** Addition of 55 mm water to wet fallow plots

**** Addition of 15 mm water to wet fallow plots

treatments were only irrigated in late winter and in early spring of 1975. Unirrigated treatments were considered as the "dry" treatment (Moisture level 1,M1) because the total amount of rainfall for 1974-75 fallow season was below the 63-year average rainfall (Figure 2). Normal fallow plots (Moisture level 2, M2) were irrigated once and 24 mm water was applied. Wet plots (moisture level 3, M3) were irrigated three times at 15 days intervals and had 42 mm more water than normal plots (Table 5). After establishing the moisture treatments, the seed bed was prepared. The first tillage operation was conducted with the moldboard plow on April 1, 1975. A second tillage was conducted on May 15 with a spring-tooth harrow. The plots were then cultivated three times with a rod weeder.

This trial was planted on September 22, 1975, to determine the response of the cultivars grown on the plots with different NO_3-N distribution patterns. Seeding rates of 78.5 kg/ha from wheat and barley were utilized. Row spacing was 35 cm. The nitrogen fertilizer was broadcast by hand at the three levels of 0, 56, 112 kg/ha just before planting. Since adequate levels of phosphorous and potassium were present in the soil, these elements were not applied.

The statistical design of this experiment was similar to Experiment I, except for the sequence of the experimental treatments. In Experiment I cultivar and nitrogen rate treatments were placed first; then, moisture treatments were established after harvest. In Experiment II the moisture treatments were applied during the fallow period and then cultivar and nitrogen rate treatments were applied. Crop and fallow treatments of Experiment I and II were conducted simultaneously in adjacent areas.

Soil Sampling

Experiment I-Soil samples were taken at four different times: March 24, 1975, during growing season; August 6, 1975, after harvest; April 22 and July 1, 1976, during fallow. Sampling depth was 150 cm for both the crop and the fallow period. Each 150 cm depth was divided into five increments (0-30, 30-60, 60-90, 90-120, 120-150 cm). Soil samples were collected with sampling tubes. Half of the composite samples, within the plot area (3 x 15 m) for each of the depth, was air dried immediately after field sampling for 48 hours, ground to pass a 2 mm sieve and resampled for nitrate nitrogen analysis. The second half of the composite samples was kept in a plastic bag for moisture determinations.

Table 5. Experiment II. Monthly precipitation on experimental plots with three levels of moisture during the 1974-75 fallow period.

	Moisture Level 1 (Dry Season) Monthly		Moisture Level 2 (Normal Season) Monthly		Moisture Level 3 (Wet Season) Monthly	
Months	Total mm	Cumulative mm	Total mm	Cumulative mm	Total mm	Cumulative mm
August	-	-	-	-	-	-
September	-	-	-	-	-	-
October	9.4	9.4	9.4	9.4	9.4	9.4
November	25.9	35.3	25.9	35.3	25.9	35.3
December	35.3	70.6	35.3	70.6	35.3	70.6
January	51.1	121.7	51.1	121.7	51.1	121.7
February	37.3	159.0	37.3	159.0	37.3	159.0
March	31.8	190.8	55.8*	214.8	83.8**	242.8
April	11.7	202.5	11.7	226.5	25.7***	268.5
May	13.5	216.0	13.5	240.0	13.5	282.0
June	21.3	237.3	21.3	261.3	21.3	303.3
July	10.2	247.5	10.2	271.5	10.2	313.5
August	32.0	279.5	32.0	303.5	32.0	345.5
September	-	279.5	-	303.5	-	345.5

* Addition of 24 mm water to Normal fallow plots

** Addition of 52 mm water to Wet fallow plots

*** Addition of 14 mm water to Wet fallow plots

Experiment II-Soil samples were taken in the spring of fallow period on May 3, 1975, prior to planting on September 22, 1975, during growing period on April 22, 1976, and the last samples were collected after harvest. All plots were sampled to a depth of 150 cm. To prepare the samples for moisture and nitrate nitrogen tests, the same procedure was followed as in Experiment I.

Samples from four replicate plots were separately analyzed for both experiments in the Oregon State University Soil Testing Laboratory.

Measurements

The "Gravimetric Method" was used for the moisture determinations. This method refers to the ratio of the mass of water to the mass of dry soil which is dried in an oven at $105^{\circ}C$. Gravimetric water content was calculated by using the following formula:

$$W_d(\%) = \frac{M_w}{M_s} \times 100$$

Where M_w is the mass of water (gm), M_s is the mass of dry soil practicles (gm).

The steam distilation method of Bremmer (1966) was used for determining nitrate nitrogen. Calculations were conducted according to the following formula:

$$\text{ppm of nitrate nitrogen in the soil sample} = \frac{(\text{sample-blank titration in mls.}) \times \text{N of } H_2SO_4 \times 14000 \text{ mgN/Meq}}{\text{weight of soil sample represented by aliquot}}$$

Grain yield in kg/ha was obtained by harvesting 18 m^2 area within each plot and to eliminate the border effects the ends of the plots were trimmed prior to harvest. 1000 kernel weight was determined by counting and weighing 300 seeds from each plot. Spikes per m^2 were calculated by counting the number of spikes in one meter in two center rows.

Mean values of the various data collected were compared by means of the analysis of variance and Student Newman Keul's tests. Coefficient of variation was calculated for the data to obtain a measure of precision.

RESULTS AND DISCUSSION

Experiment I

NO_3-N Movement and Accumulation under Cultivars

The movement and accumulation patterns under the cultivars for the two sampling dates of the Walla Walla silt loam soil are shown in the Figures 4 and 5.

There were no significant differences observed between the two cultivars for the movement and accumulation of NO_3-N in the soil profile between the first or the second sampling date (Table 6). However, 23 weeks after N application, slightly more nitrogen movement occurred under barley than under wheat. Hudson had slightly less NO_3-N in the 0 to 60 cm depths and more NO_3-N in the 60 to 90 cm depths than Mcdermid. This was true for the 112 and 168 kg/ha nitrogen rates. These data suggested that with high rates of nitrogen application, downward movement of NO_3-N may occur down to 90 cm depth under barley cultivars.

From the second sampling after harvest total NO_3-N in the soil profile under wheat was found slightly higher than under barley, even though the difference was not significant. This indicates that Hudson barley utilized more NO_3-N than Mcdermid because there was no indication of leaching of NO_3-N beyond the root penetration depth (Table 7).

Highly significant differences were noted among the nitrogen rates. The higher rates resulted in higher profile NO_3-N. The mean value for total NO_3-N in the soil profile increased with higher nitrogen rates at the first and the second sampling dates. At the second sampling date, however, differences between 56 kg/ha nitrogen and 112 kg/ha

Table 6. Experiment I. Observed mean squares for soil profile NO_3-N during 1974-75 cropping season.

Source of variation	Degrees of Freedom	Soil Profile NO_3-N, ppm
Reps	3	12.85
Sampling Time	1	1047.38**
Cultivars	1	3.90
Sampling Time x Cultivars	1	3.2×10^{-2}
Sampling Depth	4	315.33**
Sampling Time x Sampling Depth	4	145.41**
Cultivars x Sampling Depth	4	3.67
Sampling Time x Cultivars x Sampling Depth	4	1.37
Error (a)	57	2.806
Nitrogen Rate	2	189.86**
Sampling Time x Nitrogen Rate	2	15.75**
Cultivars x Nitrogen Rate	2	0.85
Sampling Time x Cultivars x Nitrogen Rate	2	0.67
Sampling Depth x Nitrogen Rate	8	38.24**
Sampling Time x Sampling Depth x Nitrogen Rate	8	8.65**
Cultivars x Sampling Depth x Nitrogen Rate	8	1.05
Sampling Time x Cultivars x Sampling Depth x Nitrogen Rate	8	0.42
Error (b)	120	1.381
Total	239	

* Significant differences at 5% probability level

** Significant differences at 1% probability level

nitrogen rates in total soil profile NO_3-N were not significant (Table 8). The total amount of NO_3-N in the soil profile during the growing period was directly related to the rate of N application. Distribution of NO_3-N in the soil profile was also closely related to the rate of application (Figures 4 and 5). As a highly significant sampling depth x nitrogen rate interaction showed, increasing the rate of application increased the NO_3-N content of the soil up to 60 cm and NO_3-N accumulated monthly in the 30-60 cm depth. There was no significant difference in amount of NO_3-N beyond 60 cm depth among the nitrogen rates for a given depth. The data suggested that no mass movement of NO_3-N occurred from 0-60 cm layer to the lower layers after 191 mm rainfall. Moisture utilization by the crop reduced the leaching effects during the rapid growing season (Boswell and Anderson, 1970).

Table 7. Experiment I. NO_3-N distribution in the soil profile under the wheat and barley cultivars during the 1974-75 growing season and after harvest.

Sampling Date	Soil Depth cm	Nitrogen Rate-Kg/ha 56	112	168
MCDERMID		.......NO_3-N, ppm		
March 24, 1975	0-30	5.00	9.44	13.63
	30-60	6.90	11.70	16.84
	60-90	2.70	3.07	3.82
	90-120	2.03	2.13	2.20
	120-150	2.20	2.28	2.84
August 7, 1975	0-30	1.17	3.08	8.20
	30-60	0.50	0.86	3.20
	60-90	0.42	0.38	0.96
	90-120	0.35	0.10	0.90
	120-150	0.77	1.14	1.94
HUDSON				
March 24, 1975	0-30	4.71	8.43	10.13
	30-60	6.96	10.48	15.05
	60-90	3.02	3.60	5.77
	90-120	1.97	2.01	2.50
	120-150	2.09	2.20	2.40
August 7, 1975	0-30	1.09	2.56	6.24
	30-60	0.44	1.25	2.91
	60-90	0.50	0.63	0.91
	90-120	0.05	0.52	0.73
	120-150	0.31	0.83	1.42

Table 8. Experiment I. Mean 1000 kernel weight, spikes/m^2, soil profile moisture and NO_3-N at three nitrogen levels.

Nitrogen Rate kg	1000 Kernel Weight gm	Spike/m^2	Average Soil Profile Moisture in Aug.	Total Soil Profile NO_3-N ppm in March	in Aug.
56	34.4 b	360.9 a	6.7 b	18.80 a	2.79 a
112	30.7 a	429.9 b	6.5 ab	27.68 b	5.68 a
168	29.9 a	426.5 b	6.4 a	38.41 c	13.73 b
Cultivars					
Mcdermid	30.2 a		6.1 a		
Hudson	33.1 b		7.0 b		

[1] Student Newman Keul's Test - Means in a column followed by the same letter are not significantly different at 5% probability level.

From March 24 to August 6, the nitrate content of the soil under both cultivars declined drastically as a result of plant uptake. Most of the NO_3-N not removed by the crop was found in the soil within the root zone of 0 to 30 cm. This was probably due to the net upward movement of soil moisture after a prolonged dry period (Krantz et al. 1943).

Soil Profile Moisture after Harvest

Nitrogen fertilizer had a significant effect on water depletion by the cultivars. As the rate of application of nitrogen increased the depletion of soil profile moisture increased for both the wheat and barley. Increasing the nitrogen rate from 56 kg/ha to 112 kg/ha resulted in a

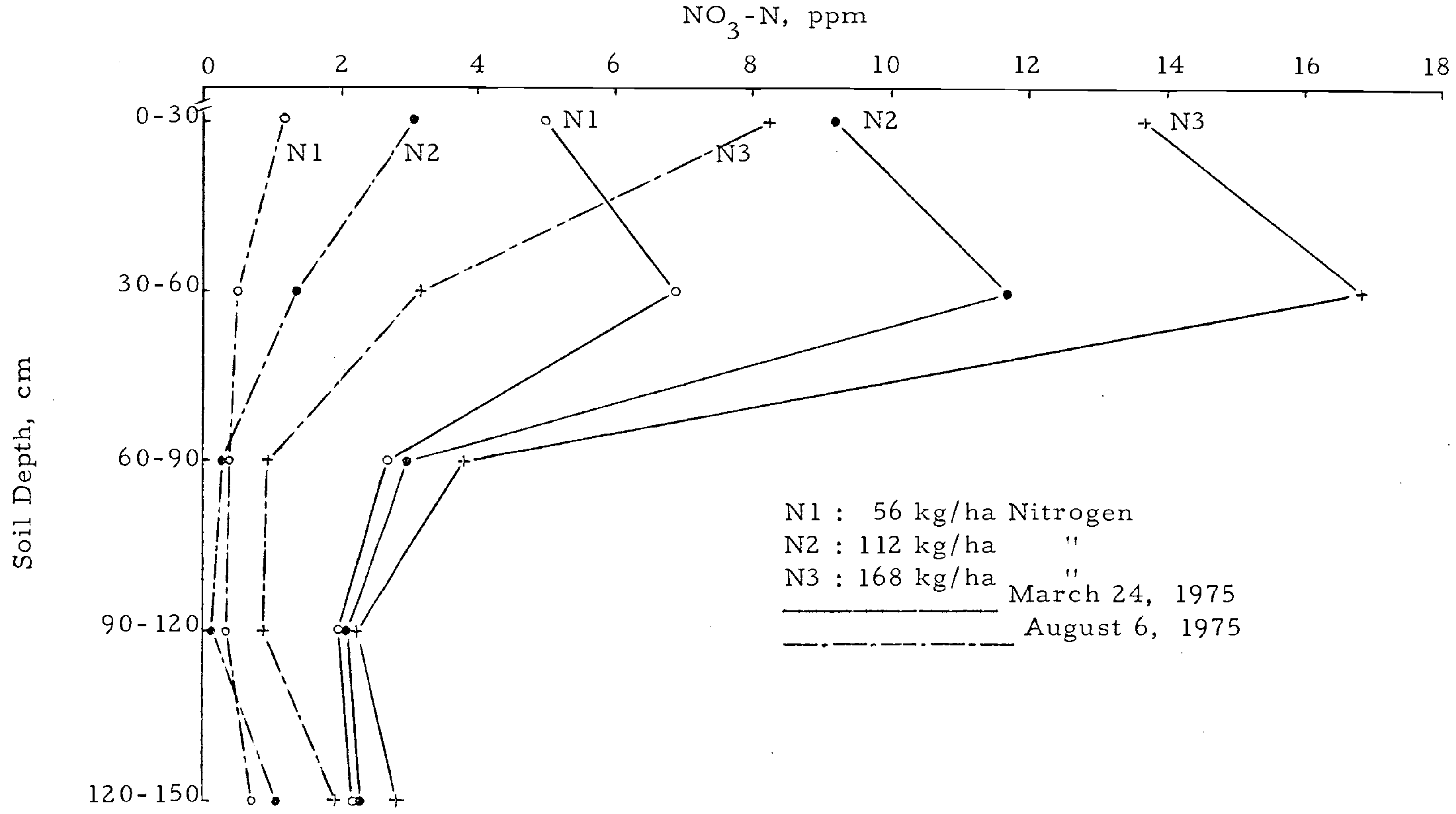

Figure 4. Experiment I. NO_3-N distribution in the soil profile under the wheat cultivar with three levels of nitrogen at two sampling dates.

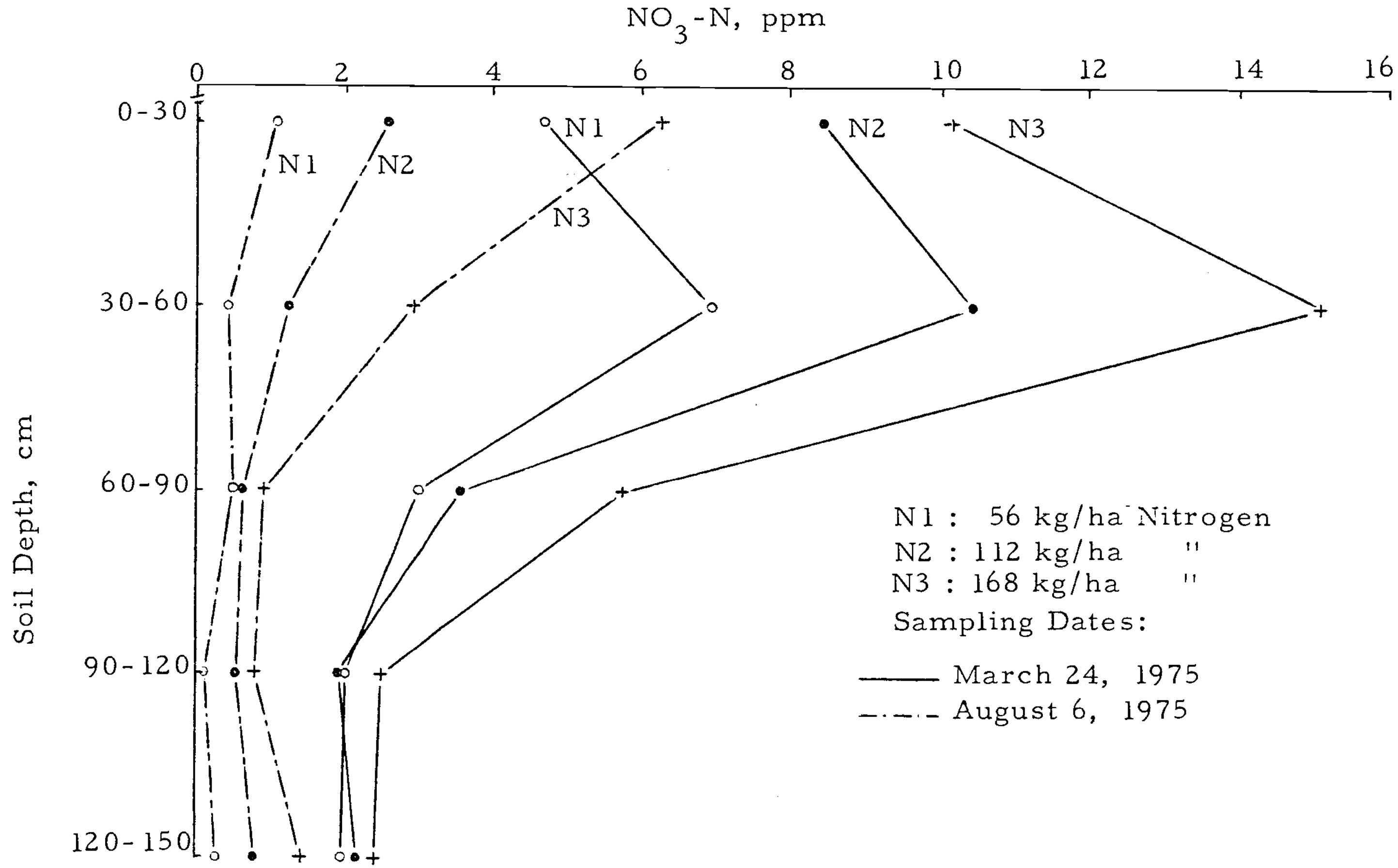

Figure 5. Experiment I. NO_3-N distribution in the soil profile under the barley cultivar with three levels of nitrogen at two sampling dates.

slight decrease in average soil profile moisture for both the wheat and barley cultivars. When the nitrogen rate was increased up to 168 kg/ha nitrogen, the difference between 56 kg/ha and 168 kg/ha nitrogen was significant. The water depletion of the cultivars was slightly higher at the rate of 168 kg/ha nitrogen but the differences were not significant (Tables 9 and 10, Figure 6).

Table 9. Experiment I. Moisture distribution in the soil profile under the wheat and barley cultivars after harvest.

Soil Depth cm	Mcdermid Nitrogen Rates Kg/ha 56	112	168	Hudson Nitrogen Rates Kg/ha 56	112	168
	............Soil Profile Moisture, %............					
0-30	5.6	5.3	4.7	5.9	5.7	5.5
30-60	6.5	6.4	6.2	6.9	6.7	6.5
60-90	6.2	6.0	6.0	6.7	6.4	6.3
90-120	6.3	5.8	5.9	6.4	6.5	6.4
120-150	7.2	6.9	7.3	9.5	9.9	9.0

There was a highly significant difference between the cultivars in water depletion. Mcdermid used more water than Hudson even though it produced slightly less yield (Figure 7). This was probably due to the earlier maturity of Hudson barley which headed about seven to eight days earlier than Mcdermid wheat. This allowed the barley cultivar to utilize the soil moisture during a cooler growth period.

Grain Yield

No significant difference in grain yield between Mcdermid and Hudson cultivars was observed within any level of nitrogen treatments.

Table 10. Experiment I. Observed mean squares for three agronomic traits of two cultivars and total soil profile NO_3-N and average soil profile moisture during the 1974-75 crop season.

Source of Variation	Degrees of Freedom	Grain Yield Kg/ha	1000 Kernel Weight gm	Spikes per M^2	Profile in March ppm	Total NO_3-N in August ppm	Average Soil Profile Moisture in August %
Reps	3	510234	26.35	10560	63.67	21.27	0.28
Cultivars	1	1123940	48.53*	28642	10.31	6.37	38.2**
Error (a)	3	882325	3.7	5640	35.33	5.71	0.515
Nitrogen Rates	2	54563	46.44**	12080	771.28**	259.15**	1.74*
Error (b)	6	205507	3.49	687	6.62	14.27	0.265
Cultivars x Nitrogen Rates	2	201393	2.93	2357	2.2	3.87	2.08
Error (c)	6	85495	5.45	1182	15.64	2.53	2.69
Total	23						
Means		4227.3	31.65	405.8	28.25	7.4	6.57
C. V. %		6.9	7.3	10.7	13.9	21.5	7.9

* Significant differences at the 5% probability level

** Significant differences at the 1% probability level

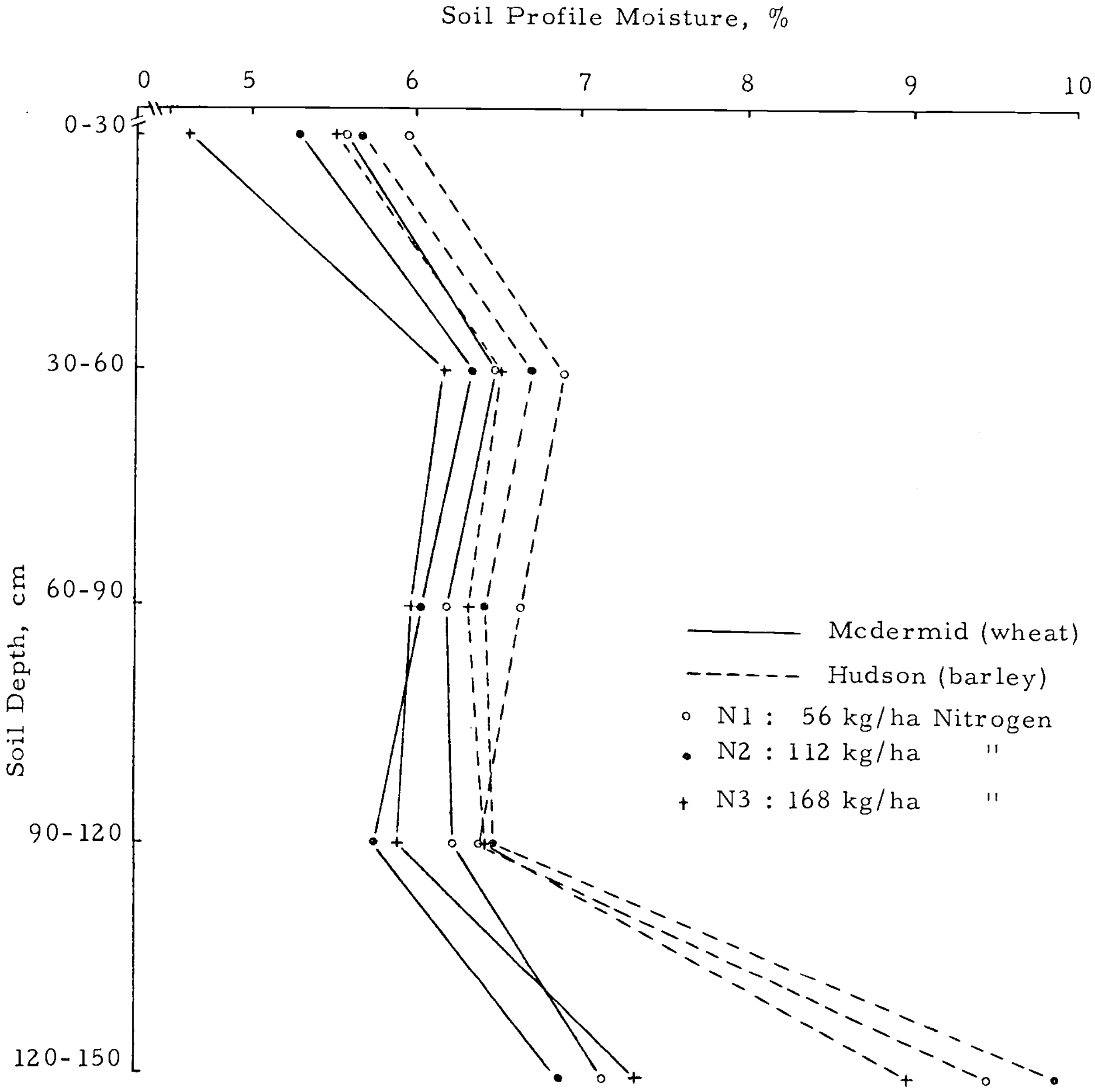

Figure 6. Experiment I. Moisture distribution in the soil profile under the barley and wheat cultivars after harvest for the 1974-75 crop season.

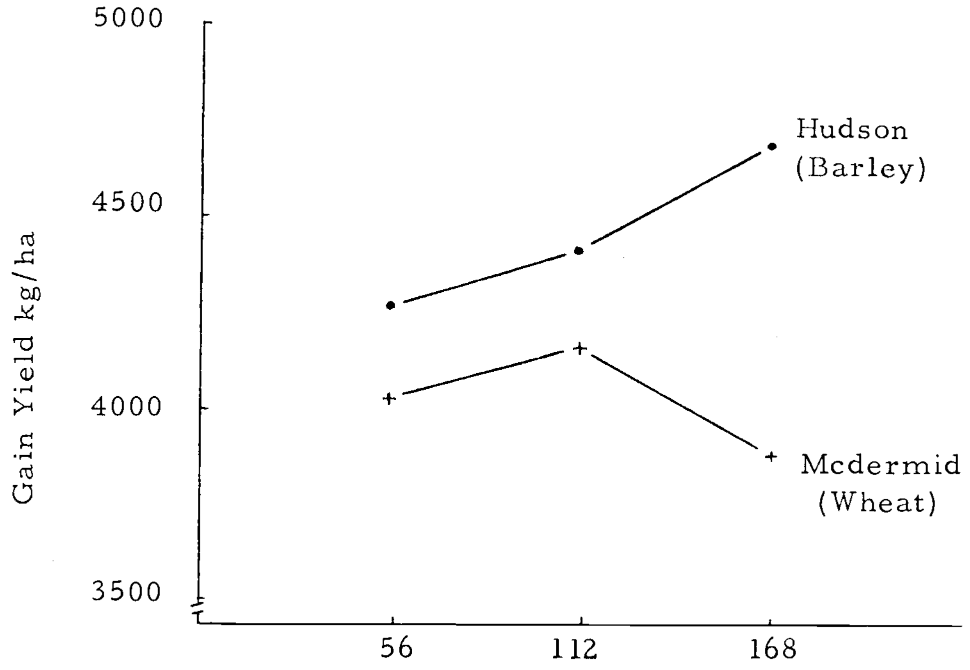

Figure 7. Experiment I. Effects of nitrogen rate on yields of barley and wheat for the 1974-75 crop season.

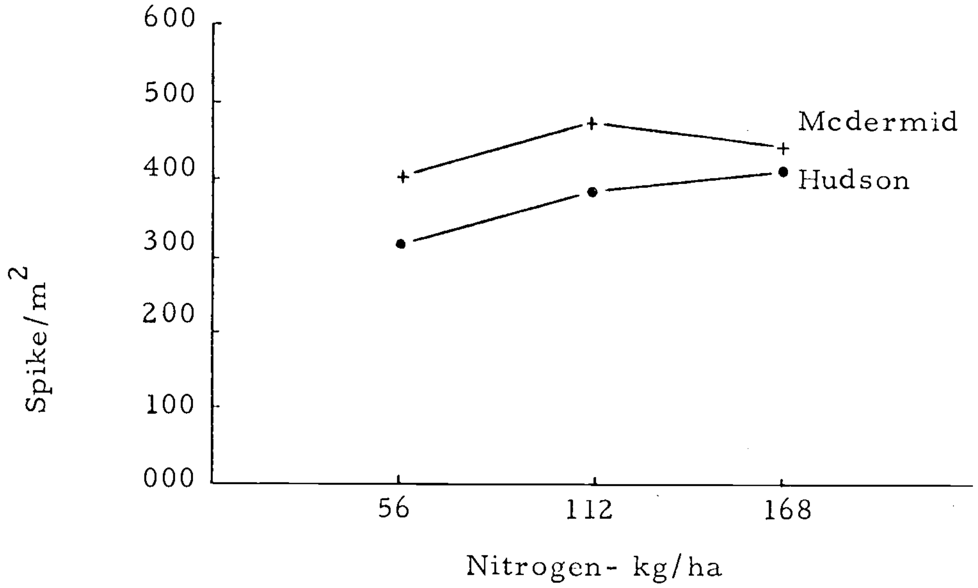

Figure 8. Experiment I. Effect of nitrogen rate on spike/m^2 of barley and wheat for the 1974-75 crop season.

However, Hudson slightly out-yielded Mcdermid by a small amount (432.8 kg/ha) on the average.

The effect of nitrogen levels on grain yield was not significant for both Mcdermid and Hudson. However, a small yield increase was obtained by addition of fertilizer to 112 kg/ha for both cultivars, and to 168 kg/ha for Hudson. This indicated that Hudson made efficient use of nitrogen in excess of 168 kg/ha (Table 10, Figure 7). In case of Mcdermid higher levels of nitrogen than 112 kg/ha resulted in a reduction in grain yield.

1000 Kernel Weight

Mean 1000 kernel weights were 30.2 and 33.1 for Mcdermid and Hudson, respectively, and a significant difference was noted between the cultivars. There was also a highly significant difference in 1000 kernel weight at the different levels of nitrogen. Increasing nitrogen rate to 112/kg/ha resulted in a reduction of 1000 kernel weight for both cultivars. Beyond this level decrease due to increasing nitrogen rate was not significant. Both cultivars responded similarly to nitrogen since no cultivar x nitrogen rate significant interaction was observed (Tables 8 and 10, Figure 9).

Spikes per Square Meter

There were highly significant differences among the nitrogen levels in the number of spikes per m^2 (Table 10). As the rate of nitrogen increased to 112 kg/ha, the number of spikes per m^2 increased for both cultivars. Further increase in the rate of nitrogen created a non-significant decrease for Mcdermid and a non-significant increase for Hudson in the number of spikes per m^2 (Figure 8). Non-significant

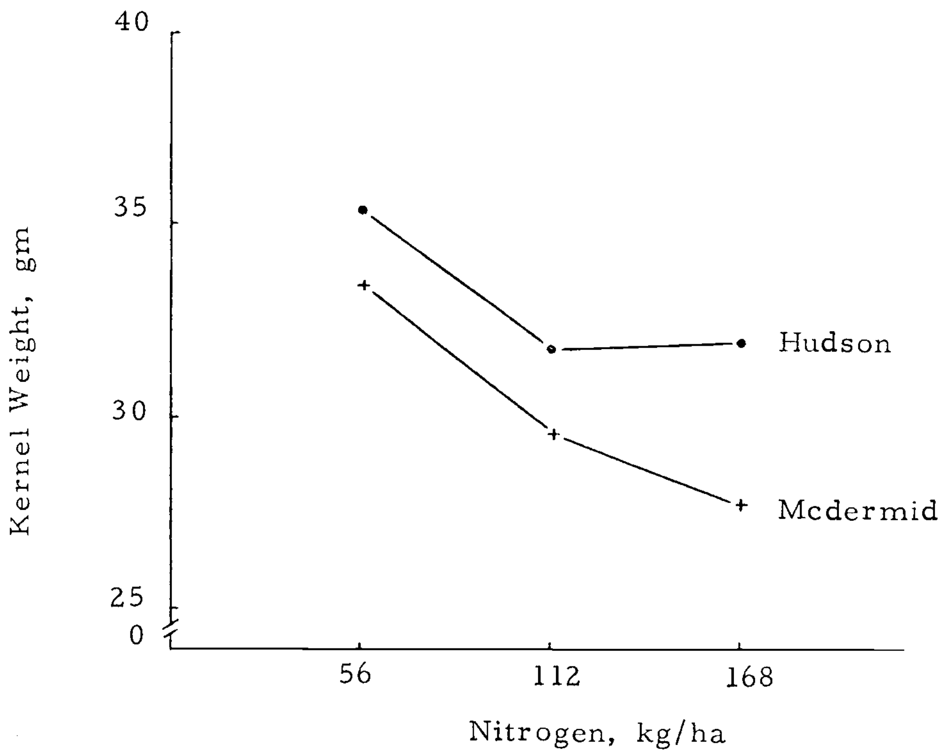

Figure 9. Experiment I. Effect of nitrogen rate on 1000 kernel weight of wheat and barley cultivars for the 1974-75 crop season.

cultivar x nitrogen rate interaction showed that both cultivars responded similarly at all levels of nitrogen.

Effect of Soil Profile Moisture Level on NO_3-N Accumulation

Moisture distribution in the soil profile under dry, normal and wet fallow conditions is reported in Figure 10 and tabulated in Table 11. It is apparent that increasing the amount of rainfall did not result in a high soil profile moisture from April 22 to July 1 due to high evaporation. Soil profile moisture content was significantly decreased with time at each moisture treatment. The differences in soil moisture content among the fallow moisture levels were highly significant at each sampling date.

Table 11. Experiment I. Moisture distribution in the soil profile at three fallow moisture levels at two sampling dates during the 1975-76 fallow season.

Soil Depth cm	(Moisture Level 1) Dry Fallow Season	(Moisture Level 2) Normal Fallow Season	(Moisture Level 3) Wet Fallow Season
April 22, 1976	....	Soil Moisture, %	....
0-30	14.7	16.0	17.6
30-60	13.1	14.6	15.6
60-90	10.9	13.1	14.5
90-120	9.9	11.9	13.7
120-150	11.3	12.1	14.8
July 1, 1976			
0-30	12.1	13.5	14.6
30-60	12.6	13.1	14.1
60-90	11.4	13.3	13.3
90-120	10.9	13.0	13.0
120-150	11.8	12.2	13.3

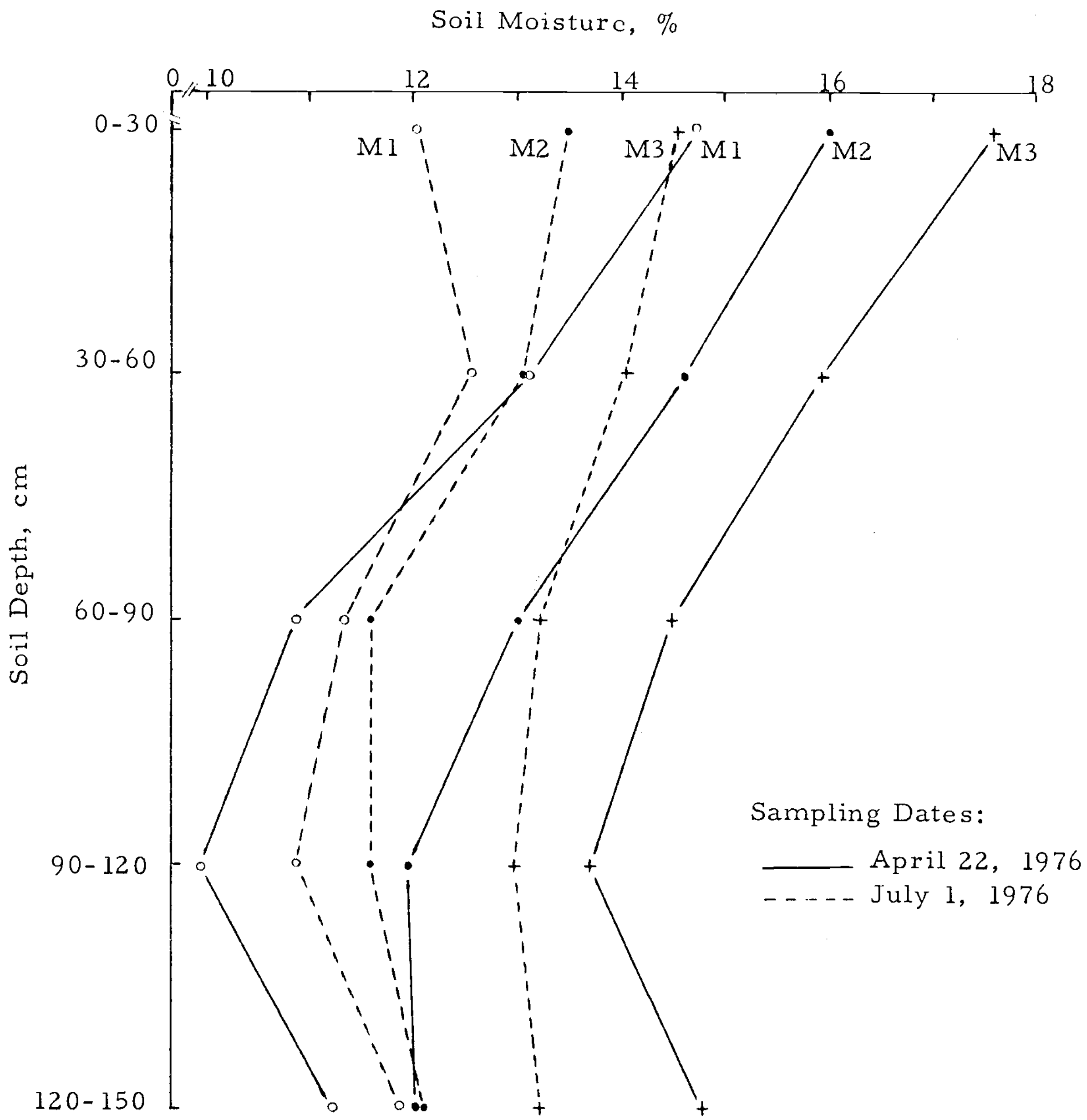

Figure 10. Experiment I. Soil profile moisture at three fallow moisture levels at two sampling dates during the 1975-76 fallow season.

The soil NO_3-N content in the wheat and barley plots, which were harvested in August 1975 at five sampling depths for each of the three moisture treatments on April 22, and July 1, 1976, is reported in Table 12 and Figures 11, 12, 13 and 14.

On August 1975, residual NO_3-N concentrations in the soil profile of the wheat plots were 3.23, 5.56, 15.2 ppm for the 56, 112, 168 kg/ha nitrogen rates respectively (Table 13). On April 22, 1976, after 183 mm precipitation, the total NO_3-N content in the soil profile under dry fallow conditions was found to be 4.92, 7.02, 9.76ppm at 56, 112, 168 kg/ha nitrogen rate, respectively, with an average soil profile moisture of 12 percent. The 30-60 cm soil depth appeared to be a zone of nitrate accumulation. This indicated a very limited downward movement of nitrate nitrogen. In the same treatments on July 1, total NO_3-N concentration reached 5, 9.3 and 13.6 ppm at 56, 112, 168 kg/ha nitrogen rates. NO_3-N concentration at 0-30 cm depth signficiantly increased while there was a drastic decrease in NO_3-N concentration at 30-60 cm depth. This decrease suggests an upward movement of NO_3-N during prolonged dry periods. At moisture level two, fallowing 251 mm precipitation total NO_3-N concentration in the soil profile was 4.9, 8.6, 10.2 ppm at the rates of 56, 112, 168 kg/ha nitrogen, respectively. The 60-90 cm soil depth was a NO_3-N accumulation zone. The data indicated an effective downward movement of NO_3-N in the normal fallow season. Total NO_3-N concentration was 8.5, 10.1, 14.8 ppm at 56, 112, 168 kg/ha nitrogen rates on July 1. Very high NO_3-N concentration at the top 0-30 cm depth also indicated upward movement of NO_3-N from lower depths to the surface. In the plots under a wet fallow condition, 5.2, 10.2, 11.8 ppm NO_3-N was found at the rates of 56, 112, 168 kg/ha nitrogen, respectively, and after 306 mm precipitation, average soil profile moisture was 15.2 percent. The highest NO_3-N accumulation which indicated possible leaching loss of NO_3-N

Table 12. Experiment I. NO_3-N in the soil profile at three fallow moisture levels and three residual nitrogen rates at two sampling dates from plots grown in winter wheat and barley the previous season (1974-75).

Sampling Date	Sampling Depth cm	Dry Fallow Season Nitrogen Rate Kg/ha 56	112	168	Normal Fallow Season Nitrogen Rate Kg/ha 56	112	168	Wet Fallow Season Nitrogen Rate Kg/ha 56	112	168
HUDSON										
April 22, 1976	0-30	1.14	1.31	2.33	1.32	1.76	2.71	1.06	1.63	2.11
	30-60	0.48	1.07	1.65	1.06	2.86	2.15	0.83	1.29	1.71
	60-90	0.45	1.05	1.92	1.71	3.25	3.60	1.07	2.37	2.46
	90-120	0.24	0.88	1.29	0.83	1.66	3.15	0.92	2.24	3.31
	120-150	0.90	1.06	1.61	0.91	1.05	1.86	0.65	1.19	2.54
Total		3.21	5.37	8.80	5.83	10.58	13.42	4.53	8.72	12.13
July 1, 1975	0-30	3.14	3.88	4.69	3.90	3.66	8.00	3.20	4.64	5.24
	30-60	1.10	1.78	2.02	1.23	1.89	1.29	0.89	0.93	1.20
	60-90	1.31	1.53	3.73	1.09	2.33	4.11	1.01	1.48	2.31
	90-120	0.62	0.65	1.22	0.83	2.30	4.73	0.93	1.49	5.41
	120-150	0.52	0.96	1.16	0.42	0.93	2.33	0.52	1.28	3.31
Total		6.69	8.80	12.82	7.47	11.11	20.46	6.55	9.82	17.47
MCDERMID										
April 22, 1976	0-30	0.76	1.50	1.79	1.10	1.29	2.33	0.97	1.17	1.27
	30-60	2.00	2.82	3.09	0.36	2.05	1.82	0.50	0.83	0.70
	60-90	0.72	1.02	2.68	1.46	2.48	2.78	1.16	3.20	2.51
	90-120	0.34	0.60	0.80	1.12	1.47	1.40	1.38	3.42	3.93
	120-150	1.10	1.08	1.40	0.93	1.36	1.86	1.23	1.55	3.44
Total		4.92	7.02	9.76	4.97	8.65	10.19	5.24	10.17	11.85
July 1, 1976	0-30	1.73	3.34	5.22	2.77	2.75	5.10	2.63	2.28	3.87
	30-60	1.06	1.86	1.60	1.58	2.32	2.28	0.65	1.03	1.14
	60-90	0.70	1.82	2.77	1.19	2.29	2.59	1.07	4.45	3.02
	90-120	0.62	0.79	2.22	1.79	1.09	3.21	1.22	2.28	4.82
	120-150	0.98	1.55	1.81	1.24	1.69	1.65	1.48	1.14	2.97
Total		5.09	9.36	13.62	8.57	10.14	14.83	7.05	11.18	15.82

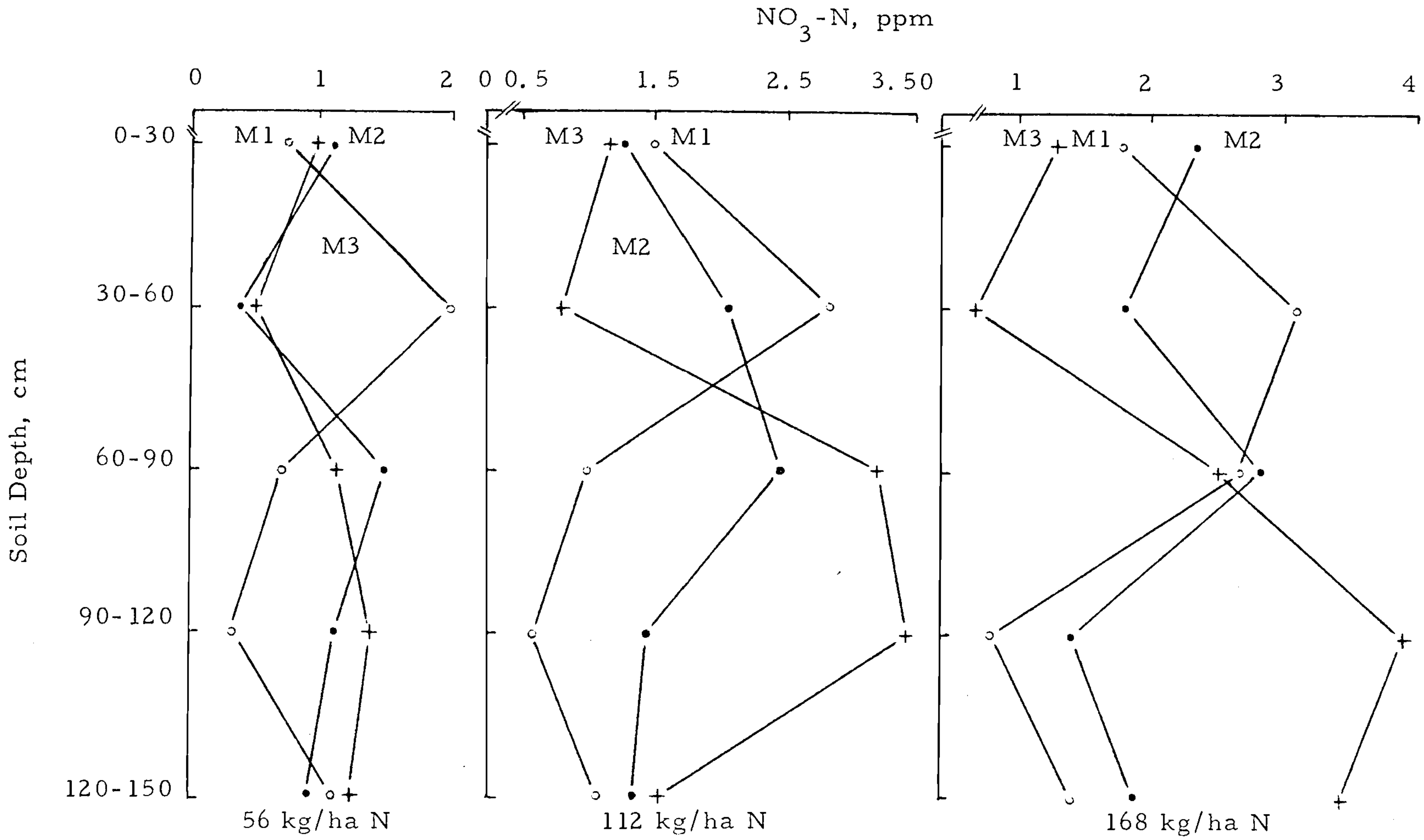

Figure 11. Experiment I. NO_3-N in the soil profile at three fallow moisture levels and three residual nitrogen rates on April 22, 1976, from plots grown in winter wheat the previous season.

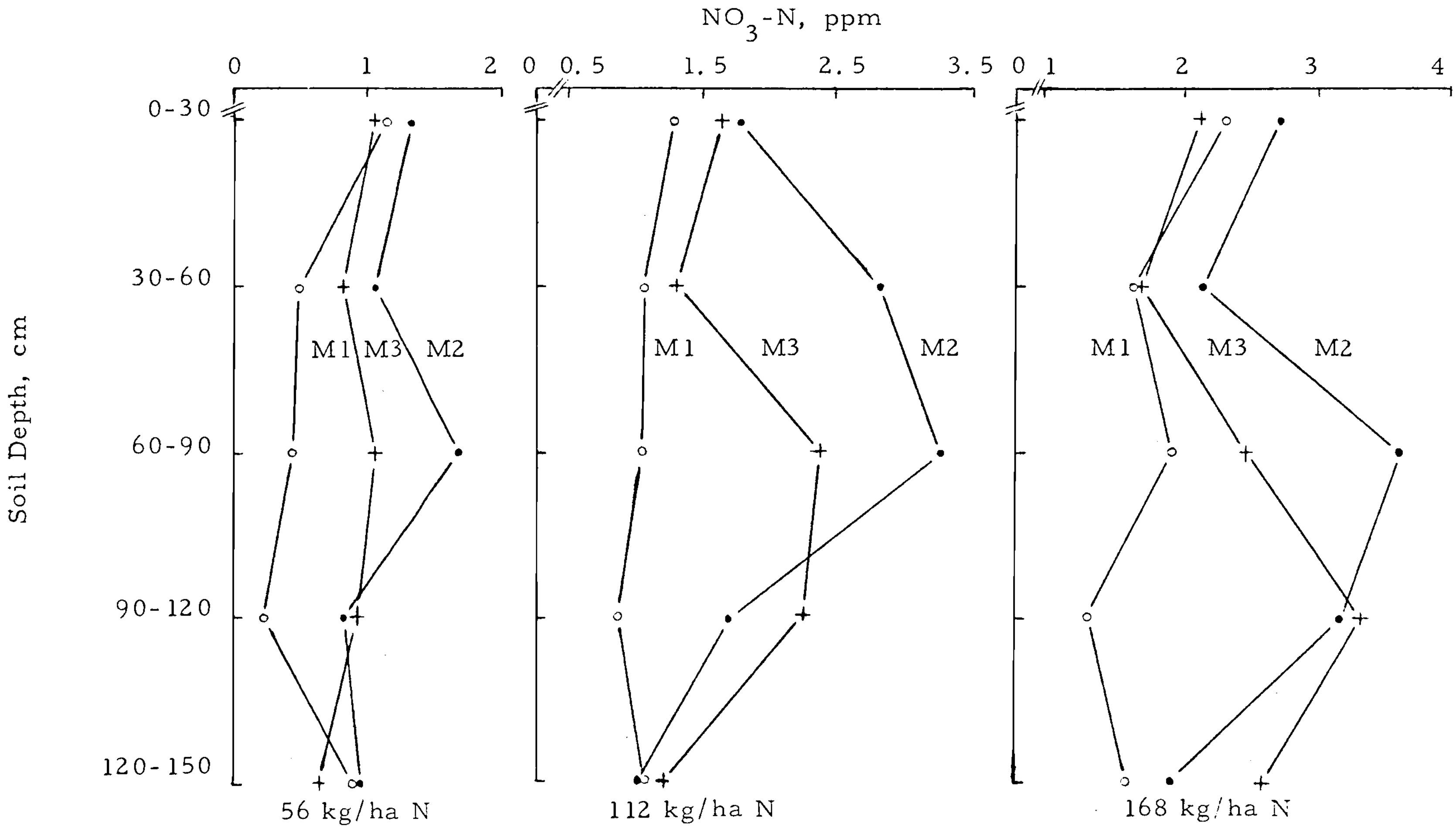

Figure 12. Experiment I. NO_3-N in the soil profile at three fallow moisture levels and three residual nitrogen rates on April 22, 1976 from plots grown in barley the previous season.

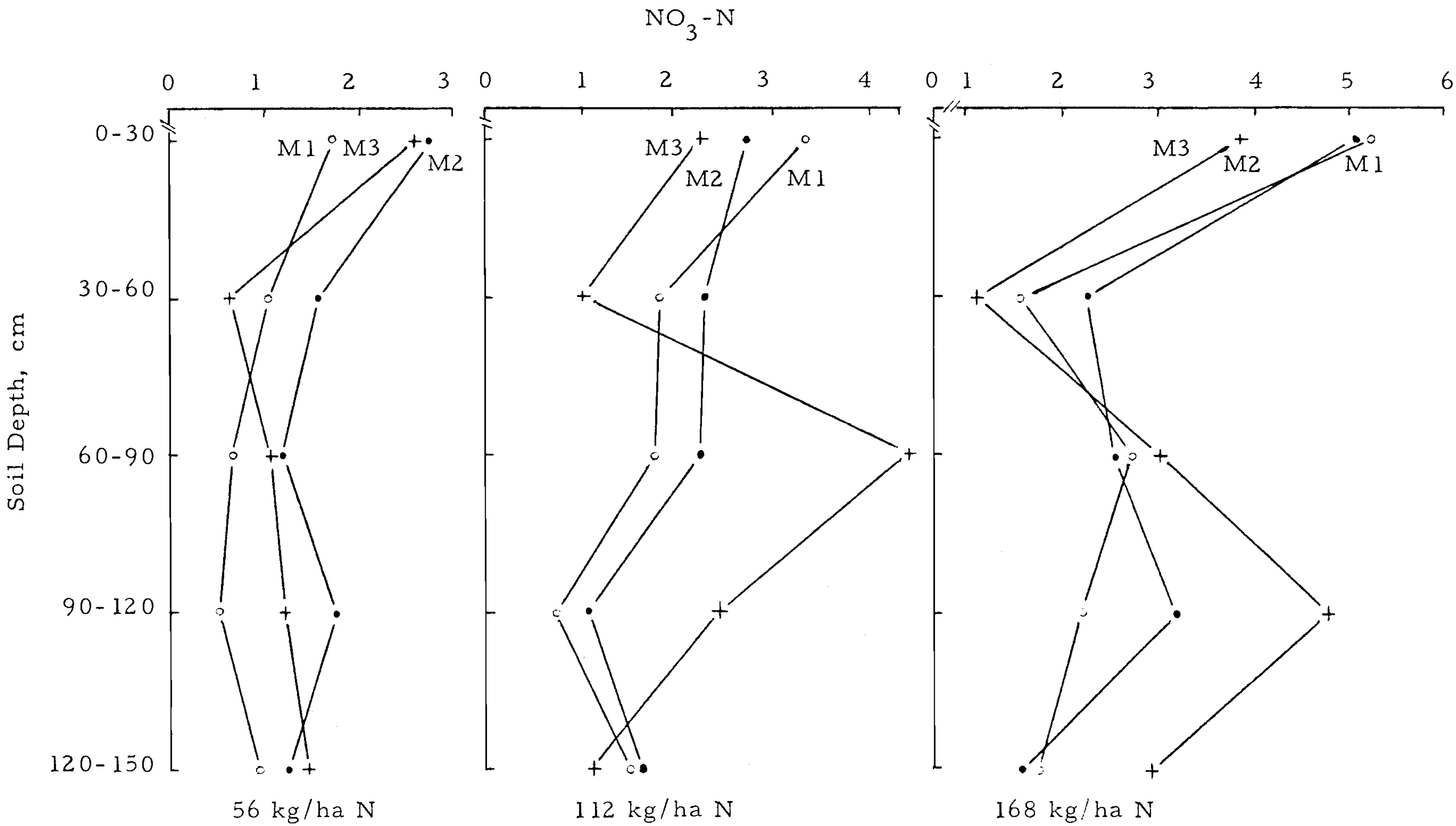

Figure 13. Experiment I. NO_3-N in the soil profile at three fallow moisture levels and three residual nitrogen rates on July 1, 1976 from plots grown in winter wheat the previous season (1974-75).

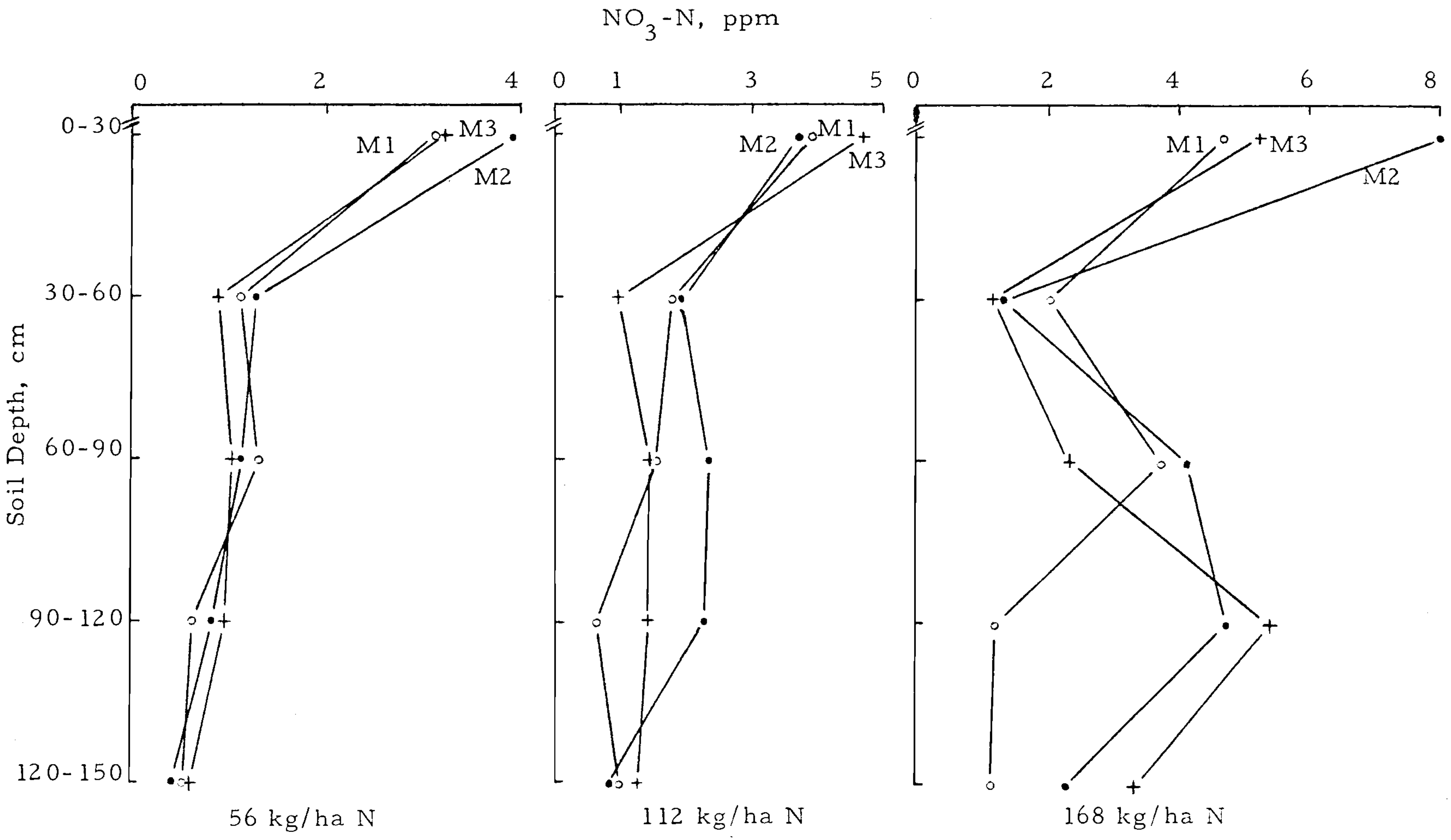

Figure 14. Experiment I. NO_3-N in the soil profile at three fallow moisture levels and three residual nitrogen rates on July 1, 1976 from plots grown in barley the previous season (1974-75).

Table 13. Experiment I. NO_3-N accumulation in the soil profile as influenced by three levels of soil profile moisture x residual nitrate nitrogen after wheat and barley cultivars in the 1975-76 fallow season.

Nitrogen Rate Kg/ha	Sampling Date	Residual NO_3-N	Moisture Treatments M1	M2	M3
MCDERMID		...........NO_3-N, ppm.........			
56	Aug. 7, 1975	3.23			
	April 22, 1976*		4.92	4.97	5.24
	July 1, 1976**		5.09	8.57	7.05
112	Aug. 7, 1975	5.56			
	April 22, 1976		7.02	8.65	10.17
	July 1, 1976		9.36	10.14	11.18
168	Aug. 7, 1975	15.20			
	April 22, 1976		9.76	10.19	11.85
	July 1, 1976		13.62	14.83	15.82
HUDSON					
56	Aug. 7, 1975	2.39			
	April 22, 1976		3.21	5.83	4.53
	July 1, 1976		6.69	7.47	6.55
112	Aug. 7, 1975	5.79			
	April 22, 1976		5.37	10.58	8.72
	July 1, 1976		8.80	11.11	9.82
168	Aug. 7, 1975	12.21			
	April 22, 1976		8.80	13.42	12.13
	July 1, 1976		12.82	20.46	17.47

* Second sampling after 183, 251, 306 mm rainfall for M1, M2, M3

** Third sampling after 205.9, 275.1, 329.9 mm rainfall for M1, M2, M3 during wet fallow season occurred at the 90-120 cm depth. On July 1, NO_3-N concentration was found to be 7.0, 11.1, 15.8 ppm at 56, 112, 168 kg/ha nitrogen rates. NO_3-N content of the top 0-30 cm soil depth increased from April to July but the 60 to 120 cm soil depth was still an accumulation zone. This suggests that the recovery of NO_3-N moved to deep layers as much as 120 cm depth is very slow.

In the treatments on which barley was harvested during August 1975, residual NO_3-N content in the soil profile was 2.3, 5.7, 12.2 ppm at 56, 112, 168 kg/ha nitrogen rate, respectively. On April 22, total NO_3-N in the soil profile under dry fallow conditions was found to be 3.2, 5.3, 8.8 ppm at the rate of 56, 112, 168 kg/ha nitrogen, respectively. Total NO_3-N concentration in the same plots was 6.6, 8.8, 12.8 ppm on July 1. The 0-30 cm soil depth had highest NO_3-N concentration. Under normal fallow conditions, total NO_3-N in the soil profile was 5.8, 10.5, 13.4 ppm at the rates of 56, 112, 168 kg/ha nitrogen, respectively. NO_3-N accumulation zone was at the 60-90 cm soil depth. On July 1, the total amount of NO_3-N in the soil profile reached 7.4, 11.1, 20,4 ppm at the rates of 56, 112, 168 kg/ha nitrogen. Under wet fallow conditions 4.5, 8.7 and 12.1 ppm NO_3-N were found in the soil profile on April 22, at the rates of 56, 112, 168 kg/ha nitrogen. On July 1, NO_3-N concentration was 6.5, 9.8, 17.4 ppm at the same rates of nitrogen. The 60-120 cm soil depth for 56 and 112 kg/ha nitrogen rates was an accumulation zone. At the rate of 168 kg/ha nitrogen, the 90-150 cm soil depth appeared to be an accumulation zone.

Statistical analysis of the data does not show any significant differences in NO_3-N accumulation in the soil profile between the cultivars at any sampling time (Tables 14 and 15).

Table 14. Experiment I. Observed mean squares for NO_3-N in the soil profile on April 22 and July 1, 1976.

Source of Variation	Degrees of Freedom	Soil Profile in April ppm	in July
Reps	3	0.80	761.6
Cultivar	1	2.8×10^{-4}	816.1
Fallow Moisture Level	2	8.60**	900.0*
Fallow Moisture Level x Cultivar	2	4.08**	717.2
Nitrogen Rate	2	46.4**	269.5
Fallow Moisture Level x Nitrogen Rate	4	0.76	90.8
Cultivar x Nitrogen Rate	2	0.76	112.2
Fallow Moisture Level x Cultivar x Nitrogen Rate	4	0.131	92.9
Error (a)	51	0.73	277.8
Sampling Depth	4	3.65**	123.4**
Fallow Moisture Level x Sampling Depth	8	7.41**	35.7*
Cultivar x Sampling Depth	4	1.00	33.7
Fallow Moisture Level x Cultivar x Sampling Depth	8	2.61**	16.6
Nitrogen Rate x Sampling Depth	8	1.29**	20.1
Fallow Moisture Level x Nitrogen Rate x Sampling Depth	16	1.3**	8.5
Cultivar x Nitrogen Rate x Sampling Depth	8	0.31	17.4
Fallow Moisture Level x Nitrogen Rate x Cultivar x Sampling Depth	16	0.42	12.6
Error (b)	216	0.257	15.57
Total	359		

* Significant differences at the 5% probability level
** Significant differences at the 1% probability level

The effects of fallow moisture levels on NO_3-N accumulation in the soil profile was highly significant. High soil profile moisture is associated with high NO_3-N concentration in the profile. The difference in amount of NO_3-N accumulated in the soil profile between dry fallow and normal fallow plots, also between dry fallow and wet fallow plots, was highly significant (Table 16). There was no significant difference between normal and wet fallow moisture levels although the amount of

Table 15. Experiment I. Observed mean squares for the total NO_3-N in the soil profile on July 1, 1976.

Source of Variation	Degrees of Freedom	Total NO_3-N in the Profile ppm
Reps	3	0.76
Sampling Time	1	296.7**
Cultivar	1	3.5
Sampling Time x Cultivar	1	3.6
Fallow Moisture Level	2	87.8**
Sampling Time x Fallow Moisture Level	2	1.5
Cultivar x Fallow Moisture Level	2	24.7
Sampling Time x Cultivar x Fallow M. Level	2	2.3
Error (a)	33	4.22
Nitrogen Rate	2	689.2**
Sampling Time x Nitrogen Rate	2	36.7**
Cultivar x Nitrogen Rate	2	13.5
Sampling Time x Cultivar x Nitrogen Rate	2	0.9
Fallow Moisture Level x Nitrogen Rate	4	5.5
Sampling Time x Fallow Moisture Level x Nitrogen Rate	4	4.2
Cultivar x Fallow Moisture Level x Nitrogen Rate	4	7.8
Sampling Time x Cultivar x Fallow Moisture Level x Nitrogen Rate	4	3.5
Error (b)	72	4.136
Total	143	

**Significant differences at the 1% probability level

Table 16. Experiment I. Mean total NO_3-N in the soil profile at three levels of fallow moisture and three nitrogen rates on July 1, 1976.

	Total NO_3-N in the Profile ppm
Fallow Moisture Levels	
M1	7.9 a[1]
M2	10.5 b
M3	10.0 b
Nitrogen Rates	
N1	5.8 a
N2	9.2 b
N3	13.4 c

[1]Student Newman Keul's Test-Means in a column followed by the same letter are not significantly different at the 5% probability level.

NO_3-N accumulated in the wet fallow plots was less than the amount of NO_3-N in the normal fallow plots. These data suggest that the increase in moisture could have caused losses in NO_3-N due to leaching and/or denitrification over normal fallow moisture level.

There were also highly significant differences in amount of NO_3-N among the sampling depths for both of the sampling dates. The data reported in Table 12 and Figures 11 and 12 show that until April 22, NO_3-N accumulated in the lower layers of soil profile with increasing soil profile moisture level. Highly significant fallow moisture level x sampling depth interactions also support this result (Table 14). However, on July 1, there was an apparent increase in NO_3-N in the top 30 cm of soil in all treatments (Figures 13 and 14). The research reported by Campbell, et al. (1975) suggests that a considerably high portion of the increase in NO_3-N which occurs in surface soil could have resulted from upward movement due to evaporation. Nitrification accounted for 12 percent of the increases in the top 2.5 cm of soil.

The effect of residual nitrate on NO_3-N accumulation was found to be highly significant from the April 22 sampling (Tables 14 and 15). Increasing residual nitrate with increasing moisture level had a significant effect on NO_3-N accumulation in the soil profile for all treatments. Low residual nitrate appeared to be more favorable to the nitrate accumulation in the soil profile under dry fallow conditions. Increasing residual NO_3-N failed to increase nitrate content of soil at the same rate as at the lowest residual nitrate levels. However, high total NO_3-N concentration in the soil profile was always associated with the highest residual NO_3-N for all treatments at each sampling time. With the highest residual NO_3-N from 168 kg/ha nitrogen rate, NO_3-N accumulation was suppressed at each fallow moisture level or compared to the initial level. Reduction in NO_3-N concentration in the soil profile from August to April 22 was the highest under dry fallow conditions and the lowest under wet fallow conditions. On the other hand an increase in residual nitrate-nitrogen to about 6 ppm was associated with an increase in NO_3-N accumulation.

There was no significant difference in the amount of NO_3-N in the soil profile among the residual NO_3-N levels from 56, 112, 168 kg/ha nitrogen rates on July 1 (Table 14).

Experiment II

Effect of Fallow Moisture Level on NO_3-N Accumulation

The soil nitrate-nitrogen content at five sampling depths for each of the three moisture treatments at both the beginning and end of the fallow season are shown in Table 18 and Figure 16. Distribution of the soil profile moisture of each moisture treatment is graphically presented in Figure 15 and tabulated in Table 17.

Table 17. Experiment II. Moisture distribution in the soil profile at three levels of fallow moisture at two sampling dates during the 1974-75 fallow season.

Sampling Date	Soil Depth cm	Moisture Treatments M1	M2	M3
May 3, 1975	0-30	14.5	14.9	16.0
	30-60	14.9	15.3	15.8
	60-90	14.3	14.5	15.4
	90-120	12.8	13.2	14.8
	120-150	11.4	12.0	13.6
September 22, 1975	0-30	10.5	11.1	11.7
	30-60	11.5	11.7	12.1
	60-90	11.5	11.8	12.3
	90-120	11.3	11.5	12.3
	120-150	11.0	11.4	12.0

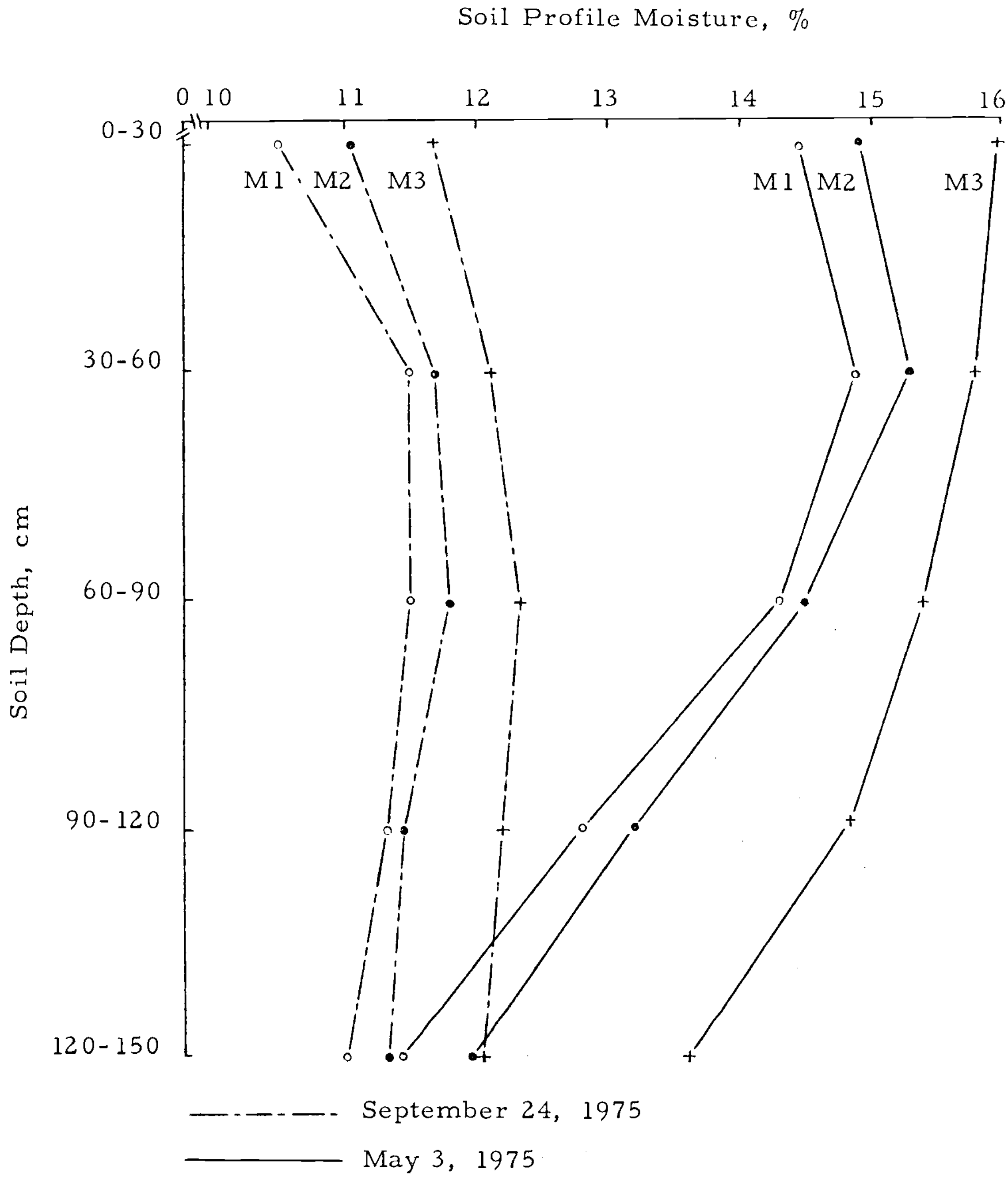

Figure 15. Experiment II. Soil profile moisture at three fallow moisture levels at two sampling dates during the 1974-75 fallow season.

Table 18. Experiment II. NO_3N distribution in the soil profile as influenced by three levels of fallow moisture during the 1974-75 fallow season.

Sampling Date	Soil Depth cm	Amount of NO_3-N ppm	Amount of NO_3-N kg/ha	Moisture Level 1 Amount of NO_3-N ppm	Moisture Level 1 Amount of NO_3-N kg/ha	Moisture Level 1 Fraction to Total %	Moisture Level 2 Amount of NO_3-N ppm	Moisture Level 2 Amount of NO_3-N kg/ha	Moisture Level 2 Fraction to Total %	Moisture Level 3 Amount of NO_3-N ppm	Moisture Level 3 Amount of NO_3-N kg/ha	Moisture Level 3 Fraction to Total %
Sept. 24, 1974	0-30	1.8	7.8									
	30-60	1.6	6.4									
	60-90	1.9	7.8									
	90-120	0.9	3.6									
	120-150	0.8	3.3									
	Total	7.0	28.9									
May 3, 1975	0-30			0.47	2.03	12.7	0.50	2.16	10.7	0.83	3.59	19.6
	30-60			0.29	1.16	7.8	0.36	1.44	7.7	0.34	1.36	8.1
	60-90			1.04	4.27	28.0	1.28	5.26	27.3	0.42	1.73	10.0
	90-120			1.77	7.12	47.7	1.84	7.40	39.3	1.38	5.55	32.7
	120-150			0.14	0.58	3.8	0.70	2.92	15.0	1.25	5.21	29.6
	Total			3.71	15.16		4.68	19.18		4.22	17.45	
	Total Rainfall, mm			202.5				226.5			268.5	
Sept. 22, 1975	0-30			4.03	17.41	48.6	8.21	35.46	58.0	6.86	29.64	58.2
	30-60			0.72	2.87	9.4	0.94	3.75	6.7	1.09	4.35	9.3
	60-90			1.04	4.27	12.5	1.42	5.84	10.0	0.96	3.95	8.1
	90-120			1.59	6.39	15.3	2.29	9.21	15.8	1.22	4.90	10.4
	120-150			1.18	4.92	14.2	1.31	5.46	9.5	1.78	7.42	14.0
	Total			8.56	35.86		14.17	59.72		11.91	50.26	
	Total Rainfall, mm				279.5			303.5			345.5	

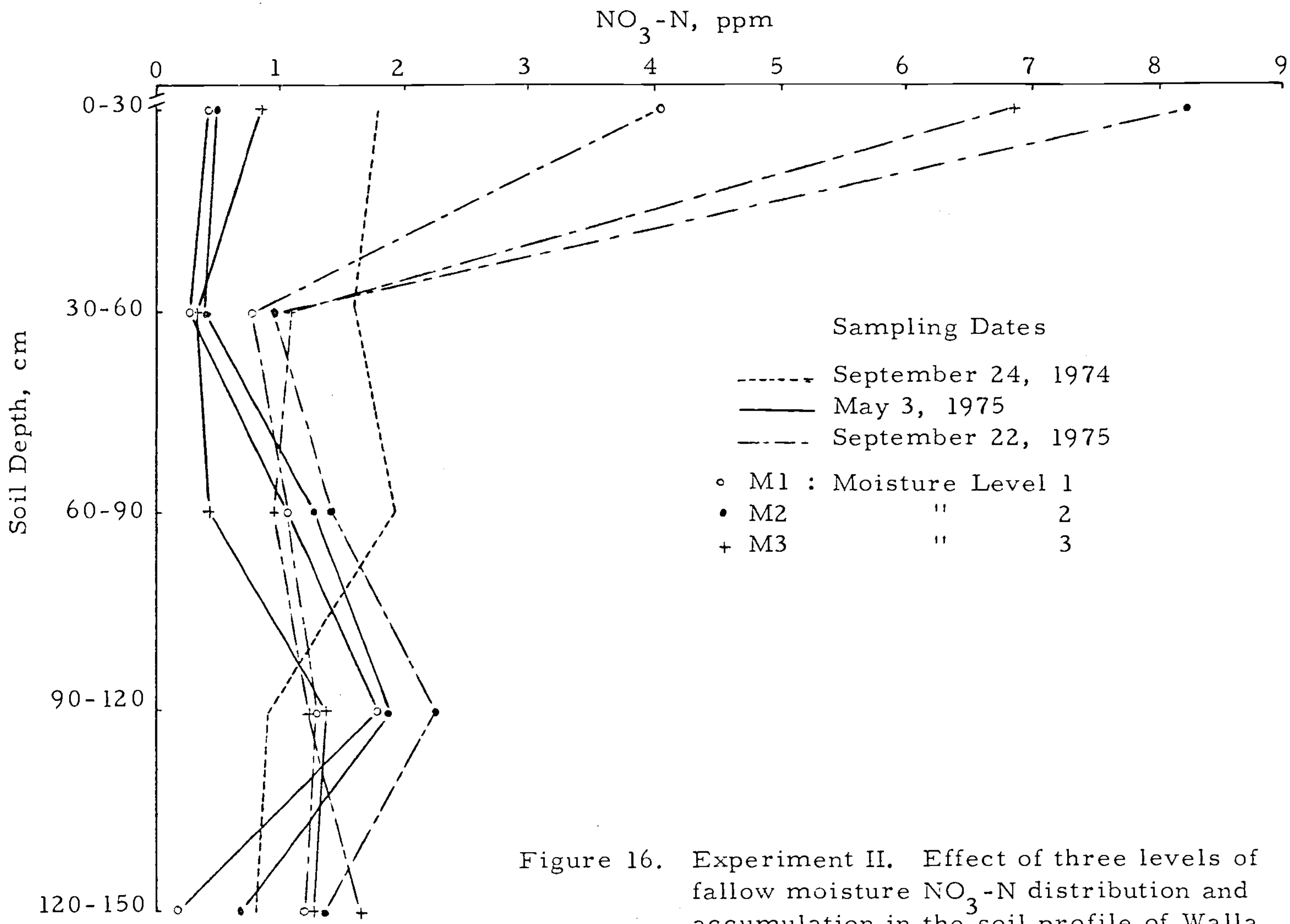

Figure 16. Experiment II. Effect of three levels of fallow moisture NO_3-N distribution and accumulation in the soil profile of Walla Walla silt loam under fallow with three moisture levels at three sampling dates.

On September 24, 1974, Walla Walla silt loam contained 7 ppm nitrate to a depth of 150 cm. On May 3, 1975, after 202.5 mm rainfall the total nitrate content of the soil profile under dry fallow conditions was 3.71 ppm with an average soil profile moisture of 13.6 percent. The 90 to 120 cm soil depth appeared to be a zone of nitrate accumulation of 1.77 ppm. At moisture level two representing normal fallow season, 4.58 ppm of nitrate-nitrogen accumulated after 226.5 mm of rainfall with an average soil profile moisture of 14 percent. At the 90-120 cm soil depth there was a nitrate-nitrogen accumulation zone with 1.84 ppm nitrate. In the treatments with 268.5 mm rainfall plus added water to simulate wet fallow conditions, the accumulation zone was shifted to the 120-150 cm depth and the soil profile contained a total of 4.22 ppm nitrate with an average soil profile moisture of 15 percent.

The decrease in NO_3-N content of soil for each of the three moisture treatments from September 1974 to May 3, 1975, in the 0 to 30 cm depth is probably due to the assimilation of the nitrate by microorganisms during mineralization of organic matter (Blair and Prince, 1928) and to the downward movement of the nitrate ions from the 30 to 90 cm depth. It was evident that increasing the amount of rainfall above 226.5 mm accelerated the movement of the nitrate ions even beyond the 150 cm depth since an increase of nitrate occurred within the 120 to 150 cm layer. On the other hand, there was no indication of nitrate movement beyond 120 cm depth for the dry and normal fallow treatments (Figure 16).

On September 20, 1975, on dry, normal and wet fallow treatments after 279.5 mm, 303.5 mm rainfall, respectively, the levels of soil nitrate in the lower sampling depths remained fairly constant (Figure 17, Table 21) while in the 0 to 30 cm depth, nitrate content reached 8.6, 14.2, 11.9 ppm on dry, normal and wet fallow treatments,

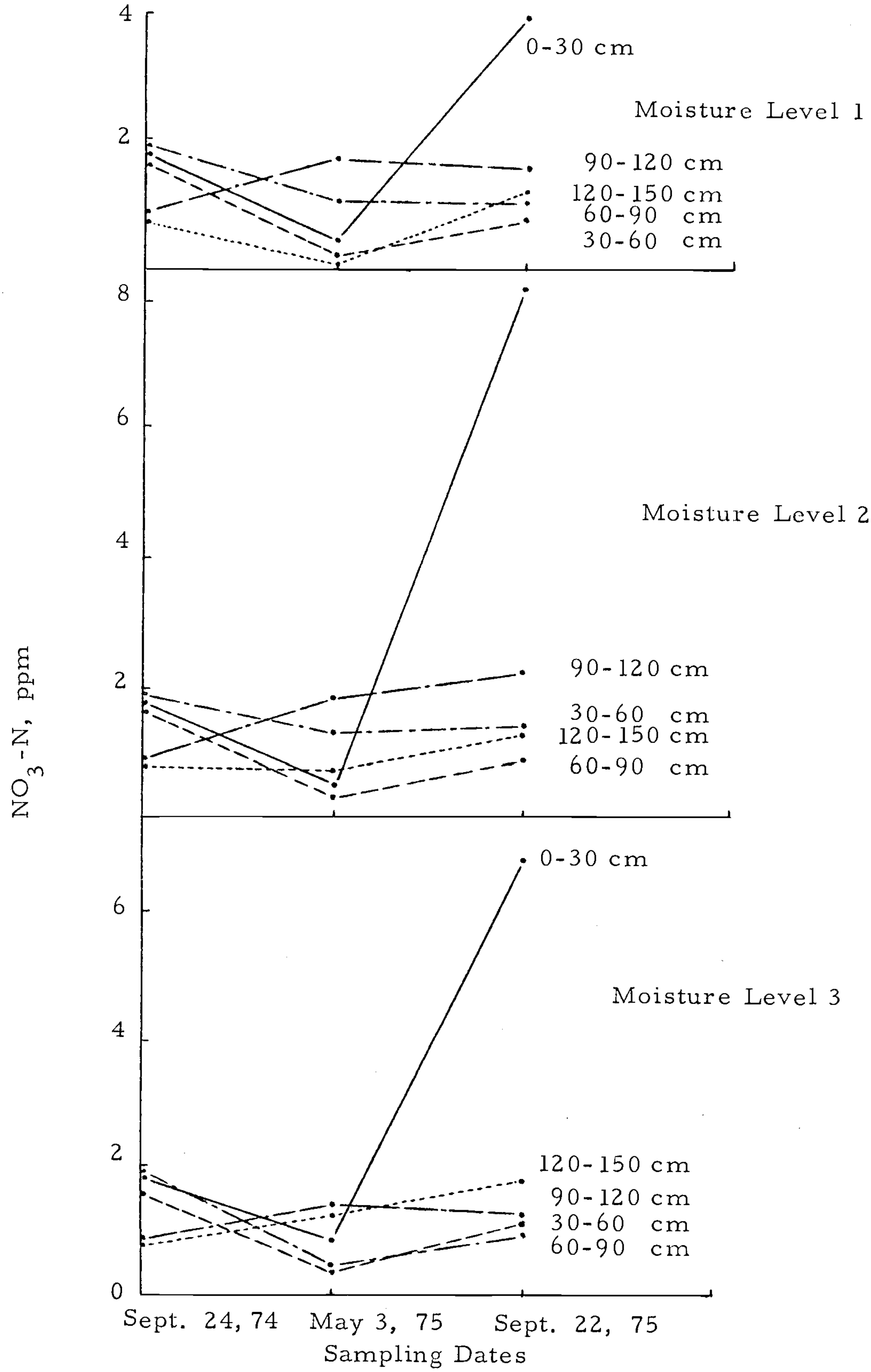

Figure 17. Experiment II. NO_3-N distribution in the soil profile as affected by sampling time x sampling depth at three fallow moisture levels during the 1974-75 fallow season.

respectively, with an average soil profile moisture of 11.2, 11.5, 12.1 percent, respectively. These substantial increases in nitrate in the top 30 cm of soil can be accounted for by nitrification of NH_4-N which has been released during organic matter decomposition and/or upward movement of NO_3-N due to high evaporation rate.

The difference between dry fallow and normal fallow moisture levels in amount of nitrate accumulated was significant. No significant difference however, was observed between dry and wet, normal and wet fallow moisture levels in nitrate-nitrogen (Tables 19 and 20).

The data as a whole showed that high soil profile moisture had a marked effect on increasing nitrate content of the soil up to a certain point then caused a reduction probably by inhibiting nitrification in the early season and/or due to denitrification of nitrate. However, the nitrate accumulation on the wet plots was still higher than those on the dry fallow plots.

Grain Yield

The grain yield response of cultivars to application of nitrogen at each fallow moisture level is shown in Table 22 and Figure 18. The grain yields of the two cultivars were significantly different at each fallow moisture level. Hudson out-yielded Mcdermid by an average of 333.7 kg/ha. The difference in grain yield for both cultivars between dry fallow and wet fallow moisture levels was significant. There were no significant differences between dry and normal and also between normal and wet fallow seasons. Highly significant differences in grain yield were recorded at each moisture level for both cultivars when the nitrogen rates are compared. The application of the first 56 kg/ha of nitrogen increased the grain yield by 422, 125, 348 kg/ha for Mcdermid and 1027, 678, 842 kg/ha for Hudson in the dry, normal and wet fallow

Table 19. Experiment II. Observed mean squares for soil profile NO_3-N during the 1974-75 fallow season.

Source of Variation	Degrees of Freedom	Soil Profile NO_3-N ppm
Reps	3	1.10
Sampling Time	1	64.96**
Error (a)	3	1.68
Sampling Depth	4	30.59**
Fallow Moisture Level	2	4.56*
Sampling Depth x Fallow Moisture Level	8	2.13
Error (b)	42	1.015
Sampling Time x Sampling Depth	4	35.1**
Sampling Time x Fallow Moisture Level	2	2.28
Sampling Time x Sampling Depth x Fallow Moisture Level	8	1.77
Error (c)	42	4.118
Total	119	

* Significant differences at the 5% probability level

** Significant differences at the 1% probability level

Table 20. Experiment II. Mean soil profile NO_3-N at three levels of fallow moisture during the 1974-75 fallow season.

Fallow Moisture Level	Soil Profile NO_3-N ppm
Dry Fallow	1.23 a[1]
Normal Fallow	1.90 b
Wet Fallow	1.62 ab

[1] Student Newman Keul's Test - means in a column followed by the same letter are not significantly different at the 5% probability level.

Table 21. Experiment II. Mean NO_3-N distribution in the soil profile as influenced by three levels of fallow moisture during the 1974-75 fallow season at two sampling dates.

Soil Depth cm	0-30	$LSD_{.01}$	30-60	$LSD_{.05}$	60-90	$LSD_{.05}$	90-120	$LSD_{.05}$	120-150	$LSD_{.05}$
Moisture Level 1					NO_3-N ppm					
May 3, 1975	0.47	a	0.29	a	1.04	a	1.77	a	0.14	a
Sept. 22, 1975	4.03	a	0.72	b	1.04	b	1.59	b	1.18	b
Moisture Level 2										
May 3, 1975	0.50	a	0.36	a	1.28	a	1.84	a	0.70	a
Sept. 22, 1975	8.21	a	0.94	b	1.42	b	2.29	b	1.31	b
Moisture Level 3										
May 3, 1975	0.83	a	0.34	a	0.42	a	1.38	a	1.25	a
Sept. 22, 1975	6.86	a	1.09	b	0.96	b	1.22	b	1.78	b

a : Mean values having significant LSD at the 1% level
b : Mean values not having significant LSD at the 5% level

Table 22. Experiment II. Effect of three nitrogen levels at three levels of fallow moisture on grain yield, water use (W. U. E.) and nitrogen use (N. U. E.) efficiencies.

Treatments	Soil NO_3-N at Planting	Soil NO_3-N at Harvest	Recovery	Grain Yield	Yield Increase	W. U. E.	N. U. E.
	Kg/ha			Kg/ha	Kg/ha	Kg/ha-mm	
MCDERMID							
M1NO	35.86	11.71	24.15	3243.2		9.8	134.3
M1N1	91.86	14.43	77.43	3665.6	422.4	11.0	47.3
M1N2	147.86	25.71	122.15	3160.1	-83.1	9.4	25.9
M2NO	59.72	15.02	44.70	3335.0		9.8	74.6
M2N1	115.72	18.11	97.61	3460.9	125.9	10.0	35.5
M2N2	171.72	27.26	144.46	3218.5	-116.5	9.4	24.2
M3NO	50.26	13.82	36.44	3483.6		9.9	95.6
M3N1	106.26	17.51	88.75	3832.3	348.7	10.7	43.2
M3N2	162.26	25.38	136.88	3325.3	-158.3	9.4	24.2
HUDSON							
M1NO	35.86	9.34	26.52	3092.9		10.1	116.6
M1N1	91.86	13.62	78.24	4120.0	1027.1	13.1	52.7
M1N2	147.86	13.89	133.97	3780.4	687.5	11.9	28.2
M2NO	59.72	10.45	49.27	3310.9		10.7	67.2
M2N1	115.72	17.79	97.93	3988.9	678.0	12.3	40.7
M2N3	171.72	21.60	150.12	3868.0	557.1	11.9	25.8
M3NO	50.26	8.01	42.25	3349.4		10.6	79.3
M3N1	106.26	10.81	95.45	4191.5	842.1	12.5	43.9
M3N2	162.26	15.19	147.07	4035.3	685.9	12.0	27.4

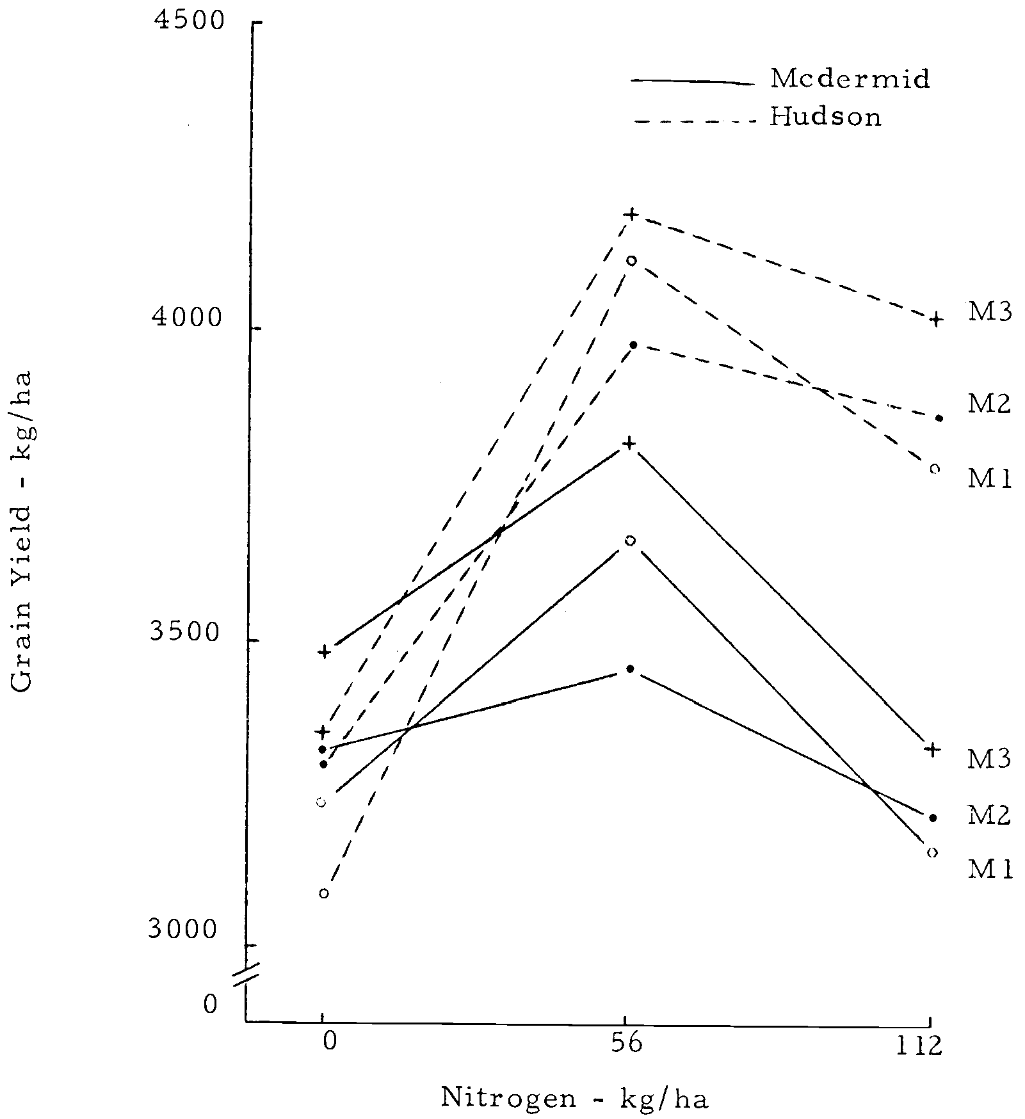

Figure 18. Experiment II. Effect of three levels of fallow moisture x three levels of nitrogen on grain yield.

plots, respectively, as compared to no applied nitrogen. It should be noted that the yield increase for both cultivars from 56 kg/ha nitrogen was the highest in the dry fallow plots and the lowest in the normal fallow plots. Also the yields from the dry fallow-O nitrogen treatments were higher than the yields from normal fallow, 56 kg/ha treatment. The failure of 56 kg/ha nitrogen rate to increase the grain yield in the normal fallow plots is an evidence supporting the hypothesis that after a normal fallow season the need for supplemental nitrogen might be reduced due to high NO_3-N accumulation in the soil profile. Therefore, the 56 kg/ha rate appeared to be a relatively high rate to produce an optimum yield after the normal fallow season. The same results are also true for the 112 kg/ha nitrogen rate after the wet fallow season. The data discussed above indicates that after a dry fallow season, supplemental nitrogen is needed at least at the rate of 56 kg/ha for both cultivars (Tables 23 and 24).

Spikes per Square Meter

The difference in spikes per square meter between two cultivars was not significant. It is indicated that Mcdermid and Hudson responded similarly to supplemental nitrogen at each fallow moisture level. There were highly significant differences in spike/m^2 between dry fallow and wet fallow moisture levels and also between normal and wet fallow moisture levels. Both cultivars produced more spikes per square meter when nitrogen rate increased to 112 kg/ha. A highly significant nitrogen rate x fallow moisture level interaction indicated that spikes per square meter did not respond similarly at each moisture level when the nitrogen rate increased. Spikes per square meter was almost constant in the wet fallow plots when nitrogen rate was increased (Tables 23, 24 and Figure 19).

Table 23. Experiment II. Observed mean squares for grain yield, spike/m^2, 1000 kernel weight, water use efficiency (W. U. E.), soil profile total NO_3-N, and average soil profile moisture after harvest during the 1975-76 season.

Source of Variation	Degrees of Freedom	Yield Kg/ha	Spike/m	1000 Kernel	W. U. E.	Total Profile NO_3-N	Average Profile Moisture
Reps	3	509133	1541.9	9.48	5.85	2.26	0.185
Cultivar	1	2017170*	9954.6	115.0**	54.7*	27.1*	20.81**
Error (a)	3	160674	6154.0	1.9	2.01	0.98	0.085
Fallow Moisture Levels	2	268915*	24530**	5.39	0.27	6.87**	0.08
Fallow Moisture Levels x Cultivar	2	11140	6966	2.39	0.07	0.83	0.10
Error (b)	12	56603	3002	2.775	0.39	0.778	0.029
Nitrogen Rate	2	1982260**	17035**	449.5**	12.59**	29.67**	2.05**
Nitrogen Rate x Fallow Moisture Levels	4	57115	6679.5*	6.83**	0.07	0.55	0.11**
Nitrogen Rates x Cultivar	2	929742**	5523	38.8**	5.87**	2.24	0.90**
Nitrogen Rates x Cultivar x Fallow Moisture Levels	4	8408	517	1.6	0.08	1.34	0.08*
Error (c)	36	28344	2082	1.45	0.28	0.92	0.025
Total	71						
Mean		3580.5	424.5	31.7	10.8	3.8	6.03
C. V. %		4.7	10.7	3.8	4.9	25.2	2.6

* Significant differences at the 5% probability level

** Significant differences at the 1% probability level

Table 24. Experiment II. Mean grain yield, spike/m^2, 1000 kernel weight, W. U. E., soil profile total NO_3-N, and average soil profile moisture after harvest during the 1975-76 season.

Source of Variation	Yield kg/ha	Spike/m^2	1000 Kernel Weight	W. U. E. kg/ha-mm	Total Profile NO_3-N	Average Profile Moisture %
Cultivars						
Mcdermid	3413.8 a[1]		33.0 a	9.9 a	4.42 b	5.5 a
Hudson	3748.5 b		30.4 b	11.7 b	3.10 a	6.6 b
Fallow Moisture Levels						
Moisture Level 1	3510.3 a	397.8 a			3.48 a	
Moisture Level 2	3530.3 ab	416.4 a			4.43 b	
Moisture Level 3	3702.8 b	460.1 b			3.52 a	
Nitrogen Rates						
NO	3302.4 a	331.4 a	36.2 c	10.1 a	2.75 a	6.4 b
N1 (56 kg/ha)	3876.5 c	447.9 a	31.5 b	11.6 b	3.70 b	5.9 a
N2 (112 kg/ha)	3564.5 b	494.9 b	27.5 a	10.6 a	4.96 c	5.8 a

[1]Student Newman Keul's Test - Means in a column followed by the same letter are not significantly different at 5% probability level.

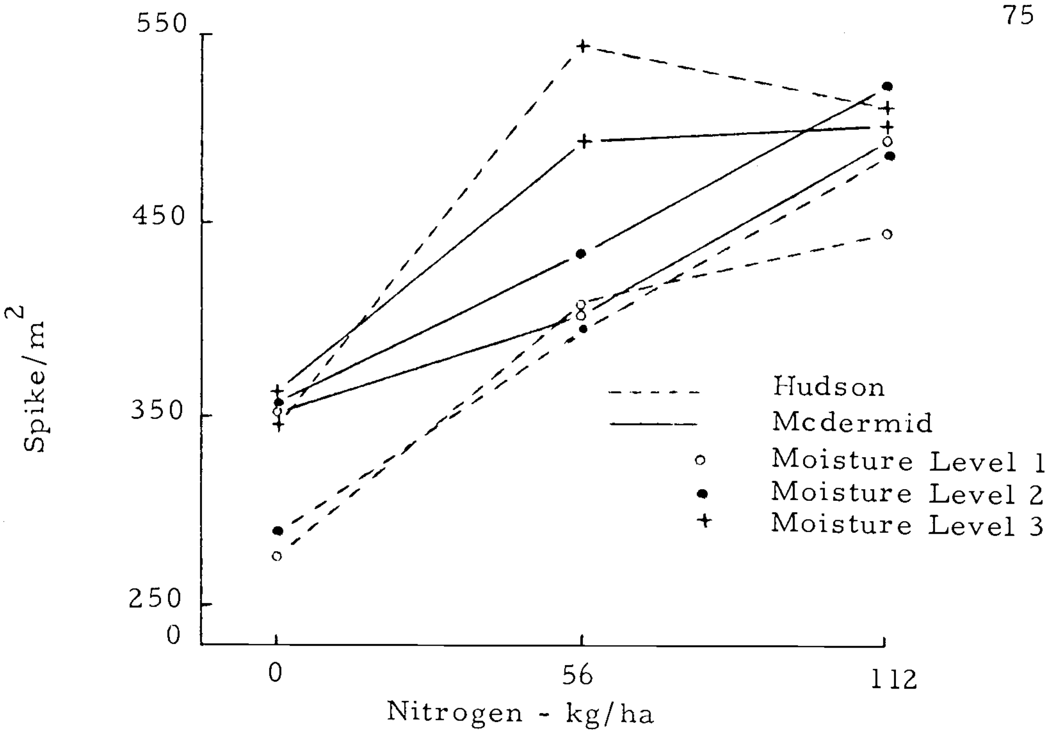

Figure 19. Experiment II. Effect of three levels of fallow moisture x three levels of nitrogen on spike/m^2.

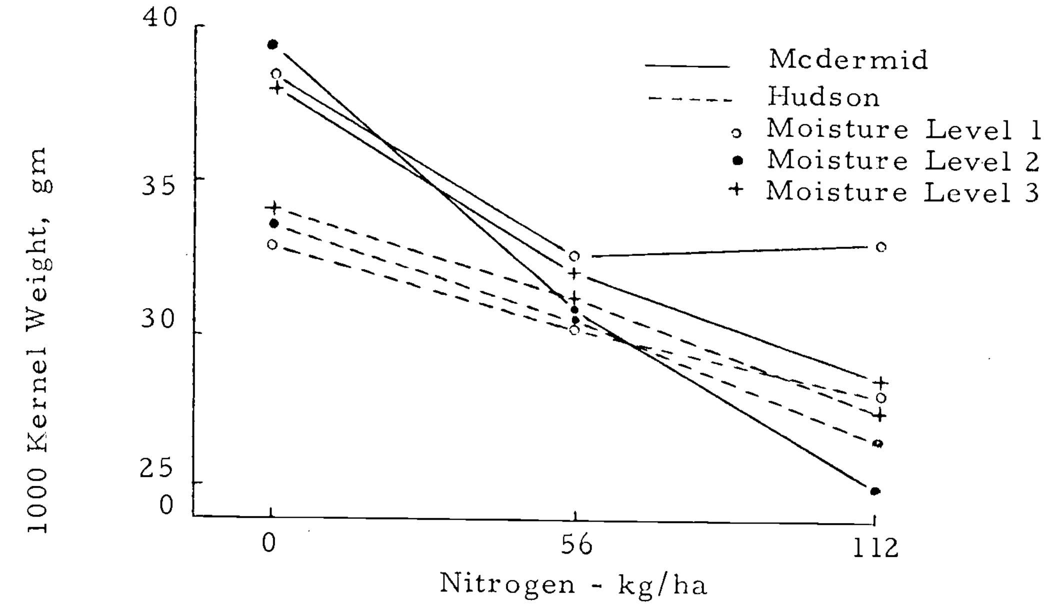

Figure 20. Experiment II. Effect of three levels of fallow moisture x three levels of nitrogen on 1000 kernel weight.

The data shows that lower numbers of spikes per square meter could account for the lower yields. However, increasing numbers of spikes per square meter was not always associated with the high yield at each moisture level or with increasing nitrogen rate. Increased nitrogen rates significantly decreased 1000 kernel weight. Therefore, the increased number of spike/m^2 was not adequate to account for the reduced kernel weight and consequently the yield was decreased.

1000 Kernel Weight

A highly significant difference in 1000 kernel weight was observed between the cultivars (Table 23, Figure 20). Mcdermid had significantly higher 1000 kernel weight than Hudson except in the normal fallow plots to which 112 kg/ha nitrogen was applied. There were also highly significant differences among the nitrogen rates. As the nitrogen rate increased, 1000 kernel weight decreased drastically. There was, however, no decrease in kernel weight due to applied nitrogen beyond 56 kg/ha nitrogen in the dry fallow plots for both cultivars as it is indicated by highly significant nitrogen rate x fallow moisture level interaction. Kernel weight for Mcdermid decreased sharply as nitrogen rates increased to 112 kg/ha. Decrease in kernel weight was highest on the normal fallow plots with 56 and 112 kg/ha nitrogen. Hudson had slightly lower kernel weight when nitrogen rates increased.

Water Use Efficiency

Water use efficiency was calculated with the ratio of grain yield to total water use. Total water use indicates crop season precipitation plus soil moisture used (measured by difference in soil moisture content of the 150 cm soil profile at planting and after harvest) by crop. That is, W. U. E. is equal to soil profile moisture at planting + crop season precipitation - soil profile moisture after harvest. Highly significant differences in average soil profile moisture at harvest were measured between the cultivars. Average soil profile moisture was 5.5 percent for Mcdermid and 6.6 percent for Hudson. It was indicated that Mcdermid used more water than Hudson. There were highly significant effects of nitrogen rates on the water use of cultivars (Tables 23, 24, 25, Figures 21 and 22).

Table 25. Experiment II. Moisture distribution in the soil profile after harvest at three fallow moisture levels as influenced by nitrogen rates during the 1975-76 season.

Soil Depth	Moisture Level 1			Moisture Level 2			Moisture Level 3		
	Nitrogen Rates, kg/ha								
cm	0	56	112	0	56	112	0	56	112
MCDERMID									
0-30	5.2	5.4	5.4	5.6	5.3	5.3	5.7	4.9	5.3
30-60	5.9	5.5	5.3	5.8	5.6	5.4	5.9	5.4	5.4
60-90	5.5	5.3	5.2	5.4	5.3	5.2	5.5	5.3	5.1
90-120	5.6	5.4	5.3	5.3	5.1	5.1	5.4	5.2	5.5
120-150	6.2	5.6	5.8	5.8	5.5	5.7	5.8	5.6	6.2
HUDSON									
0-30	5.9	5.7	5.6	6.3	6.2	5.5	6.6	6.1	6.5
30-60	7.6	6.6	6.3	7.1	6.5	6.1	7.4	6.4	6.1
60-90	6.7	6.4	6.0	6.8	6.3	5.6	7.1	6.2	5.9
90-120	7.0	6.3	6.1	6.6	6.1	5.8	7.2	5.9	5.5
120-150	7.3	6.9	7.1	8.0	7.0	6.5	8.5	7.0	7.4

However, highly significant nitrogen rate x cultivar interaction indicated that water extraction from the soil was equal for all nitrogen rates for Mcdermid.

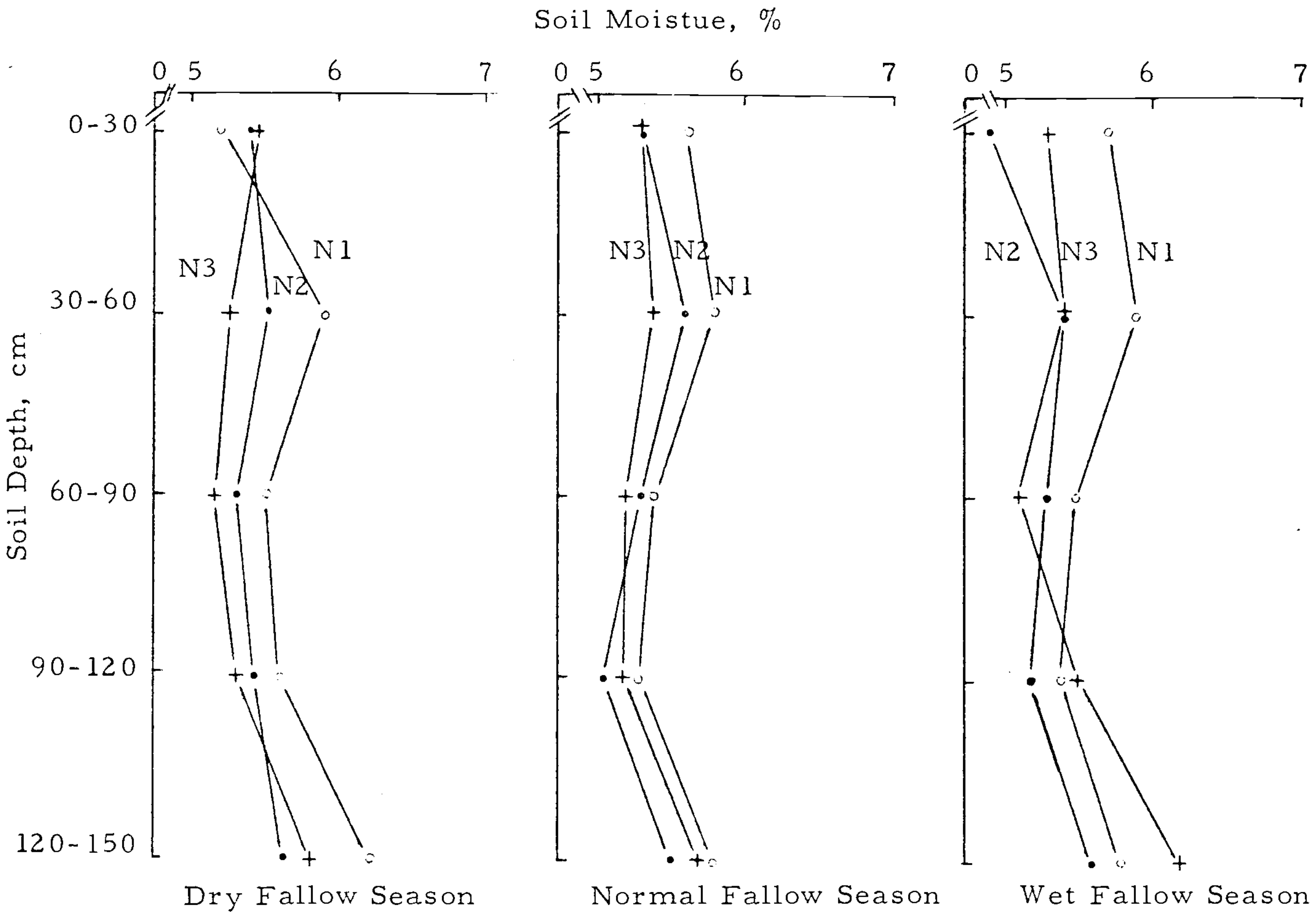

Figure 21. Experiment II. Moisture distribution in the soil profile after harvest as influenced by the wheat cultivar x three nitrogen levels and three fallow moisture levels (1975-76).

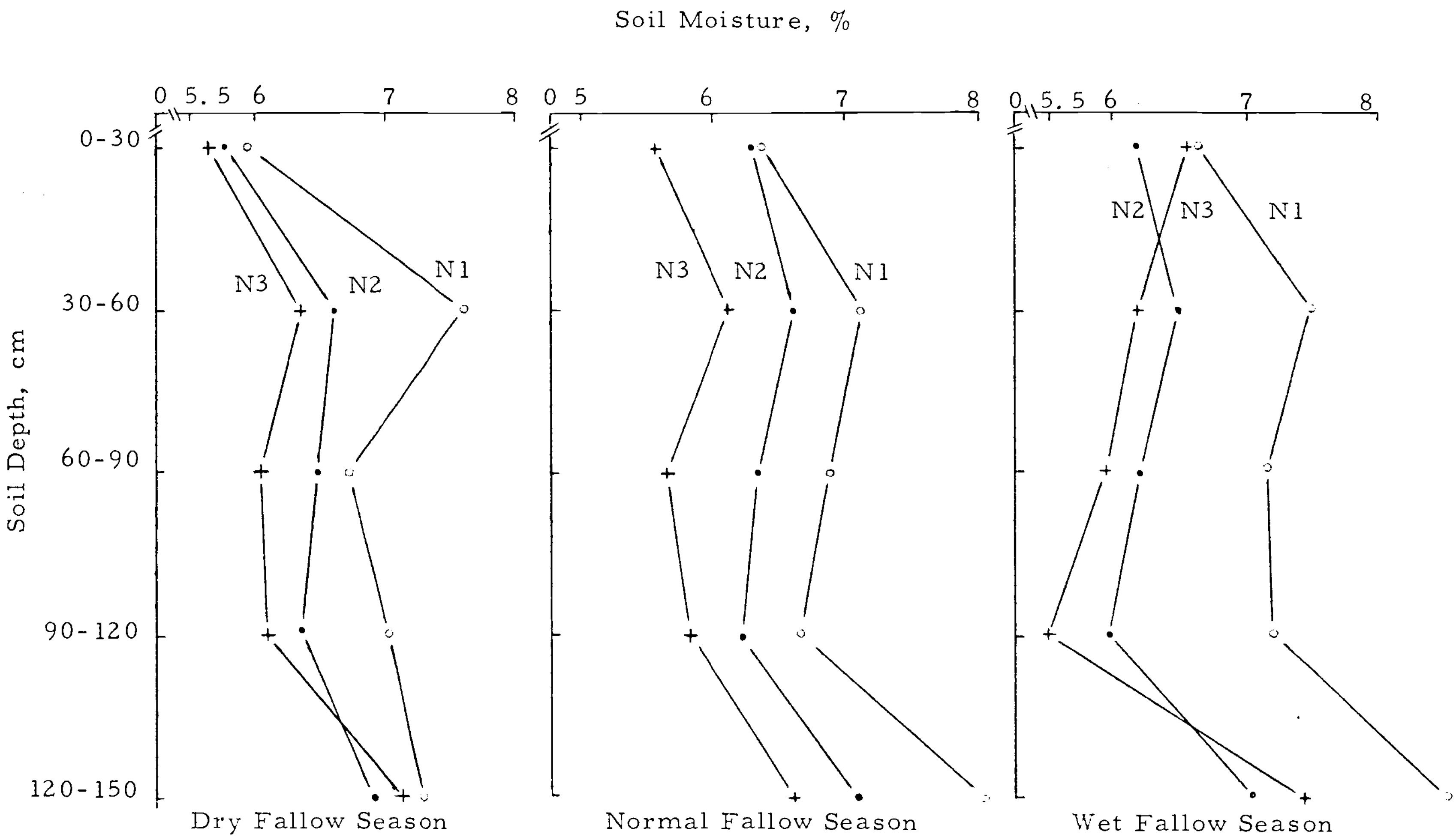

Figure 22. Experiment II. Moisture distribution in the soil profile after harvest as influenced by the barley cultivar x three nitrogen levels and three fallow moisture levels (1975-76).

The interrelationships between Water Use Efficiency, nitrogen use efficiency and grain yields are shown in Table 22. There is a highly significant difference in Water Use Efficiency between the cultivars. The mean water use efficiency values are 9.9 and 11.7 kg/ha - mm for Mcdermid and Hudson. There were no significant effects of fallow moisture levels on W.U.E. at any nitrogen rate. These results indicate that water use efficiency may be independent of water availability. W.U.E. increased significantly with an increasing amount of nitrogen applied to 56 kg/ha for both cultivars, but at the 112 kg/ha nitrogen rate there was a reduction in W.U.E. for Mcdermid as compared to the check. The higher rate of nitrogen (112 kg/ha) apparently resulted in excessive vegetative growth and inefficient conversion of water into grain. The time to full maturity was increased by the higher rate of nitrogen and consequently resulted in poor grain development at the end of the growth period. Highly significant nitrogen rate x cultivar interactions indicate that the W.U.E. values of Hudson at the rate of 112 kg/ha nitrogen were slightly lower than those at 56 kg/ha nitrogen, but they were still higher than those at no nitrogen rates.

As it was shown in Table 22, the highest W.U.E. values corresponded to the highest grain yields. It might be attributed to the demand for water which was not increased to any appreciable extent by the highest grain yields resulting from supplemental nitrogen.

Total Soil Profile NO_3-N after Harvest

The residual NO_3-N in the soil profile for all treatments are reported in Table 26 and Figures 23 and 24. Residual NO_3-N values show significant differences when the two cultivars are compared. It is shown that Hudson used significantly more NO_3-N than Mcdermid. The difference in residual NO_3-N among the fallow moisture levels

Table 26. Experiment II. NO_3-N in the soil profile under the wheat and barley cultivars during the 1975-76 crop season.

Sampling	Sampling Depth, cm	Moisture Level 1			Moisture Level 2			Moisture Level 3		
		Nitrogen Rates, kg/ha								
		0	56	112	0	56	112	0	56	112
MCDERMID		..................NO_3-N, ppm..........................								
July 21, 1976	0-30	1.12	1.50	3.21	1.39	2.04	2.75	1.24	1.72	3.23
	30-60	0.44	0.46	0.54	0.57	0.68	1.41	0.67	0.67	0.82
	60-90	0.38	0.49	0.80	0.62	0.60	0.80	0.39	0.67	0.45
	90-120	0.59	0.62	0.78	0.54	0.46	0.68	0.59	0.57	0.64
	120-150	0.29	0.39	0.77	0.49	0.55	0.90	0.44	0.57	0.90
Total		2.82	3.46	6.10	3.61	4.33	6.54	3.33	4.20	6.04
HUDSON										
July 7, 1976	0-30	1.06	1.64	1.75	0.93	2.03	2.69	0.70	1.24	1.65
	30-60	0139	0.47	0.32	0.47	0.47	0.39	0.42	0.44	0.31
	60-90	0.39	0.21	0.55	0.40	0.49	0.62	0.13	0.39	0.47
	90-120	0.24	0.36	0.21	0.46	0.67	0.48	0.26	0.31	0.93
	120-150	0.16	0.57	0.47	0.26	0.59	0.67	0.46	0.21	0.28
Total		2.24	3.25	3.30	2.52	4.25	4.85	1.97	2.59	3.64

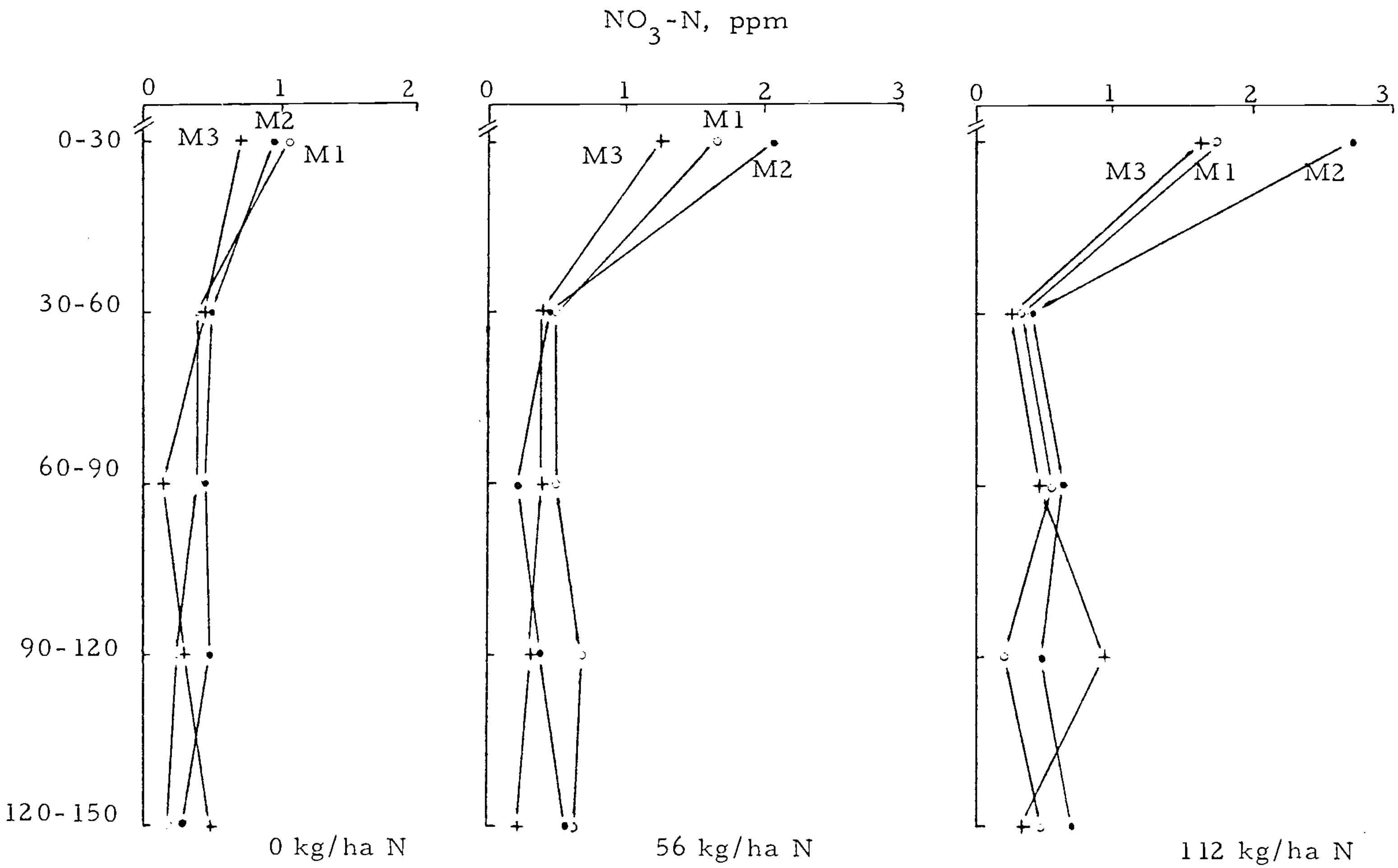

Figure 23. Experiment II. NO_3-N distribution in the soil profile after barley harvest as influenced by three nitrogen rates x three fallow moisture levels during the 1975-76 season.

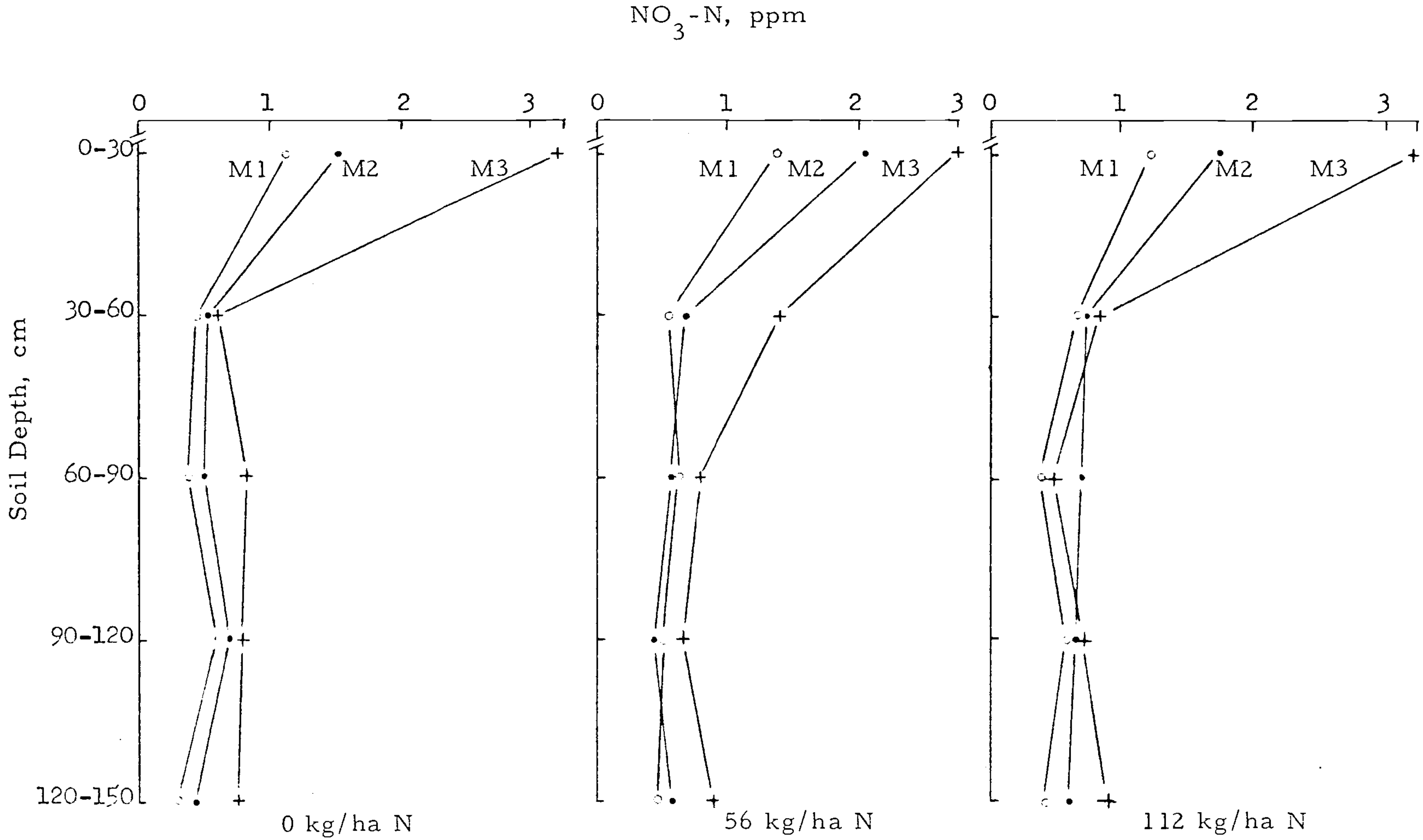

Figure 24. Experiment II. NO_3-N distribution in the soil profile after wheat harvest as influenced by three nitrogen rates x three fallow moisture levels during the 1975-76 season.

and among the nitrogen rates was highly significant (Tables 23 and 24). It should be noted that the residual NO_3-N in the normal fallow plots was highest at each nitrogen rate. It was pointed out by Olsen (1970) that the total amount of NO_3-N in the soil profile is closely related to the rate of application. Highly significant increases in residual NO_3-N with increasing nitrogen rates after harvest were in agreement with this conclusion. That is, the significant difference in residual NO_3-N between the two fallow moisture levels at the same nitrogen rate might be another evidence of the high initial NO_3-N before planting, which accumulated in the soil profile during normal fallow conditions.

SUMMARY AND CONCLUSIONS

The objective of this study was to determine the effects of different soil moisture levels on the amount and location of nitrate-nitrogen accumulated in the soil profile during the fallow periods.

Moisture treatments simulating dry, normal and wet fallow seasons were created by observing the actual precipitation pattern during the season and adjusting the accumulated averages to equal the calculated averages.

Data were obtained for soil profile NO_3-N, soil profile moisture grain yield, spike/m^2 and 1000 kernel weight.

A significant effect of fallow moisture levels on NO_3-N accumulation in the soil profile was noted during the 1974-75 and 1975-76 fallow seasons. It might be concluded that high soil profile moisture is associated with high NO_3-N accumulated in the soil profile up to a certain point then causes a reduction probably by inhibiting nitrification and/or due to denitrification of nitrate. The differences in the amount of NO_3-N accumulated in the soil profile between dry fallow and normal fallow plots and between dry fallow and wet fallow plots were highly significant. There was no significant difference between normal and wet fallow moisture levels.

At the end of the fallow periods, the 0-30 cm soil depth appeared to be an accumulation zone for NO_3-N for all fallow moisture levels. This indicates that NO_3-N moved down in the early season with increasing soil profile moisture, and then, recovered with upward movement of soil moisture due to high evaporation rate late in the season.

The effect of residual nitrate on NO_3-N accumulation was found to be highly significant early in the season. In July, it did not show any significant effect on NO_3-N accumulation. Low residual NO_3-N appeared to be more favorable to the nitrate accumulation under dry fallow conditions. Increasing residual NO_3-N over about 6 ppm not only failed to increase NO_3-N content of soil but also suppressed NO_3-N accumulation at each fallow moisture level as compared to the initial level.

There were no significant differences in grain yield among treatments at any level in the 1974-75 crop season. In the 1975-76 season the grain yields of two cultivars were significantly different at each fallow moisture level. The difference in grain yield for both cultivars between dry fallow and wet fallow moisture levels was significant. Highly significant differences in grain yield were recorded at each moisture level for both cultivars when the nitrogen rates were compared. The failure of 56 kg/ha nitrogen rate to increase the grain yield in the normal fallow plots indicated that this rate is a relatively high rate. Therefore, it could be concluded that after a normal fallow season, the best nitrogen rate is somewhat less than 56 kg/ha. After a wet season, the best rate appears to be somewhat higher than 56 kg/ha, but less than 112 kg/ha. After a dry fallow season, supplemental nitrogen is needed at the rate of about 56 kg/ha.

The lower number of spikes per square meter may account for the lower yields. However, increasing the number of spikes per square meter was not always associated with the higher yield at each moisture level or with increasing the nitrogen rate. Increased nitrogen rates significantly decreased 1000 kernel weight. Thus, the increased number of spikes/m^2 was not adequate to account for the reduced kernel weight and the yield was decreased.

The mean water use efficiency values which are significantly different were 9.9 and 11.7 kg/ha-mm for Mcdermid and Hudson. There were no significant effects of fallow moisture levels on W. U. E. at any nitrogen rate. It is suggested that water use efficiency may be independent of water availability. W. U. E. increased significantly with an increasing amount of nitrogen applied to 56 kg/ha for both cultivars, but at the 112 kg/ha nitrogen rate there was a reduction in W. U. E. for Mcdermid as compared to the no nitrogen treatment. However, W. U. E. values of Hudson were still higher than those at the no nitrogen rates. Since the highest W. U. E. values correspond to the highest grain yields, it could be concluded that the demand for water is not increased to any appreciable extent by the highest grain yields resulting from supplemental nitrogen.

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