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Implication of Rate and Time of nitrogen application on Yield and Nitrogen Use Efficiency of Barley in Sandy Soil

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Abstract: A field experiment was conducted during the winter season of 2013/2014 in the barley production area of Dakhala – New Valley Governorate, Egypt to assess the effect of nitrogen rate and time of N fertilizer application on barley grain yield, yield components and N use efficiency of barley and their association with grain yield. The treatments consisted of three levels of nitrogen (0, 70 and 100 kg N/acre) and five application times. The experiment was laid out as a randomized complete block design with three replication. Results revealed that barley grain yield and yield components increased significantly in response to N rate. Splitting N fertilizer amount at several times result in significant effect on grain yield, yield components, protein content and N uptake efficiency when compared with the entire N was applied at once.

Application N fertilizers by rate of 70 Kg N/acre and splitting nitrogen fertilizers at many doses recorded the highest value of nitrogen use efficiency.

Application of N at rate of 100 kg N/acre resulted in accumulation of nitrate in the subsurface soil > 30cm. When N application timing considered, less NO_3 was found in the soil profile with splitting N application compared with all preplant application.

Key words: nitrogen use efficiency, splitting N fertilizer, barley, NO_3.

1. Introduction

Barley is the major cereal in many dry areas of the world and is vital for the livelihoods of many farmers. Barley is an annual cereal crop and grown in environments ranging from the desert of the Middle East to the high elevation of Himalayas (Hayes et al., 2003). It is the major food source in many North African countries. In Egypt, it is mainly grown for grain and straw for small ruminants during winter, with green fodder sometimes used for winter grazing. Barley can replace wheat as the dominant crop due to its tolerance to drought and salinity. Barley assumes fourth position in total cereal production in the world after wheat, rice, and maize. Barley is more productive under adverse environments than other cereals. Barley serves as a major animal fodder, base malt for beer and certain other distilled beverages. Nitrogen (N) is commonly the most limiting nutrient for crop production in the majority of the world's agricultural areas and therefore adoption of good N management strategies often results in large economic benefits to farmers. Among the most important management practices influencing grain protein content is N fertilizer application rate and timing. Increasing N fertilizer rates can result in higher grain protein content (Buskiene and Uselis 2008)..

Plant use efficiency of nitrogen depends on several factors including application time, rate of nitrogen applied, cultivar and climatic conditions (Moll et al., 1982). In most cases, applying nitrogen during growing season is more efficient than applying it at planting. Ramos et al. (1995) found that split nitrogen equally between sowing and tillering, or else with the greater proportion applied at tillering led to higher grain yield. Roy and Singh (2006) indicated that N fertilizer strategies for malting barley should ensure relatively small amount of available one-third N at sowing for crop establishment and initial tiller development. Additional one-third N would then be applied at first irrigation (35 days after sowing) and one-third N at flowering (70 days after sowing) gained the highest values of all the yield components, grain yield and nutrient uptake. Splitting nitrogen fertilizer to many doses increase efficiency of the fertilizers used by decreasing leaching to a large extent and increased both yield and quality of crops in favor of the highest number of splitting as indicated by Patke et al. (2003), Shalaby et al. (2006) and Ali (2010).

Maximum efficiency should be obtained by the latest possible application compatible with the stage of development that still permits rapid N uptake (Olsen and Kurtz, 1982), thus avoiding unnecessary vegetative growth, which may result in lodged plants and subsequent grains yield reduction. Furthermore, the opportunities for N losses by leaching, denitrification, volatilization and runoff are reduced, because an active root system is present for absorbing the fertilizer N when it is applied.

Work by Liang et al. (1991) found that under irrigation, 100 kg NO3-/ha was lost from the rooting zone (0-60cm) during four growing seasons, with the majority coming from the surface 40 cm. Nitrate studies in field microplots showed that 17% of applied N'" (120 kg N/ha equivalent) was still in the 45cm soil profile after 1 yr (Kowalenko, 1989). Webster et al. (1986) evaluated the movement of N15 (92 and 102 kg NH_4NO_3/ha) in clay and sandy loam field microplots and found that < 1% of the fertilizer was leached beyond 130cm in the first winter following application. Solhi et al., (2012) indicated that the application of Ammonium sulfate caused the lowest reduction in soil salinity of depth 0-30 cm as compared to urea and ammonium NO_3.Shabab et al., (2009) reported that reduction of soil pH can be attributed to the effect of nitrification process from basic (ammonium) form to mildly acidic (nitrate) form through the activity of the nitrifying bacteria in soil.

Nitrogen uptake efficiency (NUE) was significantly influenced by N rate and time of N-application. Ortiz- Monasterio et al. (1997) and Sinebo et al.(2004) also reported that N uptake efficiency was higher at lower rates of N-application but drastically decreased with further increases in the rates of nutrient.

The objective of this research was to determine proper rate application and timing of N fertilizer which affects on yield components of barley, protein content, nitrogen use efficiency and residual soil NO_3 distribution with soil depth.

2. Material and Methods

A field experiment was conducted during the winter season of 2013/2014 at El Dakhla, Balat, New Valley on a sandy loamy soil.

The experiment was conducted at Balat is latitude: 25° 27' N, longitude: 30° 32' E and 78.8 m above sea level.

The treatments consisted of three levels of nitrogen (0, 70 and 100 kg N acre), and five timings of N application. Timing of N application for the different treatment is presented in Table (1). The timings of N application were adjusted according to Zadoks decimal growth stage for barley (Zadoks *et al.*, 1974) at the time when moisture is available for nutrient dissolution and absorption.

The experiment was laid out in randomized complete block design (RCBD) with three replications. The size of each plot was 3.0 m x 3.0 m (9.0 m^2).

All field activities were carried out following the standard production practices. Seeds (Barley var., Giza 123) were sown at the recommended rate of 50 kg $acre^{-1}$. N fertilizer in the form of ammonium nitrate (33.5% N) and phosphate fertilizer in the form of Calcium superphosphate (15.5 % P_20_5) were used for the study. Phosphate fertilizer at the recommended rate of 31 kg P_2O_5 $acre^{-1}$ was applied equally to all plots by surface broadcasting and mixing with the soil at planting.

Similarly, for the N application at planting ammonium nitrate was broadcasted and incorporated into the soil. The other N fertilizer applications as dry ammonium nitrate were done by top-dressing at the specified Zadoks growth stages. All broad leaf and grass weeds were removed by hand weeding. Additionally, weeding of late-emerging weeds was done to avoid competition with the crop plants for applied N. In order to avoid damage and variability due to outbreak of rust disease which often occur in the area, fungicide (suomy 8) was applied at the rate of 35 cm/100 L water immediately at the start of disease appearance.

Soil samples from each plot were collected after barley harvesting to determine pH and EC from the soil surface and at depths of 0-15, 15-30, 30-60, and 60-90cm; NO_3 was extracted with 2M KCl *(Technicon, 1977)*.The samples were air dried, ground using a pestle and a mortar and allowed to pass through a 2 mm sieve. The samples were analyzed for selected physic-chemical properties mainly organic carbon, total N, soil pH, available phosphorus (P), available NO_3-N, and textural analysis using standard laboratory procedures. Organic carbon content was determined by the volumetric method (Walkley and Black, 1934) as described in Food and Agriculture Organization of the United Nations (FAO) guide to laboratory establishment for plant nutrient analysis (FAO, 2008) using 1.0 g of the prepared soil sample. Total soil N was analyzed by Micro-Kjeldahl digestion method with sulphuric acid (Jackson, 1962). The pH of the soil was determined according to FAO (2008) using 1:2.5 (weight/volume) soil sample to $CaCl_2$ solution (0.01M) ratio using a glass electrode attached to a digital pH meter. The EC of the soil was determined according to FAO (2008) using 1:1 (weight/volume) soil sample to distilled water ratio using a glass electrode attached to a digital EC meter. Available P was extracted by the Olsen method, and P analysed with a spectrophotometer (Olsen *et al.*, 1954). Total carbonate were estimated using a Collin,s calcimeter as described Piper (1950). Particle size distribution was done by hydrometer method according to FAO (2008). The used soil was a sandy loamy soil having the following haracteristics: pH (1: 2.5)8.1; EC (1:1) 0.91; O.M. 0.31%; $CaCO_3$ 5.2%; available NO_3-N 18.7 ppm and the total-N 111.2ppm and available P 7.2ppm.

Plant N concentration was determined by Micro-Kjeldahl digestion method as indicated in FAO guide to laboratory establishment for plant nutrient analysis (FAO, 2008). At maturity representative samples of non-grain above ground plant parts (stems, leaves and chaff) were obtained from the central unit areas. The plant samples were washed with distilled water, oven dried at 70 °C to a constant weight and the dry weight measured using an electronic balance. The samples were ground by a rotor mill and allowed to pass through a 0.5 mm sieve to prepare a sample of 10 g. For the digestion with mixture of sulphuric and percloric acids (Jackson 1967), 1 g of each treatment's ground sample were used. Likewise, total grain N contents of treated and untreated plots were estimated from 1 g dry flour samples by digestion method of Micro-Kjeldahl's apparatus according to American Association of Cereal Chemists (AACC, 2000).

Data measurements:

Grain Protein Concentration (%).

The protein content of flour dry samples taken from the harvested grain yields of each treatment was calculated as *% protein = % N x 5.7* (AACC, 2000)

Nitrogen use efficiency

$$\text{N Use Efficiency (\%)} = \frac{\mathbf{GDWf\ (kg\ acre-1)-GDWc\ (kg\ acre-1)(100}}{\mathbf{Ns\ (kg\ acre-1)}}$$

Where, GDWf = grain dry weight of fertilized treatment
GDWc = grain dry weight of control treatment
Ns = N supplied

$$\textit{N-uptake efficiency (\%)} = \frac{N-Recovery\ (100}{N-\ applications}$$

Where N-recovery= total N-uptake(kg/acre) - control N-uptake (kg/acre).

Table (1): Description of rate and time of N application (kg/acre).

Treat. No.	Rate and time of N application(kg/acre)				
	A	B	C	D	E
T1	0	0	0	0	0
T2	70	0	0	0	0
T3	0	35.5	35.5	0	0
T4	0	35.5	0	35.5	0
T5	0	35.5	0	0	35.5
T6	0	23.3	23.3	23.3	0
T7	0	23.3	23.3	0	23.3
T8	0	17.5	17.5	17.5	17.5
T9	100	0	0	0	0
T10	0	50	50	0	0
T11	0	50	0	50	0
T12	0	50	0	0	50
T13	0	33.3	33.3	33.3	0
T14	0	33.3	33.3	0	33.3
T15	0	25	25	25	25

A= at sowing, B= two weeks, C= four weeks, D= six weeks, and E after eight weeks after sowing,

3. Results. And Discussion

3.1 Effects of nitrogen rate and time of application

on grain and straw yields

Grains and straw yield of barley at maturity as influenced by rate and time of N-fertilizer application are shown in (Fig. 1). Grains and straw yields with 70 kg N/acre were less compared to 100 kg N/acre, probably because insufficient N was applied. Similar results has been reported by Siam et al. (2012). The straw and grains yield were the lowest for control (0 kg N/acre). Splitting applied N resulted in higher grains and straw yield at both application rates than when N applied once. Higher response of yield to different times of N application may indicate the growth and yield enhancing effect of applying N in four splits (T15). This may be attributed to the synchrony between the time of high need of the plant for N uptake and the time of availability of sufficient N in the soil at the specified growth stages. The yield enhancing effect of the four split applications of N may also be attributed to reduction in loss of nitrate by leaching during the wet growing season. Thus, at the time of high need for N, the plant may have taken most of the nitrate from the soil, leaving less of it available for leaching by the percolating rain water. Reports indicated that in-season N application improves synchrony between crop demand and nutrient supply, especially in high water application areas where nitrate leaching is very common, was meant to enhance crop yield by improving N use efficiency (Zafar and Muhammad, 2007).With splitting applied N fertilizer, N availability apparently matched crop needs during the growing period (Taalab,2002). Applying N at 2 and 4 weeks (T4) or at 2 and 6 weeks (T5) after sowing resulted in higher grain, straw and biological yields than applying N at 2 and 8 weeks (T3). The higher yield with N application at earlier growth stages may be due to the greater number of spikes produced per meter (Mercedes et al. 1993*)*. On the other hand, nitrogen application at 8 weeks apparently was late. The same results were found when N split into three applications. Splitting N application rats (70kg N/acre or 100 kg N/acre) into four applications increased grains yield by 3.1and 3.6 times that of control and 1.5 and 1.6 times that of one application, respectively. The same trend was found for straw and biological barley yield.

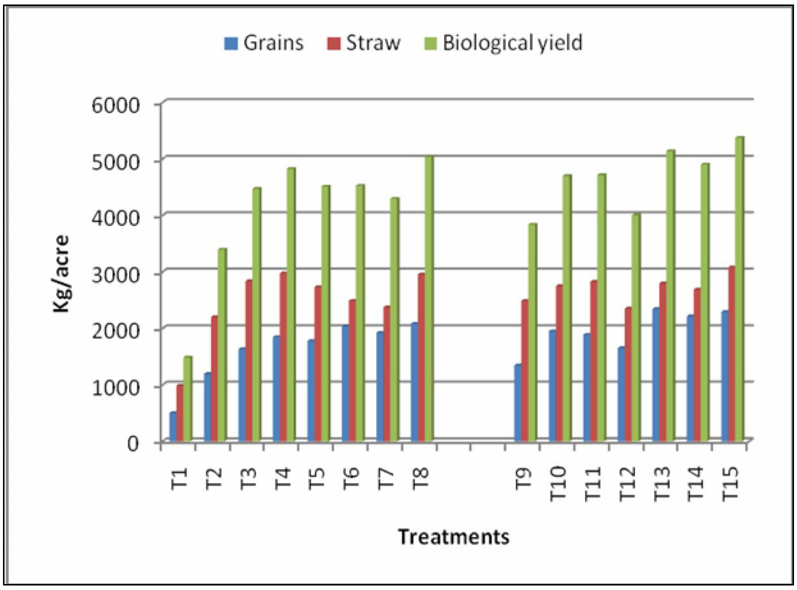

Fig. 1. Effects of nitrogen rate and time of application on grain and straw yields and biological yield

3.2 Effects of nitrogen rate and time of application on harvest index

Harvest index was computed as the ratio of grain yield to the total above ground dry biomass yield. The main effect of timing of nitrogen significantly affected harvest index whereas the interaction effect of rate and timing of nitrogen application highly significantly affected this parameter of the plant (Table 2).

Harvest index tended to increase with increased application of nitrogen. So, there was consistent trend of increase in harvest index with the times and doses of nitrogen application. For the rates of 70 kg and 100 kg N/ acre, the highest harvest index were scored under three splits application of nitrogen (T6, T7,T13 and T14) . This may indicates that, three splits application of nitrogen may have led to relatively less shoot biomass growth due to less leaching at the seedling stage of the crop, when the plant had sufficient capacity to take up larger amounts of the nutrient. This is due to the results obtained in proportionally higher seed yield than vegetative biomass yield.

Table (2): Nitrogen use efficiency, grain protein and harvest index of barley as affected by rate and timing of nitrogen fertilizer application.

Treat. No.	Yield (kg/acre)		
	Nitrogen use efficiency	Grain protein (%)	Harvest Index
T1	-	10.83	0.34
T2	9.9	10.83	0.35
T3	16.2	11.97	0.37
T4	19.2	11.4	0.38
T5	18.3	11.97	0.39
T6	22.0	11.97	0.45
T7	20.3	11.97	0.45
T8	22.6	11.97	0.41
T9	8.5	11.4	0.35
T10	14.5	11.97	0.35
T11	13.8	12.54	0.40
T12	11.5	12.54	0.41
T13	18.4	13.11	0.46
T14	17.1	13.11	0.45
T15	17.9	13.68	0.43

Harvest Index =Grains/ Biological yield

3.3. Effects of nitrogen rate and time of application on nitrogen use efficiency

The study highlighted significant differences among N treatments Table 2. A application N fertilizer by the rate of 70 kg N /acre recorded the highest nitrogen use efficiency (NUE) values as compared to the rate of 100kg/acre. The result is consistent with that of Dhugga and Waines (1989), Ortiz-Monasterio et al. (1997) and Roberts (2008) who found significant decreases in NUEGY with increasing rates of N application.

Splitting nitrogen fertilizer to many doses increase efficiency of the fertilizers used by decreasing leaching to a large extent and increased both yield and quality of crops in favor of the highest number of splitting as indicated by Shelby et al. (2006) and Ali (2010).

3.4 Effects of nitrogen rate and time of application on grain protein

Grain protein content was found to be significantly influenced by N application rate, and N time of application (Table 2). Grain protein content under different N application rates ranged from 10.83 to 13.68 %. Over all, grain protein content was found to increase with increasing N application rate.

The highest grain protein content (13.68 %) was obtained at the highest N rate (100 kg N acre^{-1}) under four splits application of nitrogen.

In other studies, similar findings indicating lower grain protein concentration due to early N application at planting and tillering compared to split N application up to anthesis were reported by Ayoub et al. (1995) and Brian et al. (2007).

3.4 Effects of nitrogen rate and time of application on nitrogen concentration.

Nitrogen concentration in grain yield increased with increasing the dose of nitrogen from 70 to 100 kg N/acre (Table 3). But in straw yield, this parameter decreased significantly in response to increasing the frequency of split application at 100 kg N /acre. This indicates increasing the frequency of split application, resulted low nitrogen content in straw. This might be split applications of nitrogen fertilizer cause high amount of nitrogen content to be taken by the grain rather than by straw of barley.

In general, the higher grain nitrogen concentrations were obtained in response to levels of 100 kg N /acre at four spliting dose (T15). The lowest value of this parameter was obtained under 70 kg N /acre (T2). when it was applied at splits of half dose at sowing and the remaining half at mid-tillering. Thus, the maximum grain nitrogen content exceeded the minimum grain nitrogen content by about 26%. This implies a positive response of grain N concentration to increased N rate but a negative response to increased frequency of application of the nutrient. This result is in line with that of Campbell *et al.* (1993) who reported that grain N content of wheat increased in response to increasing rates of nitrogen application.

Table (3): Effect of nitrogen fertilizer application rate and timing on nitrogen uptake, its concentration (%) and grain protein in barley plants

Treat. No.	N concentration (%)		N uptake (g/acre)		N- uptake efficiency
	Grains	Straw	Grains	Straw	
T1	1.9	0.15	9519	1476	-
T2	2.0	0.28	23900	4400	24.7
T3	1.9	0.33	31046	9362	42.0
T4	2.0	0.30	36920	8931	49.8
T5	2.1	0.34	37359	9285	50.9
T6	2.1	0.36	42798	8956	58.2
T7	2.1	0.30	40383	7116	52.1
T8	2.1	0.30	43722	8865	59.4
T9	2.0	0.20	26920	4978	20.9
T10	2.1	0.22	40929	8027	38.0
T11	2.2	0.23	41470	6504	37.0
T12	2.2	0.20	36344	4702	30.0
T13	2.3	0.20	53866	5590	48.5
T14	2.3	0.21	50899	5644	45.5
T15	2.4	0.20	55056	6160	50.2
L.S.D 0.05	0.10	0.10	2890	605	

3.5 Effects of nitrogen rate and time of application on nitrogen uptake.

Straw and grain nitrogen uptake was highly significantly affected by N fertilizer rate and timing of application. It is clearly evident from the data presented in Table (3) that values of N uptake by barley straw represents 18 to 31% its uptake by grains.

Nitrogen uptake by grains and straw of barley from nitrogen fertilizer application was higher than that of control treatment. It is also noticed that amount of N uptake by barley yield with 100 kg N/acre was higher than 70 kg N/acre.

Spliting N treatments yielded more N uptake by grain yield of barley than N applied preplant treatment. The highest uptake by grain yield was achieved by the four-split treatments at levels 100kg N (T15) was 5.8 times that of the control treatment. This treatment also at level 70 kg N was 4.6 times that of the control treatment. These treatments also produced the greatest grains yield (51524 and 49968 Kg grains/acre, respectively) (Fig. 1). These findings confirmed the importance of four-split applying N to yield more grains and straw yield. This result is consistent with that of Fageria and Baligar (2001) who reported that N uptake in grain has positive significant associations with grain yield. Similarly, Mahmoud et al.(2007) Panda et. al. (1995) reported that the uptake of N by rice crop and concentration in the tissues were increased by increase in N levels.

The highest uptake of nitrogen for the straw was recorded at T3 and T4 for 70 kg N/acre and at T10 for 100 kg N/acre (Table 3). The maximum straw N uptake was, however, obtained at 100 kg N/acre with the application of nitrogen applied at tow split (two weeks + four weeks from sowing). This result is in line with the findings of Woldeyesus *et al.* (2004) and Muurinen (2007) who reported significant increase in straw nitrogen uptake with increased N rates. However, the other split applications did not show significant increment as the rates of nitrogen increased.

3.6. Effects of nitrogen rate and time of application on nitrogen uptake efficiency

Nitrogen uptake efficiency (NUPE) was significantly influenced by N rate and time of N-application (Table 3). The highest (NUPE) are 59.4 and 58.2% for lower rate of N-application (70kg/acre) was recorded when the nitrogen was applied in four and three splits. The lowest N-uptake efficiency 20.9% for higher rate of N-application (100kg/acre) was recorded when the nitrogen was applied once at sowing. In general, the results indicated that NUPE of all time applied decreased with increased the rate of nitrogen applied but drastically increased with further increases in the spilt of applied nitrogen. Corroborating these results, Ortiz- Monasterio et al. (1997) and Sinebo et al., (2004) also reported that N uptake efficiency was higher at lower rates of N-application but drastically decreased with further increases in the rates of nutrient. Compared to the NUPE of barley plants grown with N- application 1/2 after 2 weeks of sowing + 1/2 after 4 weeks of sowing (T3) and the efficiency of barley plants grown with N- application of 1/2 after 2 weeks +1/2 after 8 weeks of sowing (T5) with superior by 8.9 % at the same rate (70 kg/acre). Corroborating these results, Ortiz - Monasterio et al., (1997) and Tran and Tremblay (2000) also indicated lower NUPE in early application of N fertilizers at planting and tillering compared to applications in the later stage of crop growth.

3.7. Inorganic-N distribution and movement in the soil:

Data depicted in Figure (2) showed the distribution of NO_3 through the soil profile. There are no significant differences in NO_3 concentration with depth when N applied at rate of 70kg N/acre. Applying nitrogen at rate of 100 kg N/acre resulted in increasing NO_3 content with the depth (30-60cm) (Robert et al. 1994 and Taalab, 2002). Excess N not consumed by microbial pools, assimilated by the crops, fixed on the exchange complex, denitrified, volatized and/or immobilized via other pathways was expected to a marked accumulation in subsurface (> 30crn) layer (Fig. 2). Also, NO_3 accumulation was expected to occur below 30cm, where total barley root volumes are reduced. The decrease in NO_3 at depth 60cm may have been the result of increases denitrification.

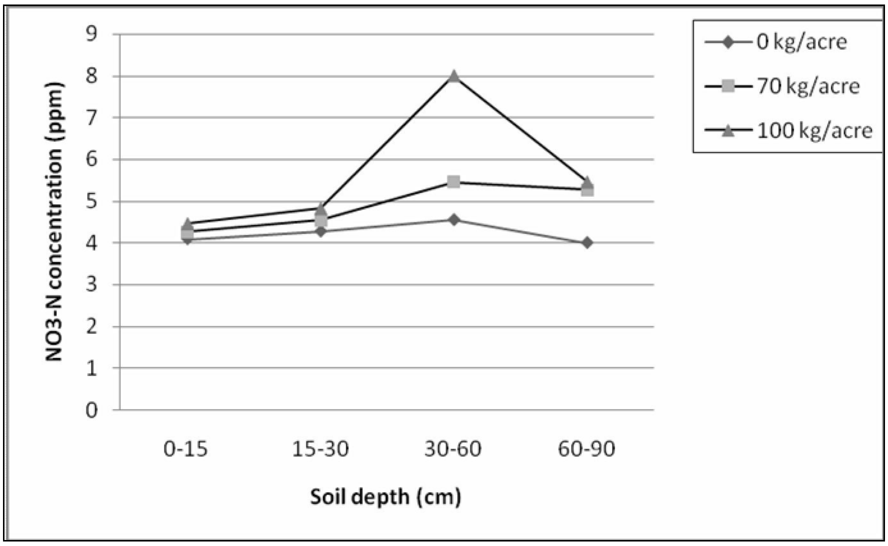

Fig. 2. Soil NO_3-N by depth after barley harvest as affected by N fertilizer rate.

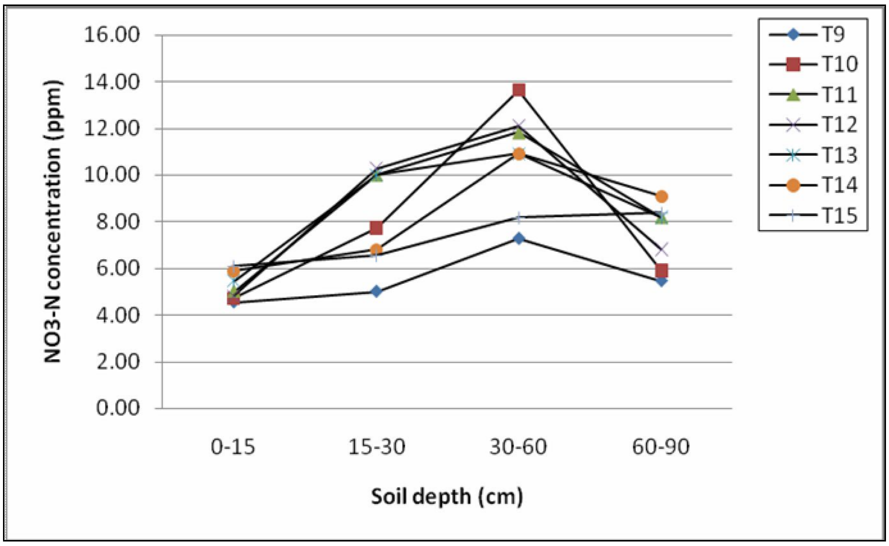

Fig. 3. Soil NO_3-N by depth after barley harvest as affected by N fertilizer timing at rate 100 kg N/acre.

When N application timing was considered, less NO_3 was found in the soil profile after harvesting for all preplant treatment compared with split treatment (Fig. 3). Lower soil NO_3 values for the preplant treatment could not be accounted for by greater grain or straw N content. Grain and straw tissue N concentration were never higher in the preplant treatment as compared with the other treatments (Table 3). Therefore, applying all fertilizer N preplant appeared to result in lower total recovery of added N.

Split N application at 100 kg N/acre (T15) also tended to result in lower soil NO_3 concentrations compared with other applications. This effect, however, could be attributed at least in part to greater grain yield (Fig. 1) and grain N concentration (Table 3).

3.8. Soil pH and EC:

Data in Table (4) represent soil pH and electrical conductivity (EC) as a result of nitrogen fertilizer application rate and timing. Nitrogen timing did not affect pH values but N fertilizer application rate affected pH values. When comparing the treatments which received 70 kg N/acre and those received 100 kg N/acre, at the highest rate, the pH was usually lower than the lowest rate of N fertilizer application. Similar results were obtained by Taalab, 2002. Shaban et al. (2009) and Shaban et al. (2012) stated that the effect of urea on reducing soil pH is probably because of its hydrolyzes upon application of irrigation water and hence ammonia releases. Thomson et al. (1993).During pre- incubation found that, the nitrification of NH4 was reflected by an equivalent increase in the level of NO_3 in the soil, resulted in the observed decrease in soil pH from 6.8 to 5.5.

Similar results were obtained by Berg, 1986 ; Schwab et al., 1989. The obtained results also confirmed that fertilization of soils for extended periods with excessive rates of ammonia - base fertilizer can result in lower pH. This decrease was consistent with the concept of " over -fertilization" of this soil (Schwab et al., 1989 in which the pH remained relatively stable if the amounts of NH_4-based fertilizer did not exceed plant demand.

With respect to electrical conductivity there was no clearly differences in the electrical conductivity as a result of nitrogen fertilizer application rate and timing.

Table (4): Effect of nitrogen fertilizer application rate and timing on changes in soil pH and EC(dS/m) at the surface soil.

Treat.No.	pH (1:2.5)	EC(1:1)
T1	8.0	0.20
T2	8.0	0.23
T3	7.9	0.26
T4	7.9	0.32
T5	7.8	0.20
T6	7.8	0.30
T7	7.9	0.26
T8	7.8	0.27
T9	7.7	0.23
T10	7.5	0.30
T11	7.6	0.34
T12	7.8	0.25
T13	7.7	0.24
T14	7.6	0.26
T15	7.6	0.25

Conclusion:

From the present study it is evident that split nitrogen applications 100 kg N /acre generally improved the yield of barley compared to a single low application of 70 kg N /acre at sowing. It was also found that the growth stage at which supplementary nitrogen is supplied , had a significant effect on the biological of the barley. Treatment 15, with four split nitrogen applications, significantly increased most of the parameters of barley yield compared to a single application at sowing.

It is therefore evident that the highest values are obtained when supplementary nitrogen applications are done at cardinal growth stages, viz. sowing, spikelet initiation, spikelet differentiation and ear emergence. Thus a continued supply of nitrogen is ensured throughout the life of the plant.

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