4. RESULTS AND DISCUSSIONS

Response of wheat plants to mineral N fertilization as affected by bacterial inoculation and or nitrification inhibition:

Doubtless , the mineral N fertilization represents an urgent agricultural practice for increasing the productivity soils , particulary those of low organic matter content . Therefore such essential agricultural treatment should be practiced properly in order to maximize efficiency of fertilizer N utilization with consequent minimization of N loss and enviornmental hazards .

4.1. Exeriment I

The work carried out herien aimed to investigate the efficiency of two ^{15}N labelled sources i.e U and AS , to nonsymbiotic fixation and / or nitrification inhibition . The treatments involved in this experiment were as follows :

1 - The whole rate (1600 mg N pot^{-1}) was applied before sowing with or without NI " Noninoculated " .

2 - The half rates (800 mg N pot^{-1}) , were applied before sowing with Azotobacter inoculation and in presence or absence of NI.

4.1.1. Dry matter yield:

Values of dry matter yield of both wheat grain and straw as influenced by N - sources , nitrification inhibition and Azotobacter inoculation are presented in Table (2) and illustrated by Fig (1)

Data generally showed that fertilization either with urea or ammonium sulfate (^{15}N labelled) indicated the dry matter yield of wheat plants as

Table (2) Straw , grain and total biomass (g. pot^{-1}) of wheat plants as affected by Azotobacter inoculation, N source and *nitrification inhibition.*

Fertilization treatments	**Azotobacter treatments**					
	Noninoculation			**Inoculation**		
	Straw	**Grain**	**Total**	**Straw**	**Grain**	**Total**
Control	41.3	30.2	71.8	47.2	35.2	82.4
Urea (U)	61.6	49.3	110.9	73.4	60.2	133.5
U + N - Serve	69.2	56.1	125.3	79.1	67.7	146.8
U + DCD	73.0	60.1	133.1	86.0	71.8	157.7
Mean	68.0	55.2	123.1	79.5	66.5	146.0
Ammonium sulfate (AS)	60.5	49.0	109.5	75.5	62.4	137.9
AS + N - Serve	73.2	59.2	132.4	84.3	70.2	154.5
AS + DCD	77.5	63.5	141.0	91.4	76.6	168.0
Mean	70.4	57.2	127.6	83.7	69.7	153.5

L.S.D$_{5\%}$

	Straw	grain
N. Source	1.00	0.98
Inoc.	1.00	0.98
NI	1.22	1.19
N.NI	1.73	1.69
Inoc.NI	1.73	-

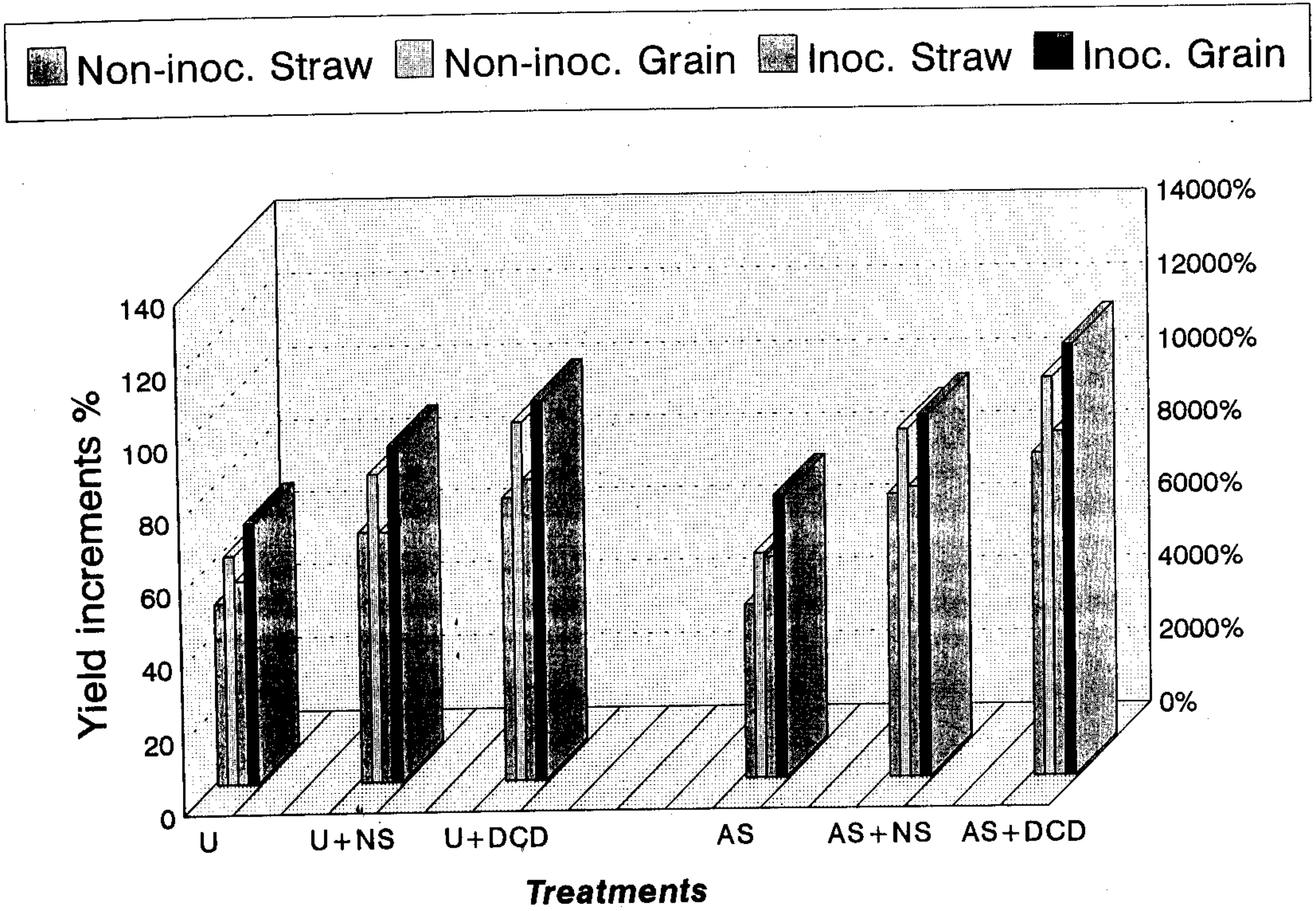

Fig. (1) Yield increment (%) of wheat straw and grain as affected by Azotobacter inoculation, N - source and nitrification inhibition.

compared with the unfertilized control. The increments varied due to the N - source and kind of nitrification inhibitor , where mixing the N source with DCD gave the highest values of dry matter yield as compared with those obtained with NS . Also , the application of DCD with ammonium sulfate gave the highest values of both straw and grain yields as compared with urea .

Results showed that the straw yield of wheat was 41.25 ,61.64 and 60.52 g pot^{-1} , for control , urea and ammonium sulfate , respectively. Thus values increased by 49 % and 47 % over control , when urea and ammonium sulfate were applied respectively .

Combined application of the nitrification inhibitor either (N - Serve or DCD) and the nitrogen fertilizer increased in straw yield by 68 % and 77 % over the control for N - Serve + urea and N - serve + ammonium sulfate, respectively. The rate of increase yielded reached 77 % and 88 % over the control when DCD applied in combination with urea and ammonium sulfate, respectively . Irrespective of the inhibitor , application of either urea or ammonium sulfate increased dry weight of wheat grain by 62 % and 61 % over the control respectively. Data of Frye *et al.* (1989) show an average increase of 35 % in corn yield as affected by DCD application to urea on the sandy soils of Florida . Soliman and Abdel Monem (1995) show that dry matter yield of corn plant was increased from 4.1 to 10.5 g / plant not only with N fertilization applied as urea but also by better management of the applied fertilizer through application of nitrification inhibitors (DCD or N - Serve) .

Results show significant increase in grain yield due to inhibitors application with N - source as compared with the control treatment . Application of DCD either with urea or ammonium sulfate yielded higher values of dry weights as compared N - Serve with urea or ammonium sulfate . Moreover , the highest values of grain yields were obtained when DCD was applied with ammonium sulfate (63.53 g pot^{-1}) as compared with urea (60 g / pot^{-1}) .

The increments percentages were 84 % and 95 % over the control , when N - Serve was applied with urea and ammonium sulfate , respectively. These increments reached thier maximum 98 % and 109 % over the control , when DCD was applied with urea and ammonium sulfate, respectively.

Similar results were obtained by (Frye *et al.* , 1989) who explained that the yield response to nitrification inhibitor depends on a number of factors and their interactions including texture , organic matter and biological activity of the soil . (Amberger , 1989) who reported that , DCD interferes with the respiration oh the Nitrosomonas bacteria , which are responsible for the first step in nitification and in addition to the fact that DCD completly decomposes in the soil to CO_2 and NH_4 over several weeks and thereby acts as a high analysis (66.75 %) slow release fertilizer.

Although , nitrogen fertilizer was applied at half dose (800 mg N / pot^{-1}), when wheat was inoculated with Azotobacter , data in Table (2) showe significant increase in dry matter yield of both straw and grains as compared with corresponding treatment of uninoculation which had received full dose (1600 mg N / pot^{-1}) .

Using Azotobacter as N - fixer increased average values of straw dry weight over all treatments from 67.96 and 70.38 g / Pot^{-1} in absense of incoulation to 79.47 and 83.74 g / pot^{-1} in case of inoculation with Azotobacter in the presence of urea and ammonium sulfate , respectively. Also, average values of grain weight without inoculation were 55.17 and 57.23 g / Pot^{-1} and increased with inoculation to 66.54 and 69.72 g / Pot^{-1} for urea and ammonium sulfate, respectively.

In this investigation , the two targets were achieved , where the soil inoculation with a symbiotic N2 - Fixers stimulated plant growth and reduced the inorganic N requirements . The beneficial effect of inoculation may be the production of growth promoting substances (Saleh , *et al.* 1988). In addition , they explained that inoculation of wheat plants with N2 - fixers had stimulative effects on root exudates due to gradually increased in nitrogenase activity with the increase of wheat plant growth , and this is a logical result due to the continuous exhaustion of nitrogen by plant roots during its growth stage .

It is clearly shown that the application of DCD with ammonium sulfate yielded the highest rates of increase in both wheat straw (94 %) and grains (118 %) over the control , as wheat seeds were bacterized with Azotobacter.

Similar results were obtained by El - Hoseiny and Rabie (1979) , who found that bacterization maize with Azotobacter tended to stimulate the growth of treated plants as represented in the increase of root and shoots lentgths , fresh and dry matter weights . Eweda (1983) showed that production of thiamin , micotinic acid and other compounds of auxin type gives positive effect of plant growth in addition to its role in fixing atmospheric nitrogen .

Results of Table (2) show that dry matter yield of straw wheat plant was increased from 47.23 to 83.74 g / pot^{-1} due to application with nitrification inhibitors (DCD or N - Serve), also by using Azotobacter as N - fixer in addition to the ammonium sulfate fertilizer .

4.1.2. N - uptake by wheat plants as influenced by N-sources, nitrification inhibitors and inoculation with Azotobacter

Data of Table (3) , illustrated by Fig (2) indicat that N - uptake by wheat plants was significantly increased by application of fertilizer N either combined or not with the nitrification inhibitor . Irrespective with Azotobacter inoculation, N - uptake of wheat straw increased by about 139 , 214 and 194 % over the control with urea ., urea + DCD and urea + N - Serve, applications , respectively. These corresponding values in case of AS increased to 157 , 234 and 213 % over the control , respectively.

N - uptake in wheat grain increased by about 133, 228 and 190 % , over the control in absence of inoculation due to application of urea , urea + DCD and urea + NS , respectively . The corresponding increases in case of ammonium sulfate instead of urea were 138 , 247 and 217 % over the control, respectively . The increase in N - uptake in grain would have a positive effect on nutrientive value of the wheat bread . The increas in N uptake by wheat plants in presence of nitrification inhibitors may be due to the reduction in N losses and preserving the applied N in soil for longer time . Francis *et al.* (1995) attributed the increase in strow and grain yield the spring wheat crop to the application of DCD which reduces N leaching losses by inhibiting the convernsion of relatively immobile ammonium N ; mineralized from organic - N to mobile NO_3 - N .

Inoculation of wheat seeds with Azotobacter significantly increased nitrogen of both wheat straw and grain . Comparing to uninoculation treatments N - uptake by wheat straw increased with inoculation at 50 kg $N.fed^{-1}$ of N - fertilizer by about 10.5 , 15.3 , 10.2 and 7.3 % for control, U , U + DCD and U + NS , respectively . When U was subtitueted with ammonium sulfate increasing percentages were 11, 10.8 and 7 % , respectively. These results

Table (3) ***N - uptake (mg.pot^{-1}) of wheat plants as affected by Azotobacter inoculation, N - source, and nitrification inhibition .***

Fertilization treatments	Azotobacter treatment					
	Noninoculation			Inoculation		
	Straw	Grain	Total	Straw	Grain	Total
Control	207	310	517	229	323	551
Urea (U)	494	735	1228	569	836	1406
U + N -	608	914	1522	653	1007	1661
U + DCD	696	1034	1683	715	1112	1827
Mean	584	894	1478	646	986	1631
Ammonium sulfate (AS)	531	750	1280	589	905	1494
AS + N -	647	1001	1648	693	1081	1774
AS + DCD	690	1093	1782	764	1133	1897
Mean	623	947	1570	682	1040	1722

$L.S.D_{5\%}$	Straw	Grain
N. Source	8.32	20.73
Inoc	8.32	20.73
NI	10.19	25.73
Inoc.NI	14.41	35.90

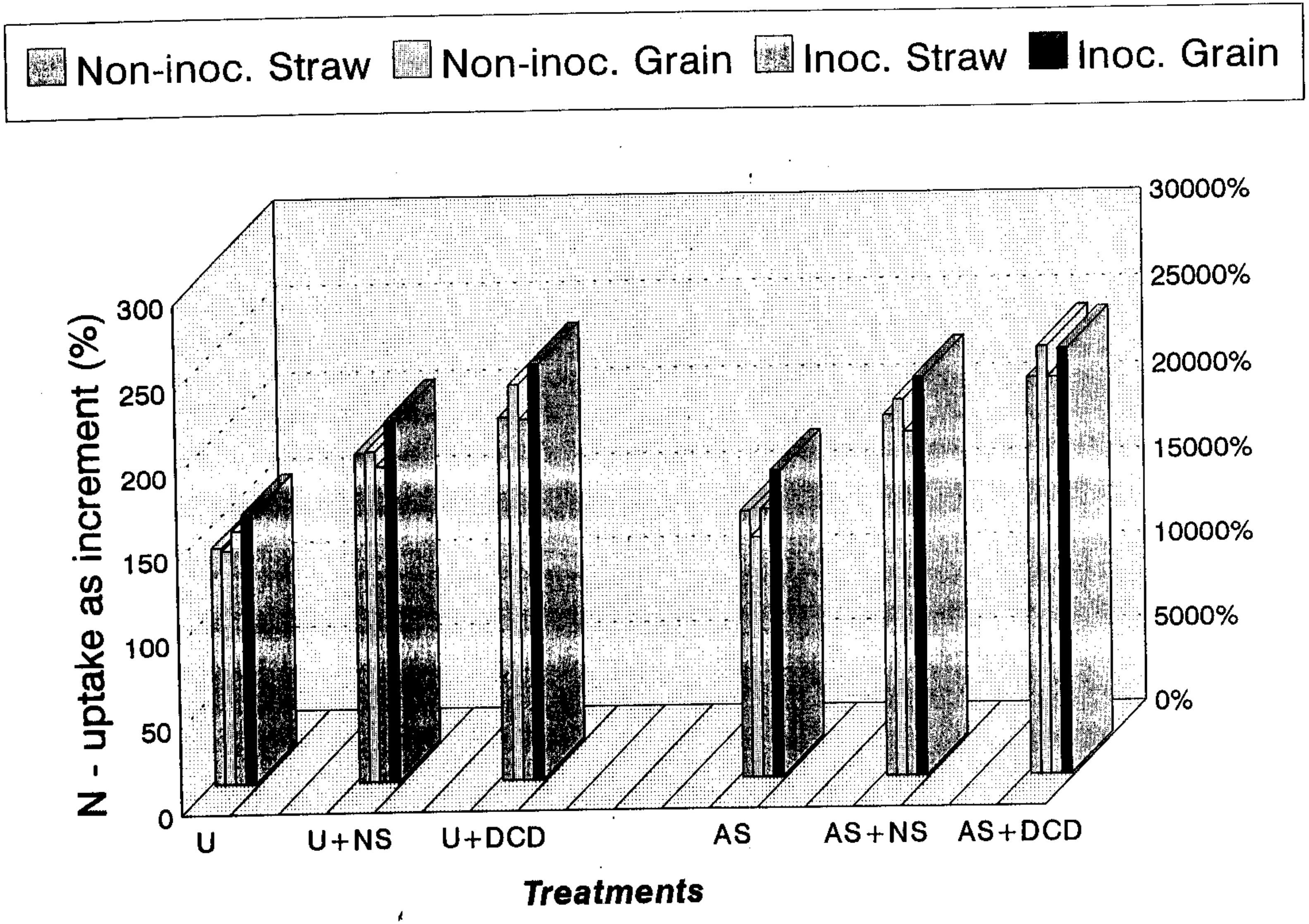

Fig. (2) Increment (%) ofN - uptake in wheat straw and grain as affected by Azotobacter inoculation, N - source and nitrification inhibition

indicate that inoculation of wheat plants with biofertilizer in combination with mineral sources was more efficient in increasing both growth and nitrogen uptake by wheat plants.

Malik and Bilal , (1988), explained that the free living bacteria change root morphology , i.e increase in roots , hence enhanc nutrient uptake and improve plant growth . Data indicate also , that N - uptake in wheat grain was increased by about 4 , 13.9 , 8 and 10 % for control, urea , U + DCD and U + NS , respectively . These values were 21 , 4 and 8 % for AS, AS + DCD and AS + NS , respectively . As shown in Table (3) N - uptake was increased from 206,66 mg. Pot^{-1} (control) to a maximum value , of 1132.94 mg. Pot as Azotobacter inoculated wheat seeds were used undermineral N fertilization and in presence of the nitrification inhibitor (DCD).

The positive effect of inoculating non - legumes with Azotobacter on crop yield and N - uptake has been reported by Abdel - Aziz and Ishac (1990) ; Omer *et al.* (1991) , Galal (1993), and Soliman and Abdel Monem (1995).

4.1.3. Nitrogen derived from fertilizer , Soil , air and fertilizer use efficiency as influenced by nitrification inhibitors and inoculation with Azotobacter.

Using ^{15}N labelled urea and ammonium sulfate facilitates the quantitify of atmospheric nitrogen fixed by wheat plants inoculated with Azotobacter and also the fractions derived from both soil and fertilizers.

Values of total nitrogen translocated in straw and grain of wheat plants as affected by sources of N - fertilizer (U & As) , nitrification inhibitors and Azotobacter inoculation are represented in Table (4) and illustrated by Figs (3, 4 and 5).

Data, generally , showed that the larger portion of nitrogen utilized by noninoculated plants was that drived from fertilizer i.e Ndff % followde by that derived from soil i.e Ndfs % . The highest values of Ndff in wheat were recorded when the N - fertilizer was combined with DCD , comprising 357.8 and 398.9 mg. Pot^{-1} in wheat straw corresponding to 605.4 and 670.4 mg. Pot^{-1} in grain with application of urea and ammonium sulfate, respectively . The increase in Ndff could because the utilization of fertilizer N was improved with nitrification inhibition .

The obtained data generally showed that the application of N - fertilizer at a half dose (800 mg N Pot^{-1}) in combination with wheat inoculation markedly increased the portion of (Ndfs) followed by (Ndfa).

Regarding N_2 - fixed by wheat plants , data presented in Figs. (3 ,4) showed that the amount of N_2 - fixed by inoculated plants increased when U or AS combined with DCD or NS . Data also show that there is no difference effect between U or AS on % Ndfa . The percentage of Ndfa is about 27 % and 29 % for straw and grain under both N - sources at 50 mg N kg^{-1} soil treated with NI respectively . However , it was 24 % upon application of U or AS alone . Such significant response of wheat plants to inoculation with Azotobacter was explained by Day and Dobereiner , (1976) . They reported that malic acid and malate are intermediates in the C_4 photosynthetic pathway . These substances which are released from the roots to rhizosphere are considered to be the most favourable carbon sources for growth and proliferation of Azospirillum or Azotobacter. Consequently , this helps fix atmospheric N efficiency and produce growth promoting substances resulting in higher plant

Fertilization treatments	Azotobacter treatments													
	Noninoculation						Inoculation							
	Straw			Grain			Straw				Grain			
	Ndff	Ndfs	FUE	Ndff	Ndfs	FUE	Ndff	Ndfs	Ndfa	FUE	Ndff	Ndfs	Ndfa	FUE
Urea (U)	236.2	257.6	14.8	363.1	371.5	22.7	134.8	294.2	140.2	16.9	207.0	423.5	205.8	25.9
U + N - Serve	369.7	298.2	19.4	500.7	413.8	31.3	161.8	311.6	179.1	20.3	268.1	443.2	297.3	33.5
U + DCD	357.8	291.2	22.4	605.4	428.4	37.8	190.6	310.3	214.4	23.8	318.4	450.6	343.1	39.8
Mean	301.2	282.3	18.8	489.7	406.1	30.4	162.4	305.4	177.9	20.3	264.5	439.1	282.1	33.1
Ammonium sulfate (AS)	263.4	267.3	16.5	395.6	353.4	24.7	147.1	298.5	143.4	18.4	204.4	429.5	235.2	30.1
As + N - Serve	346.7	300.6	21.7	570.9	429.6	35.7	183.2	317.7	192.0	22.9	307.0	465.3	308.8	38.4
AS + DCD	398.9	290.6	24.9	670.9	422.4	41.9	218.1	317.7	228.5	27.3	339.8	427.4	366.4	42.4
Mean	336.3	286.2	21.0	545.6	401.8	34.1	182.8	311.3	188.0	22.9	295.5	440.7	303.4	36.9

Table (4) Values of Ndff, Ndfs , Ndfa and FUE as affected by Azotobacter inoculation and nitrification inhibition .

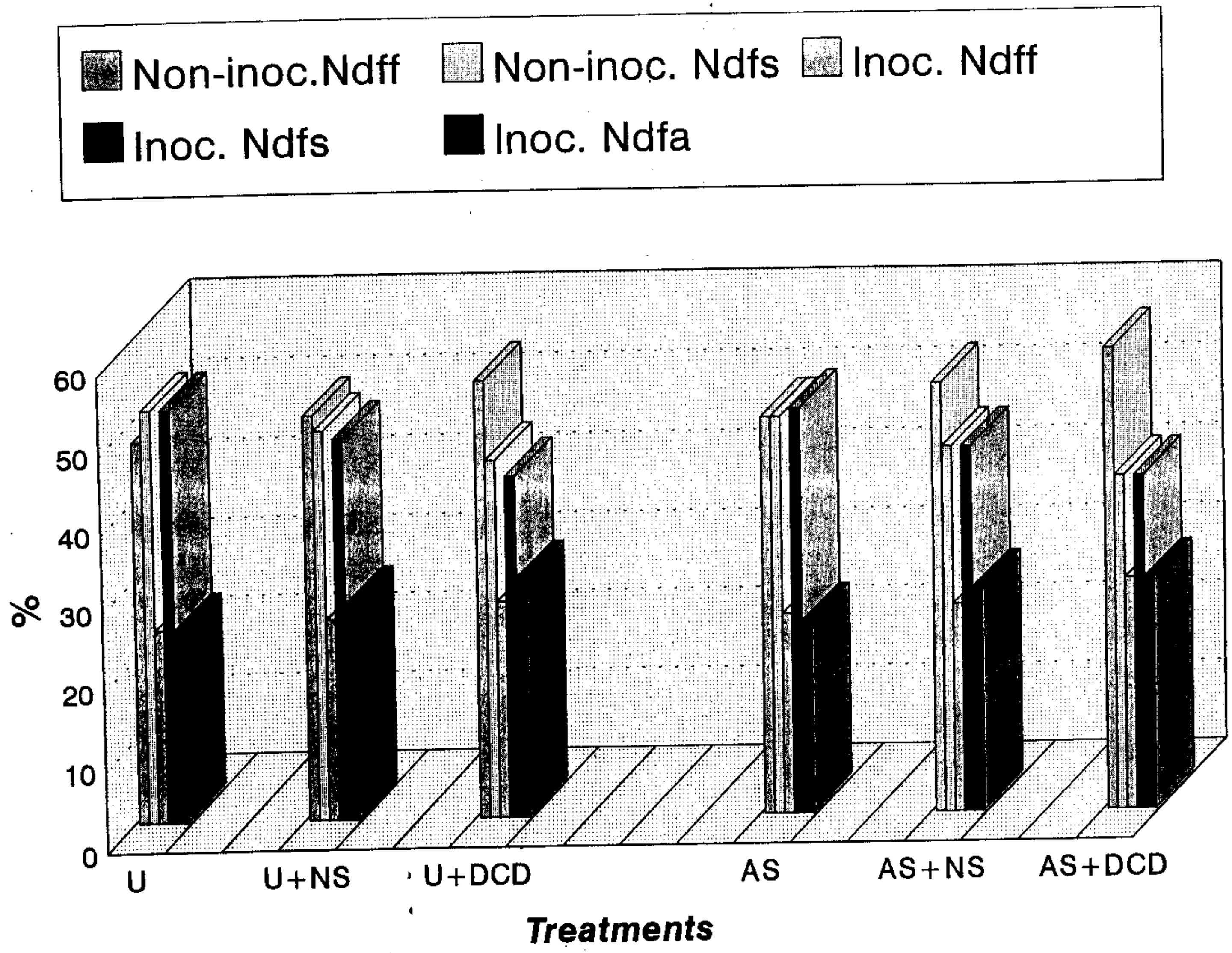

Fig. (3) The Nitrogen derived from fertilizer (Ndff) , soil (Ndfs) and air (Ndfa) as percentage by wheat straw as affected by Azotobacter inoculation , N - source and nitrification inhibition.

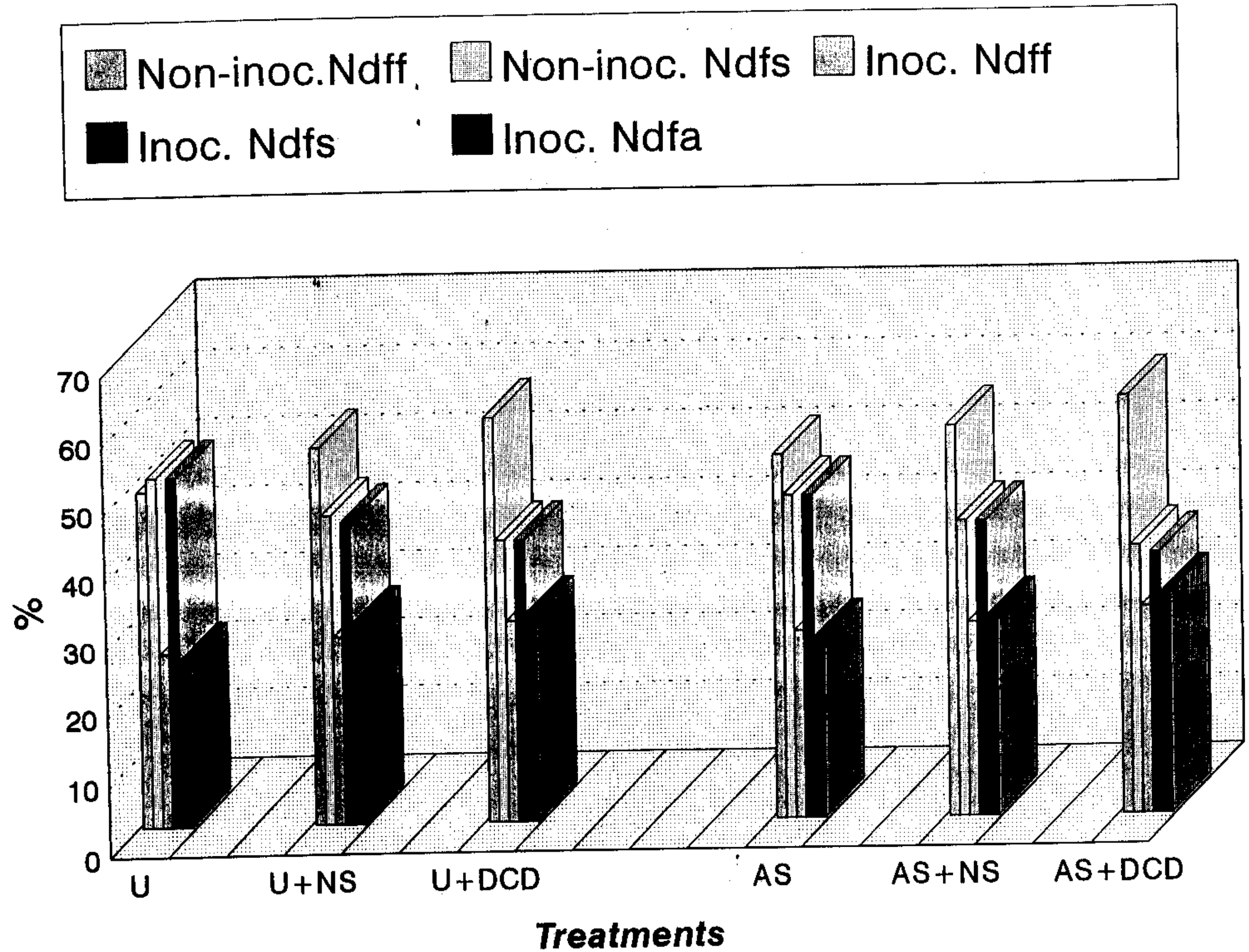

Fig. (4) The Nitrogen derived from fertilizer (Ndff) , soil (Ndfs) and air (Ndfa) as percentage by wheat grain as affected by Azotobacter inoculation , N - source and nitrification inhibition.

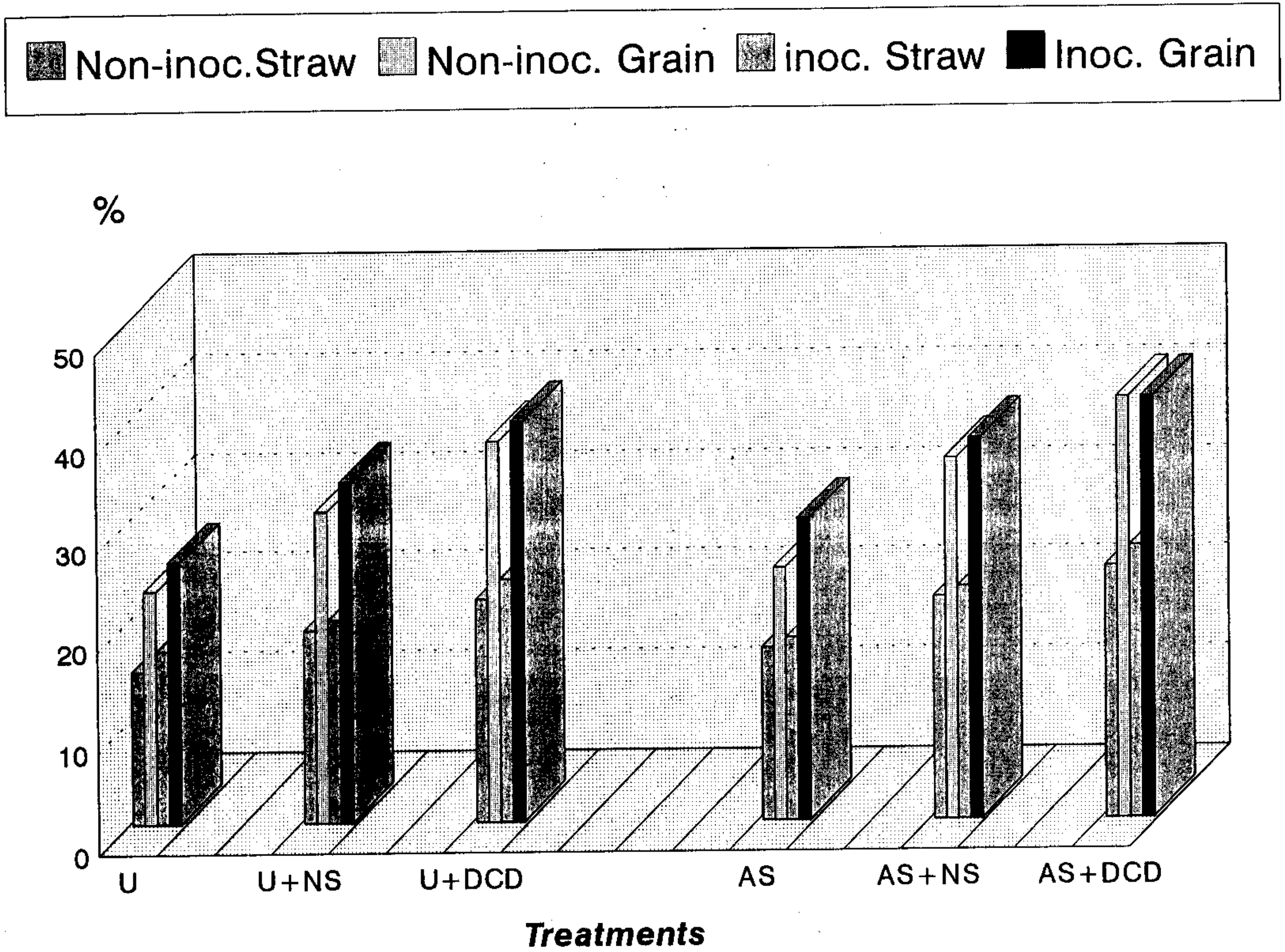

Fig. (5) The FUE values of wheat straw and grain as affected by nitrification inhibition with and without Azotobacter

growth . The values obtained were 195.58 and 228.52 mg N . pot^{-1} in straw and 343.14 and 366.39 mg N. pot^{-1} in grains for U + DCD and AS + DCD , respectively .

Almost similar results were obtained by Esiobu (1990) , Thangaraju and Kannaiyan (1990), Watanabe *et al.* (1991), Soliman and Abdel Monem (1996).

Concerning the fertilizer use efficiency (FUE %) data of Table (4) and Fig (5) indicate that this value , significantly increased due to addition of the nitrification inhibitor DCD or NS alone with the N - fertilizer.

Comparing the effectiveness of DCD or NS applied in combition with (U) or (AS) fertilizer , it is clear from Table (4) that, the AS fertilizer was not only more efficient than " U " , but also its positive effect was induced with the application of DCD or NS to an extent more than " U " source . The highest value of FUE % was recorded when AS was combined with DCD.

These results could be due to inhibiting the conversion of ammonium ion to nitrate ion by the apparent toxic action of the chemical compound (DCD) against the nitrifying bacteria (Amberger 1989) . Values of FUE in wheat straw were 14.76 , 22.36 and 19.36 % for urea , U+DCD and U+NS . With using AS as a nitrogen source , the corresponding values were 16.46 , 24.93 and 21.67 % , respectively. Values of FUE in wheat grains accounted for 22.69 , 37.83 and 31.29 % for urea, U+DCD and U+NS respectively , and the corresponding ones in case of AS were 24.72 , 41.9 and 35.68 % , respectively.

Inoculation of wheat plants with Azotobacter increased FUE either when U or AS was applied as a nitrogen source . They were 16.86 & 39.8 % in case of U + Azotobacter and urea + inhibitors + Azotobacter, whereas they were 18.38 & 42.4 % as a result of using As instead of U . These results indicate that the use of the nitrification inhibitors either with Azotobacter inoculation of wheat seeds or not , enabled a more efficient utilization of fertilizer nitrogen by wheat plants.

It may be interrseted observe that the efficiency of N utilization by wheat plants was more pronounced at low rates of fertilizer N in presence of Azotobacter . Thus , it could be inferred that inoculating wheat seed with non - symbiotic bacteria , in presence of NI saved about 50 mg N kg^{-1} soil without much affecting the grain yield . Similar results were obtained by Wilson *et al.* (1990), Galal (1993) . They found that the use efficiency was in general , in the range from 40 % to 65 % , and it followed the descending order :
AS + Asospirillum > As + Azotobacter = U + Azospirillum > AS > U + Azotobacter > U .

4.1.4 *Plant and soil recorvery of applied ^{15}N :-*

Data in Table (5) and Fig (6) the distribution of fertilizer N between soil and wheat plant was affected by nitrification inhibition and Azotobacter inoculation.

Plant recorvery of fertilizer N in case of Azotobacter inoculation + NI was greater than in absence of each of them . However , the sum values of plant recovery and residual N in soils due to DCD application were higher as compared with the NS corresponding treatment.

Results indicated that values total N recovery averaged 39.5 and 43.57 % with U and AS treatments , respectively . Application of NI (DCD or NS) to the noninoculated plants , increased total N recorvery by 53.02 % and 60.47 % when NS was applied with U and AS , respectively . The corresponding values when DCD was applied were 62.72 % and 69.69 % , respectively . When wheat plants were inoculated with Azotobacter , values of total N recorvery were 45.92 for U and 52.93 % for AS . Corresponding increments when NS was applied were 57.9 and 65.62 % for U and AS , respectively . However, these increments reached 67.68 and 74.16 % when DCD was applied instead of NS with U and AS , respectively . Similar results were obtained by Wilson *et al.* (1990) , and Soliman and Abdel Monem (1995). They found that , application of NI increased nitrogen recovery by plant from 29 % when noninoclated corn was fertilized with U to 49 % and 45 % , as it was treated with U + DCD and U + NS, respectively . Corresponding values for corn inoculated with Azotobacter were 52 , 69 % and 56 % for U , U+DCD and U+NS , respectively .

Concerning N - losses, i.e differences between applied N - fertilizer and total recovery , data of Table (5) indicate that the losses of fetilizer N from U or AS was variably affected by NI application . Application of NI with both N - fertilizers reduced N - losses and therefore enabled more efficient nitrogen utilization by maintaining more N either-as-fertilizer or soil , in the NH_4^+ form.

Values of N losses from U were reduced from 60.5 to 37.28 and 46.98 % with application of U + DCD and U + NS , respectively.

Corresponding values of AS were reduced from 56.43 with AS alone , to 30.31 % and 39.53 when AS was applied with DCD and NS , respectively . However, inoculation of wheat plants with Azotobacter, increased nitrogen recovery by plant and reduced N losses .

Fertilization treatments	Azotobacter treatment							
	Noninoculation				Inoculation			
	Plant N*	Soil N**	Total	N Loss	Plant N	Soil N	Total	N Loss
Urea (U)	599.2	32.8	632.0	968.0	341.9	25.4	367.4	432.6
U + N - Serve	810.4	37.9	848.3	751.7	429.9	33.3	463.2	336.8
U + DCD	963.0	40.5	1003.5	596.5	509.0	32.4	541.4	258.6
Mean	790.9	37.1	828.0	772.1	427.0	30.4	457.3	342.7
Ammonium sulfate	658.9	382.4	697.1	902.9	387.4	28.0	415.4	384.6
AS + N - Serve	917.6	49.9	967.5	632.5	490.2	34.7	525.0	275.0
AS + DCD	1069.3	45.8	1115.0	485.0	557.3	36.0	593.3	206.7
Mean	881.9	44.6	926.6	673.4	478.3	32.9	511.2	288.8

* N recovery by wheat plant.

** Soil residual N .

Table (5) Nitrogen balance of ^{15}N labelled U and AS as affected by Azotobacter inoculation and nitrification inhibition.

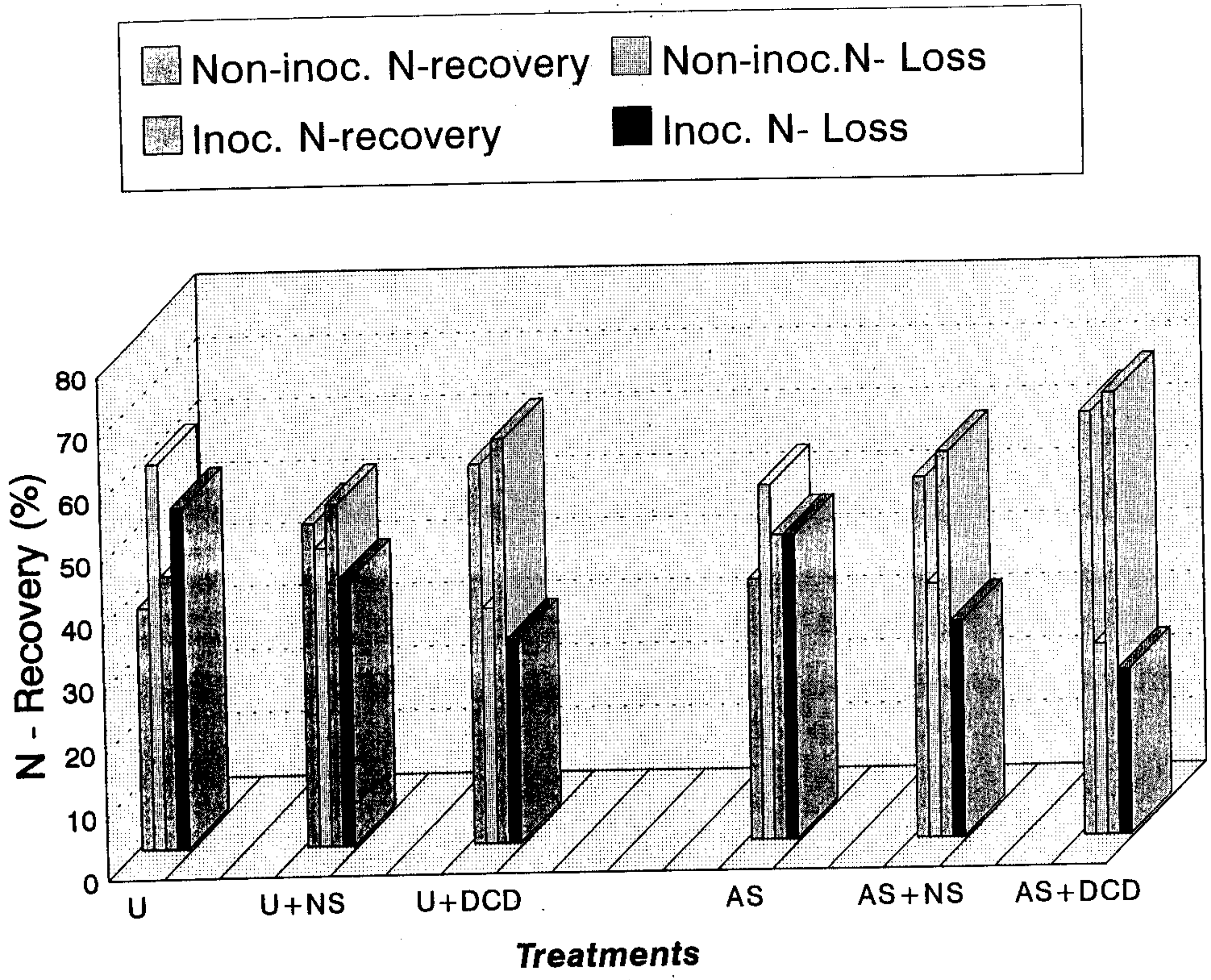

Fig. (6) Balance of N Labelled U or AS as affected by Azotobacter inoculation , N - source and nitrification inhibition

Values of losses were decreased from 60.5 , 37.28 and 46.98 % with noninoculation to 54.68, 32.32 and 42.1 % with Azotobacter inoculation for U, U + DCD and U + NS , respectively . The corresponding values withe AS were decreased from 56.43, 30.31 and 39.53 % in case of noninoculated plants to 48.07, 25.84 and 34.38 % with inoculated plants for AS, AS + DCD and AS + NS , respectively.

It is clearly shown that nitrification inhibition are more effective in reducing fertilizers loss and hence enabling a more FUE N by wheat plants. This was acheived mainly by regulating N release in soil and reducting N losses via NO_3^- leaching and denitrification processes and hence regulating the N supply to growing plants . Similar results were obtained by Warren *et al.* (1980). Soliman and Abdel Monem (1995) , found that N losses from urea was reduced from 45 % as urea was applied alone to 22 % and 25 % with U + DCD and U + NS , respectively . Abdel Monem *et al.* (1995) found that addition of DCD to U decreased the N losses from 64 % to 24 % and from 52 % to 25 % for wheat and corn , respectively .

4.2. Effect of sources and placement of N fertilizer and nitrification inhibition on wheat productivity

4.2.1 Dry matter yield .

Placement of N fertilizer and controlling nitrification of NH_4^+ from NH_4 - forming fertilizers could provide management altrernatives to minimize fertilizer - N losses .

Data of dry matter yield of wheat plants as affected by N source , and placement as well as nitrification inhibition are shown in Table (6) and illustrated by Fig (7) . Data revealed a significant effect due to the subsurface

Table (6) Straw , grain and total yield (g pot^{-1}) of wheat plants as affected by N - placement and nitrification inhibitions.

Fertilizer treatments	N - Placement					
	Surface			Subsurface		
	Straw	Grain	Total	Straw	Grain	Total
Control (NF)	41.2	30.4	71.7	41.3	30.4	71.7
Urea (U)	61.6	49.3	110.9	68.5	57.6	126.0
U + N - Serve	69.2	56.1	125.3	78.5	65.5	144.0
U + DCD	73.0	60.1	133.1	82.55	69.9	152.4
Mean	68.0	55.2	123.1	76.5	64.3	140.8
Ammonium sulfate (AS)	60.8	49.0	109.5	70.7	58.9	129.6
AS + N - Serve	73.2	59.2	132.4	81.2	68.6	149.8
AS + DCD	77.5	63.5	141.0	84.6	72.3	156.9
Mean	70.4	57.2	127.6	78.8	66.6	145.4

L.S.D $_{5\%}$	Straw	Grain
N - source	1.09	1.01
Placement	1.09	1.01
NI	1.34	1.24

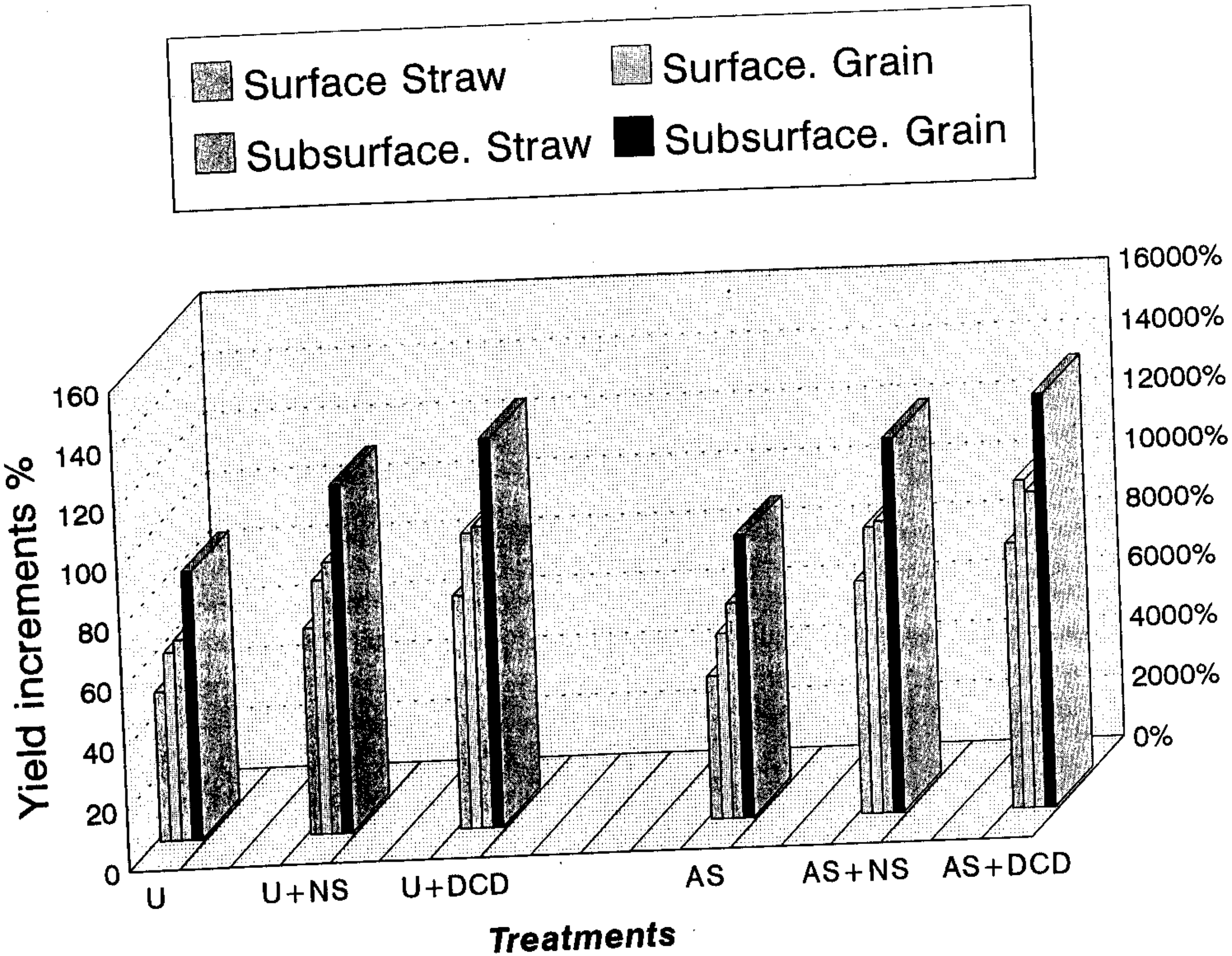

Fig. (7) Yield increment (%) of wheat straw and grain as affected by N - placement , N - source and nitrification inhibition.

placement of N fertilizer as compared with the surface N application . This trend was still consistent with all the other treatments (N sources and nitrification inhibition) . Yadvinder . Singh and Beauchamp (1988) reported that placement of NH_4-based fertilizer in nests at a depth of 5 cm to winter wheat may be a practical means of controlling nitrification in soils and increasing the efficiency of N use by plants as well as dry matter production . They added that the combined use of urea or nest placement at a depth of 5 cm with a suitable nitrification inhibitor should help in achieving optimum inhibition under widely differing soil and climatic conditions . This will help to reduce the cost of inhibitor because less chemical will be needed.

Urea application increased the yield of wheat straw and grain by about 49.4 % and 62 % 0ver control , respectively . Ammonium sulfate effect did not differ significantly from that of urea.

The positive effect due to mineral nitrogen fertilization on dry matter yield of wheat was materially induced with nitrification inhibition . The rate of increase was 68 and 77 % for straw , 84 % and 98 % for grain when applied urea was combined with NS and DCD , respectively . The corresponding values when ammonium sulfate was applied with NS or DCD were 77 % and 88 % for strow and grain , respectively.

The effect of the inhibitor on straw and total yield of wheat was almost similar to that on grain yield . Data indicate that the highest values of total wheat dry matter were obtained when DCD was applied either with urea or AS comparing with NS . The maximum increase percent was obtained when AS was combined with DCD amounting to 88 % , 109 % , and 97 % for straw , grain and total yield , respectively .

Surface application of NS can result in substantial loss of inhibitor by photolysis and volatilization ; however , its application to soils of high organic matter content can result in sufficient adsorption to lower these losses considerably (Briggs , 1975 , Hendrickson and Keeny , 1979 b) .

Irrespective of the inhibition treatment , deep application of both U and AS significantly increased straw yield of wheat by about 13 % and 12 % and grain yield by 17 % and 16 % , as compared with surface application when U and AS were applied , respectively .

Similar results were obtained by Craswell and Vlek (1979) who state that placing N fertilizer deeply in the soil increased grain yield and greatly reduced N loss . Also , soliman and Abdel Monem , (1996) found that deep application of U resulted in significant increase in straw and grain yield of rice averaging, about 25 % in straw and 20 % in grain due to deep placement , as compared with surface application .

The increments obtained as a result of " U " application in combination with the nitrification inhibitor , NS and DCD amounted to 90 % & 100 % in straw & 116 % , 130 % in grain yield . The corresponding values with AS were 97 % & 105 % for straw and 125 % & 138 % for grain in presence of NS and DCD , respectively . Also, the highest yield of total wheat dry matter was achieved when AS was mixed with DCD, amounting to 119 % compared with 97 % in case of surface placement .

The less effect of NS may be because it can not be granulate with solid N fertilizers (like urea) without loss of the inhibitor during processing , storage and handling due to its high vapor pressure . This limitation of NS is one of the reasons for prefering of useing of DCD (Yadvinder - Singh *et al.* 1994) rather than NS as a nitrification inhibitor . Keeney (1983) added that NS is seldom effective because of its sorption on soil colloids and hydrolysis to 6 - chloropicolonic acid and loss by volatilization .

4.2.2 N - uptake

Nitrogen uptake by wheat plants as a function of N fertilizer placement and nitrification inhibition are presented in Table (7) and illustrated by Fig (8). Values of N - uptake were higher when N - fertilizer was applied at a depth of 10 cm as compared with the surface application . An average increase of (18 % & 22 %) in straw and (16 % & 21 %) for grain N - uptake occurred due to deep placement in case of U and AS , respectively .

Combined N fertilizer and NI applcation either to soil surface or subsurface , significantly increased N - uptake of wheat plants . Results reveal that most of the nitrogen taken up was accumulated in grains .

Generally , values of N - uptake due to AS treatment were higher than those of U when both forms were applied to soil surface or subsurface . The influence of the two forms on N - uptake by wheat straw and grain showed a trend almost similar to that of total uptake by wheat plants . The total N - uptake was maximized with combined application of AS and DCD . The tested treatments could be arranged , according to their efficiency in increasing N - uptake in the following a decreasing order : AS + DCD > U + DCD > AS + NS > U + NS > AS > U . The incremenets corresponding to these treatments in the case of surface fertilizer application amounted to 234 % , 214 % , 213 % , 194 % , 157 % and 139 % for grain and 245 % , 226 % , 219 % , 195 % , 148 % and 1'38 % for total yield respectively.

Table (7) N - uptake (mg.pot^{-1}) of wheat plants as affected by N - placement and nitrification inhibition.

Fertilizer treatments	N - Placement					
	Surface			Subsurface		
	Straw	Grain	Total	Straw	Grain	Total
Control (NF)	206.7	310.3	516.9	206.7	310.3	516.9
Urea (U)	493.7	734.6	1228.3	616.9	926.9	1543.8
U + N - Serve	607.9	914.4	1522.4	715.1	1107.6	1822.8
U + DCD	649.1	1033.7	1682.8	763.59	1229.7	1993.3
Mean	583.6	894.2	1477.8	698.6	1088.1	1786.6
Ammonium sulfate (AS)	530.8	748.9	1279.7	641.8	971.9	1613.6
AS + N - Serve	647.4	1000.5	1647.9	744.6	1178.2	1922.8
AS + DCD	689.5	1092.7	1782.2	783.4	1280.2	2063.6
Mean	622.5	947.4	1570.0	723.3	1143.4	1866.7

L.S.D 5 %	Straw	Grain
N - source	9.69	16.98
Placement	9.69	16.98
NI	11.87	21.43

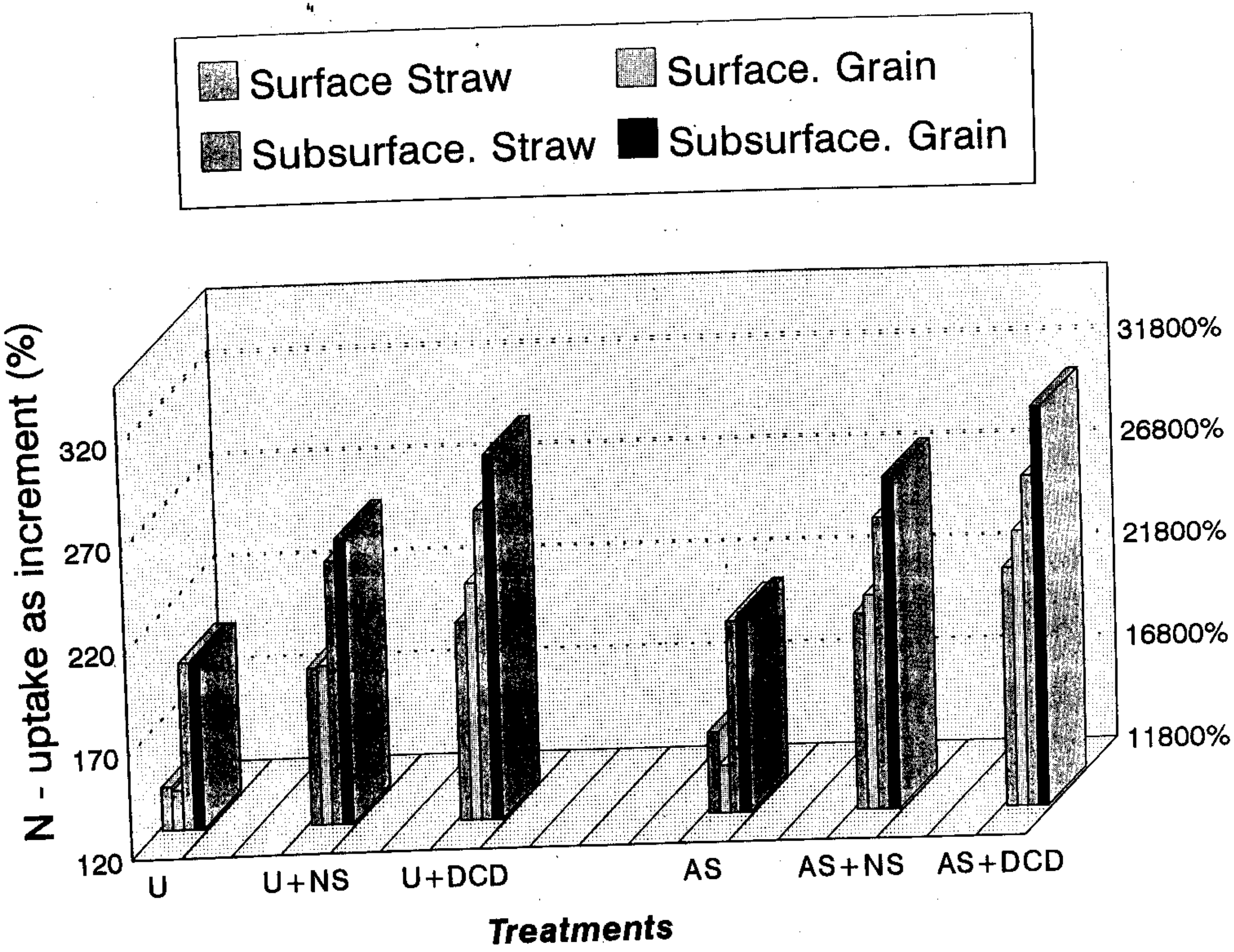

Fig. (8) Increment (%) ofN - uptake in wheat straw and grain as affected by N - placement , N - source and nitrification inhibition.

The higher effeiciency of DCD as compared with NS may be because DCD is completely decomposable in soil forming CO_2 and NH_4^+ , as final products (Amberger and Vilsmeier , 1979 and Vilsmeier , 1980) . While the DCD is a non volatile and relatively water stable product containing 67 % N . These properties allow DCD to be effectively formulated with a wide variety of N - fertilizers , including ammonium salts and urea (Reidar and Michaud , 1980). Data , illustrate that subsurface application of N - fertilizer led to the same trend , but with higher N - uptake values . The increments corresponding to the above mentioned six treatments in the case of subsurface fertilizer application , amounted to 279 % , 269 % , 260 % 246 % , 211 % and 199 % for straw and 313 % , 296 % , 280 % , 257 % , 213 % and 199 % for grain and 299 % , 286 % , 272 % , 253 % , 212 % and 199 % for total yield of wheat , respectively . Malhi and Nyborg (1984 and 1985) reported that recovery of fall - applied urea as NH_4 - N in spring wheat was greater with nest placement than with banding . Nest placement of urea in the presence of nitrification inhibitors further increased the recovery of NH_4 - N . They added that yields with fall banding were still less than those with spring incorporation. Further , banding of urea and nitrification inhibitor (ATC , thiourea or NS) in the fall slowed nitrification and increased grain yield and N uptake of barley compared to banding urea alone . Malhi *et al.* (1989) explained N uptake of barley due to decreased of both nitrification and immobilization of fall applied N and increased recovery of ^{15}N in barley plants .

Increasing the N - uptake of wheat due to the tested treatments could be attributed to inducing N utilization by plants probably as a result to controlling the rate of N supply as well as reducing N loss as ammonia gas or leached nitrate.

The lower response degree of wheat to surface placement of N fertilizer agrees with the findings of Rodgers and Ashworth (1982) , Rodgers *et al.* (1985) Wilson *et al.* (1990) Hamid and Ahmed (1995) , Srinivas and Thanl (1996) Soliman and Abdel Monem (1996).

4.2.3 *Nitrogen derived from fertilizer , soil and fertilizer use efficiency .*

Data obtained for N fractions , Ndff , Ndfs and FUE in wheat straw and grains are presented in Table (8) and illustrated by Figs (9 , 10 and 11) . Data generally show that subsurface placement of N fertilizers increased the Ndff values higher than those with surface application . Combination of both fertilizer with inhibitor yielded higher Ndff for values with both placement methods . The proportion of Ndff in straw averaged 301.24 and 336.34 mg N .pot^{-1} when U and AS were applied to soil surface , while it averaged 489.7 and 545.61 mg N pot^{-1} in wheat grain , respectively . Values of Ndff obtained with applied U or AS in wheat straw or grain were higher than those observed when wheat was fertilized with AS + DCD as compared with U or AS alone . Also , the Ndff fraction in both plant parts was increased by application of U + DCD , AS + NS U + NS and AS but in less degree than AS + DCD . As was reported by Malzer *et al.* (1989) the crop benefits associated with the inhibition of nitrification are most frequently related to the indirect benfit of reducing fertilizer N - losses through leaching or denitrification . Soliman and Abdel Monem (1992) reported significant increase in Ndff in whole plant of wheat grown in sandy soil as treated with U + DCD , when compared with "U" fertilization.

Values of (Ndff) accumulated in wheat grain averaged about 489.7 and 651.2 mg N. pot^{-1} when U was applied to soil surface and subsurface,

Fertilizer treatments	N - Placement											
	Surface						Subsurface *					
	Straw			Grain			Straw			Grain		
	Ndff	Ndfs	FUE	Ndff	Ndfs	FUE	Ndff	Ndfs	FUE	Ndff	Ndfs	FUE
Urea (U)	236.2	257.6	14.8	363.1	371.5	22.7	330.7	286.2	20.7	525.1	401.8	32.9
U + N - Serve	309.7	298.2	19.4	500.7	413.8	31.3	402.4	312.7	25.2	657.1	450.6	41.1
U + DCD	357.8	291.2	22.4	605.4	428.4	37.8	444.2	319.4	27.8	771.5	458.2	48.2
Mean	301.2	282.3	18.8	489.7	406.1	30.4	392.4	306.1	24.5	651.2	303.5	40.7
Ammonium sulfate	263.4	267.3	16.5	395.6	353.4	24.7	355.2	286.6	22.2	567.0	404.9	35.4
As + N - Serve	346.7	300.6	21.7	570.9	429.6	35.7	424.9	319.7	26.6	719.2	459.0	45.0
AS + DCD	398.9	290.6	24.9	670.9	422.4	41.9	471.0	312.4	29.4	824.7	455.5	51.6
Mean	336.3	286.2	21.0	545.6	401.8	34.1	417.0	306.3	26.1	703.6	439.8	44.0

* 10 cm depth

Table (8) Values of Ndff , Ndfs , and FUE as affected by N - placement and nitrification inhibition .

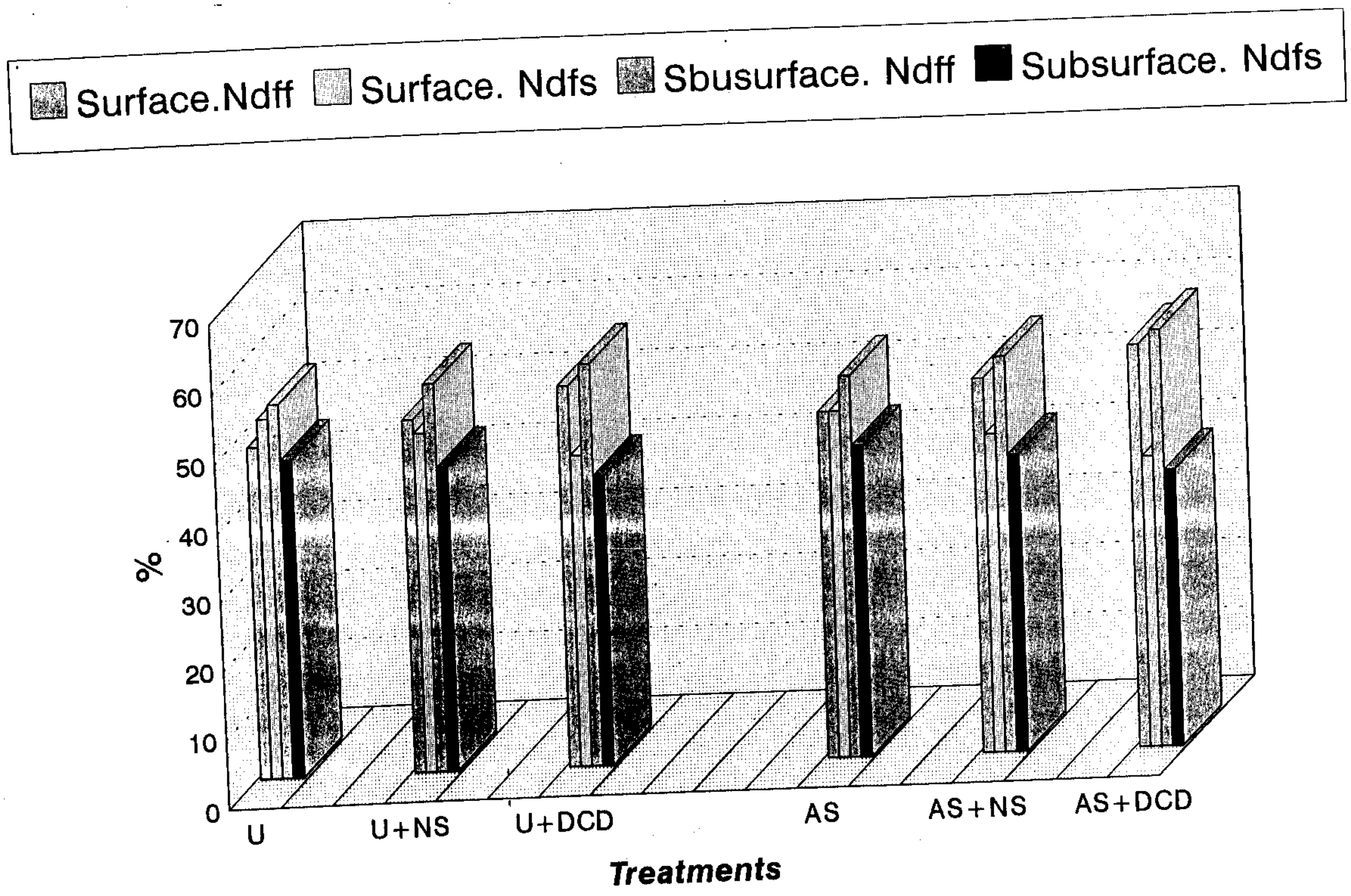

Fig. (9) The Nitrogen derived from fertilizer (Ndff) , soil (Ndfs) and air (Ndfa) as percentage by wheat straw as affected by N - placement , N - source and nitrification inhibition.

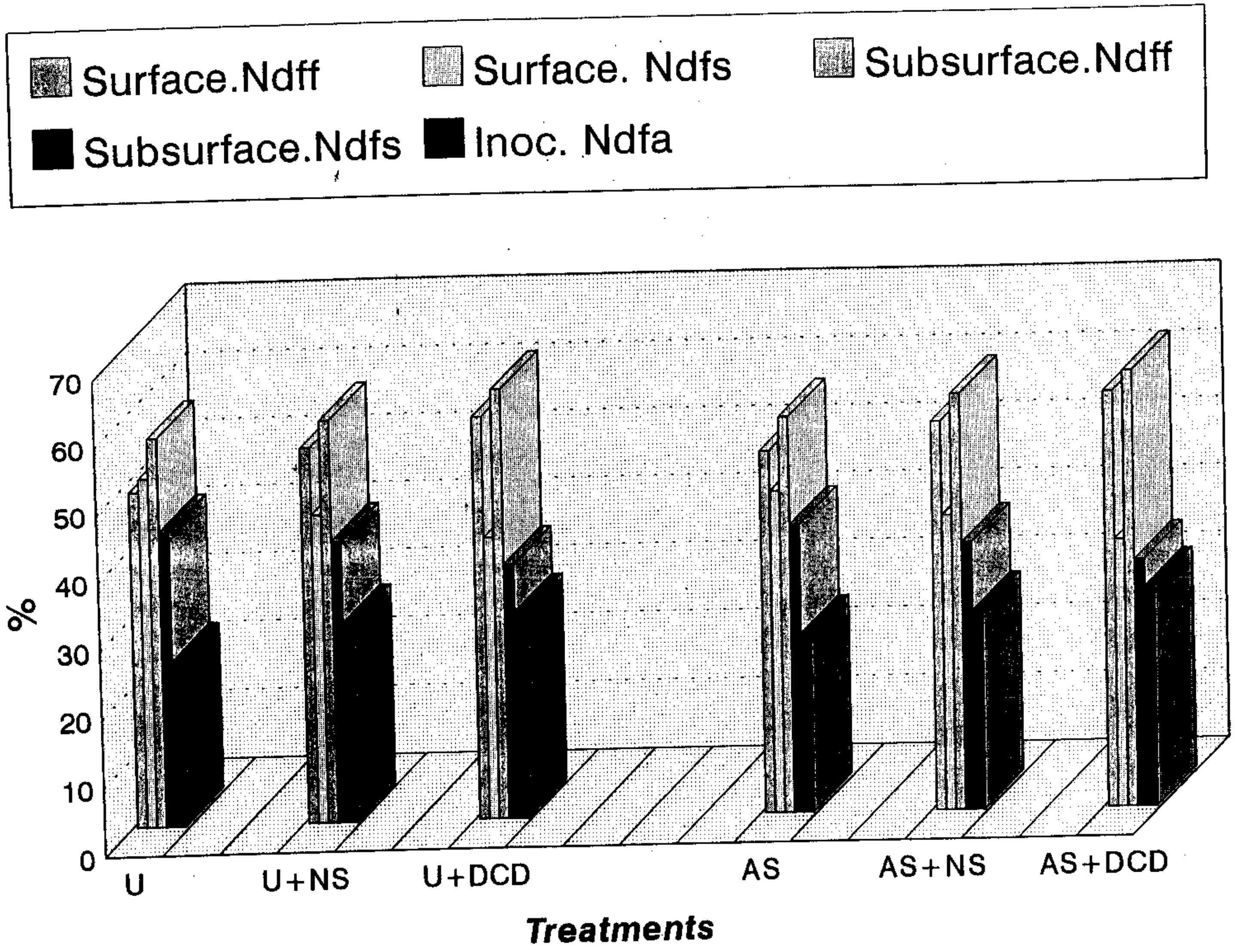

Fig. (10) The Nitrogen derived from fertilizer (Ndff) , soil (Ndfs) and air (Ndfa) as percentage by wheat grain as affected by N - placement, N - source and nitrification inhibition.

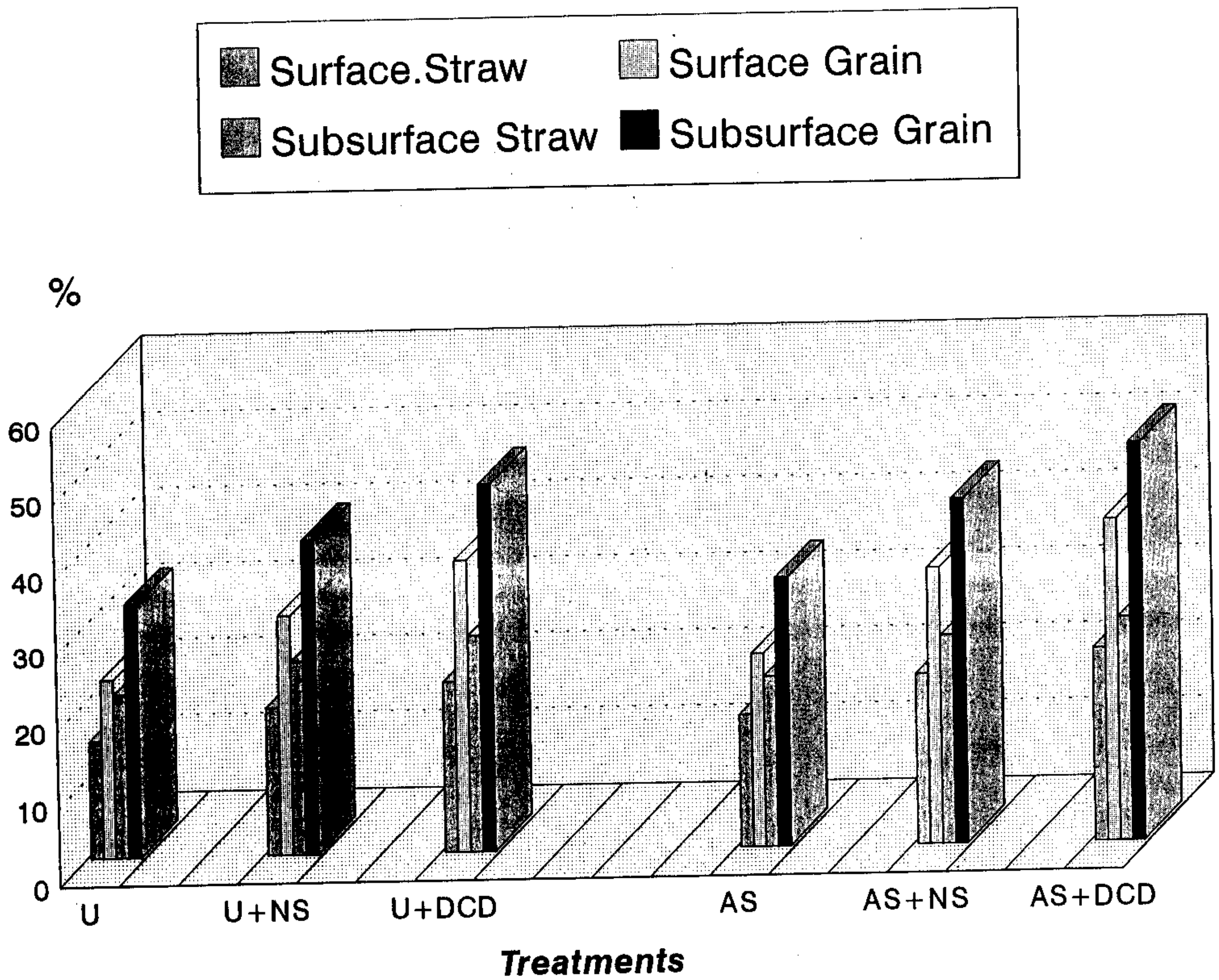

Fig. (11) The FUE values of wheat straw and grain as affected by N placement and nitrification inhibition.

respectively . This fraction amounted to 545.6 and 703.6 mg N pot^{-1} for surface and subsurface placement of AS , respectively . Thus, wheat grain derived 54 % and 60 % of their total N - uptake when "U" was applied to soil surface and subsurface , respectively and 57 % or 61 % for surface or subsurface placement, respectively . The corresponding average values with AS were 286.2 mg N. pot^{-1} and 306.3 mg N. pot^{-1} for surface and subsurface , respectively . Percentage of Ndfs in wheat straw comprised 48.78 and 44 % of the total N uptake when "U" was applied to soil surface and subsurface , respectively . The corresponding values with AS averaged 46.3 and 42.5 % for surface and subsurface placement , respectively . When N fertilizer was applied as subsurface placement , lower Ndfs values were obtained compared to those in the surface placement . With inhibitor , (DCD) application , % Ndfs was decreased to its lower extent when U or AS was applied deep under surface or subsurface placement condition.

Data generally show that about 50 % of the total nitrogen in wheat plants was derived from fertilizer "Ndff".

Concerning FUE , data indicate that values of fertilizer used by plant increased by about 24.5 % in straw and 40.7 % in grain when "U" was applied as deep placement compared to 18.8 % in straw and 30.4 % in grain in the surface placement . The corresponding average when AS was applied as deep placement 26.1 % and in straw and 44 % in grain compared to 21 % and 34.1 % in grain in the surface placement. The highest values of FUE was obtained 51.6 % mg N pot^{-1} in grain when AS was applied subsurface placement in combined with DCD.

Results clearly show that combination of NI with both forms of N -

fertilizer permitted a more efficient utilization of fertilizer N yielding higher Ndff for both fertilizer places . However, the positive effect of subsurface placement was more pronounced when combined with either N - Serve or DCD. Similar results were obtained by Wilson *et al.* (1990) , Soliman and Abdel Monem (1996) . Yadvinder - Singh *et al.* (1994) who reported that the nitrification inhibitors such as DCD and thiourea are effective in slowing nitrification , reducing overwinter N - loss and improving yield response of spring barley and winter wheat to fall applied N . They added that the practice of placement of urea in neste can eliminate or reduce the amount of nitrification inhibitor necessary to improve the efficiency of fall applied urea where losses of mineral N are a problem.

4.2.4 ^{15}N - balance as affected by N - source , N - **placement** *anbd nitrification inhibition* .

Data in Table (9) and illustrated by Fig (12) showed that total nitrogen recovery by both plant and soil was affected by N - placement and nitrification inhibition . Fertilizer nitrogen recovery when N - fertilizer was higher when fertilizer was combined with DCD .

Application of NI increased total N recovery from about 40 % with "U" added alone as surface application to 53 and 63 % for U + NS and U + DCD, respectively . These values were increased as AS was applied to the soil surface from 44 % to 61 % and 70 % with application of AS + NS or AS + DCD, respectively .

Results also show that total N recovery was much higher under subsurface application with both N - fertilizer sources comparing with surface addition . It

Fertilizer treatments	N - Placement							
	Surface				Subsurface			
	Plant	Soil	Total	Loss	Plant	Soil	Total	Loss
Urea (U)	599.2	32.8	632.0	968.0	855.8	34.9	890.7	709.3
U + N - Serve	810.4	37.9	848.3	751.7	1059.2	53.4	1113.0	487.0
U + DCD	963.0	40.5	1003.5	596.5	1215.7	46.9	1262.6	337.4
Mean	790.9	37.1	828.0	772.1	1043.7	45.1	1088.8	511.3
Ammonium sulfate (AS)	658.9	38.2	697.1	902.9	922.2	47.8	970.1	629.9
AS + N - Serve	917.6	49.9	967.5	632.5	1144.0	72.8	1216.8	383.2
AS + DCD	1069.3	45.8	1115.0	485.0	1295.8	63.04	1358.9	241.1
Mean	881.9	44.6	926.6	673.4	1120.7	61.5	1182.2	418.1

Table (9) Nitrogen balance of ^{15}N labelled "U" or "AS" as affected by N - placement and nitrification inhibition .

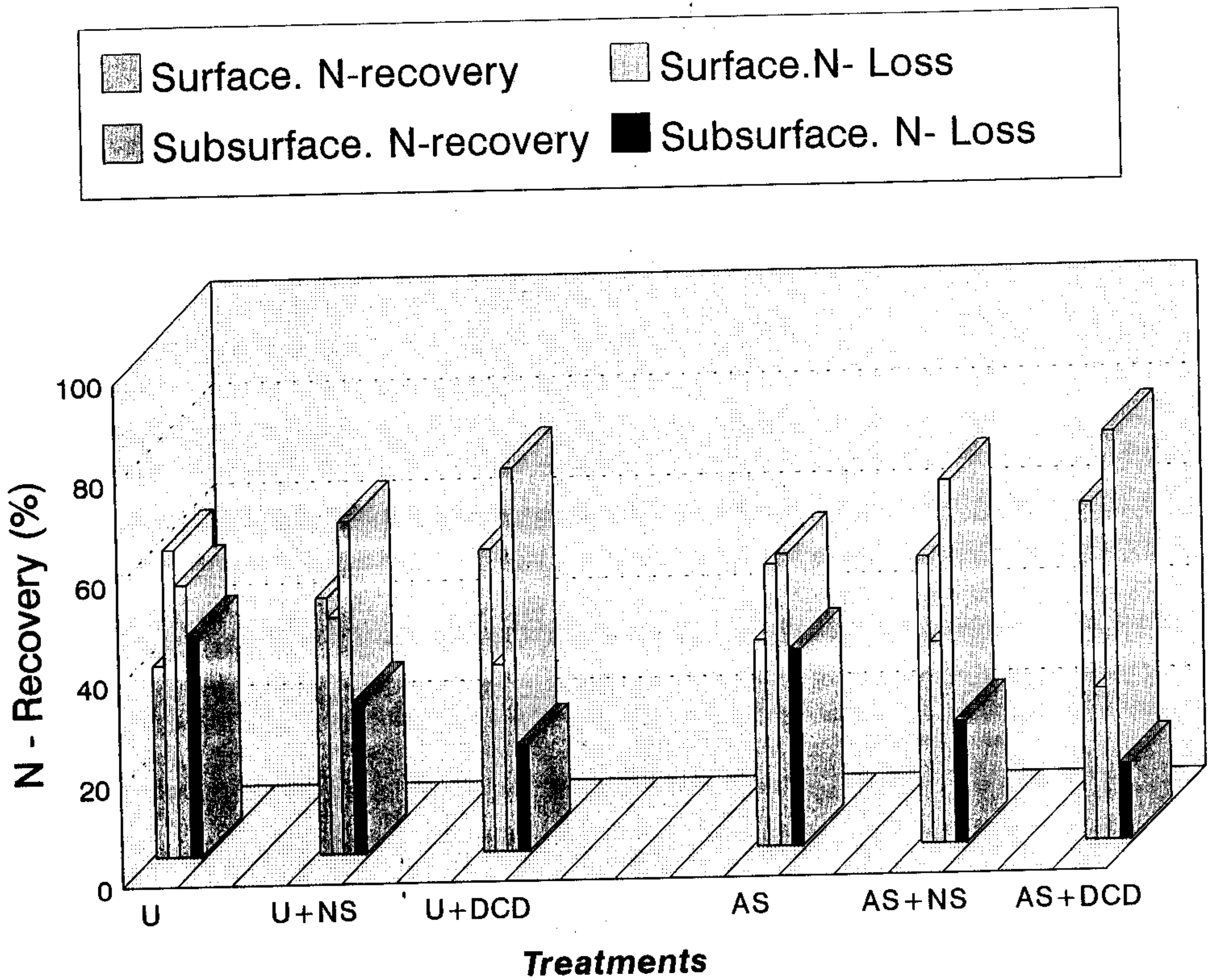

Fig. (12) Balance of N Labelled U or AS as affected by N - placement, N - source and nitrification inhibition

amounted to 56, 70 , 79 % for U , U + NS and U + DCD , respectively . The corresponding values with subsurface ammonium sulfate application were relatively higher i.e 61 , 76 and 85 over control comparing to U application, respectively .

It is clearly shown that more fertilizer nitrogen was recovered by plant with subsurface application of AS + DCD.

Values of N losses from both N sources were more affected by method of N fertilizer placement and NI . The higher rate of loss (61 %) was obtained with U applied to soil surface , while the lowest rate of loss (15 %) was achieved with subsurface combined application of AS + DCD . Such results may lead to conclusion that minimizing the losses or maximizing of nitrogen utilization by plant , could be achieved through the suitable management practices of N fertilizer + nitrification inhibitor , DCD and subsurface placement (10 cm) of the N fertilizer . Similar results were obtained by Warren *et al.* (1980) , Wilson *et al.* (1990) and soliman and Abdel Monem (1995 and 1996) . They found that approximately , 2/3 of applied "U" (64 %) was lost , when "U" was applied alone . Those losses were reduced down to 12 % with deep placement and inhibitor application . The two management practices show significant effect on minimizing N-losses and increasing plant N recovery .

4.3. Effect of N source , time of application and nitrification inhibition on yield and N - uptake and recovery by wheat:

As nitrogen is an important nutrient to wheat and is low in soil , its addition in suitable source and proper time may increase the yield and improve the fertilizer efficiency . In this experiment , the whole rate of N fertilizer was applied one time or splitted into two equal doses (half rate) or three equal doses

(1/3 rate). The whole rate was applied one time (T_1) , before planting . The half rates were applied in two times (T_2) , before planting and 50 days after planting The 1/3 rates were applied in three times (T_3) , before planting , 21 and 65 days after planting .

4.3.1. Straw and grain yield:

Data concerning the yield of wheat straw and grain in the experiment conducted with N source , time of application and nitrification inhibitors are presented in Table (10) and Fig (13) . It is noted that there was a significant effect due to different N sources and times of application on both straw and grain yield as well as total biomass . In general , data revealed that ammonium sulfate is slightly superior than urea for dry matter yield of wheat . Stevens and Laughlin (1989) reported that soil type and wheat variety would influence the response of wheat to different N - sources . Results also , show that application of N fertilizers one time before sowing or splitting those fertilizers to three equal dozes , yielded almost comprable effects on wheat dry matter yield (straw and grain) . Under urea application , straw yield recorded 67.96 and 64.29 g pot^{1-} at whole and three application dose , respectively. For grain , it amountes 55.17 and 51.73 g pot^{-1} for previous treatment . Upon AS application , it was 70.38 and 67.88 g pot^{-1} for straw and 57.23 and 55.13 g pot^{-1} for grain under N application as mentioned above whereas , splitting nitrogen into two equal doses gave significant higher yield than both N whole rate and the splitted three doses. In this concern , the rate of increase in straw and grain yield averaged about 76 and 99 % over corresponding control when urea - N was added two times (i.e one half doses) and about 86 and 111 % upon AS application , respectively . Darwinkel (1983) showed that the effect of nitrogen application on the ear formation depend greatly on the growth stage at which nitrogen was applied . He added that the maximum effect on spikelet intiation was achieved when

Table (10) Straw , grain and total biomass (g.pot^{-1}) of wheat plants as influenced by N-source and time of N-application in presence or absence of nitrification inhibitor .

Fertilizer treatments	Time of N - application								
	T1			T2			T3		
	Straw	Grain	Total	Straw	Grain	Total	Straw	Grain	Total
Control	41.3	30.4	71.7	41.3	30.4	71.7	41.3	30.4	71.7
Urea (U)	61.6	49.3	111.0	66.5	54.6	121.1	57.0	45.5	118.9
U + N - Serve	69.2	56.1	125.3	73.0	61.1	134.1	66.2	52.8	126.7
U + DCD	73.0	60.1	133.1	78.7	66.0	144.7	69.7	57.0	126.7
Mean	68.0	55.2	123.1	72.8	60.6	133.3	64.3	51.7	116.0
Ammonium sulfate (AS)	60.5	48.0	109.5	68.8	56.5	125.3	59.6	47.4	107.0
AS + N - Serve	73.2	59.2	132.4	79.1	65.8	144.9	70.5	57.0	127.5
AS + DCD	77.5	63.5	141.0	82.1	70.1	152.2	73.5	61.0	134.5
Mean	70.4	57.2	127.6	76.7	64.1	140.8	67.9	55.1	123.0

$L.S.D_{5\%}$	Straw	Grain
N-source	0.76	1.03
Time	0.93	1.26
NI	0.93	1.26
N.NI	1.31	1.78

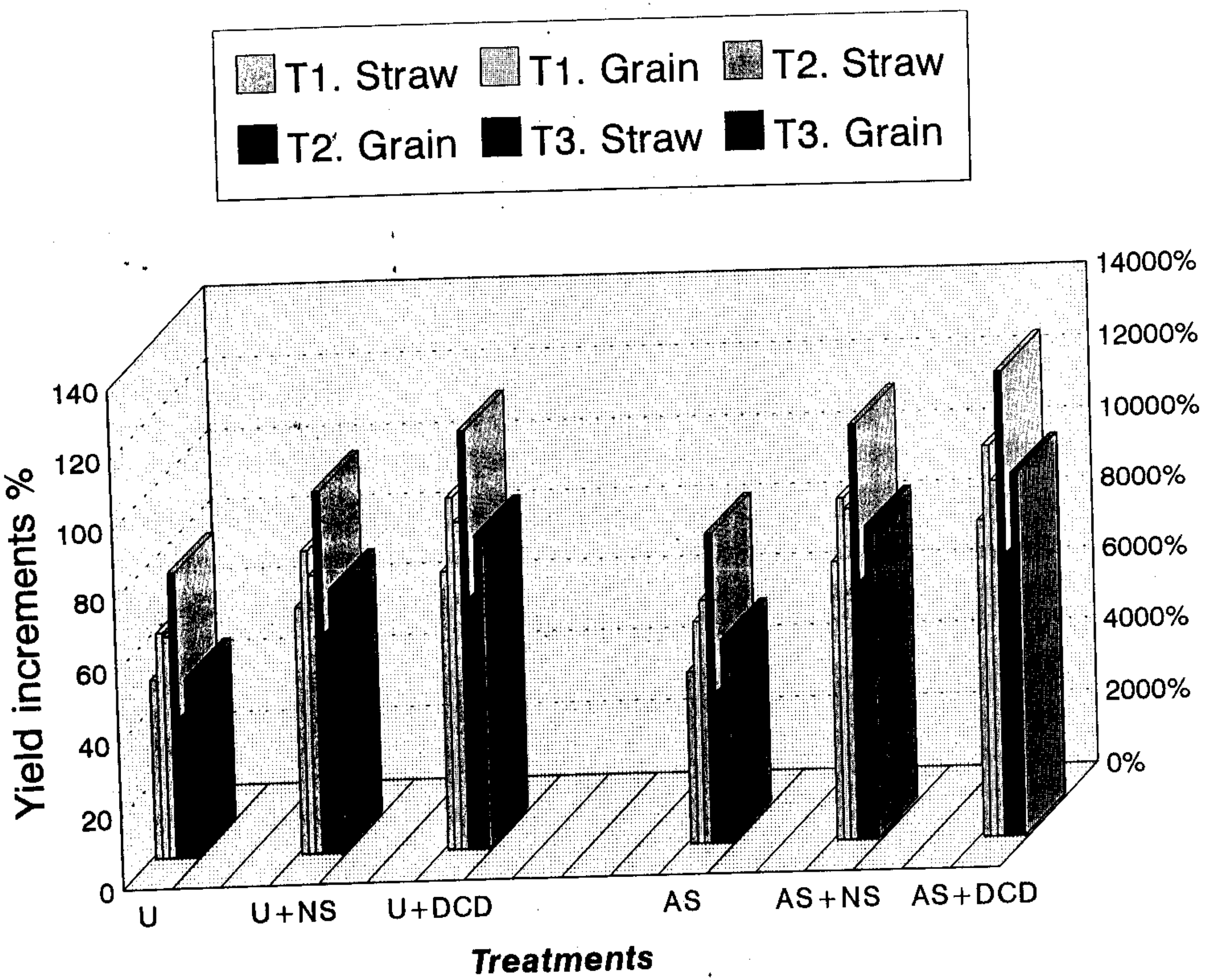

Fig. (13) Yield increment (%) of wheat straw and grain as affected by time of N - application and nitrification inhibition.

additional nitrogen was applied at the begining of tillering . Mahmoud (1996) reported that splitting N application into two equal N doses was more effective for increasing grain yield of wheat comparing with three equal N doses.

Concerning nitrification inhibitors , data presented in Table (10) showed that ammonium sulfate treated with DCD had a more favourable effect for increasing wheat straw and grain under two equal splitting N dose than AS + N - Serve as compared to U + DCD or U + NS . In this respect , total biomass (straw + grain) significantly increased by about 97 , 122 and 88 % over the control in presence of AS + DCD and 86 , 102 and 78 % under U + DCD at T_1 , T_2 and T_3 , respectively . In the presence of N - Serve , AS significantly improved the total biomass i.e by about 85 , 102 and 78 % while urea application increased this parameter by 75 , 87 , and 66 % for T_1 , T_2 and T_3, respectively . However , without nitrification inhibitor application , total dry matter increased by about 55 , 69 and 43 % over the control for urea and about 53 , 75 and 49 % for AS added alone at T_1 , T_2 , and T_3 , respectively . It is clear shown that the effect of nitrification inhibitor and times splitting of nitrogen application on both wheat straw and grain showed a trend almost similar to total dry matter yield . similar results were obtained by Hamissa *et al.* (1978) ; Korkor *et al.* (1984) and Darwish (1989). Yadvinder - Singh *et al.*(1994) reported that delaying the application of urea granule probably reduced nitrification appreciably , helping to conserve much of the urea - N in the NH_4 form over the winter , thereby reducing N - loss . They added that inclusion of a nitrification inhibitor DCD with urea increased the grain yield and N - uptake of winter wheat , whether the N fertilizer was applied at sowing or one month after sowing , compared to the spring top - dressing treatment .

4.3.2. N - uptake:

Data of N - uptake by wheat plants at maturity are show in Table (11) and Fig (14) . Results obtained reveal that the highest values of N - uptake were obtained when a half dose of the N fertilizer was applied only at sowing and the other half after fifty days from sowing (T_2) , followed by T_1 and finally T_3 . Average increases in N - uptake of 529.0 , 583.6 and 620.0 mg N pot^{-1} in straw and 805.9 , 894.2 and 974.8 mg N pot^{-1} in grain due to T_3 , T_1 and T_2 in case of U . The corresponding increases were 578.8 , 622.5 and 666.6 mg N pot^{-1} in straw and 876.4 , 947.4 and 1052.2 mg N pot^{-1} in grain in the case of AS.

Values of total increase due to T_2 treatment , when a two half dozes of N fertilizer were applied amounted to 1396 , 1606.9 and 1781 mg N pot^{-1} for U , U + NS and U + DCD , respectively . Increases averaged 1471.4 , 1768.9 and 1915.4 mg N pot^{-1} for As , AS + NS and AS + DCD , respectively . However, the tested treatments could by arranged , according to their efficiency in increasing N - uptake in the following descending order AS + DCD > U + DCD > AS + NS > U + NS > AS > U . The increments corresponding to these treatments in the case of T_2 , amounted to 281.8 % , 253.3 % , 247.8 %, 215 % , 187.7 % and 174.3 % over the control for grain , respectively . The highest values of N - uptake from fertilizer dozage treatment were obtained when the nitrification inhibitor "DCD" was applied with U or AS , but the highest superiority was attained for AS followed by U . Similar results were obtained by Grant *et al.* (1985) , Ahmadi *et al.* (1988) and Mahmoud (1996) who reported that splitting nitrogen fertilizer into two equal parts (i.e during the 1st and 2nd irrigations) led to significant increase of nitrogen content in wheat plants at vegetative stage compared with splitting nitrogen fertilizer into three equal partes (i.e. during the 1 st 2 nd and 3 rd irrigations) . Possible explanation of increasing N - uptake by wheat plants due to application of DCD is that more

Table (11) The N - uptake of wheat plants as influenced by dosage and source of N fertilizer as well as nitrification inhibition .

Fertilizer treatments	Time of N - application								
	T1			T2			T3		
	Straw	Grain	Total	Straw	Grain	Total	Straw	Grain	Total
Control	206.7	310.3	516.9	206.7	310.3	516.9	206.7	310.3	516.9
Urea (U)	493.7	734.6	1228.3	545.0	581.1	1396.1	453.8	679.4	1133.2
U + N-Serve	607.9	914.4	1522.4	629.6	977.3	1606.9	563.0	822.9	1385.9
U + DCD	649.1	1033.7	1682.8	685.3	1096.1	1781.4	600.2	917.4	1517.7
Mean	583.6	894.2	1477.8	620.0	974.8	1594.8	529.0	805.9	1335.0
Ammonium sulfate (AS)	530.8	748.9	1279.7	578.7	892.7	1471.4	492.5	711.0	1203.5
AS + NServe	647.4	1000.5	1647.9	689.8	1079.1	1768.9	602.8	911.2	1514.0
AS + DCD	689.5	1092.7	1782.2	730.7	1184.7	1915.4	640.9	1007.0	1647.9
Mean	622.5	947.4	1569.9	666.6	1052.2	1718.8	578.8	876.4	1455.2

$L.S.D_{5\%}$	Straw	Grain
N-source	6.5	15.26
Time	7.97	18.69
NI	7.97	18.69
N.NI	-	26.43

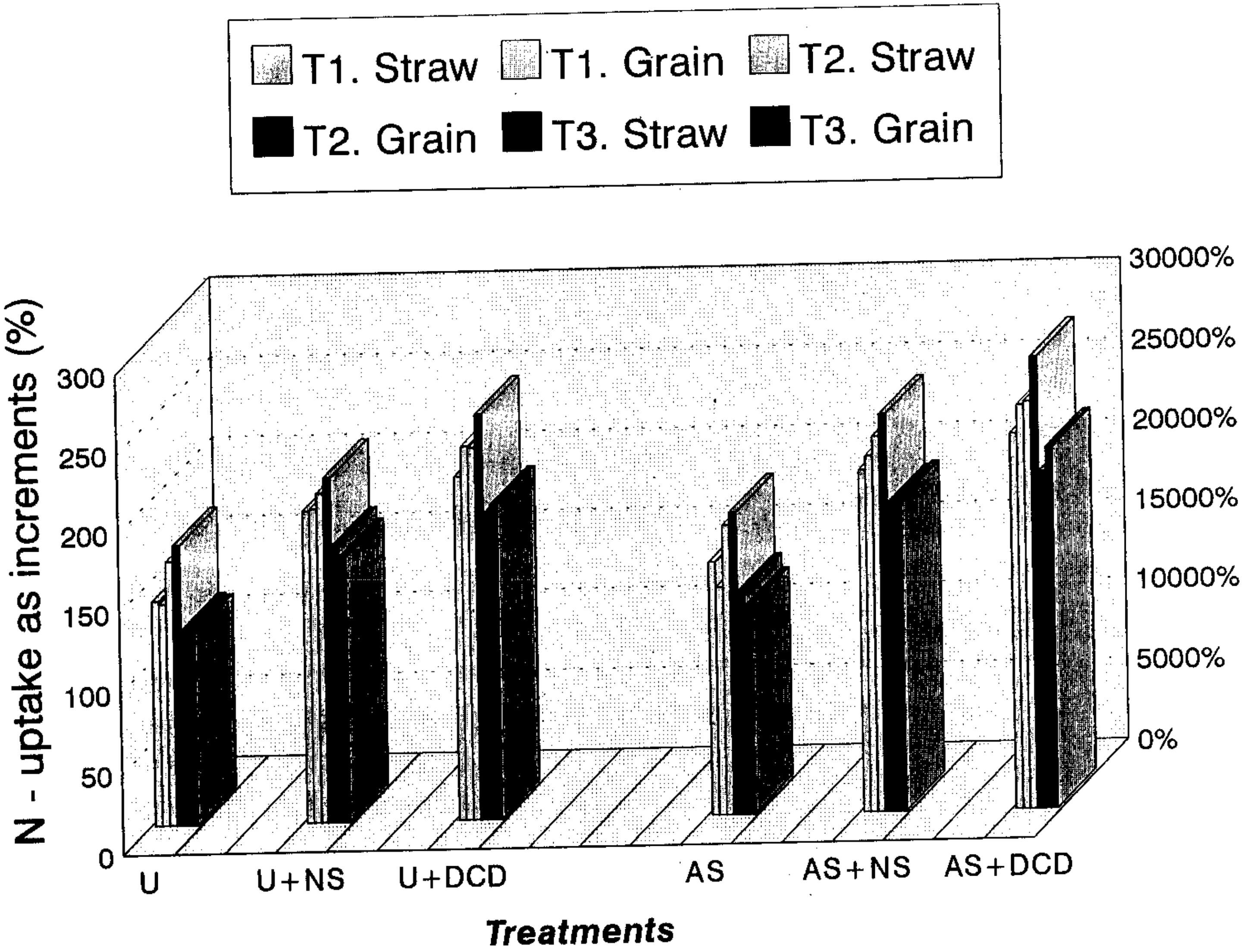

Fig. (14) increment (%) of N - uptake in wheat straw and grain as affected by time of N - application , N - source and nitrification inhibition

N accumulated in soil organic fraction in presence of DCD . This accumulation may be related to DCD maintaining more fertilizer N in NH_4 , which is more readily utilized by microorganisms , (Wilson *et al.* , 1990) . Thus , it could concluded that delayed nitrogen fertilization for wheat may decrease crop yield.

4.3.3. Nitrogen derived from fertilizer or soil and fertilizer use efficiency :

The nitrogen derived from fertilizer (Ndff) parameter provides a sensitive criterion to assess specific fertilizer practices . Data presented in Table (12) and illustrated in Fig (15 , 16 and 17) show that the fertilizer N accounted in straw ranged from 48.54 % to 55.77 % ; 52.47 to 57.29 % in grain . Data also show that Ndff or Ndfs values in either straw or grain were not affected by the application of urea or As and the presence or absence of nitrification inhibitor , the same trend was observed . Hamissa *et al.* (1983) and Soliman *et al.*(1993) reported that urea and ammonium nitrate had hearly the same effect on Ndff and nitrogen utilized by wheat plants .

Concerninig , N use efficiency , results in Table (12) and Fig (17) revealed that splitting N application improved N utilization by wheat plants . It is clear from Table (12) that application of U or AS at (T_2) significantly increased the FUE value by both straw or grain as compared to T_1 and T_3 treatments . In this respect , FUE of wheat straw comprised about 15 , 18 and 13 % of total fertilizer N added as urea and about 17 , 19 and 15 % for AS at T_1 , T_2 and T_3 treatments , respectively . Values of FUE by wheat grain amounted to 23 , 29 or 21 with U and 25 , 32 or 23 with AS application at T_1, T_2 and T_3 , respectivily . Such trend indicate that splitting applied N fertilizer into two equal doses applied at sowing and 50 days later led to the highest uptake of N by plant as compared with either the whole rate application or the

Ferilizer treatments	Time of N - application																	
	T1						T2						T3					
	Straw			Grain			Straw			Grain			Straw			Grain		
	Ndff	Ndfs	FUE	Ndff	Ndfs	FUE	Ndff	Ndfs	FUE	Ndff	Ndfs	FUE	Ndff	Ndfs	FUE	Ndff	Ndfs	FU
Urea (U)	236.2	257.6	14.8	363.1	371.5	22.7	281.8	263.2	17.6	459.5	391.6	28.7	208.8	245.0	13.1	338.4	341.0	21.2
U + N - Serve	309.7	298.2	19.4	500.7	413.8	31.3	342.3	287.3	21.4	561.1	416.2	35.1	271.9	291.1	17.0	431.8	391.1	27.0
U + DCD	357.8	291.2	22.4	605.4	428.4	37.8	393.4	291.9	24.6	662.7	443.4	41.4	308.1	292.1	19.3	505.8	411.7	31.6
Mean	301.2	282.3	18.8	489.7	406.1	30.4	339.2	280.8	21.2	561.1	413.7	35.1	262.9	176.1	16.4	425.3	381.3	26.6
Ammonium sulfate (AS)	263.4	267.3	16.5	395.6	353.4	24.7	305.7	273.0	19.1	505.5	387.2	31.6	236.0	256.6	14.7	366.9	344.1	22.9
As + N - Serve	346.7	300.6	21.7	570.9	429.6	35.7	381.7	308.0	23.9	646.8	423.3	40.4	306.2	295.6	19.1	515.4	395.8	32.2
AS + DCD	398.9	290.6	24.9	670.9	422.4	41.9	432.1	298.6	27.0	741.4	443.3	46.3	349.6	291.4	21.9	590.0	417.0	36.9
Mean	336.3	286.2	21.0	545.6	401.8	34.1	373.2	293.2	23.3	631.3	420.9	39.5	297.3	281.5	18.6	490.8	385.7	30.6

Table (12) Values of Ndff and Ndfs of wheat straw and grain mg. Pot^{-1} as affected by time of N -application and nitrification inhibition .

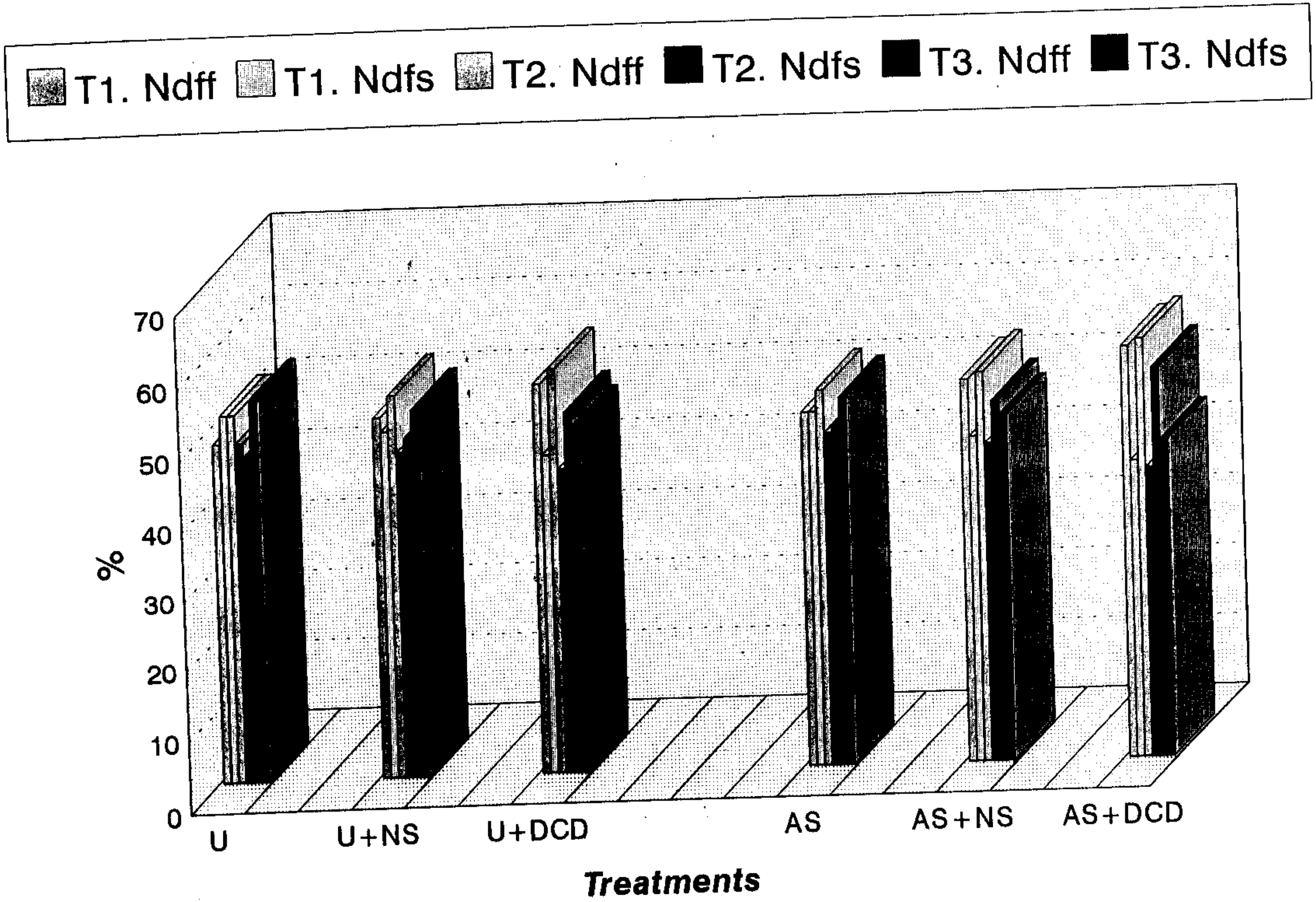

Fig. (15) Nitrogen derived from fertilizer (Ndff) and soil (Ndfs) as percentage by wheat straw as affected by time of N application and nitrification inhibition

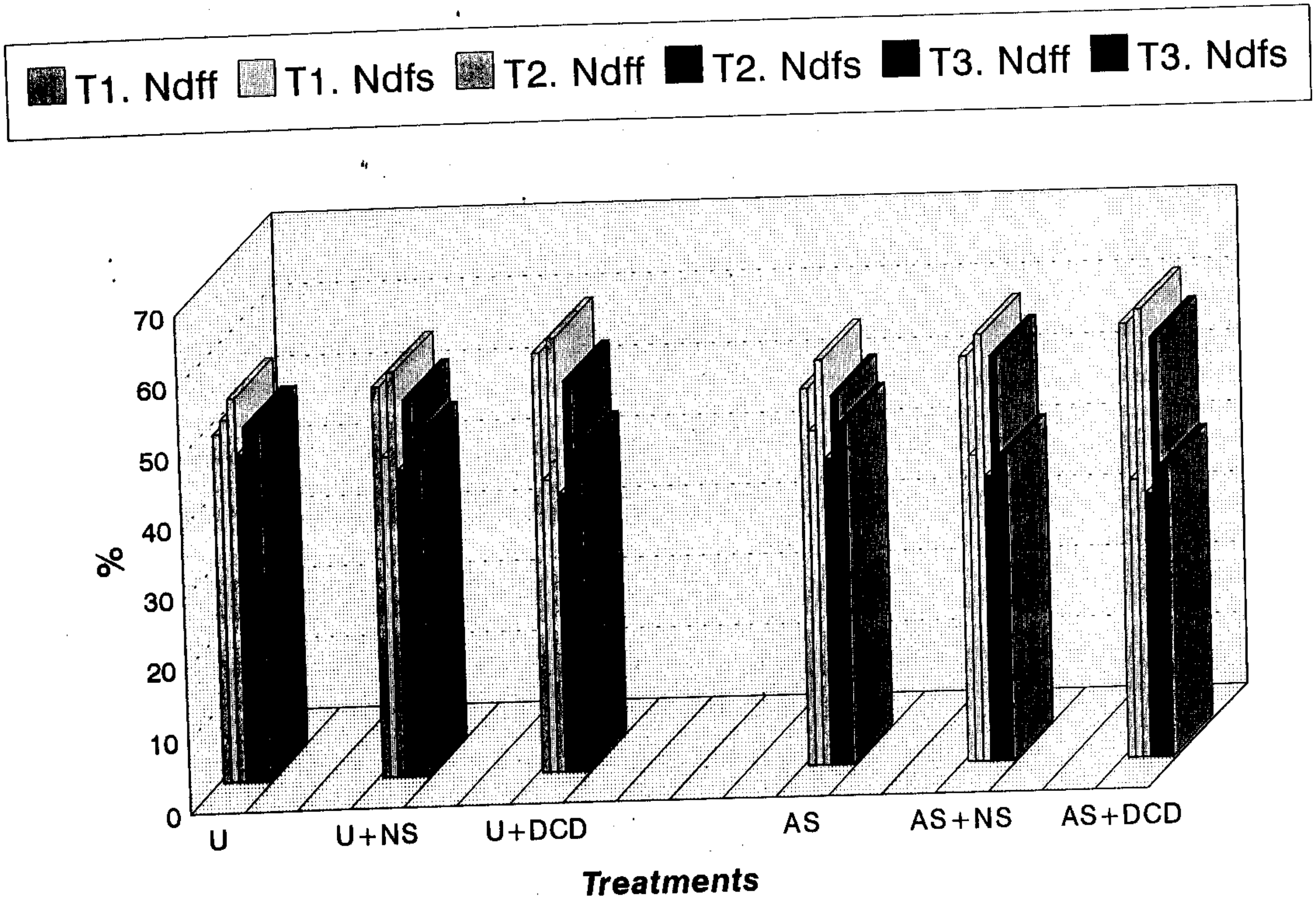

Fig. (16) Nitrogen derived from fertilizer (Ndff) and soil (Ndfs) as percentage by grain as affected by time of N application and nitrification inhibition

three partes - splitted dose . The benificial effect was more pronounced when U or AS was modified with DCD or NS nitrification inhibitors . In this concern, the combined effect between time of N application and nitrification inhibitor increased the FUE by straw from 15 to 22 % at T_1 ; from 18 to 25 % at T_2 and from 13 to 19 % at T_3 when U was treated with DCD. While , AS + DCD increased FUE from 17 to 25 at T_1 ; 19 to 27 % at T_2 and from 15 to 22 % at T_3 . For grain , FUE was increased from 23 to 38 % at T_1 , from 29 to 41 % at T_2 and from 21 to 32 % at T_3 upon application of U + DCD . While , AS + DCD application increased FUE by grain from 25 to 42 % at T_1 , from 32 to 46 % at T_2 and from 23 to 37 % at T_3.

Data also show that the application of N serve was less effective for increasing FUE as compared to DCD with respect to fertilizer use efficiency . Values of FUE in wheat straw treated with U alone amounted to 15 , 18 and 13 compared with 19 , 21 and 17 % for U + NS and 22 , 25 or 19 with U + DCD at T_1 , T_2 and T_3 , respectively .

The corresponding fterilizers in case of AS were ; 17 , 19 , 15 ; 22 , 24 or 19 and 25 , 27 or 22 for T_1 , T_2 and T_3S , respectively . This is due to that application of nitrification inhibitors such as DCD are more effective in slowing nitrification rate , reducing over winter N loss and thus improving yield response of wheat to applied N (Yadvinder - Singh ; *et al.* 1994) .

4.3.4. Nitrogen balance.

Total plant recovery of ^{15}N labelled urea Table (13) and Fig. (18) show a wide range (34.2 to 46.3 %) under different times doses of N application , a range of 37.7 to 50.7 % of the AS . Soliman and Abdel Monem (1992) found that not more than 20 to 50 % of fertilizer nitrogen was recovered by wheat plants grown on a sandy soil under green house conditions.

Comparing the effectiveness of DCD or NS applied with U or AS (Table (13) and Fig. (18)) indicate that , not only AS is more efficient fertilizer to wheat than U , but also with addition of DCD as NI the infleunce was induced.

The total recovery by wheat plants recorded was about 66.8 , 73.4 and 58.7 % of the total nitrogen applied at T_1 , T_2 and T_3 in the presence of AS + DCD , respectively , while with application of U + DCD , FUE amounted to about 60, 66 and 51 % with previous treatments , respectively . Data also show that when U or AS was combined with NS , an effectless than that of DCD occurred . The value of total N recovery recorded were 51 , 57 and 44 % for U + NS ; 57 , 64 and 51 for AS + NS at T_1 , T_2 and T_3 , respectively . Fox and Bandel (1989) reported that the most promosing potential use of DCD for wheat is its application with U or ammonium containg fertilizer.

The relatively extensive losses of applied ^{15}N from the soil plant system (Table , 13) , could be the major cause for the poor recoveries of applied N by the plant. The maximium losses from U was obtained at T_1 and T_3 , ranging from 61 to 64 % but reduced to 52 % of total nitrogen fertilizer added at T_2. In the presence of AS , the nitrogen loss was about 56 or 60 % at T_1 and T_3 , respectively but reduced to 47 % when AS - N was applied at two equal dozes.

It is a serious cause for concern economically and environmentally .This may explain the importance of NI which have the ability to reduce ammonia volatilization and nitrate leaching . DCD applied with U or AS reduce nitrogen losses and therefor enables more efficient nitrogen utilization by mantaining more of the fertilizer nitrogen and soil nitrogen in the NH_4^+ forms . Losses were

Fertilizer treatments	Time of N - application											
	T1				T2				T3			
	Plant	Soil	Total	Loss	Plant	Soil	Total	Loss	Plant	Soil	Total	Loss
Urea (U)	599.2	32.8	632.0	968.0	741.3	32.5	773.8	826.2	547.2	33.8	581.0	1019.0
U + N - Serve	810.4	37.9	848.3	751.7	903.4	39.8	941.1	658.9	703.7	37.8	741.4	858.6
U + DCD	963.0	40.5	1003.5	596.5	1056.2	38.6	1094.7	505.3	814.1	37.6	851.7	748.3
Mean	790.9	37.1	828.0	772.1	900.3	36.8	936.5	663.5	688.3	36.8	724.6	875.4
Ammonium sulfate (AS)	658.9	382.4	697.1	902.9	811.2	38.4	849.6	750.4	602.7	35.4	638.1	961.9
AS + N - Serve	917.6	49.9	967.5	632.5	1028.6	47.2	1075.8	524.2	821.6	39.2	860.8	739.2
AS + DCD	1069.3	45.8	1115.0	485.0	1173.6	45.0	1218.6	381.4	939.7	39.8	979.5	620.5
Mean	881.9	44.6	926.6	673.4	1004.5	43.5	1048.0	552.0	788.0	38.1	826.1	773.9

Table (13) Balance of ^{15}N labelled "U" or "AS" in soil and wheat plants as affected by dosage of N application and nitrification inhibition .

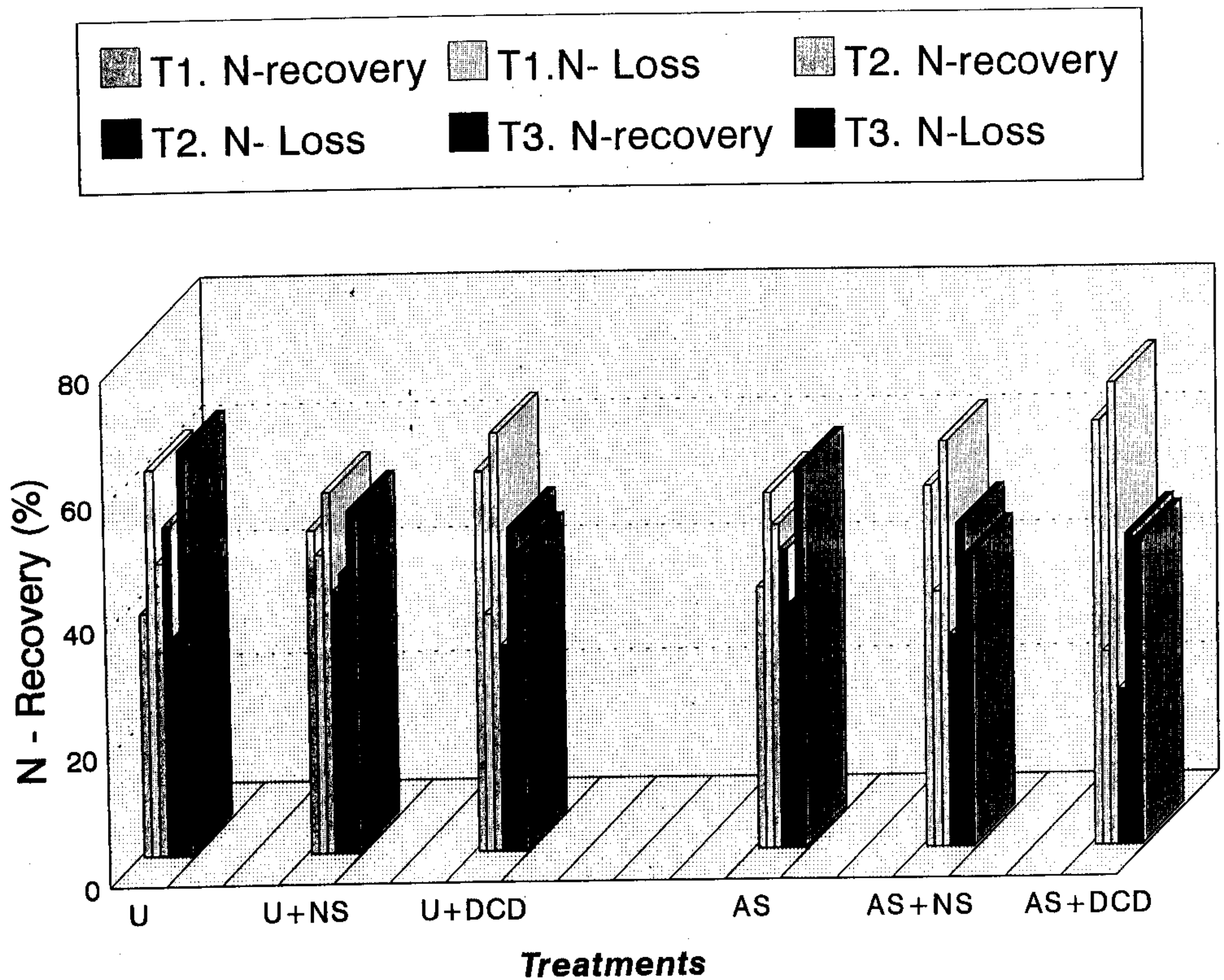

Fig. (18) Balance of N Labelled U or AS as affected by time of N - application and nitrification inhibition

down to 37 , 32 and 47 % as U + DCD was applied ; 30, 24 and 39 % as AS + DCD was added at T_1 , T_2 , and T_3 , respectively . However , it reduced to 47 , 41 and 54 % as N + NS comparing with U alone ; and down to 40 , 33 and 46 % as AS + NS comparing with AS alone at T_1 , T_2 and T_3 , respectively.

The use of ^{15}N balance technique has clearly identified N loss as a major problem in wheat management . Considerable reduction in N losses would be obtained by better N - fertilizer management either by time of N application or by application of modified nitrogen fertilizers.

It is apperant from this study that proper nitrogen application timing will reduce the potential for contamination of ground and surface waters .

بسم الله الرحمن الرحيم

"رب اشرح لي صدري، ويسر لي أمري
واحلل عقدة من لساني يفقهوا قولي"

صدق الله العظيم

5. *SUMMARY*

AND CONCLUSION