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PROJECT TITLE

Application of Nuclear Techniques in Soil-Plant-Water Relationships

Nitrogen Balance In Soil Profile As Affected By Different Soil Types, Soil Water Regimes, Nitrogen Rates And Application Methods Using ^{15}N Tracer Technique

Doctoral Thesis

OF

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Abstract

The interaction effect of “Soil type, Soil water regime, Nitrogen fertilizer application Rates and Timing” on Nitrogen balancein soil were studied; in terms of nitrogen gained by plant portions, remained in soil, and losses through different ways under wheat (*Triticum aestivum L. Giza 168*), in order to identify the most proper and effective combinations of above-studied variables that provides a satisfactory grain wheat yield and minimizes the use of chemical nitrogen fertilizers, to save the surrounding environment and to achieve good water saving.

Two fields of experiments were carried out during November and December –April 2012-13, under Egyptian conditionsrepresents two different textured soils, i.e clay located at (30^{o} 16^{-} N latitude, 30^{o} 56^{-} E longitude), and sand soils located at (30^{o} 24^{-} N latitude, 31^{o} 35^{-} E longitude) as growth media of wheat crop. The application methods of Nitrogen rates, 100, 80 and 60% of recommended rates (Clay, 178 kg N & Sand, 238 kg N), were applied as **Mode A**, 25% at seedling, 25% and tillering, 50% at jointing AND **Mode B**, 35% at seedling, 65% at tillering.

Kye words;

Wheat, Tracer Tech., ^{15}N, NUE, Nitrogen Balance, Nitrogen rates, Nitrogen Application Methods, Soil types; Sand, Clay, Water Regimes, Egypt.

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Dedication

*I herby dedicate this work to the mother of the lands, lands of civilizations, civilization of 7000 years "**EGYPT**".*

To whom my heartfelt thanks; my Parents for their all lovely offered and supports in all my life,

*To my brothers and sisters, "**MOHAMED, NORA, KHALED, FATMA, ABD EL-RAHIM, HEBA**"*

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List of Abbreviations

a.ex	atom excess
Ndff	Nitrogen Derived From Fertilizer
Ndfs	Nitrogen Derived From Soil
Ndfa	Nitrogen Derived From Air
FUE	Fertilizer Use Efficiency
NUE	Nitrogen Use Efficiency
FNR	Fertilizer Nitrogen Remained in Soil
EC	Electrical Conductivity (Ds/M)
dS/m	Decisimens Per Meter
ET	Evapotranspiration
ET_o	Reference Evapotranspiration
ET_c	Crop Evapotranspiration
K_c	Crop Coefficient Value
FAO	Food And Agriculture Organization Of The United Nations
I	Irrigation
FC	Field Capacity
PWP	Permanent Wilting Point
DW	Dry Weight
SWR	Soil Water Regime
IAEA	International Atomic Energy Agency
L.S.D	Least Significant Difference
mmt	Million Metric Tons
mth	Metric Tons per Hectare
mh	Million Hectares
GASC	General Authority for Supply Commodities

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INTRODUCTION

Chapter 1

Introduction

Egypt covers a land area of about one million km^2 in the hyper arid regions of North Africa and West Asia. The annual rainfall in most parts of Egypt is less than 50 mm. The country consists of three main parts: Sinai (61,000 km^2), the Eastern desert extending from the River Valley to Red Sea Coast (223,000 km^2) and the Western desert extending from the Nile River Valley to the Libyan border (681,000 km^2). The coastal belt extends along the Mediterranean Sea from Rafah to El-Salloum (850 km2). Egypt is situated at the crossroads of three continents, and at the junction of three biotic realms: Europe, Asia and Africa.

Wheat is one of the most important cereal food crops in the world. In Egypt, its production doesn't meet the current demand. Efforts to increase food production, in particular wheat, have received top priority in the agricultural development programs starting since 1983. In the context of Egypt's food security policy, wheat policy has two main dimensions. 1) The food availability dimension, where the main focus is to increase the self-sufficiency ratio of wheat production from the current level (55 percent) to full self-sufficiency. 2) The second is the accessibility aspect to ensure that the low-income households are able to acquire food (Siam 2006). Hence the Egyptian government is doing more efforts to reduce the imported percentage to be less than 50% from the total consumption. Wheat production is affected by different factors such as climatic condition, irrigation and soil fertility. The new reclaimed areas are in continuous increase and water irrigation is being the limiting factor. The interaction between fertilization and irrigation are considered one of the most important factors affecting wheat production.

Water requirement and Nitrogen fertilizer are two factors notably affects the growth and yield of Wheat. So, any delay in irrigation, thinning or insufficient water supply and nitrogen fertilizer would negatively affect the growth and yield. Also frequent or excessive amount of water and nitrogen fertilizer would lead to increase the losses of water and nitrogen fertilizer which directly infiltrate either to water table or the ground water. So, it is important to identify the educate amount of irrigation and nitrogen fertilizer need to maximize growth, and quality of the Wheat crop.

Irrigation scheduling is a term used for any one of a number of management technique for allocating irrigation water supplies, (Salazar *et* al, 1984), both in time and quantity over an irrigated area. The scheduling of irrigations requires knowledge of soils, crops, climates, water supplies, irrigation system flexibility and performance, system layout, social and economic factors and others constraints of the system. Proper irrigation scheduling results in equity of water allocation and distribution and increase productivity of the water and net farm income. It reduces fertilizer cost by decreasing nutrient leaching and results in much larger benefits from fertilizers by matching fertilizer application with the water supply. It is usually result in decreased weed and disease problems and increase crop yield and quality.

The changing conditions regarding environment and land reduce the availability of water resources together with the increasing water demands for new uses and also due to the shortage in irrigation water already existing in the whole world and especially in the Mediterranean basin, and principally in south Mediterranean coast, demands to develop new technologies and methods of irrigation that can be help full to utilize this precious input in an effective way, taking into account the sustainability issue by developing the management of irrigation water supply through advanced equipment and irrigation systems or, the reuse of the nonconventional water resources like brackish and drainage water and treated sewage effluents. However, fresh water resources in most arid and semi-arid countries have been exhausted under the heavy pressure of increasing utilization (Abu-Zeid, 1989). In the southern and eastern countries of the Mediterranean more than 80% of the available water resources are allocated for agriculture, but, on farm water use efficiency is generally very poor with values not exceeding the 50%. Therefore, we need to improve our systems and managing the process of water application under sustainable agricultural system.

In the same time, nitrogen represents the most applied nutrient to agricultural land. This is because available soil-N supplies are often inadequate for optimum crop production and because commercial fertilizer, manures, and other sources of N are generally easily and economically applied.Adding of N fertilizers tended to produce high grain and straw yield, regardless of quantity or distribution of water Wang et al. (2001), Sardana et al. (2002) and Camara et al. (2003) indicated that low inorganic N applications (0 or 31 kg/ha) resulted in low yields even at a high level of organic fertilizer (corn Stover + cattle manure> 4500 kg) and the yield was also limited by lack of organic fertilizer application even at an inorganic fertilizer rate of 105 kg/ha. Therefore, to overcome the problem of nutrient deficiency and to increase wheat yield, the farmers applying chemical fertilizers. An important consideration is to keep applied and residual sources of N within the soil-crop system by curtailing transport processes (leaching, runoff, erosion, and gaseous losses) that carry N into the surrounding environment.

Often N budget, or mass balance, approach is needed to understand the options to minimize and/or mitigate the environmental impacts of N that may occur and to improve N management in farming and livestock systems. The common occurrence of elevated nitrate (NO_3^-) levels in groundwater has long been a cause of concern for human/animal health (Stark and Richards, 2008) and the environment (discharge into surface-waters associated with eutrophic conditions (Howarth (1988)). In response to these problems, environmental policies have been implemented in many countries. In the European Union for instance, legislation including the Nitrates Directive 91/676/EEC and the Ground-water Directive 2006/118/EC prohibits nitrate concentrations in aquifers to exceed the mandatory limit of 50 mgL1 NO_3^- and requires that actions be taken in order to reverse or prevent any infringement (Stark and Richards, 2008). The excessive application of nitrogen fertilizer, especially in the easy moved forms like nitrate, may lead to pollution of deep soil layer and underground water. Therefore, the best management of N application practices and selection of the most proper form of fertilizer-N are urgently needed.

It is well recognized that to increase food production to meet the increasingly food gap most of the developing countries are now facing is totally depending on several food production factors. Water and fertilizers are two main factors seriously affecting the food production. The experiences demonstrate that under water scarcity conditions, the application of the fertilizer N in appreciate quantities will rise up the yield production and compensate the yield losses due to irrigation water shortage. This is the main objective of this study where irrigation will be practiced with different volumes combined with the applications of nitrogen indifferent doses using the wheat as an indicator crop in order to find out the most appreciate water volumes as well as the N-fertilizer dose both leading to maximum wheat production with optimum yieldquality, also to reduce and control the amount of nitrate leached beyond the root zoon as well as study the effect of the soil type on that movement of nitrate through the soil profile.

PROBLEM STATEMENT

Chapter 2

Problem Statement

Around 76% of the world's population lives in developing countries where more fertilizer-N is currently applied than in developed countries. Fertilizers are applied preferentially in regions where irrigation is available, and soil and climatic conditions are favourable for the growth of crop plants. Negative N balances in the soil are a characteristic feature of the crop production systems in developing countries in reference of the last 4 decades. In the future, with increasing fertilizer-N application rates, the possibility of nitrate pollution of groundwater in developing countries will be strongly linked with fertilizer-N use efficiency.

Nitrate is often a major portion of the total nitrogen lost from agricultural land to surface waters (*Neilsen et al., 1980; Ritter, 1986*). The common occurrence of elevated nitrate (NO_3^-) levels in groundwater has long been a cause of concern for human/animal health (Stark and Richards, 2008) and the environment (discharge into surface-waters associated with eutrophic conditions (*Howarth,(1988*).

Climatic water balance and soil moisture conditions do not favour leaching of nitrates from the small amount of fertilizer-N applied to Oxisols and Ultisols in Latin America. In developing countries located in the humid tropics, attempts have not been made to correlate fertilizer-N use with nitrate level in groundwater; however, fertilizers are being increasingly used. Besides high rainfall, irrigation is becoming increasingly available to farmers in the humid tropics and substantial leaching of N may also increase.

Nitrate leaching is inevitable under most agricultural production systems. While it is not possible to halt nitrate leaching, improved management practices leading to increased fertilizer-N use efficiency (FUE) can reduce the potential for nitrate contamination of groundwater. Increased crop N uptake and yield achieved through an awareness and careful integration of soil, climate and cultural variables over the entire year result in improved FUE to help ensure reduced leaching of nitrates.

Problem Statement

Due to excessive fertilizer use in developed countries during the last 3 or 4 decades, groundwater at some locations is already polluted with nitrate that has leached particularly from intensively or over irrigated soils (*Follett, 1992; Williams, 1992*).

Although there has been a concurrent rise in nitrate concentration in groundwater with fertilizer-N usage, animal excreta, sewage effluent and decomposition of soil organic matter are the other sources contributing nitrate-N significantly to groundwater bodies (*Keeney, 1989*).

Intensive agriculture with large fertilizer input is one of the major sources of soil and groundwater contamination with nitrates (*Schepers and Marter 1986*). This trend is enhanced by mismanaged irrigation practices and induced groundwater recharge. (*Toussaint 2000*).

By the development of the emission spectroscopic method of ^{15}N determination it became possible to study the assimilation pathway of nitrogenous compounds in plants in detail (*K. Kumazawa et al., 1987*).

LITERATURE REVIEW

Chapter 3

Literature Review

1. Importance of Wheat

The first cultivation of wheat occurred about 10000 years ago, as part of the 'Neolithic Revolution', which saw a transition from hunting and gathering of food to settled agriculture. Wheat is counted among the 'big three' cereal crops, with over 600 million tones being harvested annually. For example, in 2010, the total world harvest was about 653 m tones compared with 701 m tones of rice and 850 m tones of maize (FAOSTAT). However, wheat is unrivalled in its range of cultivation, from 67_N in Scandinavia and Russia to 45_S in Argentina, including elevated regions in the tropics and sub-tropics (Feldman, 1995). It is also unrivalled in its range of diversity and the extent to which it has become embedded in the culture and even the religion of diverse societies.

Moreover, wheat is the dominant crop in temperate countries being used for human food and livestock feed. Its success depends partly on its adaptability and high yield potential but also on the gluten protein fraction which confers the viscoelastic properties that allow dough to be processed into bread, pasta, noodles, and other food products. Wheat also contributes essential amino acids, minerals, and vitamins, and beneficial phytochemicals and dietary fiber components to the human diet, and these are particularly enriched in whole-grain products.

However, wheat products are also known or suggested to be responsible for a number of adverse reactions in humans, including intolerances (notably coeliac disease) and allergies (respiratory and food). Current and future concerns include sustaining wheat production and quality with reduced inputs of agrochemicals and developing lines with enhanced quality for specific end-uses, notably for biofuels and human nutrition.

2. World Wheat Production and demand

Longer term, growing global demand for wheat imports is concentrated in those developing countries where robust income and population growth underpin increases in demand. Such markets include Sub-Saharan Africa, Egypt, Pakistan, Algeria, Indonesia, the Philippines, and Brazil.

The number of major exporting countries that can supply these importers has expanded. Ukraine, Russia, and Kazakhstan have become significant wheat exporters in recent years, together surpassing U.S. exports in 2008/09, 2009/10, and again in 2011/12. Low production costs and new investment in the agricultural sectors of these countries have enabled their world market share to climb despite the region's highly variable weather and production. During the mid-1990s, their combined share of world exports was less than 5 percent, averaging less than 5 million metric tons (mmt). The following table is showing the statistical data of wheat including; Area harvested, yield, production…etc.

Table (1), World wheat supply and disappearance in the latest 12 years

Market year(1)	Area harvested (mh)	Yield (mth)	Production (mmt)	Feed use (mmt)	Domestic disappearance (mmt)	Exports (mmt)(2)	Ending stocks (mmt)
2000	215.632	2.70	583.092	108.767	586.728	101.527	207.089
2001	214.552	2.72	583.614	109.466	586.548	105.915	204.155
2002	213.663	2.66	569.360	113.508	604.285	105.673	169.230
2003	207.797	2.67	555.271	99.093	588.931	108.637	135.570
2004	216.104	2.90	626.673	108.695	606.281	111.446	155.962
2005	218.722	2.83	618.806	114.775	621.246	117.233	153.522
2006	212.231	2.81	596.112	110.092	615.694	111.880	133.940
2007	217.116	2.82	611.888	102.168	617.779	117.303	128.049
2008	224.670	3.04	682.808	121.194	643.285	144.527	167.572
2009	225.779	3.04	686.563	120.334	653.872	137.222	200.263
2010	218.281	2.99	652.243	116.006	654.737	132.483	197.769
2011	221.899	3.14	696.442	147.067	698.435	157.653	195.776
2012	217.529	3.01	654.310	132.755	673.444	131.966	176.642

Source: (USDA, Foreign Agricultural Service, Production, Supply, and Distribution Database).

1/ Aggregated based on local marketing years. Latest data may be preliminary or projected.

2/ Excludes intra-European Union trade.

mh : Million Hectares, mth : Metric Tons per Hectare, mmt : Million Metric Tons.

Table (2): Shows the top 25 commodities country for wheat Production in 2010

Area(h)	Production (t)	Area (h)	Production (t)
China	115181303	Iran	13500000
India	80803600	Kazakhstan	9638400
United States of America	60062400	Poland	9487800
Russian Federation	41507600	**Egypt**	**7177400**
France	40787000	**Italy**	**6849860**
Germany	24106700	Uzbekistan	6730400
Pakistan	23310800	Brazil	6171250
Canada	23166800	Romania	5811810
Australia	22138000	Denmark	5059900
Turkey	19674000	Morocco	4876140
Ukraine	16851300	Afghanistan	4532000
Argentina	15875700	Czech Republic	4161600
United Kingdom	14878000		

Source: (http://faostat3.fao.org/home/index.html#VISUALIZE_TOP_20)

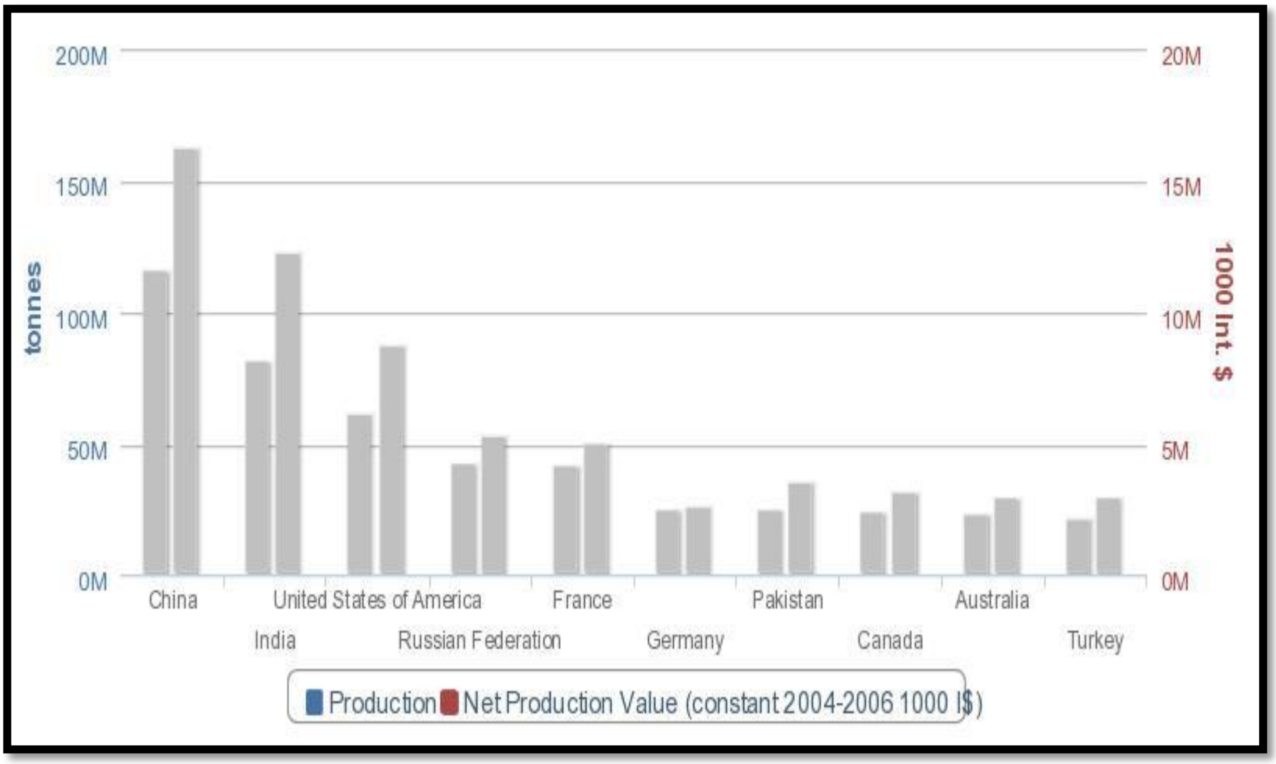


Figure (1): The top 25 commodities country for wheat Production in 2010

Competition from Ukraine, Russia, and Kazakhstan, as well as the traditional exporting countries, has resulted in a declining U.S. share of expanding world exports.

In 2010/11, a very serious drought that sharply reduced Russian production and exports changed the situation dramatically. Russian exports for 2010/11 were only 22 percent of their average of the previous two marketing years. With the return to more normal weather, Russia's production and exports recovered in 2011/12.

However, future wheat export growth by Russia is likely to be slower than previously expected because of recent policy decisions to limit the country's imports of poultry and pork products by increasing domestic production. More wheat is expected to be used domestically to supply the expanding pig and poultry sector.

3. Status of Wheat in Egypt

Wheat is the most important cereal crop in Egypt since 7000 years. Wheat (various species of the genus *Triticum*) is a grass with so many important uses that it is cultivated worldwide. Wheat is one of the first cereals known to have been domesticated. Wheat is not only an important crop today; it has also influenced human history. Wheat was a key factor enabling the emergence of city-based societies at the start of civilization because it was one of the first crops that could be easily cultivated on a large scale, and had the additional advantage of yielding a harvest that provides long-term storage of food. Bread wheat is known to have been grown in the Nile Valley by 5000 BC and it is believed that the Mediterranean region was the centre of domestication. The archaeological record suggests that this first occurred in the regions known as the Fertile Crescent, and the Nile Delta. The civilization of West Asia and of the European peoples has been largely based on wheat. Also it is the basic staple food in urban areas. Also, it is mixed with maize flour in rural areas. Durum wheat provides semolina for pasta and macaroni industries. Egypt is facing a considerable gab between its national production and consumption. In 2012, Egypt was the world’s largest wheat importer, shipping in 11.5 million tons, and highlighting the gap between official food sustainability goals and reality. "There is an urgent need to increase wheat productivity," said Nagui Saeed, head of Egypt's Wheat Producers’ Association - not just to conserve foreign currency but also to cater for Egypt’s growing population, which has nearly doubled in the last 30 years to 83 million. Egypt’s long-term food security faces a number of challenges: nearly 99 percent of the population live on about 4 percent of the land (adjacent to the River Nile where most of the fertile land is). Arable land covers around 3 percent of the country, and is under threat from desertification, urbanization and salination, particularly north of the Aswan High Dam, leading to the loss of an estimated 11,736 hectares of agricultural land every year. The policy of the country aims to raising wheat production so as to meet the increase demand of the local consumption. The total annual national production of wheat can be increased by using the appropriate agricultural practices such as irrigation and fertilization.

Egyptian civilization, one of the first and oldest civilizations of the world, has played with the environment and climatic conditions a major role in maintaining much of the history of our forefathers, which helps us to understand and chart the course of transmission. Also it helps us to know how plant species moved from regions of origins to areas of diversity.

Elouafi et.al (1998) stated that durum wheat represents 80% of wheat area in Mediterranean basin. Durum Wheat grain is processed to different end products and the most known are pasta, couscous and borghul. The grain quality parameters for these products are generally known, particularly, the gluten strength. Peterson (1997) cleared the importance of regional trials to test wheat cultivars. Moreover, Bowman (1998) indicated that two year multi- location data would be useful to select wheat cultivars. Comparing yield potential of the newly released durum wheat cultivars with the commercial durum wheat cultivars on farmers' fields over number of years is of utmost importance to verify the on agricultural research station yield potential expectations of the new durum wheat promising lines. The results of these trials help the breeder to take the right decisions regarding the new cultural distribution among farmers and enhance the diffusion of those new cultivars among wheat growers.

With personal communications, Egyptian scientists say a national experiment to boost wheat yields has succeed in increasing average national yields to 10 tonnes per hectare — one of the highest rates in the world, according to the UN Food and Agriculture Organisation Statistical Yearbook for 2012.

Literature review

Egypt's Academy of Scientific Research and Technology (ASRT) said the experiment had been carried out at more than 1,000 sites in 22 governorates across the country, and had achieved an average 30 % increase in productivity.

The experiments took place during the first year of a three-year national campaign to improve Egyptian wheat production levels and crop quality, according to the ASRT.

Its overall target had been to increase wheat productivity in Egypt by 20 % within three years, and to reduce wheat imports to a quarter of national consumption requirements. "The national campaign has exceeded its first-year targets," Maged El-Sherbiny, ASRT's president, told *SciDev.Net*.

It is being jointly implemented by the ASRT and the Egyptian Agriculture Research Center (ARC), as part of a larger regional project to enhance food security in Arab countries.

The increased yield was made possible by "high-yielding, disease-resistant, heat-tolerant wheat varieties, which were developed by the ARC, and the implementation of new agriculture methods," according to *Eman Sadek*, head of the National Campaign for Wheat Improvement at the ARC.

Table (3): Illustrated the average data of wheat harvested area, production and imported quantity.

Year	Quantity (t)	Area (ha)	Imported (t)	Exported (t)
2000	6564050	1034990	4934972	3450
2001	6254580	983741	4449673	23235
2002	6624870	1029590	5589859	13340
2003	6844690	1053020	4064887	30463
2004	7177860	1094740	4375408	5320
2005	8140960	1253820	5786056	35501
2006	8274230	1286750	5837122	31910
2007	7379000	1140980	5921396	25003
2008	7977050	1226650	8336305	29398
2009	8523000	1335300	4070357	109737
2010	7177400	1287630	--	--

Post forecasts Egypt's wheat production in 2013/2014, **Table (4),** to reach 8.7 MMT, up 2.3 percent compared to 2012/2013, due to expanded harvest area. Diesel fuel shortages can potentially disrupt this season's harvest operations as well as logistics to bring the crop to market. Imports are down sharply to 8.0 MMT in 2012/13, following the General Authority for Supply Commodities' (GASC) decision to cease international wheat purchases through the end of the current Egyptian fiscal year (July/June), but expected to rebound to 8.5 MMT in 2013/2014, (GAIN–Egypt Grain and Feed Annual 2013).

Table (4) Illustrated the post forecasts Egypt Wheat production in 2013/2014

Wheat-EGYPT	**2000-2012**		**2012-2013**		**2013-2014**	
	Market Year Begin: Jul 2011		Market Year Begin: Jul 2012		Market Year Begin: Jul 2013	
	USAD Official	New Post	USAD Official	New Post	USAD Official	New Post
Area Harvested	1.280	1.280	1.350	1.350		1.400
Beginning Stocks	5.508	**5.508**	6.718	**6.718**		**3.818**
Production	8.400	8.400	8.500	8.500		8.700
MY Imports	11.650	11.650	8.500	8.000		8.500
TY Imports	11.650	11.650	8.500	8.000		8.500
TY Imp. From U.S.	989	989	0	0		0
Total Supply	25.558	**25.558**	23.718	**23.218**		**21.081**
MY Exports	240	240	200	300		300
TY Exports	240	240	200	300		300
Feed and Residual	2.600	2.600	2.100	2.400		2.200
FSI Consumption	16.000	16.000	16.350	16.700		15.500
Total Consumption	18.600	**18.600**	18.400	**19.100**		**17.700**
Ending Stocks	6.718	6.718	5.118	3.818		3.018
Total Distribution	25.558	**25.558**	23.718	**23.218**		**21.018**

Source: GAIN–Egypt Grain and Feed Annual (2013),**MY**, Marketing Year, **TY**, Trade Year

4. Cultivated wheat today

Currently, about 95% of the wheat grown worldwide is hexaploid bread wheat, with most of the remaining 5% being tetraploid durum wheat. The latter is more adapted to the dry Mediterranean climate than bread wheat and is often called pasta wheat to reflect its major end-use.

However, it may also be used to bake bread and is used to make regional foods such as couscous and bulgar in North Africa. Small amounts of other wheat species (einkorn, emmer, spelt) are still grown in some regions including Spain, Turkey, the Balkans, and the Indian subcontinent. In Italy, these hulled wheat are together called faro (Szabo and Hammer, 1996) while spelt continues to be grown in Europe, particularly in Alpine areas (Fossati and Ingold, 2001).

The recent interest in spelt and other ancient wheat (including kamut, a tetraploid wheat of uncertain taxonomy, related to durum wheat) as healthy alternatives to bread wheat (Abdel-Aal et al., 1998) may also lead to wider growth for high value niche markets in the future.

5. Water resources

5.1. Status of fresh water resources in the Mediterranean

Fresh water resources in the Mediterranean are under increasing pressure in terms of both quantity and quality. Northern Mediterranean countries with higher, more regular rainfall also face climate-induced natural hazards, flooding and water shortages in basin ssusceptible to periodic drought.The decreasing availability of fresh water for agriculture use, while the need for production of food and fuel from plants is increasing, which is now adays a problem common to many countries in the region. As a consequence,humanand natural systems sensitive to water availability and Water quality is increasingly stressed, or coming under threat. Those countries will have to face water quality degradation and meet the increasing needs of environmental protection and restoration.

In the absence of climate change, the future population in water-stressed watersheds depends on population scenario and by 2025 ranges from 2.9 to 3.3 billion people (36–40% of the world’s population). By 2055 5.6 billion people would live in water-stressed watersheds under the A2 population future (The A2 storyline has the largest population), and ‘‘only’’ 3.4 billion under A1/B1(Arnell, 2004).The Mediterranean basin is one of the most vulnerable regions to climatic and anthropogenic changes. Since the late 1970s, mean annual temperatures have increased by 0.1°C per decade and precipitation has decreased by 25 mm per decade (Xoplaki *et al.*, 2004). These trends are set to continue between now and 2050. Temperatures should rise by 1.5–2.5°C and annual precipitation should decrease by 5 to 20% (IPCC, 2007; Milano *et al.*, 2012a). These changes should cause an aridification of the Mediterranean climate, with reduced snow cover in the Alps, Pyrenees and Atlas Mountains, faster and earlier snow melting and an expansion of arid climate in the Iberian plains and coastal regions, in Italy, in the Balkans, in Greece and in Turkey (IPCC, 2007).

Water resources in the Mediterranean basin currently account for 1.2% of the world's renewable water resources, i.e. approximately 550km^3 per year. Most of these resources are located in the Mediterranean basins of France, Italy, Greece and Turkey. Catchments of the southern and eastern rims produce respectively only 4% and 2% of the Mediterranean water resources, the first scenario. Still according to the alternative scenario, over the northern rim, total water withdrawals should only increase in Greece and over the Ebro catchment in Spain in line with a 25% increase in agricultural water withdrawals. Domestic water withdrawals should remain constant or decrease as water access systems are already adequate (few spills) and as population is projected to stabilize over the northern rim by the medium term. For most catchments of the southern rim and of south-eastern Mediterranean, the increase in total water withdrawals should be less pronounced than under the business-asusual scenario, despite the fact that they should still double due to the expansion of irrigated areas and the high projected population growth, Milano *et al.*, 2012a.

The shortage of water resources of good quality is becoming an important issue in the arid and semi arid zones, for this reason the availability of water resources of marginal quality such as drainage water, saline groundwater and treated waste water deserves full consideration (Beltran, 1999).

Therefore, water shortages over the Mediterranean basin should increase and discrepancies between rims are likely to increase. Improvements of water use efficiency, alone, would not be able to significantly reduce water tensions, (Milano, 2012).

5.2. Water resources and climate change

Climate change is likely to increase drought risk during the 21st century in many parts of the world. Climate model projections, under a range of emissions scenarios, consistently show that seasonal rainfall is likely to decrease across large parts of southern Europe, North Africa, central Asia and southern Africa, and reductions are also possible in other dry parts of the world. The effects of climate change, however, will be superimposed on the patterns of natural climatic variability – such as ENSO – and the effects of land cover change which also tends to lead to increased regional temperatures and lower regional rainfall. Quantitative estimates of change in drought risk are therefore very uncertain.

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) concluded that warming of the climate system was unequivocal, was very likely to be due to the observed increase in anthropogenic greenhouse gas emissions, and that continued emissions of greenhouse gases would cause climate changes during the 21st century that would very likely be larger than those observed during the 20 the century (IPCC, 2007).

5.2.1. Trends in drought occurrence during the 20th century

Assessments of trends in drought occurrence over a long time period need to employ consistent quantitative indicators which can readily be calculated from available data. The Palmer Drought Severity Index (PDSI) has been widely used (Dai et al., 2004; Burke et al., 2006). The index for a given time period is basically a function of the difference between actual precipitation and the amount of precipitation required to maintain a "normal" water balance level, where the amount required is a dependent on evaporation, soil water recharge and runoff as calculated using a very simple hydrological model. Figure 1 shows the dominant spatial pattern in the PDSI over the period 1900 to 2002, calculated from observed precipitation and temperature data (Dai et al., 2004; Trenberth et al., 2007). This analysis suggests that very dry areas (with a PDSI less than -3) increased from 12% of the global land surface to 30% since the 1970s. Drought occurrence increased particularly in western and southern Africa, southern Europe and North Africa, south Asia and eastern Australia. Part of this increase followed a large jump due to decreases in precipitation in large areas in the 1980s due to ENSO, and part was due to increasing surface temperatures and therefore evaporation.

There are, however, a number of complications with the PDSI (including the need for local calibration, the time scale at which it is calculated, and the general use of the Thornthwaite formula to estimate potential evaporation), and different indicators of drought can give different indications of trends over time. Sheffield and Wood (2008), for example, used an indicator based on simulated soil moisture contents, and did not identify an underlying long-term trend towards increasing drought during the 20th century. They did, however, find that in some regions there was a clear switch to a drying trend at the end of the 20th century Figure (2), which they attribute to higher temperatures leading to increased evaporation and, in some regions, earlier snowmelt.

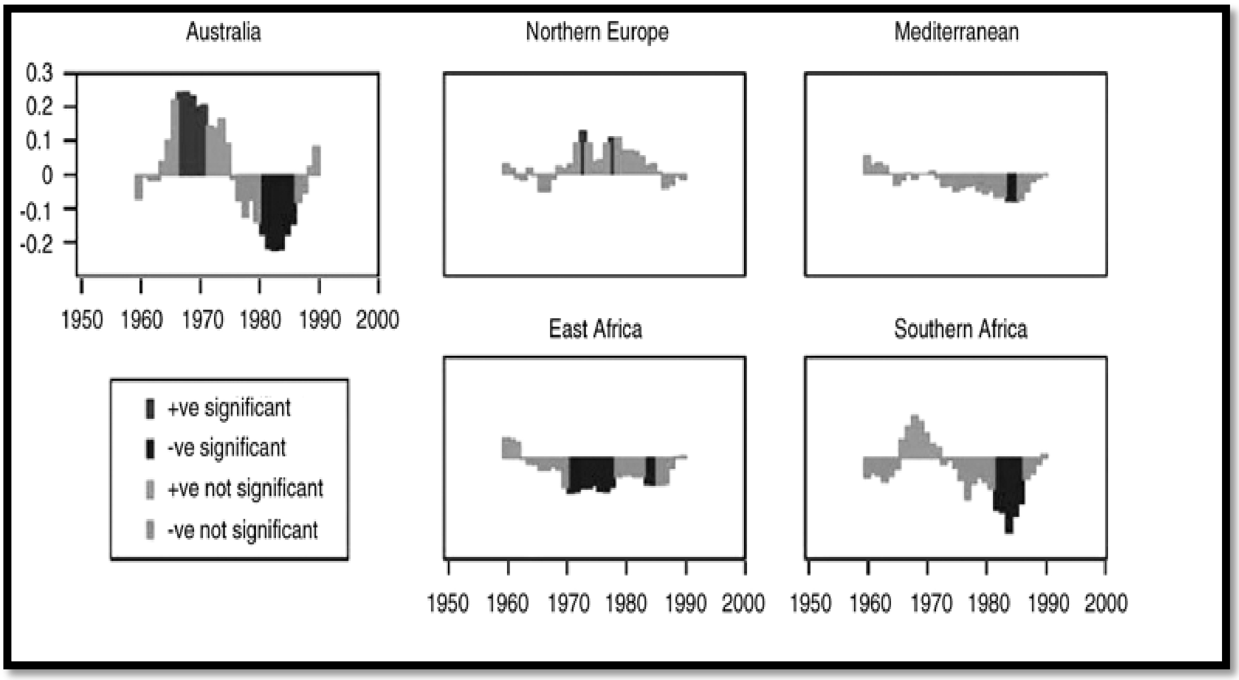


Figure (2): Trends in regional average soil moisture for a 21-year moving window. Trends significant at the 5% level are shown in darker colors (Sheffield and Wood, 2008).

5.2.2. Droughts in the 21st century

The evaluation of drought risk during the 21th century will depend on both changes in climate (and consequent changes in meteorological, agricultural and hydrological drought) and changes in exposure to drought due to altered demographic and socio-economic conditions. This section focuses on the potential changes in climate which will impact upon drought risk, rather than possible changes in socio-economic conditions.

Projections of future climate are based on simulations using global climate models forced with assumed rates of change of greenhouse gas emissions and atmospheric concentrations. The Fourth Assessment Report of the IPCC provides an overview of the characteristics of these models and the broad patterns of climate change projected under a set of emissions scenarios (Meehl *et al.*, 2007). A long-standing and robust result from climate model experiments is an increasing chance of summer drying in continental mid-latitudes, particularly in the Northern Hemisphere (Meehl *et al.*, 2007).

Burke *et al.* (2006) simulated changes in the PDSI over the 2st century using the HadCM3 climate model driven by the SRES A2 scenario. They projected an overall drying trend, accelerating through the 21st century, with particularly strong drying over Amazonia, the United States, northern Africa, southern Europe and eastern Asia. Under their projections, the percentage of land under "severe" drought increases from around 10% at the beginning of the 21St century to around 40% at the end. The frequency of "severe" drought events doubles by the end of the century, and their mean duration increases by a factor of around five (Burke *et al.*, 2006).

Climate change challenges some of the key (often implicit) assumptions in drought management. It is no longer feasible to assume that the past is the key to the future. Whilst it is necessary to ensure that drought management plans can cope with current climatic variability, this is not in itself sufficient to ensure that these plans can cope with possible *changes*in drought risk. Finally, uncertainty in projected future drought risk encourages the use of flexible and robust measures which can be readily adapted and altered as more information is gathered (Arnell, 2008).

5.2.3. Climate change and water resources in the Mediterranean

Climate change has a significant impact on water resources and their management. Along the last decade, the direct impacts of climate change registered in the Mediterranean basin consist in lower levels of precipitations, a modification of the intensity and distribution of the precipitations, an increase of floods and a raise of temperatures. Under such expectation waterprofessionals and societies will need to adapt to climate change. In theMediterranean, water resources being the most crucial element fordevelopment particularly for the southern countries, the combination of the aridity of the region with climate change impacts will particularly threat ecosystems processes (IUCN, 2003).

The world's water supply is being strained by climate change and the growing food, energy and sanitary needs of a fast-growing population. A recent United Nations study called for a radical for a radical rethink of policies to manage competing claims. Although, the 6th Water Forum and Rio +20 summit reaffirmed that climate change is one of the greatest challenges of our time and highlighted water among seven areas and critical issues which need priority attention.

Most Mediterranean countries, particularly the arid and semi-arid ones, are chronically water-stressed. Population growth, urbanization, development progress and climate change impacts will all exacerbate that stress and result in enormous pressure on available water resources. It is well recognized that a water crisis is, in many ways, a crisis of governance. It is a crisis due to the failure of institutions to manage water resources for the well-being of humans and ecosystems (Hamdy, 2012).

At present, the Mediterranean agricultural production covers almost 40% of arable land, and since climate considerably affects the crop growing cycle, significant climate changes might unquestionably cause serious effects on the economic system in all those countries where the primary sector has a major weight. It is quite important to make a thorough analysis of the climate scenarios in the Mediterranean basin. However, uncertainties in hydro-meteorological data do exist because of differences in data acquisition systems and the difficulties in data surveying in some areas (i.e mountain and ocean areas).

In the Mediterranean basin, the effects of climate changes on water resources are related both to the increase in evaporation volumes and the change in the soil water content. The reduced water flow in the Mediterranean region is the consequence of a smaller inflow from snow melting and its dependence on the rainfall regime.

To understand how climate change influences crops, concerns on the increase in CO_2 are inevitable. Climatic conditions determine the evaporative demand whereas the response to it depends on crop cover and the water status of the soil. Nevertheless, the future rainfall pattern being uncertain, the calculation of the future crop water requirements is uncertain as well. Also the effects of climate changes on coastal areas of the Mediterranean have to be carefully considered. The problem of coastal erosion caused by natural conditions and human activities has to be tackled. The sea level rise, for instance, will cause a loss of 6% of land in Italy and the disappearance of half of the present wetlands in Europe.

Increased urbanization and deforestation make the coastal situation even worse. It is already critical for about 50-80% of European inhabitants of the Mediterranean who permanently live along the strip of 60 km from the coast.

The changes in temperatures and in precipitations levels and distribution will directly affect the water demand, quality and watershed. Pollution will be intensified by runoff incatchments and from urban areas. Rivers will have lower flows particularly in summer, and the sea temperature, salinity and concentration in CO2, nitrates and phosphates will also be affected. The most visible impact will be the floods, which will be higher and more frequent. The changes in the frequency of extreme events might be the first and most important change registered in the Mediterranean. That will directly impact the vulnerability of the poorest countries. Also, Water quality will be affected by higher runoff, which will increase pollution due to agriculture chemicals and less capacity to assimilate pollution with lower flows. The intensification of rainfall will primarily be responsible for soil erosion, leaching of agricultural chemicals and runoff of urban and livestock wastes and nutrients into water bodies (IUCN, 2003).

6. Irrigation method

6.1. Drip Irrigation System

The main principle of drip irrigation is to introduce water into the soil where plant roots grow most intensively and to introduce it at the right time and rate (Goldberg et al. 1976). Drip irrigation applies water frequently at very low rates to achieve low moisture stress and optimum plant growth (Burt and Stuart 1994; Yildirim and Korukcu 2000).

Drip irrigation sometimes called trickle irrigation and involves dripping water onto the soil at very low rates (2-20 litters/hour) from a system of small diameter plastic pipes fitted with outlets called emitters or drippers. Water is applied close to plant so that only part of the soil in which the roots grow is wetted, unlike surface and sprinkler irrigation, which involve wetting the whole soil profile. With drip irrigation water, applications are more frequent (usually every 1-3 days) than with other methods and this provides a very favorable high moisture level in the soil in which plants can flourish. With drip irrigation, water is conveyed under pressure through a pipe system to the field, where it drips slowly onto the soil through emitters or drippers, which are located close to the plants. Only the immediate root zone of each plant is wetted. Therefore this can be very efficient method of irrigation, (FAO, 2001)

6.1.1. Advantages

Drip irrigation can be used in all soils and topographic conditions and particularly for vegetables, vineyards, fruitstrees, and covered crops, it can be economical to use on some crops when water resources are limited or irrigation water fairly costly (YildirimandKorukcu2000).

In drip irrigation, when planning and operation are good, no surface flow or delivery losses occur, as the water moves from source to emitter through pressurized pipes to certain points on the soil surface at a very low rate. With drip irrigation, evaporation losses and deep percolation are also very low, and thus it achieves very high irrigation efficiency and use water very effectively (Nakayama and Bucks 1986).

Irrigation water goes to lateral lines only after acquiring suspended plant nutritional elements. A control unit controls discharge rate and operating pressure and the system efficiency meets plant nutritional requirements in the right amount and at the best time (Goldberg et al. 1976; Burt and Stuart 1994).

Benefits of drip irrigation in reducing nitrate loss resulting from deep percolation and reducing water use without negatively affecting yield and quality of products have been documented by different researchers (Roth et al., 1995; Li et al., 2000; Sharmasarkar et al., 2001).

Drip irrigation has in few negative effectives on the environment because it rarely creates problem such as drainage, surface runoff, soil erosion, deep percolation, or fertilizer leaching (Yildirim and Korukcu 2000).

Drip irrigation (Ragab et al., 1984 and Hamdy, 1991) provides a greater advantage when using saline water. The prevailing moisture condition under the drip method provides the best possible conditions of total soil water potential for given quality of irrigation. The roots of the growing plants tend to cluster in the leached zone of high moisture near the emitters, avoiding salt that accumulates of the wettingfront (Shalhevet et al., 1983, Hamdy, 1991).

6.1.2. Disadvantages

The main problem with drip irrigation is clogging of emitters with suspended organic material and chemical precipitation. To prevent or, to a large extent, solve this problem, farmers should filter water very well, using hydro cyclones, gravel filters, and screen filters at the control unit, and they should wash the system with diluted acids and the pipelines at certain times during the season.

The problem with drip irrigation is the accumulation of salts at the perimeter of wetted soil volume, particularly near the surface. When more than 300 mm of total rainfall occurs before the irrigation season, it generally leaches these salts. Otherwise, farmers need leaching water, and they generally use a portable sprinkler system for leaching (Sourel and schon 1983; Yildirim and Korukcu 2000).

6.1.3. Distribution of fertilizers under drip irrigation

Trickle (drip) irrigation system, which is highly efficient for water application, is also ideally suited for fertigation and is practical to chemigating applied chemicals (Goldberg et al., 1976; Papadopoulos, 1985). In "this way, water soluble fertilizers at concentrations required are conveyed via the irrigation stream to the wetted volume of soil. Thus the distribution of chemicals in the irrigation water will likely place these chemicals in the desired location, the general root (Papadopoulos, 1985; 1986 a; 1986 b). Furthermore, with drip irrigation, the application of herbicides and pesticides for soil-borne diseases and pests due to the chemicals being more effective at lower concentration (Gerstl et al., 1981).

Fertilizer application through trickle irrigation, mineral nutrients move into the wetted volume in a manner consistent with the flux of the water in the soil, the availability of such nutrients are mostly depending on their solubility and / or reactivity with constituents in the soil solution, and their interaction, if any, with the exchange sites of the soil.

Since chemical characteristic of fertilizers differ, mineral nutrients are differently distributed in the soil when applied by trickle irrigation (Bar-Yosef, 1977;Papadopoulos, 1985).

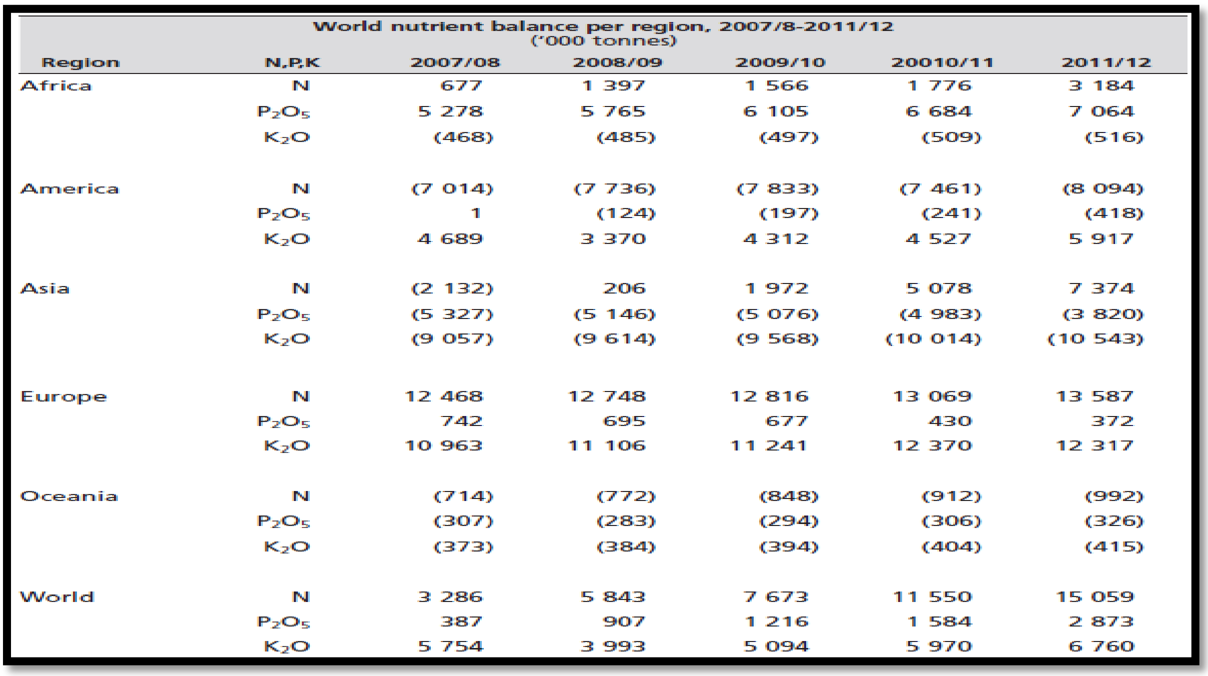
Musa (1995) reported that any advancement in the irrigation system design and management are directly reflected in the improvement and efficiency of the chemigation process and water use and that the distribution uniformity of chemication / frtigation will be equal or less than distribution uniformity of the irrigation system been used. Trickle irrigation offers flexibility in Fertigation, a benefit unique to the drip system (Lindsey and New, 1974; Isob, 1974). Other features include good fertilizer distribution with minimum leaching beyond the root zone and more options in timing fertilizer application than with other distribution system (Gobbelear and Lourens, 1974).

7. World fertilizer demand

Fertilizer demand has historically been influenced by changing and often interrelated factors such population and economic growth, agricultural production, prices and government policies.

However, three developments distinguish the current state of agricultural markets from past fluctuations, namely that the hike in world prices concern nearly all major food and feed commodities, that record prices are being achieved at a time not of scarcity but of abundance, and that linkages between agricultural commodity markets and other markets are strengthening.

Such phenomena already manifest in 2006 strengthened in 2007 a year characterized by persistent market uncertainty, record prices and unprecedented volatility in grain markets. The magnitude and nature of these changes have led some observers to refer to a paradigm shift in agriculture away from decreasing real food prices over the past thirty years. Given the inextricable link between food production and fertilizer use, it is opportune to consider such changes when reviewing prospects for fertilizer demand and supply balances until 2011/12 Figure (3) (Heffer 2007).



World nutrient balance per region, 2007/8-2011/12
('000 tonnes)

Region	N,P,K	2007/08	2008/09	2009/10	20010/11	2011/12
Africa	N	677	1 397	1 566	1 776	3 184
	P_2O_5	5 278	5 765	6 105	6 684	7 064
	K_2O	(468)	(485)	(497)	(509)	(516)
America	N	(7 014)	(7 736)	(7 833)	(7 461)	(8 094)
	P_2O_5	1	(124)	(197)	(241)	(418)
	K_2O	4 689	3 370	4 312	4 527	5 917
Asia	N	(2 132)	206	1 972	5 078	7 374
	P_2O_5	(5 327)	(5 146)	(5 076)	(4 983)	(3 820)
	K_2O	(9 057)	(9 614)	(9 568)	(10 014)	(10 543)
Europe	N	12 468	12 748	12 816	13 069	13 587
	P_2O_5	742	695	677	430	372
	K_2O	10 963	11 106	11 241	12 370	12 317
Oceania	N	(714)	(772)	(848)	(912)	(992)
	P_2O_5	(307)	(283)	(294)	(306)	(326)
	K_2O	(373)	(384)	(394)	(404)	(415)
World	N	3 286	5 843	7 673	11 550	15 059
	P_2O_5	387	907	1 216	1 584	2 873
	K_2O	5 754	3 993	5 094	5 970	6 760

Figure (3), World nutrient balance per region, 2007/8-2011/12

7.1. World Nitrogen fertilizer Demand

The forecast is for world nitrogen fertilizer demand to increase at an annual rate of about 1.4% until 2011/2012, which is an overall increase of 7.3 million tonnes. About 69%t of this growth will take place in Asia.

The world's largest consumers of nitrogen are East Asia, South Asia, North America and West Europe. While their share of global consumption is modest, it is forecast that the relative contribution of Latin America and East Europe and Central Asia (EECA) to change in nitrogen use will be 10.4% and 5% respectively. The relative contribution to change in world nitrogen consumption by East Asia and South Asia is expected to be about 65% Figure (4). North America is the largest importer followed by South Asia that still has a supply deficit of some 32%. East Asia will move from deficit to surplus during the outlook period (FAO, 2008).

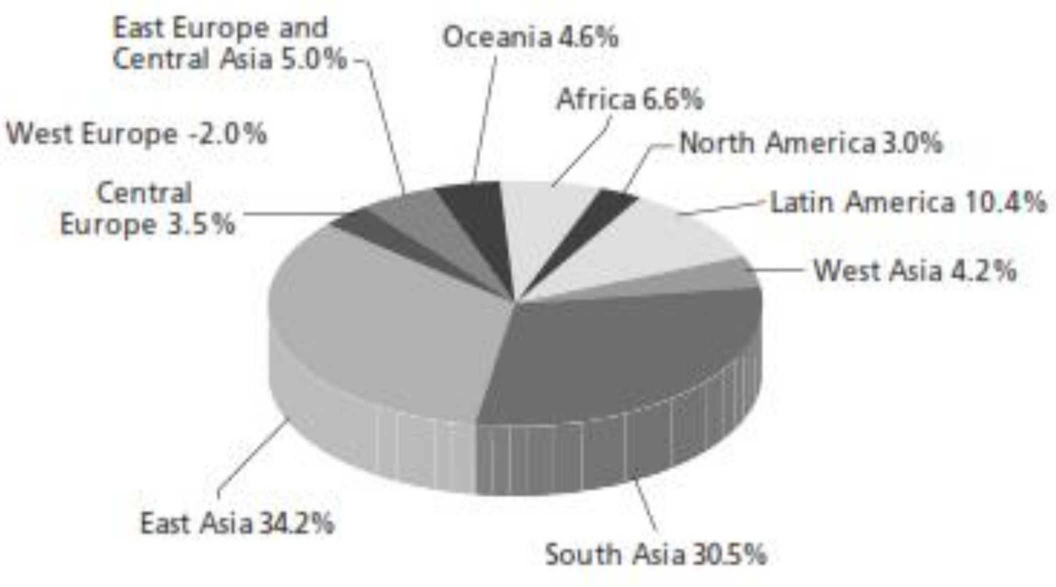


Figure (4), Regional and sub-regional contribution to change in world Nitrogen consumption 2007/8-2011/12.

Increased requirements for food and other agricultural products will undoubtedly increase demand for N fertilizers. However, determining the magnitude of the increase is not straightforward. For example, Wood et al.

(2004) pointed out that the 2.4% average annual growth in food consumption between 1961 and 2001 was accompanied by a 4.5% increase in fertilizer N use. They went on to explain that the increase in fertilizer use was largely due to a change in the structure of food demand, where consumption of meat products grew faster than cereals, increasing the demand for feed grains and for N.

Projections of future fertilizer demand also involve assumptions about N use efficiency, measured as the amount of production resulting from each unit of fertilizer N used. Will Nitrogen use efficiency (NUE) decrease because higher application rates are used and the low of diminishing returns set s in as farmers move up an unchanging N response curve? Or, will it increase due to higher energy and input costs, improved management, better technology and increased awareness of problems associated with inefficient use? Or, will it be business as usual with no change from the past?

After exceptionally strong growth of world fertilizer demand in 2003/04 and 2004/05, Heffer and Prud'homme (2006) forecast that global N consumption would increase from 90.9 Mt N in 2005/06 to 99.4 Mt in 2010/11, corresponding to an average annual growth rate of 1.8%. All projections point to an increase in fertilizer consumption in the decades to come, but the magnitude of this increase depends greatly on the underlying assumptions. For instance, Wood et al. (2004) identified three different scenarios: (i) a scenario following trends since 1969 for both crop production and fertilizer use; (ii) a scenario following the International Model for Policy Analysis of Agricultural. Commodities and Trade (IMPACT) to project food production, and assuming constant NUE based on 1997 values; and (iii) a scenario based on the IMPACT model for food production projections, and assuming relative NUE gains of 17% from 1997 levels by 2020, and of 30% by 2050. Wood et al. (2004) anticipated that fertilizer N use would grow around 1.8% annually in the short term. Average annual growth would then drop to 1.6% by 2020 and to 1.4% by 2050, unless NUE increases. With the NUE gains assumed in scenario 3, average annual growth of fertilizer N use would drop to less than 0.5% after 2010.

Another recent analysis looking at crop-specific food production gave similar results butpointed out that such gains in NUE would require substantial additional investment in research and education (Dobermann and Cassman, 2004). Forecasts to 2010/11 by Heffer and Prud'homme (2006) tended to show that projections by Wood et al. (2004) under scenario 3 cannot be achieved, as these projections for 2020 would already be exceeded in 2010. Long-term projections are subject to great uncertainty and involve many critical assumptions about our ability to improve crop productivity as demand increases, while also improving NUE. Recent projections indicate that global demand for N fertilizers in 2050 could be between 107 and 171 Mt N.

According to the four scenarios of the Millennium Ecosystem Assessment (2005), global fertilizer N consumption in 2050 is anticipated to be between 110 and 140 Mt N.

8. Nitrogen Management in Agriculture

Nitrogen (N) is a vital element for life. It is an essential component of all proteins and of deoxyribonucleic acid (DNA).

On Earth, there are two pools of N, with relatively little exchange between them: the gaseous dinitrogen (N_2) of the atmosphere, which makes up about 99% of total N, and the 1% of N that is chemically bound to other elements such as carbon (C), hydrogen (H) or oxygen (O) and has been described as "reactive nitrogen" for its tendency to react with other elements (Galloway et al., 2004). Reactive N includes inorganic reduced forms (e.g. ammonia [NH3] and ammonium [NH4 +]), inorganic oxidized forms (e.g. nitrogen oxides [NO_x], nitric acid [HNO_3], nitrous oxide [N_2O], nitrate [NO_3^-] and nitrite [NO_2^-]) and organic compounds (e.g. urea, amines, proteins and nucleic acids). Nitrogen in humus (decomposed organic matter found in soil) can be regarded as reactive in the long term only.

Gaseous N_2 cannot be used directly by plants, with the exception of some plant species (e.g. legumes) that have developed symbiotic systems with N_2-fixing bacteria. Owing to the strong bond between its two N atoms, N_2 is almost inert and thus non-reactive. It requires a high energy input to convert N_2 into plant available, reactive N forms.

The variability in soil and climatic conditions associated with processes that affect nitrogen dynamics in the soil and their relationship with the plant may lead to changes in nitrogen availability and its requirement by the plant (SIMILI et al., 2008; ESPINDULA et al., 2010). The soil-N cycle involves several N transformations, which essentially make soil organic N or fertilizer-N usable for plants.Processes increasing plant available N are mineralization, nitrification and biological N fixation, while processes such as ammonia (NH3) volatilization, immobilization, denitrification and leaching foster temporal or permanent N losses from the plant rooting zone Figure (5) (Scheffer and Schachtschabel 1998).

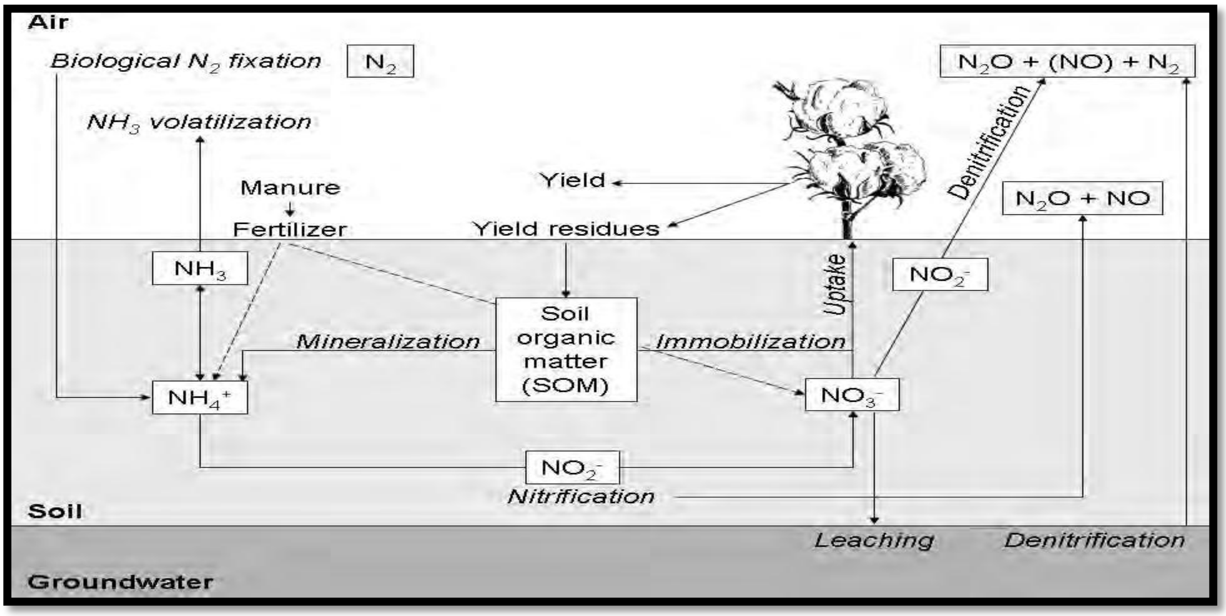


Figure (5) Simplified soil-N cycle (modified after Hofman and van Cleemput (2004) in van Cleemput and Boeckx 2005).

Appropriate N inputs enhance soil fertility, sustainable agriculture, food security (enough calories) and nutrition security (appropriate supply of all essential nutrients, including protein). On the other hand, when improperly managed, N inputs can be associated with a number of adverse effects on both the environment and human health. Lack of reactive N in the agro-ecosystem leads to soil fertility decline, low yields and crop protein content, depleted soil organic matter, soil erosion and, in extreme cases, desertification. Excess amounts of NO_3^- may move into groundwater and drinking water supplies, raising treatment costs faced by municipalities. Excess NO_3^- in drinking water wells also can be an issue in rural areas that are adjacent to farmland. In surface water, increased loading of N-based nutrients can play a role in eutrophication a process that contributes to ecological and resource degradation. In the atmosphere, NO_x and particulate matter can exacerbate several human health problems, from asthma to heart disease. Increasing the N_2O concentration in the atmosphere contributes to global warming. Adopting an integrated approach to nutrient management maximizing the benefits and minimizing the risks associated with the use of N sources contributes to raising crop productivity and N use efficiency.

8.1. Wheat Nitrogen Timing and application methods

Nitrogen present in the soil prior to crop uptake is subject to loss by volatilization, immobilization, denitrification and/or leaching, with the magnitude and pathways of loss affected by environmental conditions such as soilmoisture and temperature (Mullen, 2011).

Moreover, reducing the time that inorganic N is in the soil solution prior to crop uptake can reduce the risk of N losses and increase NUE. Split applications of N fertilizer, where a portion is applied at the time of seeding and a portion is applied later during crop growth can be used to minimize the length of time that inorganic N is present in the soil solution prior to crop uptake (Malhi et al., 2001).

The rate of N-fertilizer uptake by plants depends on many factors, such as fertilizer application rates, timing, application method, soil history and biological features of the crops (Olson and Kurtz 1982). Riley et al. (2001) compared farmers' practices with better plant-N uptake related applications and found that good timing of N in relation to crop demand is very efficient in reducing losses, i.e., adequate splits and also timing of splits. Also, meeting crop nutrient needs by applying the appropriate amount of N with the appropriate technique reduces losses and increases the N-use efficiency (NUE) (Wuest and Cassman 1992a).

Balasubramanian and Singh, (1982) reported that, by adjusting the rate and time of application N fertilizer, it is possible to achieve maximum crop yield production with great saving in the nitrogen rates. Traditionally in the Northern Great Plains of North America, N fertilizer has been applied prior to or at the time of seeding, although the majority of crop N uptake occurs later in the growing season when the crop is growing rapidly (Malhi et al., 2006).

Since splitting the dose has been considered as a strategy to increase grain N concentration, a third "late" N-fertilizer application at GS37 instead of two amendments traditionally made at the beginning of tillering (GS20) and at the beginning of stem elongation (GS30) in wheat, based on Zadoks scale Figure (6), crop has been proposed (e.g., Gate, 1995). Splitting N applications into three amendments has become a common farm practice in many regions of the United Kingdom, Germany, the Netherlands, or Denmark. However, under Mediterranean climatic conditions this late N application has led to very different results regarding grain yield (Alcoz et al., 1993; Garrido-Lestache et al., 2005) and grain quality in terms of grain N concentration (Ayoub et al., 1994; Garrido-Lestache et al., 2005, Fuertes-Mendizábal et al., 2010a, Zuliang Shiet al., 2012).

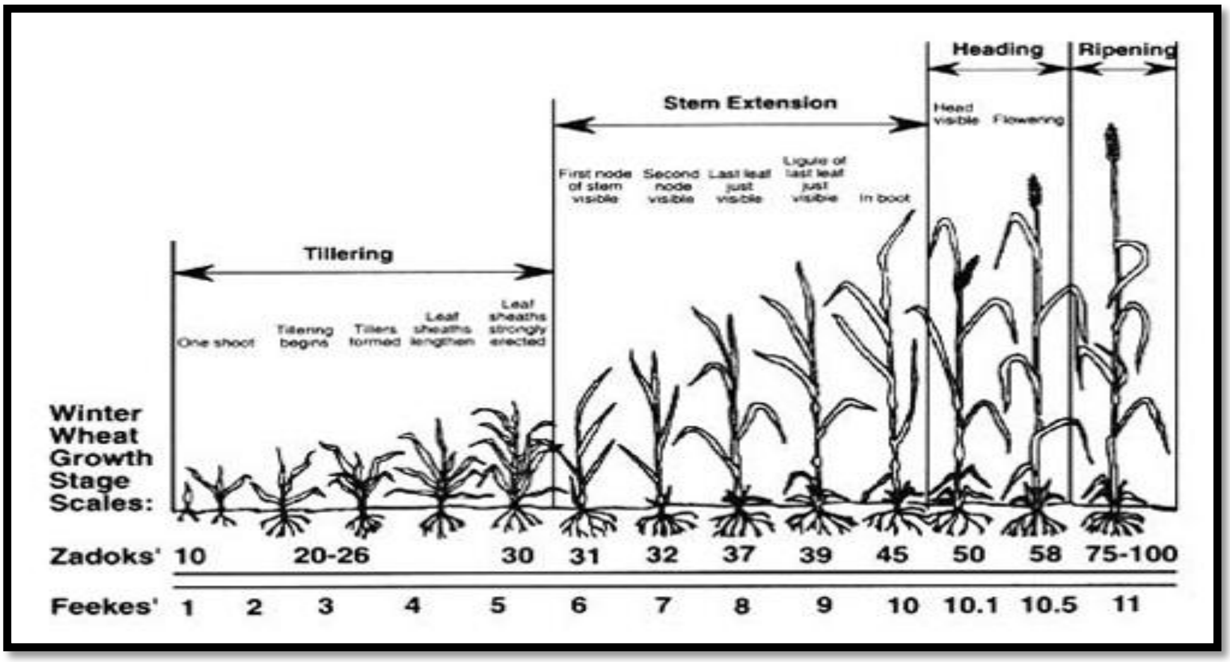


Figure (6) Growth stages of small-grain cereals. Numbers correspond to the Zadoks scale (Zadoks et al., 1974)

Literature review

Literature cited indicated that, high efficient use of N-fertilizers could be achieved, when its application is timed to coincide with the crops demand for N-during the crop growing stages. According to (FAO, 1984), most short duration crops have a small demand for nitrogen in the seedling stage of growth followed by a major demand during the successive growth stages. For cereal crops, the most effective time for N application is often related to the latest time compatible with the period of rapid N uptake by plant (Olson et al., 1964). Furthermore, applied N is available throughout the period of the grain formation without being used earlier for production of unnecessary vegetative growth (Olson and Kurtz, 1982). Grain N concentration being strongly influenced by the quantity of N assimilated before anthesis and remobilized afterwards (Dupont and Altenbach, 2003). Thus, one factor determining N-use efficiency by the plant is the extent of N redistribution from the vegetative parts to the grains (Andersson et al., 2005).

Delaying application of some or all N fertilizer until after planting may allow for precise diagnosis of N needs, by either in season soil testing (Blackmer et al., 1989), sensing crop color (Varvel et al., 1997) and Blackmer et al.,1996), or estimating weather effects on soil N availability (Honeycutt,1994). Effective N management involves selecting an application rate, source, timing and placement combination that match N availability with crop demand to maximize N use efficiency, optimize crop production and to minimize the negative impact of N on the environment (Malhi et al., 2001). Application rates that precisely match crop needs could result in less residual soil for leaching (Andraski et al., 2000) and positively impact water quality. Understanding the effect of delayed N application on yield is critical to the use of any of these management tools.

Nitrogen fertilizer recovery by the crop may sometimes be greater when N application is delayed compared with application at planting (Russelle et al., 1983; Jokela and Randall, 1997). This is probably due to greater exposure of N applied at planting to a range of possible loss processes (immobilization, leaching, denitrification, and clay fixation) at a time when N uptake rates are relatively low. Rate of N uptake as the corn plant develops is affected by weather, planting date and time silking stage (Russelle et al., 1983). This would suggest that applying N fertilizer until at least the silking stage may be a reasonable management option.

Once the need for and rate of supplemental N have been determined, either through soil and plant testing or a general knowledge of the cropping system, the next considerations are the source of N to be used and the method and timing of N application. Maximization of N efficiency requires that the best N sources be applied in a timely manner as possible, often through the use of multiple applications.

Selecting an N application method can be separated from the selection of N source. The same used ways to apply N fertilizers include banding, Fertigation, broadcasting, and injection.

Injection is using the specialized subsurface application equipment to placement the fertilizer in the soil through and is most commonly used for anhydrous NH_3 and liquid fertilizer materials such as urea-ammonium-nitrate (UAN) solutions. Fertilizer injections are normally made at deeper depths than band placements, particularly for anhydrous NH_3 which reverts to a gas following injection and can be lost from the soil via volatilization if not placed correctly.

The design of fertilization strategies leading to better N-use efficiency should consider several factors, such as the N source to be applied, the dose and the splitting of the dose in one or several applications. However, split fertilizer applications require an extra field operation as compared to application of the full rate at the time of seeding and are not commonly used in the Northern Great Plains of North America (Grant et al., 2012).

9. Nutrients and crop performance

Mineral elements have the same importance for all the plant; however, the rate, quantity and timing of uptake vary with crop, climate, variety, management and soil characteristics. Nitrogen is the nutrient most limiting to crop production in most non-leguminous crops and the nutrient generally applied in the largest amount. These combined factors influence the nutritional need, nutrient content, and overall yield of a crop. Due to the prices of N-fertilizer which represent a large portion of a producer's costs, it is very important to maximize fertilizer nutrient use efficiency. Timing fertilizer applications so that nutrients are available when plants need them should increase nutrient use efficiency and reduce potential adverse environmental effects. Knowing how nutrient needs change during the growing season is essential for matching nutrient supply with plant needs, especially for producers who can apply nutrients in season or for those considering controlled- and slow-release fertilizers.

Water and Nitrogen (N) are the key factor limiting the primary production in arid and semiarid ecosystem (Alon and Steinberger, 1999; Mazzarion et al., 1998).

Stored water in the soil from untimely rainfall events supports the development and growth of the crops. At the farming level of organization, a large proportion is lost by direct soil evaporation (Sadras, 2003). However, crop yields can be increased and maintained their productivity to acceptable levels when using appropriate measures that permit management to enhance the efficiency of soil use, reducing water losses by evaporation of soil water, or decreasing weed evapotranspiration.

9.1. Nitrogen and Water Interaction under wheat cultivar

If water is abundant both crop growth and yield are greatly depending on soil N supply. With evolution of high yielding varieties, N demand in agriculture is ever increasing. With little information on the amount of N required for cropping practices on different soils, farmers generally apply as much fertilizer as resources permit to increase yield (Nilsen and Halvorson, 1991). Under rainfed agriculture, lack of water in the root zone can make the applied N unavailable to plants and subject to leaching or runoff later. Hence, proper management of N is the key for a better environmental and improved crop production, therefore, there is a need for a more demand-based application of N fertilizes in light of the climatic and soil physico-chemical conditions (Saeendran et al., 2004).

Water scarcity and nitrogen shortage are the main constraints on durum wheat productivity. Nitrogen is an essential element for plant growth and maintenance, since it is considered as a key nutrient in crops production. Many workers mentioned the importance of nitrogen wheat such as Singh and Brar (1994), Hassan and Gaballah (2000) and Salem (2005) for No. of grains/spike and No of spikes/m2 and Ismail et al. (2006) for grain and straw yields. The nutrient supply and demand of root and shoot are inter-dependent due to their different functions and local environmental (Siddique et al., 1990; Li et al., 2001). The ratio of root to shoot (R/S) is an index that reflects growth and dry matter accumulation between root and shoot (Lioert el al., 1999).

Root growth is closely related to physiological metabolism and dry matter accumulation in shoot (Siddique et al., 1990). An excessively low R/S indicates poor root growth, resulting in sufficient water and nutrients for shoot growth. An extremely high R/S may lead to root redundancy, which reduces shoot growth, yield, water and nutrient use efficiencies (Shangguan et al., 2004). Therefore, it is important to coordinate root and shoot relations and maximize dry matter accumulation, water and nutrient use efficiencies (Shangguan et al., 2004; Kahn and Schroeder, 1999). Moreover Galal (2007) reported that grains weight/spike, 100- grain weight and grain and straw yield significantly increased by increasing nitrogen levels.

Partitioning of dry matter between shoot and root is one of the mechanisms involved in the adaptation of plants to particular environment. Therefore, it is important to understand how the two most important variables, Nitrogen (N) and Water, effect root and shoot growth. Nitrogen has been shown to increase the shoot: root ratio in crops and this increase in new leaf formation and leaf area expansion, which results in more dry matter accumulation in the shoot (Reed et al., 1988).

Garabet *et al.* (1998), and Tamaki *et al.*(1999) stated that yields of wheat were increased by irrigation and N fertilizer application. Furthermore, Karim *et al.* (1997) indicated that the highest yield of wheat was recorded under 35% depletion of soil available water with application of 120 kg N/ha.

In fact, nitrogen fertilizer is established to increase the water use efficiency of wheat. The additional N enables the crop to cover the ground quicker and develop a dense leaf canopy, resulting in reduced soil evaporation and better water use efficiency (Holland *et al*. 1999). Nitrogen nutrition has significant effects on root and shoot relations. The effect of nitrogen on root growth depends on the nitrogen concentration at the root surface. If the concentration is optimal, root growth is stimulated (Malzlish et al., 1980). However, if the nitrogen level is above optimal, root growth is reduced (Comfort et al., 1988). The response of root growth to nitrogen supply depends on genotype and stage of development (Arora and Mohan, 2001).

Yield may be further affected by a negative interaction between the two constraints (Passioura, 2002). Cabrera-Bosquet et al. (2007) stated that both water and nitrogen shortage had a strong positive effect on growth. Also, a steady water limitation may strongly affect biomass without consistent changes in WUE. Frequent irrigation events with large amounts of water as well as heavy rainfall increase the potential for N losses below the rooting zone or even to the groundwater via leaching of the mobile fractions (Smika and Watts 1978, Young and Aldag 1982, Burkart and Stoner 2002, Ju et al. 2006).

In addition, nitrogen is the nutrient that is most susceptible to loss (e.g. trough denitrification) and its availability is affected by soil type, tillage, N source, crop rotation and precipitation (Hatfield et al., 2001). Moreover, its recovery by the crop is usually less than 50% applied (Boswell et al., 1985).

Improving water use efficiency (WUE) and NUE are among the main targets of crop research for Mediterranean environments (Raun & Johnson 1999; Hamdy et al., 2003). NUE may also be affected by crop N and water management practices (Tavakkoli & Oweis, 2004). With four water treatments in winter wheat: non-stressed (I_1), stressed during heading and grain filling (I_2), stressed during tillering and jointing (I_3), and stressed throughout spring (I_4), the water use efficiency increased with increments of N through 140 kg ha_{-1} on treatment I_1, and through 70 kg ha_{-1} on treatments I_2 and I_3 but applied Ndid not affect WUE on treatment I_4,Eck

(1988). Abderrazak et al. (1995) reported that increasing rates of N fertilizer up to 140 kg ha^{-1} in wheat significantly increased the water use efficiency, grain yield, grain protein content and total protein yield, while capacity for N uptake decreased. Hussain and AlJaloud (1995) reported that the WUE increased with increase in N rates from 0 to 100%.

Hati et al. (2001), with experiment in black soils of India, found that fertilized plots retained less water at harvest than unfertilized ones. Soil water extraction from deeper layers was higher in fertilized plots than unfertilized ones. ET was higher for irrigated plots (303 mm) than un-irrigated ones (148.7 mm). A study by Lenka et al., (2009), shows significant effect of water and nitrogen in regulating the water use and water extraction pattern in maize and wheat, whereas in each water regime, depletion was significantly higher in treatment receiving 150% N than other treatments including control.

The effect of water availability on shoot and root growth is somewhat similar to that of nitrogen availability. However, other researchers showed that the water regime did not significantly change the rank of corn genotypes for nitrogen use efficiency at high or low soil nitrogen levels (Arora and Mohan, 2001).

10. Nitrogen Use Efficiency

Intensive agriculture with large fertilizer input is one of the major sources of soil and groundwater contamination with nitrates (Schepers and Marter, 1986). This trend is enhanced by mismanaged irrigation practices and induced groundwater recharge (Toussaint 2000).

Nitrogen use efficiency can be improved by other means as well, although practical manipulations of loss mechanisms can be difficult and expensive, and may increase one form of loss while reducing another. The use of conservation tillage practices can be expected to reduce erosion and runoff losses of N. reducing water movement off a field, however, will likely increase infiltration rate and thus NO_3 leaching and denitrification. Surface applications of wastes may also reduce soil –waste contact and accelerate waste drying, enhancing NH_3 volatilization but decreasing the rate of N mineralization. Other conservation practices that have the potential to reduce N losses include more efficient irrigation practices (e.g., versus flood), use of multiple cropping or winter cover crops to trap residual N from wastes, and controlled drainage systems or artificial wet lands to enhance denitrification in field border areas, (Pierzynski et al 1994). Plants only use about 50% of the applied N (Newbould, 1989), which implies a large loss in money and energy.

Farmers use at least double the quantity required by the plants, and unused NO_3 is leached or denitrified N causing environmental pollution (Byrnes 1990; Smith et al., 1990; Davies and Sylvester-Bradley 1995). N efficiency, the lowest the grater applied N (Brown, 1978), can be improved by maintain higher level of NH_4 compared to in the soil. This can be achieved NO_3 by nitrification inhibitors (Prasad and Power 1995), or slow release fertilizer (Shaviv and Mikkelsen 1993), or fertilization with ammonium fertilizers (Lips et al 1990) or large quantity of ammonium fertilizers (Shaviv1988). On account of the above remarks, studies carried out on nitrogen and ammonium nutrition in vegetables aimed to increasing nitrogen use efficiency. A large part of such a research work focuses on leaf vegetables which under high NO_3^-availability, N accumulate large amounts of nitrates (Santamaria et al 1997; Santamaria and Elia 1997), a compound believed to be potentially toxic to human health (Walker 1990; Gangolli et al 1994).

11. Fertilizer use efficiency

Fertilizer use efficiency is a quantitative measure of the actual uptake of fertilizer nutrient by the plant in relation to the amount of nutrient added to the soil as fertilizer. A common form of expression of fertilizer use efficiency is plant recovery or "coefficient of utilization" of the added fertilizer. This is shown in the following equation:

$$\%Utilization of added fertilizer = \frac{Amount of nutrient in the plant Dff}{Amount of nutrient applied as fertilizer} * 100$$

The concept of fertilizer use efficiency, however, is much broader. It implies not only the maximum uptake of the applied nutrient by the crop but also the availability of the applied nutrient under variable climatic and edaphic conditions. Environmental issues, such as pollution resulting from the fertilizer application, should also be considered. It is important to study the efficient use of fertilizers because we are interested to obtain the highest possible yield with a minimum fertilizer application. This is done in field trials by assessing the best fertilizer practices such as sources, timing, placement and their interactions in different farming systems (FAO, 1980; 1983a; 1985).

The measurement of fertilizer use efficiency can be established for each crop by carrying out in practice, a series of carefully designed field experiments, in several representative locations are carried out over a period of time for estimating the effect of placement, timing and source on fertilizer nutrient that result in the most efficient fertilizer uptake by the crop. Yield, particularly economic yield, is generally the most important criteria for the farmer but it is equally important that this yield is obtained with a minimum of fertilizer investment (minimum cost).

11.1. Isotopic techniques in n fertilizer use efficiency studies

In isotopic-aided fertilizer experiments, a labeled fertilizer is added to the soil and the amount of fertilizer nutrient that a plant has taken up is determined. In this way different fertilizer practices (placement, timing, sources, etc.) can be studied.

The first parameter to be determined when studying the fertilizer uptake by a crop by means of the isotope techniques is the fraction of the nutrient in the plant derived from the (labeled) fertilizer, i.e.: Ndff.

Often this fraction is expressed as a percentage, i.e.:

$$\% Ndff = Ndff * 100$$

The procedure followed in the calculation of this fraction and other derived parameters for nitrogen using ^{15}N labeled materials is **given below:**

11.1.1. Measurements needed for experiments with ^{15}N

In summary, for all field and greenhouse experiments with ^{15}N (or any other stable isotope) labeled materials, the following basic primary data need to be recorded for each plot:

- Dry Matter (D.M.) yield for the whole plant or sub-divided into plant parts.
- Total N concentration (%N in dry matter) of the whole plant or plant parts as in previous point. This is done by chemical methods, e.g. Kieldahl or combustion (Dumas.)
- Plant % ^{15}N abundance, which is analyzed by emission or mass spectrometry.
- Fertilizer % ^{15}N abundance.
- 15N labeled fertilizer(s) used and N rate(s) of application.

11.1.2. Calculations for experiments with ^{15}N

% ^{15}N abundance is transformed into atom % ^{15}N excess by subtracting the natural abundance (0.3663 atom %N) from the % N abundance of the sample. Afterwards the following calculations can be made:

$$NUptake = N\% * DryYield$$

$$\%\,Ndff = \frac{\%\,N^{15}a.ex.inPlant}{\%\,N^{15}a.ex.infertilizer} * 100$$

$$Ndff(kg.ha^{-1}) = \%Ndff * totalNinPlant$$

11.1.3. Quantification of fertilizer N uptake

The nitrogen isotope composition, i.e. the ^{15}N/total N ratio, of any material can be expressed as atom % ^{15}N (a) or simply % ^{15}N abundance. This isotopic ratio of a sample is measured directly in a single determination by optical emission or mass spectrometry. Since the % ^{15}N natural abundance (a0) is 0.3663 atom % ^{15}N this has to be subtracted from the % ^{15}N abundance (a) of any enriched material to obtain the atom % ^{15}N excess (% ^{15}N a.e. = a') or ^{15}N enrichment. What then is Ndff? It is the fraction of N in the plant derived from the ^{15}N labeled fertilizer from simple isotope dilution principles.

Therefore, for the calculation of % Ndff it is necessary to determine the atom % ^{15}N excess of the plant samples and of the fertilizer(s) used in the experiment For instance if Ndff = 0.25 this means that 1/4 of the nitrogen in the plant came from the fertilizer. If soil and fertilizer were the only sources of N available to the plant, then the remaining 3/4 of the nitrogen in the plant came from the soil. If these fractions are expressed in percentages then %Ndff = 25% and % Ndfs = 75 %, where % Ndfs is % N derived from soil

$$\%\, Ndfs = 100 - \%Ndff$$

$$Ndfs\ (kg.ha^{-1}) = \%Ndfs * totalNin(GrainORStraw)$$

$$\%\, NUE = \frac{Ndff\ (kg.ha^{-1})}{Rateoffertilizer\ (kg.ha^{-1})} * 100$$

$$\%\, FertilizerNRemainedinSoil\ (FNR) = \frac{\%N^{15}a.e.inSoilAfterHarvest}{\%N^{15}a.e.inFertilizer}$$

12. Nitrogen Status Using Isotopic Technique

12.1. Principles and applications of isotopes in fertilizer experiments

12.1.1. Introduction

Fertilizers are one of the essential inputs for maintaining or increasing the soil fertility level in intensive agricultural systems. The purpose of applying fertilizers is primarily to supply the crop with essential plant nutrients to ensure normal plant growth. The major plant nutrients (N, P and K) have to be applied regularly to compensate for the amounts exported from the soil during harvest. Other plant nutrients such as Ca, Mg, S and the micronutrients e.g. Zn, Mo, B may also need to be added to maintain adequate levels of these nutrients, or to correct deficiencies (FAO, 1983 b,1984).

Fertilizers are applied to facilitate plant uptake of a particular nutrient. Increased uptake can lead to a yield response if the particular nutrient is a limiting factor. It is important though to note that the fertilizer is not applied to obtain a yield response but to feed the plant. The yield response is a consequence of the additional uptake of the nutrient when other production factors are adequate.

A combination of all the production factors and conditions in an agricultural system results in a given yield and only if all factors are optimized (fertilizer, soil, plant, water, pest control, etc.) yield will be maximized. In fact the contribution of fertilizer to increased yield is perhaps of the greatest importance among the purchased inputs. Fertilizer, when used in combination with the other adequate inputs such as high-yielding varieties and irrigation water, can result in a positive interaction thereby further increasing its contribution to increased yield (Fried, 1978).

In the decade of 1980 due to the substantial increases in the cost of the fertilizers and their limited supplies to resource-poor farmers, enhanced nutrient management was pursued through maximizing the efficiency of nutrient uptake from various inorganic and organic sources utilizing two complementary approaches: i) identification, and /or selection of plant genotypes efficient at low levels of soil available nutrients and tolerant to predominant stress conditions, and ii) development of integrated plant nutrition systems to maximize yield responses and to reduce environmental contamination and degradation of natural resources (Zapata and Hera,1995).

12.1.2. Isotopic Methods

The recovery of N by crops may be determined using both un-labeled and labeled N-fertilizer (Harmsen and Moraghan, 1988) but the measurement of the recovery of N- fertilizer in the soil and the subsequent calculation of N losses from the crop soil system, can only be made using ^{15}N-labeled fertilizer (Powlson et al., 1992).

The use of ^{15}N isotopes for studying N-uptake by plant was reviewed by Hauck and Bremner (1976). The ^{15}N isotope labeling technique, involving the application of ^{15}N enriched fertilizers to soil, provide reliable integrated estimates of the proportions and amount of N_2-fixed by several grain and pasture legumes. The different isotopic methods used can be classed into four techniques **as follows**:

12.1.2.1. ^{15}N Natural Abundance Technique

The $^{15}N/^{14}N$ ratio of soil N has been observed to be usually slightly higher than that of atmospheric nitrogen (Hauck and Bremner, 1976), analyzed clover (Trifolium spp.), and soybean (Glycine max L. Merr) and grass for ^{15}N values. They found that the N_2-fixing species had lower of ^{15}N values than the grass or the soil in which the tested species were grown. This method makes many assumptions, which are controversial, because at the natural abundance level discrimination between ^{15}N and ^{14}N can cause serious errors.

12.1.2.2. The Isotope Dilution technique

The isotope dilution principles and the equation involved have been outlined by Danso et al. (1986). Its use for estimating N_2 –fixation requires the application of equal nitrogen rates and ^{15}N enrichment of a given fertilizer to both the legume and a suitable non-fixing reference control crop. In principle, since the legume and the reference crop are absorbing nitrogen from a similar zone, the $^{15}N/^{14}N$ ratio of soil-derived nitrogen is supported to be the same for both crops. However, in addition to the nitrogen absorbed from the soil, the N_2-fixing legume also assimilates atmospheric N_2 of lower $^{15}N/^{14}N$ ratio than the soil nitrogen. This results in a dilution of the $^{15}N/^{14}N$ ratio of the soil nitrogen assessed by the reference crop. The extent, to which this soil $^{15}N/^{14}N$ ratio is dilution, is an indication for the efficiency of N_2-fixation.

12.1.2.3. The A-Value Technique:

On soils of low nitrogen status, non-fixing crop grow poorly, while N_2-fixing plants grow well. This could cause a mistake in growth and nitrogen uptake patterns between the reference and the fixing crop. But the addition of large amounts of fertilizer nitrogen to legumes has been shown to inhibit N_2-fixation (Allos and Bartholomew, 1959; Wagner and Zapata, 1982; and Hardarson et al., 1984a). The use of the A-value approach, however, allows the application of different nitrogen rates and ^{15}N enrichments of a given fertilizer to legume and reference crop to estimate the amount of the N_2-fixed (Fried and Broeshart, 1975). The A-value for the nodulating legume represented soil and fixed nitrogen, while the A-value for the non-nodulating crop reflected by only soil nitrogen.

The amount of symbiotically fixed nitrogen is calculated by multiplying the difference in A-value between the legume and the non- nodulating crop by percentage utilization of fertilizer nitrogen by the nodulating leguminous crop. Therefore, the usual calculation requires determination of an apparent A-value for both N_2-fixing and non-fixing crops.

In determining A values, it is important to note the following:

- Since the available amount of nutrient in the soil is an inherent property of the soil, it will be constant for any set of experimental conditions.
- The "A value" is a yield independent parameter. It is only necessary to determine the respective proportions absorbed from each source, so as to determine the A value of the soil. No yield data need to be recorded. The absolute amounts of nutrient taken up from either source do not appear in the equation.
- The A value for a particular soil remains constant even at different rates of application of the same fertilizer standard. In other words, the available amount of nutrient in the soil is independent of the rate of fertilizer applied. Thus, in soil fertility studies, it is sufficient to use only one rate of application to assess the nutrient supply of a soil and make relative comparisons of fertilizer treatments (Aleksic et al., 1968; Broeshart, 1974).
- Any change in the set of experimental conditions (nature, source, placement, timing, etc) will affect the magnitude of the A value of the soil. Also changes in harvesting times are important, since the plant samples reflect the nutrient isotopic composition of the soil from the seeding time until harvesting time. These changes of the A value of a soil with time can be easily observed in a time course study of nutrient uptake using labeled fertilizers (Rennie, 1969; Smith and Legg, 1971; Broeshart, 1974; Zapata et al., 1987).
- The determination of the A value of the soil has a number of practical applications, such as the quantitative evaluation of fertilizer practices, in

particular fertilizer sources, and the design of further isotope-aided experiments (Rennie, 1969; Broeshart, 1974; Fried, 1978; IAEA, 1983b).

- Extensive research work using A values has been done for most plant nutrients, both macro-and micronutrients (Fried, 1954; IAEA, 1976; IAEA, 1980; Vose, 1980; IAEA, 1981; Wagner and Zapata, 1982).

12.1.2.4. Use of ^{15}N Technique

This method provides a direct evidence for N_2-fixation, if the ^{15}N concentration in plant exposed to $^{15}N_2$ greater than 0.3663 %. The extent to which ^{15}N is detected in the plant also provides an estimate of the proportion of the plants nitrogen that was derived from fixation, and thus a direct method for quantifying N_2-fixed. Also the use of gas tight growth chambers for the assay of N_2-fixation in legumes has been described by Witty and Day (1978).

MATERIALS AND METHODS

Chapter 4

Materials and Methods

Experimental and Site Description

Two field experiments were conducted during November-April 2012-13 onto two different sites; the **first one** was carried out at the field of farmers, beside Ismailia canal on sandy soil, and the **second one** was carried out at real field of wheat cultivation in Abou Ghaleb, Embabah, Giza on clay soil; both using drip irrigation system, water regime and nitrogen application strategy, in order to explore the next items:

- Tracing the effect of water regime and Nitrogen applications mode on N nutrition.
- Determine the long-term nitrogen mass losses from the soil under existing irrigation and fertilizer application rates.
- Drawing the relationship could exist between the water regime, nitrogen distribution, attributable to produce large crop yield without excessive losses.
- Develop strategies that would minimize the potential of nitrogen losses that pollute the surrounding environment.
- Educate the proper rate of Nitrogen fertilizer could keep optimum yield and minimize the environmental risks.
- Evaluation of the output of studied management practices on the environmental conditions.

1. Experimental layout

Field experiment trails were conducted to investigate the movement of water and nitrogen within the soil-water- plant continuum under different fertilizer rates using ^{15}N and different water regimes. Then used the data obtained to estimate the potential of proper nitrogen fertilization strategy in combination with suitable water regime on wheat production with keeping in mind the environmental impact. The application of ^{15}N isotope technique demonstrated the great power of stable isotope research in improving fertilizer use efficiency and gives us the chance to determine the exact values of nitrogen gained by plants from the different N portions. The use of other nuclear techniques related to water scheduling will help us to estimate exactly soil /water/ plant and nutrient relationships (neutron moisture gauge). The application of such nuclear techniques will give us a clear vision about the success of our applied strategies including nitrogen fertilizer and irrigation water regime.

1.1. Soils

a. Sandy soil located at Inshas area related to Kaleobeia Governorate lies 50 km distance to the north of Cairo capital, situated at 30^{o} 24^{-} N latitude, 31^{o} 35^{-} E longitude, while the altitude is 20 m above the sea level was used to conduct the first field experiment, Some chemical and physical properties of this soil are presented in Table (5)

Table (5) Some physical and chemical characteristics of experimental loamy sand soil

Particle Size distribution %			**Texture class**	**Bulk density d.cm^{-3}**	**F.C % By weight**	**PWP % By weight**	**P mg/kg**	**Total N mg/kg**	
Sand	**Silt**	**Clay**							
78.8	15	6.2	Loamy Sand	1.15	11.2	2.7	3.2	26.4	
PH 1:2.5	**CaCo$_3$%**	**O.M mg/kg**	**EC ds/m at 25^{o}C**	**Ca^{++}**	**Na^{+}**	**Mg^{++} mg/kg**	**K^{+}mg/kg**	**CO$_3^{--}$**	**HCO$_3^{-}$**
8.30	0.75	22.2	0.21	0.15	0.19	50	192	-	0.09

b. Clay Soil located at Abou Ghaleb, Embabah, Giza, lies 39 km distance to the north of Cairo capital, situated at 30^{o} 16^{-} N latitude, 30^{o} 56^{-} E longitude, was used to conduct the second field experiment. Some chemical and physical properties this soil was presented in Table (6)

Table (6) Some physical and chemical characteristics of experimental clay loam soil

Particle Size distribution %			**Texture class**	**Bulk density d.cm^{-3}**	**F.C % By weight**	**PWP % By weight**	**P mg/kg**	**Total N mg/kg**	
Sand	**Silt**	**Clay**							
14.4	26.2	59.4	Clay Loam	1.28	33.68	14.92	3.2	22.3	
PH 1:2.5	**CaCo$_3$%**	**O.M mg/kg**	**EC ds/m at 25^{o}C**	**Ca^{++}**	**Na^{+}**	**Mg^{++} mg/kg**	**K^{+}mg/kg**	**CO$_3^{--}$**	**HCO$_3^{-}$**
8.14	0.89	26.4	0.44	0.15	0.19	50	300	-	0.15

Material And Methods

1.1.1. Chemical analysis:

- Calcium carbonate was determined gas metrically using Collins calcimeter according to the method of Nelson (1982).
- Total soluble salts were determined conductmeterically in the soil paste extract according to Rhoades (1982).
- pH value was measured using a pH-meter with combined glass reference electrode in the soil water paste extract Mclean (1982).
- Soluble sodium and potassium were determined in the soil water paste extract by flame photometer as described by Knudsen et al. (1982).
- Soluble calcium and magnesium were determined titrmetricall in soil paste extract with versant solution and ammonium purpuratc as an indicator for calcium while Eirochrome black T was used as an indicator for calcium plus magnesium according to lanyon and Head (1982).
- Chloride was determined titrmetrically in soil paste extract with silver nitrate using potassium chromate as an indicator Mohr's method, as described by Adriano and Doner (1982).
- Soluble carbonate and bicarbonate were determined by titration with a standard solution of hydrochloric acid using phenolphthalein as an indicator for the former and methyl orange for the latter, Nelson (1982).
- Soluble sulfate was determined by the difference between total soluble cations and anions.
- Organic matter content was determined according to Walkly and Black's methods (Nelson and Sommers, 1982).

1.1.2. Physical analysis:

- Mechanical analysis was carried out according to the international pipette method and Calgon solution was used as a dispersing agent as described by Gee and Bauder (1986).

- Soil bulk density was determined according to Klute and Dirksen (1986).
- Soil moisture characteristics were determined in the laboratory (F.C & W.P.), can be determined using a pressure plate apparatus. At the permanent wilting point the soil moisture coefficient is defined as the moisture content corresponding to a pressure of -15 atmospheres from a pressure plate test. Although actual wilting points can be somewhere between -10 and -20 atm, the soil moisture content varies little in this range. Thus, the -15 atm moisture content provides a reasonable estimate of the wilting point. Figure (7)

Figure (7) Pressure plate apparatus

1.2. Fertilization strategies

- Ammonium Sulphate (20%N) was broadcasting at rate of 178 and 238 kg N ha^{-1} for clay loam and loamy sand soils, respectively (about 873 and 1152kg Ammonium Sulphate ha^{-1}, respectively, according to the *staff of Agronomy Department, Agriculture Research Center* (2012), Labeled Nitrogen Fertilizer (2% ^{15}N atom excess) as Ammonium Sulphate with three rates as: 60%, 80% and 100 % N from recommended rate of 178 and 238 kg N ha^{-1} for clay and sand soil, respectively,representing;
- **In Clay loam Soil:**100% (178 kg N),80% (142.4 kg N) and 60% (106.8 kg N),
- **In loamy Sand Soil:**100% (238 kg N), 80% (190.4 kg N) and 60% (142.8 kg N).

Spitted into tow modes of application, Figure (9) asfollows:

- **Mode A**: = (25%) of Nitrogen at Seedling, 25 days after sowing, (25%) of Nitrogen at Tillering, and Jointing (50%).
- **Mode B**: 1/3, 35%, of Nitrogen at Seedling, 25 days after sowing, and 2/3, 65%, at Jointing.

Note: Selecting the Nitrogen applications time and methods was according to FAO, 2005, time and method of fertilizer application, *Fertilizer use by crop in EGYPT*, chapter 7. And also, following the results showed by Z. Shi et al.,(2012).

- Super phosphate (15.5% P_2O_5),and Potassium Sulphate (48%K_2O), were added at rate of 240 and 360 Kg P_2O_5 ha^{-1} for the clay and sand soil, respectively, and 120 Kg K_2O $ha^{-1}$for the sand soil. All are mixedwith soil during seedbed preparation.

1.3. Irrigation treatments (Water Application Regimes)

Irrigation water was applied at three regimes SWR_1:(100 %), SWR_2:(80 %), and SWR_3:(60%) from the crop evapotranspiration (Et_c mm/day), by using CLIAMWAT 2.0 for FAO-PM (CROPWAT program, SMITH, 1992), which is a joint publication of the Water Development and Management Unit and the Climate Change and Bioenergy Unit of FAO, to calculating the reference evapotranspiration (ET_omm/day), and the crop water requirement, whereas, obtaining the crop coefficient value ($K_c$mm/day) of Wheat (*Triticum aestivum*) from the publication data of FAO (*Doorenobs and Pruitt 1977*).

Note; CLIMWAT is a climatic database to be used in combination with the computer program CROPWAT. and allows the calculation of crop water requirements, irrigation supply and irrigation scheduling for various crops for a range of climatological stations worldwide.

1.4. Layout of the experimental dimensions

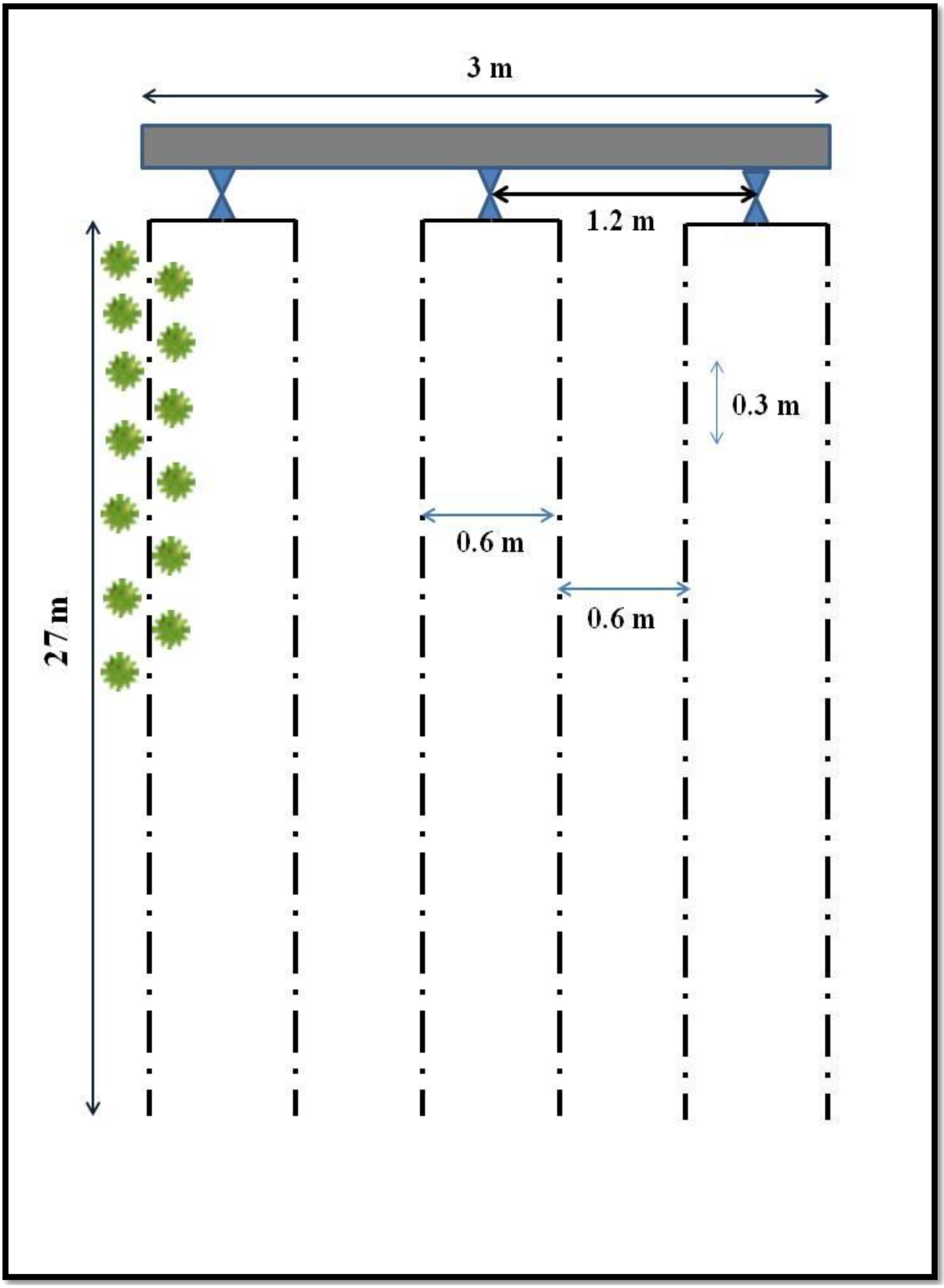
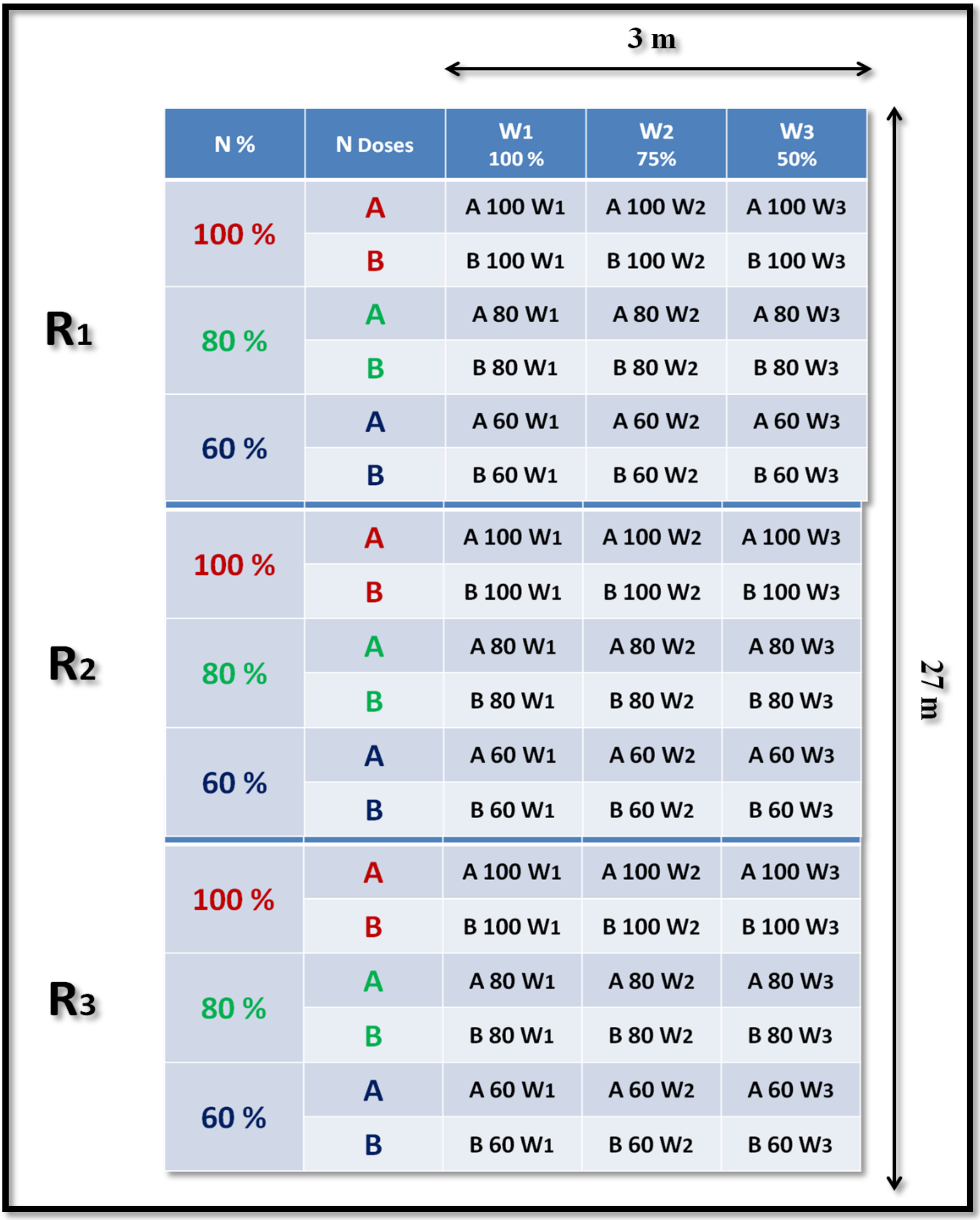


Figure (8) Layout of the experimental dimensions

1.5. Layout of the experimental unites



	N %	N Doses	W1 100 %	W2 75%	W3 50%
R1	100 %	A	A 100 W1	A 100 W2	A 100 W3
		B	B 100 W1	B 100 W2	B 100 W3
	80 %	A	A 80 W1	A 80 W2	A 80 W3
		B	B 80 W1	B 80 W2	B 80 W3
	60 %	A	A 60 W1	A 60 W2	A 60 W3
		B	B 60 W1	B 60 W2	B 60 W3
R2	100 %	A	A 100 W1	A 100 W2	A 100 W3
		B	B 100 W1	B 100 W2	B 100 W3
	80 %	A	A 80 W1	A 80 W2	A 80 W3
		B	B 80 W1	B 80 W2	B 80 W3
	60 %	A	A 60 W1	A 60 W2	A 60 W3
		B	B 60 W1	B 60 W2	B 60 W3
R3	100 %	A	A 100 W1	A 100 W2	A 100 W3
		B	B 100 W1	B 100 W2	B 100 W3
	80 %	A	A 80 W1	A 80 W2	A 80 W3
		B	B 80 W1	B 80 W2	B 80 W3
	60 %	A	A 60 W1	A 60 W2	A 60 W3
		B	B 60 W1	B 60 W2	B 60 W3

Figure (9) Layout of Experiment Unites

Total experiment unites was;

3(N) * 2 (M) * 3 (W) * 3 (R) = 54 Unites.

Where;
N = Nitrogen rates, 100, 80 and 60 % from the recommended rate.
M = Nitrogen Mode, A and B,
W = Water Regimes, 100, 75 and 50% from Crop Water Requirements.
R = Number of Replicates.

1.6. Drip irrigation system components

A drip irrigation system was used to carry out this experiment with PVC main lines of (50 mm) diameter, 32 mm diameter as sub main lines and 16 mm low laterals laid parallel to serve crop rows with 30 cm distance between each other. GR built in emitters with nominal discharge 4 L/hr spaced with 60 cm between each other. Sandy screen filter, pressure gauges and control valves.

2. Tested crop

Two field experiments were established during November & December-April 2012-13 onto two different sites, Clay loam and New reclaimed loamy sand soils, using wheat (*Triticum aestivum* L. Giza 168) provided by Field Crops Research Institute, Agriculture Research Center, Giza, Egypt under drip irrigation system on 15 cm distances between plants, and the recommended sowing dates were applied as following:

a. <u>Clay loam Soil</u> in 20th of November, 2012.
b. <u>New reclaimed Loamy Sand Soil</u> in 10th of December, 2012.

2.1. Determinations

At the end of the experiment, 21st "sand" and 23rd "clay", April 2013, the harvesting processes have been started in terms of collecting the plant, and soil samples.

2.2. Water

2.2.1. Total water Applied

The total applied water in both field were;

- In Clay Soil = 535.7 mm (5400 m^3/ha^{-1}),
- In Sand Soil = 560.1 mm (5645.808 m^3/ha^{-1}).

2.2.1.1. Loamy Sand (New reclaimed Soil)

Table (7) Water applied in new reclaimed loamy sand soil field

Dates	Plant Stage (BBCH-scale)		Gross Irrigation (mm)	Irrigation Intervals (days)	Operating time (Hours)	Operating time (Minutes)		
						SWR (100%)	SWR (75%)	SWR (50%)
10-Dec	00	Initial	0.9	5	0.04	2.4	1.8	1.2
19-Dec	09		5.1	5	0.23	13.8	10.3	6.9
29-Dec	12		5.9	5	0.27	15.9	11.9	8.0
3-Jan	13		3	5	0.14	8.1	6.1	4.1
8-Jan	1.		3	5	0.14	8.1	6.1	4.1
13-Jan	19	Development	3.8	5	0.17	10.3	7.7	5.1
18-Jan	22		4.3	5	0.19	11.6	8.7	5.8
23-Jan	23		6.1	5	0.27	16.5	12.4	8.2
28-Jan	2.		7.2	5	0.32	19.4	14.6	9.7
2-Feb	29		9.7	5	0.44	26.2	19.6	13.1
7-Feb	32		10.5	5	0.47	28.4	21.3	14.2
12-Feb	3.		9.2	5	0.41	24.8	18.6	12.4
17-Feb	39	Mid-season	10.1	5	0.45	27.3	20.5	13.6
22-Feb	45		13.4	5	0.60	36.2	27.1	18.1
27-Feb	51		15.4	5	0.69	41.6	31.2	20.8
4-Mar	56		20.2	5	0.91	54.5	40.9	27.3
9-Mar	61		21.4	5	0.96	57.8	43.3	28.9
14-Mar	65		25.1	5	1.13	67.8	50.8	33.9
19-Mar	69		26	5	1.17	70.2	52.7	35.1
24-Mar	73		28.8	5	1.30	77.8	58.3	38.9
29-Mar	77		29.5	5	1.33	79.7	59.7	39.8
3-Apr	83		31.5	5	1.42	85.1	63.8	42.5
8-Apr	85		32.9	5	1.48	88.8	66.6	44.4
13-Apr	87	Late-season	34.9	5	1.57	94.2	70.7	47.1
18-Apr	89		36.3	5	1.63	98.0	73.5	49.0
23-Apr	92		38.8	5	1.75	104.8	78.6	52.4

2.2.1.2. Clay Loamy Soil

Table (8) Water applied in Clay loamy soil field

Dates	Plant Stage (BBCH-scale)		Gross Irrigation (mm)	Irrigation Intervals (days)	Operating time (Hours)	Operating time (Hours)		
						SWR (100%)	SWR (75%)	SWR (50%)
21-Nov	00	Initial	47.9	10	2.16	2.16	1.62	1.08
15-Dec	12		48	10	2.16	2.16	1.62	1.08
25-Dec	1.	Development	21.2	10	0.95	0.95	0.72	0.48
5-Jan	19		25.2	10	1.13	1.13	0.85	0.57
15-Jan	23		28.9	10	1.30	1.30	0.98	0.65
25-Jan	32		32.9	10	1.48	1.48	1.11	0.74
5-Feb	3.	Mid-season	38.4	10	1.73	1.73	1.30	0.86
15-Feb	45		29.6	10	1.33	1.33	1.00	0.67
25-Feb	51		30.6	10	1.38	1.38	1.03	0.69
5-Mar	69		32.2	10	1.45	1.45	1.09	0.72
15-Mar	71		40.1	10	1.80	1.80	1.35	0.90
25-Mar	75		46.8	10	2.11	2.11	1.58	1.05
5-Apr	85	Late-season	53.6	10	2.41	2.41	1.81	1.21
15-Apr	89		60.3	10	2.71	2.71	2.04	1.36

2.3. Plant

At the maturity, the harvest area was cut at ground level and bounded, then, a sub-sample of 10 plants was collected at random from each replicate experimental unite, weight was recorded and the plant samples were oven dried and kept for nitrogen analysis. A sub-sample of 10 stems was threshed separately and the straw and grain saved for analyzing and estimating total N in deferent plant parts and total N uptake by plant organs (straw and grains), using the standard equation, and the following determinations were taken:

2.3.1. Total yield, Grain & Straw (ton/ha^{-1}),

2.3.2. Plant Height (cm),

2.3.3. Spikelet Height (cm)

2.3.4. Thousand Seed Weight (TSW),

2.3.5. Harvest Index (HI)

2.3.6. Total N uptake (kg ha^{-1}),

2.3.7. Total N uptake by deferent plant parts (kg ha^{-1});

Nitrogen content was determined in dried and finely grounded plant parts by wet digestion using semi micro-Kjeldahl method (Bremner and Mulvaney, 1982). Samples of 0.2 gm of the dry material "Straw, Grain" were digested by sulphuric acid and perchloric acid (1:1). Distillation of the digested material was carried out using 40% NaOH and ammonia was received in 4% Boric acid solution. The distillates were then titrated with N/70 H_2SO_4 Solution using the mixed methyl-red-bromo cresol green indicator. Nitrogen percentage was calculated on the dry weight basis. Total nitrogen content "nitrogen uptake" (mg) calculated by multiplying N% by dry weight of different plant parts. ***Calculation according to Chapman and Pratt (1961).***

$$\% = T * N * 14 * \left(\frac{f}{s}\right) * (\frac{100}{w})$$

Where
T : volume of N of H2SO4 consumed in titration
N : normality H2SO4 (N/70)
14: Equivalent weight of nitrogen
f : Volume of final dilution of digested sample (50 ml)
S : aliquot sample
W : sample weight

2.4. Soil available Nitrogen;

Nitrogen found in soils in two forms, ammonium-N and Nitrate-N. Ammonium ions are produced in soil through breakdown of organic matter or manures. Nitrate ions are the final form of N breakdown/reactions, but it can also be supplies to soil by fertilizers.

Mineral-N is determined using 1% K_2SO_4 as the extracting solution in a 1:10 (soil :

water) ratio. Ammonium (NH_4) and Nitrate (NO_3) plus Nitrite (NO_2) are determined by stream distillation of ammonia (NH3), Devard's Alloy for NO_3 (Bremner and Keeney, 1965). The distillate is collected in saturated $H_3BO_3$and titrated to pH 5.0 with dilute H_2SO_4. This method determines dissolved and observed forms of NH_4^+, NO_3^- and NO_2- in soil. The summation of this method if referred to as Mineral-N (Keeney and Nelson, 1982; Buresh et al., 1982).

Reagents

- Potassium sulphate solutions (K_2SO_4), 1% dissolve 100 g reagent-grade potassium sulphate in DIW and bring to 1 L volume with DIW.
- Devarda's Alloy.
- Boric acid solution (H_3BO_3), 4%: prepare as in Kjeldahl-N.
- Sulphouric acid solution (H_2SO_4), 0.01 N prepare as in Kjeldahl-N.

Procedure

- Weight 10 g air-dry soil (2 mm) into a 250 ml Erlenmeyer flask, and add 100 ml 1% potassium sulphate solution (1:10 soil: solution ratio).
- Stopper flasks, shake for 1 hour on an orbital shaker at 200-300 rpm, and filter suspensions using Whitman No. 42 filter paper.
- Before starting distillation, the distillation unit should be steamed out for at
- Least 10 minutes; adjust steam rate to 7-8 ml distillate per minute.
- Water should flow through the condenser jacket at a rate sufficient to keep distillate temperature below 22°C.
- Carry out distillation as follow:
- For the ammonia-nitrogen, do the distillation as Kjeldahl-N.
- For the nitrate-nitrogen, the same procedure will be followed but with adding 0.2 g of the Devarda's alloy before adding the Na-OH; in this case the result will be the total mineral nitrogen (Ammonia + Nitrate-N).

Calculations

- For ammonium-N in air-dry soil;

$$NH_4 - N(ppm) = \frac{(v_1 - B_1) * N * R * 14.01 * 1000}{W_t}$$

- For the total mineral N in soil;

$$NH_4 - N(ppm) = \frac{(v_2 - B_2) * N * R * 14.01 * 1000}{W_t}$$

Where;
V1 = Volume of 0.01 N H_2SO_4 titrated for sample (ml),
V2 = Volume of 0.01 N H_2SO_4 titrated for the sample, with Devarda's Alloy (ml),
B1 =Blank titration volume (ml),
B2 =Blank titration volume with Devarda's Alloy (ml),
N = Normality of H_2SO_4 solution,
14.01 = Equivalent weight of Nitrogen,
R = Ratio between total volume of the extract and the extract volume used for distillation,
Wt = Weight of air-dry soil (10g),
NO_3-N = Total mineral Nitrogen-ammonia-N.

2.5. Use of ^{15}N technique

Nitrogen ^{15}N is one of the most common stable isotopes used in a large scale in studies of soil/plant/fertilizer relationships. Stable isotopes are used in the same way as radioactive isotopes in soil/plant studies. Whereas radioactive isotopes emit particles which are captured in photomultiplier tubes and counted, stable isotopes are separated from each other by passing a gascontaining them through a strong magnetic field which deflects them differentially according to their mass.

2.5.1. Measurement of stable isotopes

Isotopes have identical chemical properties but some slightly different physical properties. Detection methods use one of these properties such as mass, emission spectrum, IR absorption. The most common and most precise method to measure stable isotopes is mass spectrometry. For the determination of ^{15}N emission spectrometry can also be used, but with much less precision.

2.5.2. On-line sample preparation

The NOI-6 and NOI-7 emission spectrometers have a built-in sample preparation system, which converts NH_4^+ nitrogen to N_2 gas on-line by the Rothenberg conversion. The N_2 sample and He carrier gas passes through a drying tube and a discharge tube where the pressure is adjusted to about 10 tore by means of a vacuum pump and two flow restrictors. Measurement time is about 1 minute per sample with a standard deviation of about 1 % Figure (10)

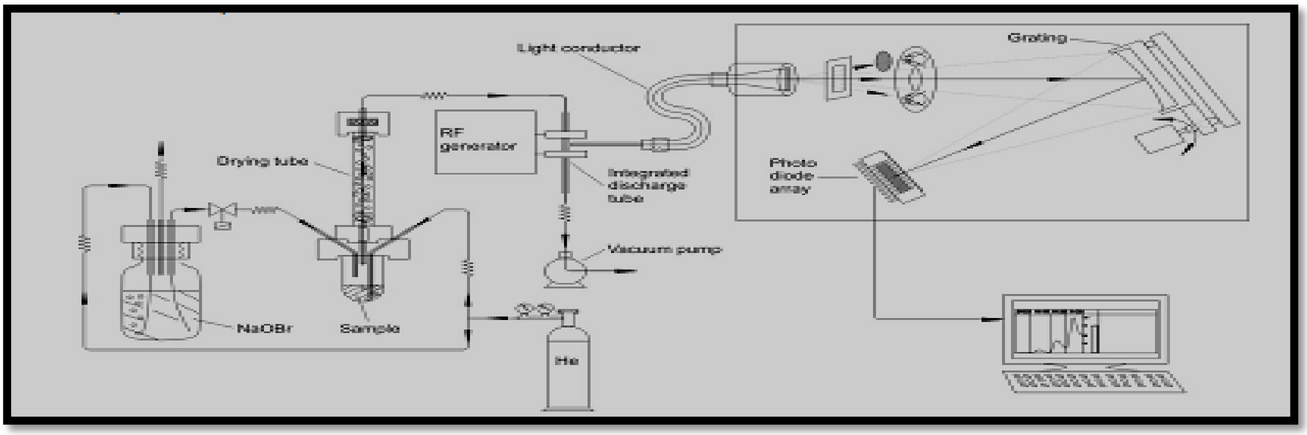


Figure (10) Modern emission spectrometer with integrated sample preparation system (NOI-6 PC)

2.5.3. Principles and equation

The following equation of the "Isotope balance" or "Isotope dilution" was used to obtain the desired ^{15}N enrichment when N-fertilizer labeled and N-fertilizer un-labeled was mixed.

$$m = (m_1 + m_2)\frac{a'}{a''} \qquad \text{(IAEA, 1983)}$$

Where;
m_1 =quantity of material with ^{15}N abundance,
m_2 =quantity of material with ^{14}N,
a' =% ^{15}N atom excess of material and
a" =% 1^{5}N atom excess desired in the final mixture.

2.5.4. ^{15}N-Analysis

The Dumas dry combustion method (Fidler and Proksch, 1975) was used to convert the nitrogen compounds in the dry samples into nitrogen gas. In this method, all the organic or inorganic nitrogen compounds are converted in one step to N_2 gas as follow see Figure (10)

$$N - Drysample + \frac{CuO + CaO}{550\ C^{o}} N_2 gas$$

The reaction was carried out on dry material at 550°C for 6 hours, in a closed nitrogen free atmosphere (discharge) Pyrex-tubes, using copper oxide (CuO) as an oxidizing agent and calcium oxide (CaO) to absorb water and gases like CO_2. When the reaction was completed and the system reached room temperature, the $^{15}N/^{14}N$ ratio was determined by emission spectrometry ^{15}N-analyzer (FAN Fisher NOI-6PC Spectrometer Figure (10) in the ^{15}N-Laboratory, Soils and Water Research Department, Atomic Energy Authority, Cairo, Egypt, using the following equations developed by *Hauck and Bremner* (1976).

$$\% N^{15} Atomex. = \frac{100}{2R+1}$$

$$R = \frac{I_{28}}{I_{29}} * M$$

Where:
I_{28}=Spectralintensityfor28N,peakheight,
I_{29}=Spectralintensityfor29N-30Nand
M=Multipliervaluefor29N-30N,attenuationV

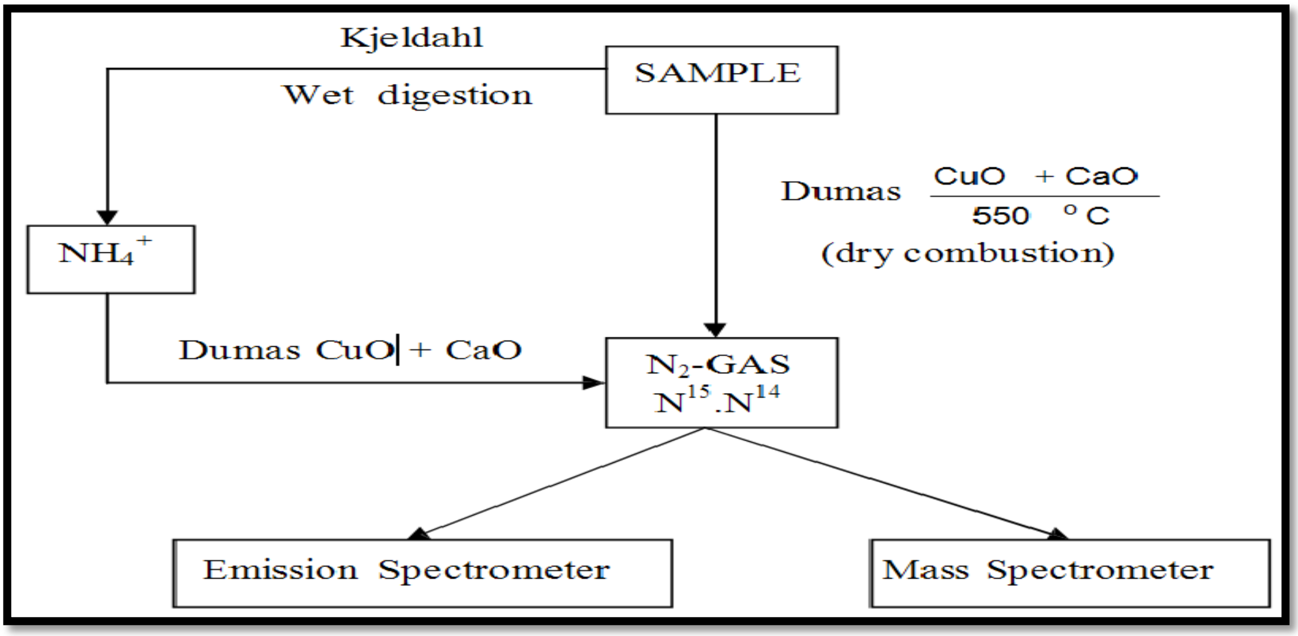


Figure (11) Methods of sample preparation for ^{15}Nanalysis

2.5.5. Nitrogen Isotope Calculation

Total nitrogen, Nitrogen sources (% Ndff and % Ndfs), N-Remain in soil, ^{15}N-Recovery, Nitrogen Balance, and (NUE), were calculated according to (*Hardarson and Danso*, 1990) as follows:

$$NUptake = N\% * DryYield\ (GrainORStraw)$$

$$\% \, Ndff = \frac{\% \, N^{15} a.ex.in \, (GrainORStraw)}{\% \, N^{15} a.ex.infertilizer} * 100$$

$$Ndff \, (kg.ha^{-1}) = \%Ndff * totalNin(GrainORStraw)$$

$$\% \, Ndfs = 100 - \%Ndff$$

$$Ndfs \, (kg.ha^{-1}) = \%Ndfs * totalNin(GrainORStraw)$$

$$\% \, NUE = \frac{Ndff \, (kg.ha^{-1})}{Rateoffertilizer \, (kg.ha^{-1})} * 100$$

$$\% \, FertilizerNRemainedinSoil \, (FNR) = \frac{\%N^{15} a.e.inSoilAfterHarvest}{\%N^{15} a.e.inFertilizer}$$

$$FNRemained(kg.ha^{-1}) = \% \, FNRinSoil * RateofFertilizeradded \, (kg.ha^{-1})$$

$$N^{15} Recovery(kg.ha^{-1}) = SumofDW(GrainORStraw) * N^{15} a.ex.insample$$

Where:
% Ndff = % Nitrogen derived from fertilizer,
% NUE = % Nitrogen use efficiency,
% Ndfs = % Nitrogen derived from the soil,
Ndff = Total nitrogen derived from the fertilizer (kg ha^{-1})
Ndfs = Total nitrogen derived from the soil (kg ha^{-1}),
DW = Dry Weight (ton ha^{-1}).

2.6. Statistical analysis

Data collected were subjected to the proper statistical analysis of variance of split-split plot design according to the procedures outlined by Snedecor and Chochran (1967). The three **Water Regimes** were taken as (**A**) level, **Nitrogen Mode** treatments as (**B**) level and **Nitrogen Doses** as (**C**) level. To compare treatment means; L.S.D. at 5% level of significance was used according to Steel and Torrie (1980). All statistical analysis was performed by using analysis of variance technique of (M-stat-C) Computer software package.

RESULTS AND DISCUSSION

Chapter 5

Results and Discussion

Crop yields must increase substantially over the coming decades to keep pace with global food demand driven by population and income growth. Ultimately global food production capacity will be limited by the amount of land and water resources available and suitable for crop production, and by biophysical limits on crop growth. The present study was carried out under Egyptian conditions in two field experiments represents two different textured soils, i.e clay and sand soils as growth media of wheat (*Triticum aestivum* L. Giza 168) crop. Evaluation of nitrogen fertilization practices and irrigation water regime was taken into consideration. Data released from this study will be discussed in the following chapter.

Vegetative Growth Parameters

A. CLAY SOIL EXPERIMENT

1. Plant height

The plant height of wheat crop affected by nitrogen fertilization practices and irrigation water regime is presented in **Table (9)**, and graphically illustrated by **Figure (12).**Plant height was, to somewhat extent, differentially affected by nitrogen application dose or mode as well as water regime. In this respect, the application of 100% nitrogen dose induced variable values of plant height as affected by water regime. Means indicated that plant height under 100% water regime (114.5 cm) was a little bit higher than those of 50% (96.5 cm) and 75% (111.3 cm) water regime, respectively.

There was no significant difference between the modes of application when plant height was concerned. This holds true with the other two rates of nitrogen fertilizer applications (60 and 80%). In conclusion, the plant height was significantly higher with the application of 100% nitrogen fertilizer than those of 80% and 60%, respectively. Concerning the effect of water regime, the plant height values reflected no significant difference between 100% and 75% water regime but both of them were higher than those of 50% water regime. Since there was no big significant difference between 100% and 80% nitrogen dose as well as 100% and 75% water regime, we can conclude that the

80% nitrogen dose in combination with 75% water regime could be accepted as suitable treatment that gave the best values of plant height. In other turn, 20% of nitrogen fertilizer and 25% of water requirements could be saved without significant reduction of plant height as representative of plant growth.

Table (9): Effect of nitrogen fertilizer application strategy and irrigation water regime on plant height (cm) of wheat grown on clay soil.

N Level %	N Mode	Water Regime			Mean
		50	75	100	
100	A	101.0^{A}	109.5^{A}	112.5^{A}	**107.7^{A}**
	B	92.0^{A}	113.0^{A}	116.5^{A}	**107.2^{A}**
Mean		**96.5^{d}**	**111.3^{ab}**	**114.5^{a}**	**107.4^{a}**
80	A	106.5^{A}	108.5^{A}	98.5^{A}	**104.5^{A}**
	B	98.5^{A}	96.5^{A}	105.5^{A}	**100.2^{A}**
Mean		**102.5^{bcd}**	**102.5^{bcd}**	**102.0^{bcd}**	**102.3^{ab}**
60	A	85.0^{A}	99.5^{A}	101.5^{A}	**95.3^{A}**
	B	81.5^{A}	102.5^{A}	112.0^{A}	**98.7^{A}**
Mean		**83.3^{e}**	**101.0^{cd}**	**106.8^{abc}**	**97.0^{b}**
A		97.5^{cd}	105.8^{ab}	104.2^{bc}	**102.5^{A}**
B		90.7^{d}	104.0^{bc}	111.3^{a}	**102.0^{A}**
Mean		**94.1^{b}**	**104.9^{a}**	**107.8^{a}**	**102.3**

LSD value $_{0.05}$ A: 4.2 B: 5.6 C: n.s AB: 9.6 AC: 6.9 BC: n.s

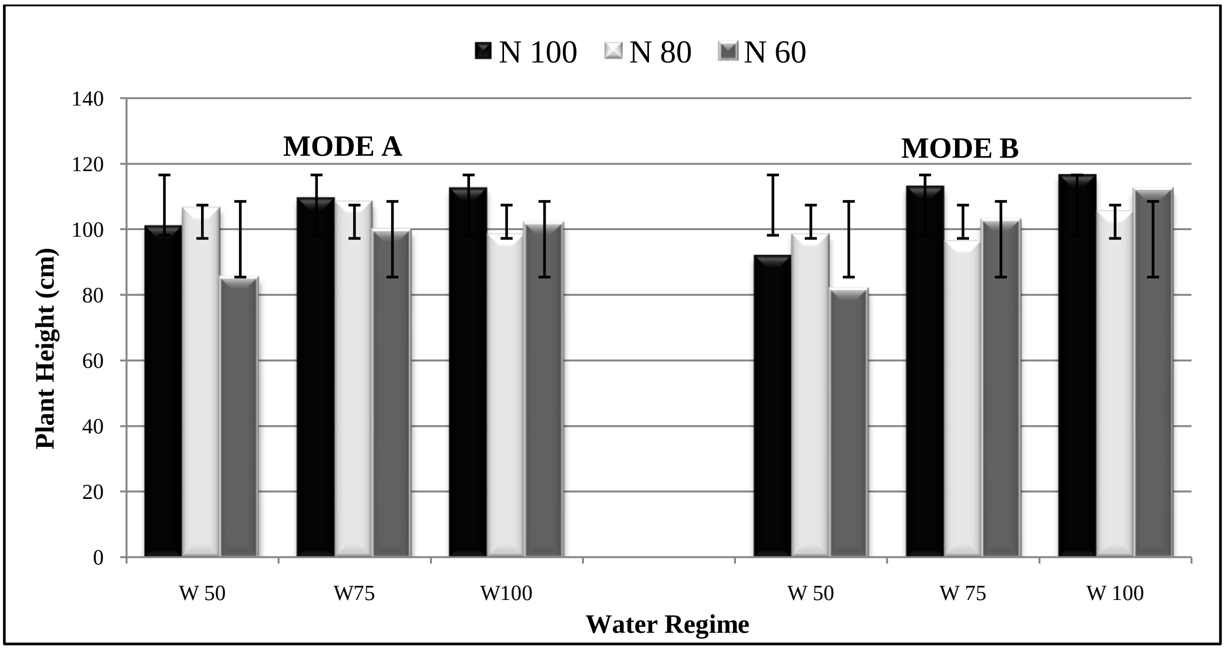


Figure (12): Effect of nitrogen fertilizer application strategy and irrigation water regime on plant height (cm) of wheat grown on clay soil.

2. Spikelet Length

The Spikelet Length of wheat crop affected by nitrogen fertilization practices and irrigation water regime is presented in **Table (10)** ,and graphically illustrated by **Figure (13)** . Data showed fluctuated values of Spikelet Length as affected by water regime and mode of application under 100% nitrogen additions. At 50 and 75% water regime, Spikelet Length was a little bit different in mode B comparing to mode A, while the 100% water regime doesn't reflect any significant difference between application modes. Similar trends but in fluctuation were noticed under 80% and 60% dose of nitrogen application. Means of water regime indicated no significant difference in Spikelet Length as affected by water regime. This was true under all nitrogen application doses.

The overall means of either nitrogen doses or mode of application showed the superiority of 100% (18.83 cm) and 80% (18.17 cm) doses over 60% (16.5 cm). At the same time, mode B (19.33 cm) surpass mode A (18.33 cm) under 100% N dose. Reversible trend was recognized with 80% N dose where mode A resulted in 19.17 cm against 17.17 cm for mode B. There was no significant difference between mode A and mode B when 60% N was added. Likewise plant height, the moderate amount of nitrogen fertilizer and water requirement seems to be most suitable treatments that achieve reasonable Spikelet Length without adverse effects. It seems that the impact of mode of nitrogen application is related to water regime and rate of application.

Table (10): Effect of nitrogen fertilizer application strategy and irrigation water regime on spike Length (cm) of wheat grown on clay soil.

N Level %	N Mode	Water Regime			Mean
		50	75	100	
100	A	19.00^{abc}	16.00^{def}	20.00^{a}	**18.33^{ab}**
	B	20.50^{a}	17.50^{bcd}	20.00^{a}	**19.33^{a}**
Mean		**19.75^{A}**	**16.75^{A}**	**20.00^{A}**	**18.83^{a}**
80	A	19.00^{abc}	19.50^{ab}	19.00^{abc}	**19.17^{a}**
	B	17.00^{cde}	14.50^{f}	20.00^{a}	**17.17^{bc}**
Mean		**18.00^{A}**	**17.00^{A}**	**19.50^{A}**	**18.17^{a}**
60	A	16.50^{def}	16.00^{def}	17.50^{bcd}	**16.67^{c}**
	B	15.00^{ef}	16.50^{def}	17.50^{bcd}	**16.33^{c}**
Mean		**15.75^{A}**	**16.25^{A}**	**17.50^{A}**	**16.50^{b}**
A		18.17^{A}	17.17^{A}	18.83^{A}	**18.06^{A}**
B		17.50^{A}	16.17^{A}	19.17^{A}	**17.61^{A}**
Mean		**17.83^{ab}**	**16.67^{b}**	**19.00^{a}**	**17.83**

LSD value $_{0.05}$ A:2.30 B: 1.40 C: n.s AB: n.s AC: n.s BC: 1.36 ABC: n.s

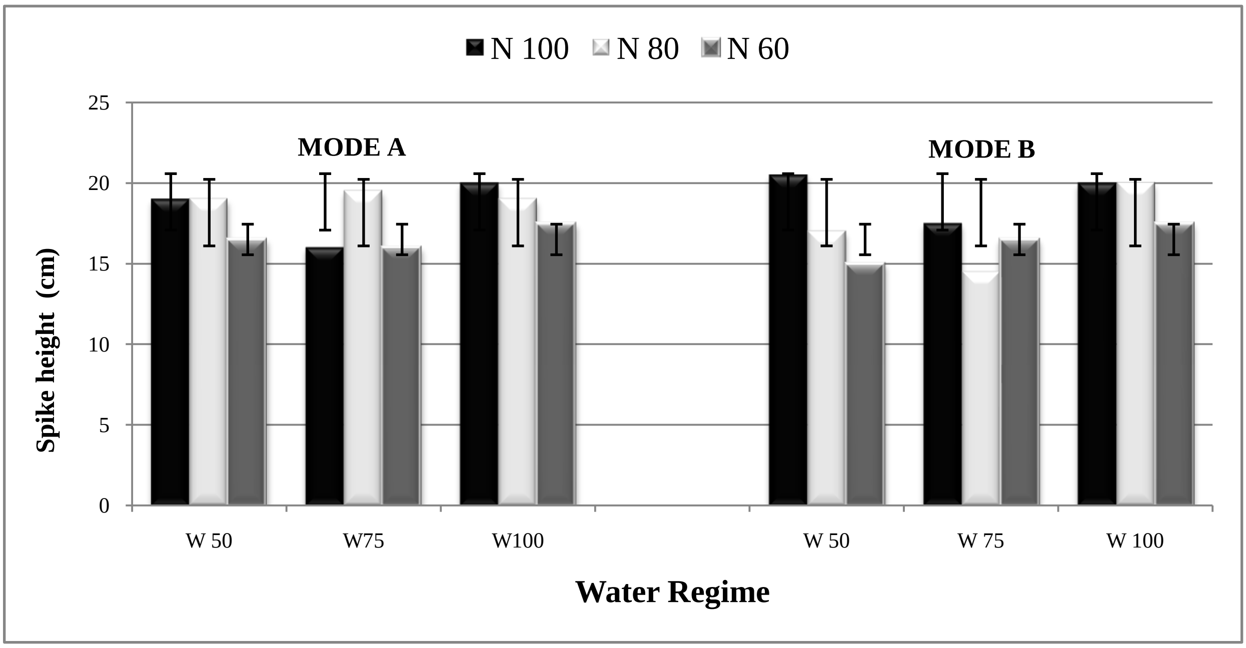


Figure (13): Effect of nitrogen fertilizer application strategy and irrigation water regime on spike length (cm) of wheat grown on clay soil.

3. Straw yield t.ha^{-1}

The dry straw yield of wheat crop affected by nitrogen fertilization practices and irrigation water regime is presented in **Table (11),** and graphically illustrated by **Figure (14).**Straw yieldof wheat plants fertilized with100% of recommended N rate was significantly varied according to water regime and mode of application. The highest value (9.2 t.ha^{-1}) of straw dry yield was detected with 50% water regime followed by 75% (7.2 t.ha^{-1}) then 100% (6.8 t.ha^{-1}) of water requirement, when mode A was considered. Reverse was noticed when mode B was followed where the best value (5.8 t ha^{-1}) of straw dry yield was recorded with 100% water regime while the lowest value (4.1 t.ha^{-1}) was at 75% water regime. Mean value of straw yield resulted from the interaction between water regime and mode of N application indicated the superiority of Mode A (7.733 t.ha^{-1}) over Mode B (5.133 t ha^{-1}).

The overall means of straw yield as affected by water regime reflected surpass of 50% over 100% and 75% treatments, respectively. Similar trends but with some exception and to somewhat low extent, were observed with the application of 80% of N recommended rate. Another picture was drawn with the application of 60% of N recommended rate, where the best value of straw yield (8.2 t.ha^{-1}) was noticed with 100% water regime when mode A was concerned against mode B (6.5 t.ha^{-1}). Reverse was noticed with 75% water regime, while there was no significant difference between N application mode under 50% water regime.

From the abovementioned data, we can conclude that straw yield was significantly progressed by addition of 100% and 60% N rates using mode A of application. Concerning water requirement, the overall means indicated the superiority of 100% followed by 50% then 75% water regime.

Few years ago, different wheat cultivars were grown on Egypt's different main soil types, old irrigated land of the Nile valley, newly reclaimed sandy soil and plants exposed to different rates of nitrogen fertilizer labeled with ^{15}N (Abdel Monem 2000). He reported that the efficiency of applied nitrogen is low and better management of both fertilizer and irrigation water is needed to improve plant production. In old irrigated soil, he found that the application of N fertilizer resulted in significant increases in grain and straw yields of both cultivars with differential responses. On the other hand, there were significant decreases in yield with 40% less irrigation. Similar trends were indicated in newly reclaimed soil but to lower extent. His results of straw and grain yields on old irrigated soil were nearly closed to our results but ours were to some extent higher.

Table (11): Effect of nitrogen fertilizer application strategy and irrigation water regime on straw dry yield (t.ha^{-1}) of wheat grown on clay soil.

N Level %	**N Mode**	**Water Regime**			**Mean**
		50	**75**	**100**	
100	**A**	9.20^{A}	7.200^{A}	6.800^{A}	**7.733^{A}**
	B	5.50^{A}	4.100^{A}	5.800^{A}	**5.133^{A}**
Mean		**7.350^{ab}**	**5.650^{ab}**	**6.300^{a}**	**6.433^{A}**
80	**A**	5.800^{A}	5.800^{A}	4.400^{A}	**5.333^{A}**
	B	5.500^{A}	4.400^{A}	5.500^{A}	**5.133^{A}**
Mean		**5.650^{ab}**	**5.100^{ab}**	**4.950^{ab}**	**5.233^{A}**
60	**A**	4.800^{A}	5.800^{A}	8.200^{A}	**6.267^{A}**
	B	4.800^{A}	6.200^{A}	6.500^{A}	**5.833^{A}**
Mean		**4.800^{b}**	**6.000^{ab}**	**7.350^{ab}**	**6.050^{A}**
A		**6.600^{ab}**	**6.267^{ab}**	**6.467^{ab}**	**6.444^{A}**
B		**5.267^{ab}**	**4.900^{b}**	**5.933^{a}**	**5.367^{A}**
Mean		**5.933^{b}**	**5.583^{c}**	**6.200^{a}**	**5.906**

LSD value $_{0.05}$ A: 0.09 B: n.s C: n.s AB: 0.62 AC: 0.48 BC: n.s ABC: n.s

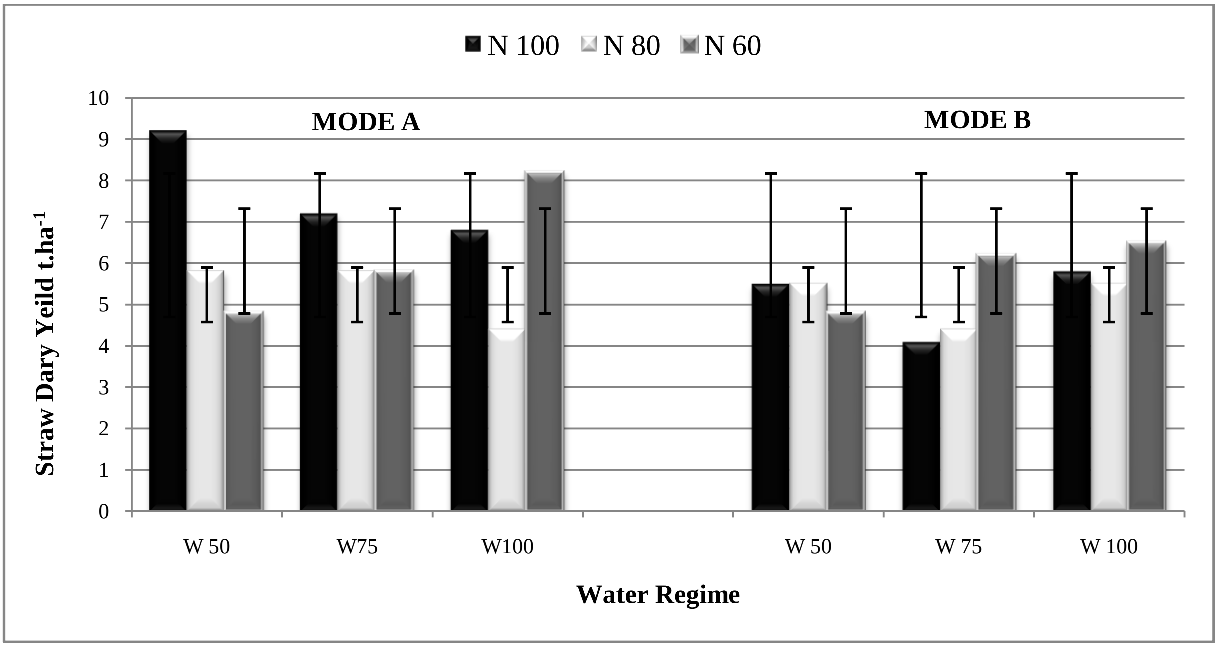


Figure (14): Effect of nitrogen fertilizer application strategy and irrigation water regime on straw dry yield (t.ha^{-1}) of wheat grown on clay soil.

4. Grain yield t.ha^{-1}

The dry grain yield of wheat crop affected by nitrogen fertilization practices and irrigation water regime is presented in**Table (12)**, and graphically illustrated by **Figure (15)**. It not seems that grain yield was improved by addition of water regime; it tends true when the mode B was followed where the best values was (7.05 t.ha^{-1}). Revisable tendency appear when mode A if used, where the highest value (5.0 t.ha^{-1}) obtained when 100% N rate combined with 100% water regime.

Application of 80% N rate showed that the best values of grain yield were obtained with 50% (8.39t.ha^{-1}) and 75% (8.01 t.ha^{-1}) water regime, respectively when nitrogen was applied in mode B. These result might be supported by Singh et al. (1987) "The yield and yield attributes were highest and irrigation efficiency was maximum when irrigation was applied at an IW/CPE ratio of 0.75 in a normal-rainfall year and at 0.90 in a low-rainfall year. Also, nitrogen fertilization increased the yield of wheat linearly and was maximum at 120 kg nitrogen per hectare".

However, some researchers were in consistent with these finding as found by (Espindula et al., 2010; Freitas et al., 1995; Teixeira Filho et al., 2007, 2010; Vieira et al., 1995), "The best yields were usually achieved with nitrogen fertilization levels ranging from 70 to 120 kg ha^{-1}.

Results And Discussion

Considering the mode of application method, at any water regime interacting with any nitrogen rate, the mode B shows significance different over mode A among all the attributed studies. In this respect with somewhat exception at 60% of recommended nitrogen rate, the best values; 7.05 and 8.39 (t.ha^{-1}) at 100% and 80%, respectively, were recorded with mode B.

Under mode A, all the detected values showed that the grain yield increased when water regime reduced, it holds true under all treated water regime, with a slight difference when 100% water regime interacted with 60% of recommended rate of nitrogen.

Comparing 100% and 80% of recommended rate of nitrogen among the water regimes, it wroth mentioned that the grain yield is increased wherever the nitrogen rate decreased. In this respect, the 80% of recommended rate of nitrogen still has the superiority over 100% of recommended nitrogen rate. At 60% of recommended rate of nitrogen the values are fluctuating among all water regimes. That is in contrary to some reports of nitrogen use in wheat crops, ranging from 90 to 225 kg ha^{-1} of N, without significant responses in grain yield under more favorable environment and management conditions (Penckowski et al., 2009).

Overall means of grain yield as affected by interaction of N fertilizer rates and mode of application as well as water regime indicated the superiority of 80% N recommended rate and mode B of application over other treatments. Concerning water regime, the best values of wheat grain yield were obtained when either 50% or 100% was applied.

Table (12): Effect of nitrogen fertilizer application strategy and irrigation water regime on grain yield (t. ha^{-1}) of wheat grown on clay soil.

N Level %	N Mode	Water Regime			Mean
		50	75	100	
100	A	4.00	2.72	5.00	**3.91**
	B	7.05	6.30	6.48	**6.61**
Mean		**5.53**	**4.51**	**5.74**	**5.26**
80	A	5.67	5.42	7.04	**6.04**
	B	8.39	8.01	6.90	**7.77**
Mean		**7.03**	**6.72**	**6.97**	**6.91**
60	A	6.78	5.71	3.40	**5.29**
	B	5.00	2.65	6.34	**4.66**
Mean		**5.89**	**4.18**	**4.87**	**4.98**
A		**5.48**	**4.62**	**5.15**	**5.08**
B		**6.82**	**5.65**	**6.57**	**6.35**
Mean		**6.15**	**5.14**	**5.86**	**5.71**

LSD value $_{0.05}$ A: 0.49 B: 0.44 C: sig. AB: 0.77 AC: 0.61 BC: 0.61 ABC: 1.06

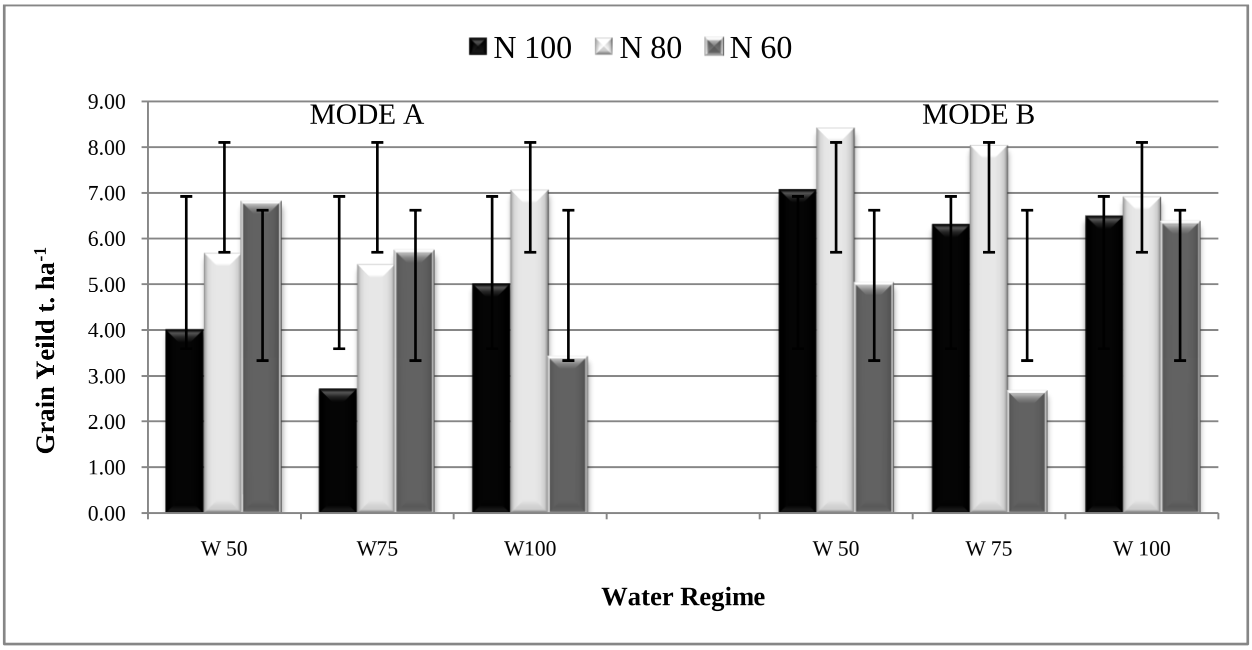


Figure (15): Effect of nitrogen fertilizer application strategy and irrigation water regime on grain yield (t.ha^{-1}) of wheat grown on clay soil.

5. Thousand-Seed-Weight (TSW gram)

The Thousand-Seed-Weight of wheat crop affected by nitrogen fertilization practices and irrigation water regime is presented in **Table (13)**, and graphically illustrated by **Figure (16)**. Thousand-Seed-Weight tended to increase with increasing water regime up to 100%. This holds true when 100% N recommended rate was either applied using mode A or B. In case of 50% water regime, application of 100% N rate, mode A resulted in higher significant value (35.67 g) of Thousand-Seed-Weight than those recorded with mode B (25.01 g). There was no significant difference between mode A and B when 75% and 100% water regime were applied.

Mean of Thousand-Seed-Weight of wheat plants treated with 100% N recommended rate showed no significant difference between the two modes while it improved by application of 100% (42.79 g) water regime as compared to other water treatments.

Thousand-Seed-Weight of plants treated with 80% N recommended did not reflect any significant differences between either water regimes or modes of nitrogen application. Reversible trend was observed with application of 60% N rate where the best values of Thousand-Seed-Weight (45.54 g and 43.11 g) were detected with 100% water regime for mode A and mode B, respectively.

A little bit difference was noticed between mode A and mode B. This holds true under all water regimes and nitrogen added rates. Overall means indicated a little bit difference between 80% and 60% N rates but both of them were higher than 100% N rate. In the same time, overall means of water regime indicated the leading of 100% water regime over others. This holds true with all nitrogen application rates.

Table (13): Effect of nitrogen fertilizer application strategy and irrigation water regime on Thousand-Seed-Weight (g) of wheat grown on clay soil.

N Level %	**N Mode**	**Water Regime**			**Mean**
		50	**75**	**100**	
100	**A**	35.67^{A}	34.52^{A}	41.75^{A}	**37.31^{A}**
	B	25.01^{A}	34.91^{A}	43.82^{A}	**34.58^{A}**
Mean		**30.34^{b}**	**34.71^{b}**	**42.79^{a}**	**35.94^{b}**
80	**A**	41.89^{A}	40.19^{A}	40.30^{A}	**40.79^{A}**
	B	43.84^{A}	44.19^{A}	43.33^{A}	**43.78^{A}**
Mean		**42.86^{a}**	**42.19^{a}**	**41.81^{a}**	**42.29^{a}**
60	**A**	43.10^{A}	36.59^{A}	45.54^{A}	**41.74^{A}**
	B	39.97^{A}	24.61^{A}	43.11^{A}	**35.89^{A}**
Mean		**41.53^{a}**	**30.60^{b}**	**44.33^{a}**	**38.82^{ab}**
A		40.22^{A}	37.10^{A}	42.53^{A}	**39.95^{A}**
B		36.27^{A}	34.57^{A}	43.42^{A}	**38.08^{A}**
Mean		**38.24^{ab}**	**35.83^{b}**	**42.97^{a}**	**39.02**

LSD values $_{0.05}$ A: 5.59 B: 3.81 C: n.s AB: 6.60 AC: n.s BC: n.s ABC: n.s

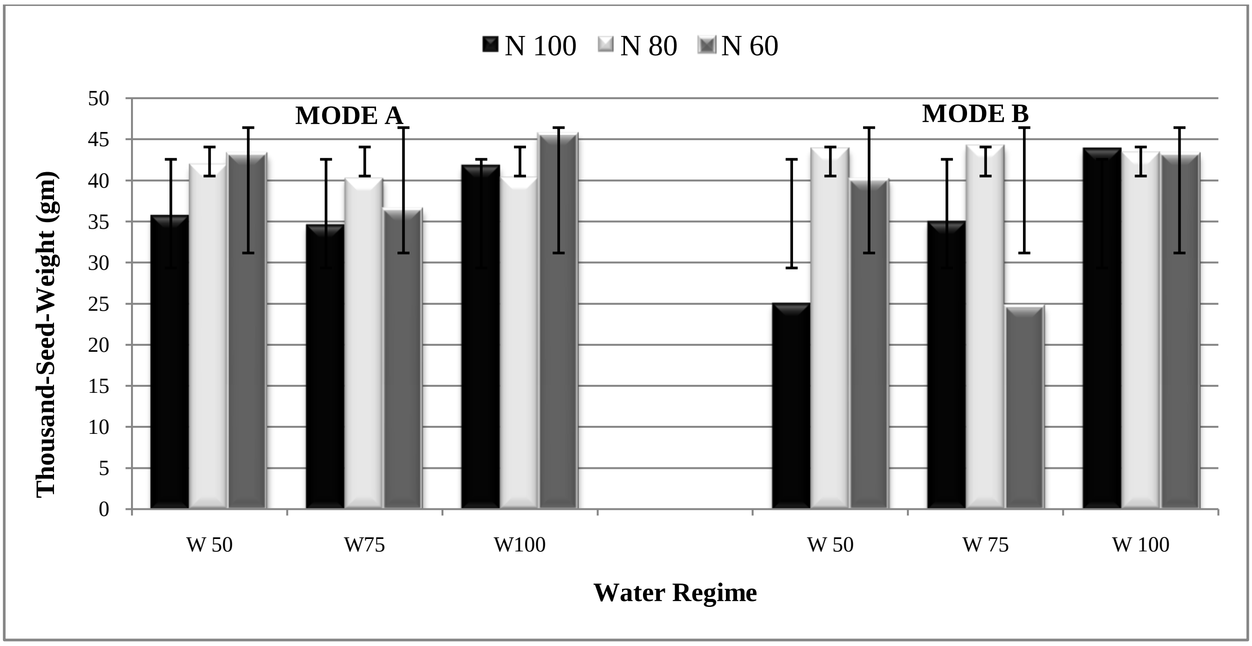


Figure (16): Effect of nitrogen fertilizer application strategy and irrigation water regime on Thousand-Seed-Weight (g) of wheat grown on clay soil.

6. Harvest Index (HI)

The harvest index of wheat crop affected by nitrogen fertilization practices and irrigation water regime is presented in **Table (14)**, and graphically illustrated by**Figure (17),** the harvest index in case of 100% N rate tended to increase with increasing water regime percentage when mode A of N application was followed. In case of mode B under the same treatment, some exception was noticed with 75% water regime where the best HI (0.61) was detected.

The overall means of this treatment indicated the superiority of mode B over mode A and 100% water regime over others. Similar trend but to somewhat higher extent, was noticed with 80% N recommended rate. Reversible trend was observed with 60% N rate where HI tended to decrease with increasing water regime and in the same time there was no significant difference between the two modes of N application.

The overall means indicated no significant difference between either N rates or water regime. Comparison held between N application modes reflected superiority of mode B over mode A when 100% and 80% N rates were concerned while there was no difference when 60% N rate was applied.

Concerning harvest index, our results are nearly closed to those obtained by Feng et al. (2011), who found that harvest index (HI) was ranged from 0.36 up to 0.62 in correlation to water treatments, i.e. moderate drought stress (MD); well-watered condition (WW); irrigated (IR); rainfed (RF).

Table (14): Effect of nitrogen fertilizer application strategy and irrigation water regime on harvest index (HI) of wheat grown on clay soil.

N Level %	N Mode	Water Regime			Mean
		50	75	100	
100	A	0.30	0.27	0.42	**0.33**
	B	0.56	0.61	0.53	**0.57**
Mean		**0.43**	**0.44**	**0.48**	**0.45**
80	A	0.49	0.48	0.62	**0.53**
	B	0.60	0.65	0.56	**0.60**
Mean		**0.55**	**0.56**	**0.59**	**0.57**
60	A	0.59	0.50	0.29	**0.46**
	B	0.51	0.30	0.49	**0.43**
Mean		**0.55**	**0.40**	**0.39**	**0.45**
A		**0.46**	**0.42**	**0.44**	**0.44**
B		**0.56**	**0.52**	**0.53**	**0.53**
Mean		**0.51**	**0.47**	**0.48**	**0.49**

LSD value $_{0.05}$

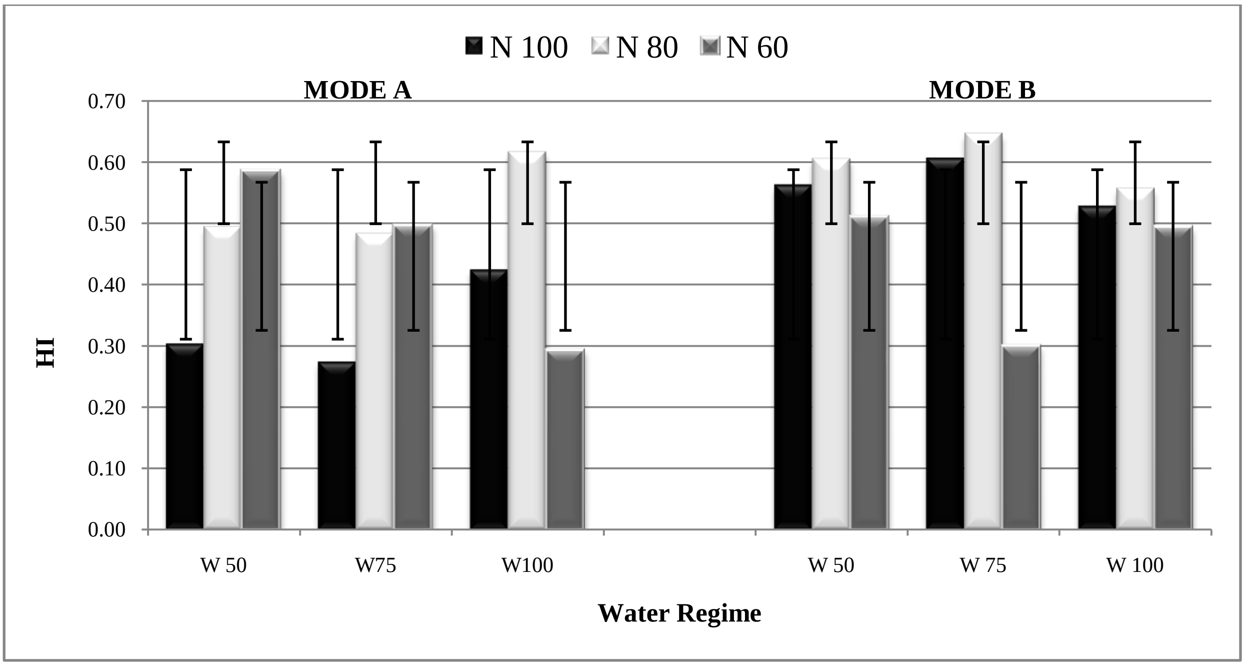


Figure (17): Effect of nitrogen fertilizer application strategy and irrigation water regime on harvest index (HI) of wheat grown on clay soil.

B. SAND SOIL EXPERIMENT

The new reclaimed areas are continuously increasing and water for irrigation will became the limiting factor. The interaction between fertilization and Irrigation are considered the important factors for increasing yield production.

1. Plant Height

The plant height of wheat crop affected by nitrogen fertilization practices and irrigation water regime is presented in**Table (15)**, and graphically illustrated by **Figure (18)**. Plant height was, to somewhat extent, differentially affected by nitrogen application dose or mode as well as water regime. In this respect, the application of 100% nitrogen dose induced variable values of plant height as affected by water regime. Means indicated that plant height under 100% of water regime (86 cm) was a little higher than those of 50% (81 cm) and 75% (82 cm) water regime, respectively. These results corroborated the findings of Haikel and Melegy, (2005), and Mesbah, (2009). There was no significant difference between the modes of application when plant height was concerned. This holds true with 80% of N doses with somewhat exception in 60% N doses, where the Mode A has a superior values than those under Mode B.

In conclusion, the plant height was significantly higher with the application of 100% nitrogen fertilizer than those obtained with 80% and 60%, respectively.

Concerning the effect of water regime, the plant height values reflected no significant between all water regimes. Since there was no big significant difference between 100% and 80% nitrogen dose as well as 100%, 75% and 50% water regime, we can conclude that the 80% nitrogen dose in combination with 50% water regime could be accepted as suitable treatment that gave the best values of plant height. In other turn, 20% of nitrogen fertilizer and 50% of water requirements could be saved without significant reduction of plant height as representative of plant growth.

Table (15): Effect of nitrogen fertilizer application strategy and irrigation water regime on plant height (cm) of wheat grown on sand soil.

N Level %	N Mode	Water Regime			Mean
		50	75	100	
100	A	80.00^{cde}	83.50^{abc}	86.50^{a}	**83.33^{A}**
	B	82.00^{bcde}	80.50^{cde}	85.50^{ab}	**82.67^{A}**
Mean		**81.00^{A}**	**82.00^{A}**	**86.00^{A}**	**83.00^{a}**
80	A	80.00^{cde}	83.00^{abcd}	81.00^{cde}	**81.33^{A}**
	B	80.00^{cde}	82.00^{bcde}	79.50^{def}	**80.50^{A}**
Mean		**80.00^{A}**	**82.50^{A}**	**80.25^{A}**	**80.92^{a}**
60	A	79.00^{ef}	80.00^{cde}	76.00^{fg}	**78.33^{A}**
	B	73.50^{g}	75.00^{g}	79.00^{ef}	**75.83^{A}**
Mean		**76.25^{A}**	**77.50^{A}**	**77.50^{A}**	**77.08^{b}**
A		79.67^{A}	82.17^{A}	81.17^{A}	**81.00^{A}**
B		78.50^{A}	79.17^{A}	81.33^{A}	**79.67^{A}**
Mean		**79.08^{A}**	**80.67^{A}**	**81.25^{A}**	**80.33**

LSD value $_{0.05}$ **A: n.s B: 2.58 C: n.s AB: n.s AC: n.s BC: n.s ABC: 3.66**

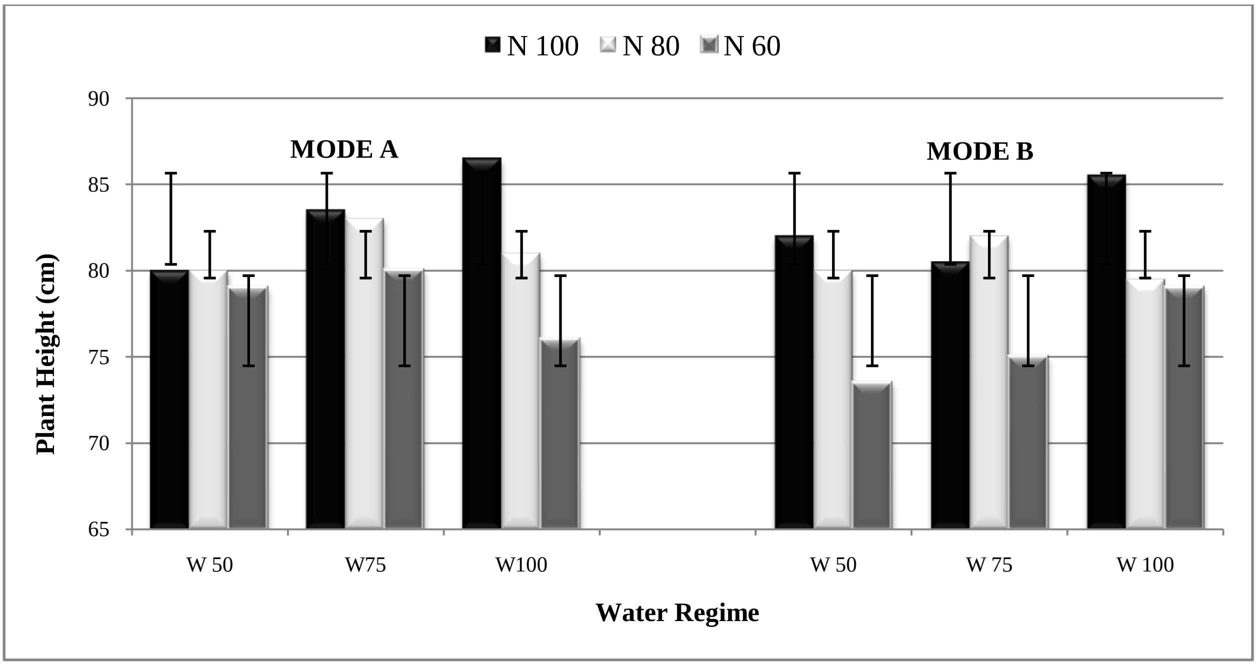


Figure (18): Effect of nitrogen fertilizer application strategy and irrigation water regime on plant height (cm) of wheat grown on sand soil

2. Spikelet Length

The Spikelet Length of wheat crop as affected by nitrogen fertilization practices and irrigation water regime is presented in **Table (16)**, and graphically illustrated by **Figure (19)**. Data showed fluctuated values of Spikelet Length as affected by mode of application and water regime, with a little exception under 100% water regime, in 100%

and 80% nitrogen additions science there was no that significant difference between modes of application.

At 75% and 100% water regime, Spikelet Length doesn't reflect any significant difference in mode B comparing to mode A, while at 50% water regime there was a little difference between application modes. Thus the availability of high amount water regime may cause a shortage/losses of nitrogen per plant, and this led to reduce the spike height. These obtained results could be inconsistent with many researchers which as they have reported the reversal effect of water deficit on the spike length in wheat "the spike length increased as irrigation increased" (Swati et al., 1985; Ahmad, 1994 and Mesbah, 2009).

The results under 60% dose of nitrogen application showed that there were no significant among either Nitrogen modes or water regimes. Means of water regime indicated no significant difference in Spikelet Length as affected by water regime. This was true under all nitrogen application doses.

The overall means of either nitrogen doses or mode of application showed the superiority of 100% (17 cm) and 80% (15.75 cm) doses over 60% (14 cm). At the same time, mode A (18.33 cm) surpass mode B (15.67 cm) under 100% N dose. Reversible trend was recognized with 80% N dose where mode B resulted in 16.17 cm against 15.33 cm for mode A. There was no significant difference between mode A and mode B when 60% N was added.

The above-results are tended to follow the same plant height way in the strategy, in terms of the moderate amount of nitrogen fertilizer and water requirement seems to be most suitable treatments that achieve reasonable Spikelet Length without adverse effects. It seems that the impact of mode of nitrogen application is related to water regime and rate of application.

Table (16): Effect of nitrogen fertilizer application strategy and irrigation water regime on Spikelet Length (cm) of wheat grown on sand soil.

N Level %	N Mode	Water Regime			Mean
		50	75	100	
100	A	19.50^{a}	19.00^{ab}	16.50^{cd}	**18.33^{a}**
	B	14.00^{efg}	16.50^{cd}	16.50^{cd}	**15.67^{b}**
Mean		**16.75^{A}**	**17.75^{A}**	**16.50^{A}**	**17.00^{a}**
80	A	13.50^{fg}	17.50^{bc}	15.00^{def}	**15.33^{b}**
	B	19.50^{a}	15.50^{de}	13.50^{fg}	**16.17^{b}**
Mean		**16.50^{A}**	**16.50^{A}**	**14.25^{A}**	**15.75^{a}**
60	A	14.50^{efg}	14.00^{efg}	13.00^{g}	**13.83^{c}**
	B	14.50^{efg}	14.00^{efg}	13.50^{fg}	**14.00^{c}**
Mean		**14.50^{A}**	**14.00^{A}**	**13.25^{A}**	**13.92^{b}**
A		15.83^{b}	16.83^{a}	14.83^{c}	**15.83^{A}**
B		16.00^{ab}	15.33^{bc}	14.50^{c}	**15.28^{A}**
Mean		**15.92^{a}**	**16.08^{a}**	**14.67^{b}**	**15.56**

LSD value$_{0.05}$ **A:** 0.29 **B:**1.46 **C:**n.s **AB:**n.s **AC:**0.93 **BC:**0.93 **ABC:**1.61

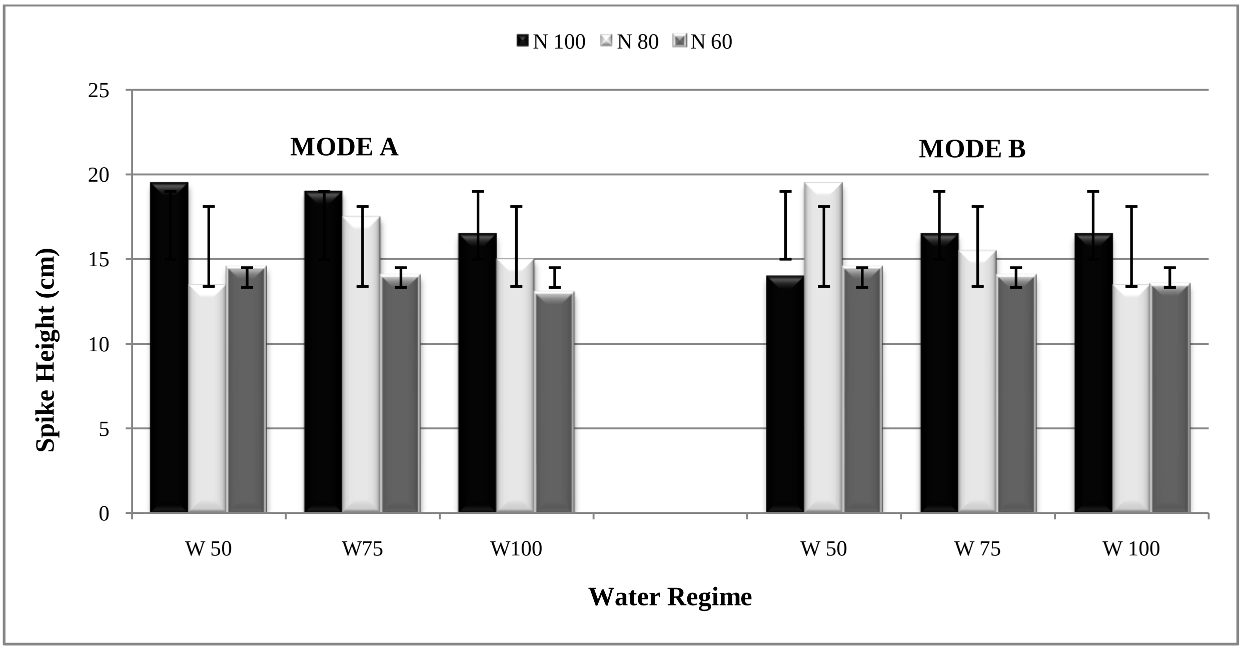


Figure (19): Effect of nitrogen fertilizer application strategy and irrigation water regime on spike length (cm) of wheat grown on sand soil

3. Straw yield $t.ha^{-1}$

The dry straw yield of wheat crop affected by nitrogen fertilization practices and irrigation water regime is presented in **Table (17)**, and graphically illustrated by **Figure (20).**Straw yieldof wheat plants fertilized were fluctuated overall the N rate according to water regime and mode of application. The highest value (8.6 $t.ha^{-1}$) of straw dry yield was detected with 50% water regime treated with 100% of recommended rate of nitrogen. This tendency may be supported by the findings of Elemery et al. (1994) indicating that "the increase in water supply decreased element of what grain".

Similar values have been observed with 100% and 75% of water regime but under different nitrogen rate (60% and 80%), respectively. It is worth mentioning that even the highest values above-mentioned were noticed under mode B in all water regimes as well as under all the nitrogen rates, when the nitrogen mode of applications considered, the lowest value of straw yield in all treatment was recorded under the combination 50% water regime and 60% of nitrogen rate. This supports the conclusion of Ridley and Hedlin (1980) and Camara (2003) that addition of nitrogen tended to produce high yield regardless of quantity or distribution of water.

Taken in consideration mode A the highest value, (8.2 t. ha^{-1}), which was a little bit close to those obtained in mode B, (8.6 $t.ha^{-1}$), observed under 100% of water regime in interaction with 100% of nitrogen rate; while the lowest value (5.5 $t.ha^{-1}$) was under 50% water regime and 80% of nitrogen rate.

Mean value of straw yield resulted from the interaction between water regime and mode of nitrogen application indicated the superiority of Mode B (7.8 t. ha^{-1}) over Mode A (6.5 t. ha^{-1}). The overall means of straw yield as affected by water regime reflected surpass of 100% over 75% and 50% treatments, respectively. In same time means value of straw yield obtained from the interaction between water regime and nitrogen rate indicated surpass of 100% nitrogen rate over 80% and 60%, respectively.

From the abovementioned data, we can conclude that straw yield was significantly progressed by addition of 100% and 80% N rates using mode B of application. Concerning water requirement, the overall means indicated the superiority of 100% followed by 75% then 50% water regime.

Few years ago, different wheat cultivars were grown on Egypt's different main soil types, old irrigated land of the Nile valley, newly reclaimed sandy soil and plants exposed to different rates of nitrogen fertilizer labeled with ^{15}N (Abdel Monem 2000). He reported that the efficiency of applied nitrogen is low and better management of both fertilizer and irrigation water is needed to improve plant production. In old irrigated soil, he found that the application of N fertilizer resulted in significant increases in grain and straw yields of both cultivars with differential responses. On the other hand, there were significant decreases in yield with 40% less irrigation. Similar trends were indicated in newly reclaimed soil but to lower extent.

Table (17): Effect of nitrogen fertilizer application strategy and irrigation water regime on straw dry yield (t.ha^{-1}) of wheat grown on sand soil.

N Level %	N Mode	Water Regime			Mean
		50	75	100	
100	A	6.200^{A}	7.500^{A}	8.200^{A}	**7.300^{ABC}**
	B	8.600^{A}	6.500^{A}	7.500^{A}	**7.533^{AB}**
Mean		**7.400^{A}**	**7.000^{AB}**	**7.850^{ABC}**	**7.417^{A}**
80	A	5.500^{A}	6.200^{A}	7.900^{A}	**6.533^{C}**
	B	6.200^{A}	8.600^{A}	8.600^{A}	**7.800^{A}**
Mean		**5.850^{A}**	**7.400^{AB}**	**8.250^{C}**	**7.167^{A}**
60	A	7.200^{A}	7.900^{A}	7.900^{A}	**7.667^{AB}**
	B	4.950^{A}	5.100^{A}	8.600^{A}	**6.217^{BC}**
Mean		**6075^{A}**	**6.500^{BC}**	**8.250^{A}**	**6.942^{A}**
A		**6.300^{A}**	**7.200^{A}**	**8.000^{A}**	**7.167^{A}**
B		**6583.3^{A}**	**6.733^{A}**	**8.233^{A}**	**7183^{A}**
Mean		**6441.7^{A}**	**6.967^{A}**	**8.117^{A}**	**7175**

LSD value$_{0.05}$ **A**: n.s **B**: n.s **C**: n.s **AB**: 0.39 **AC**: n.s **BC**: 0.3 **ABC:** n.s

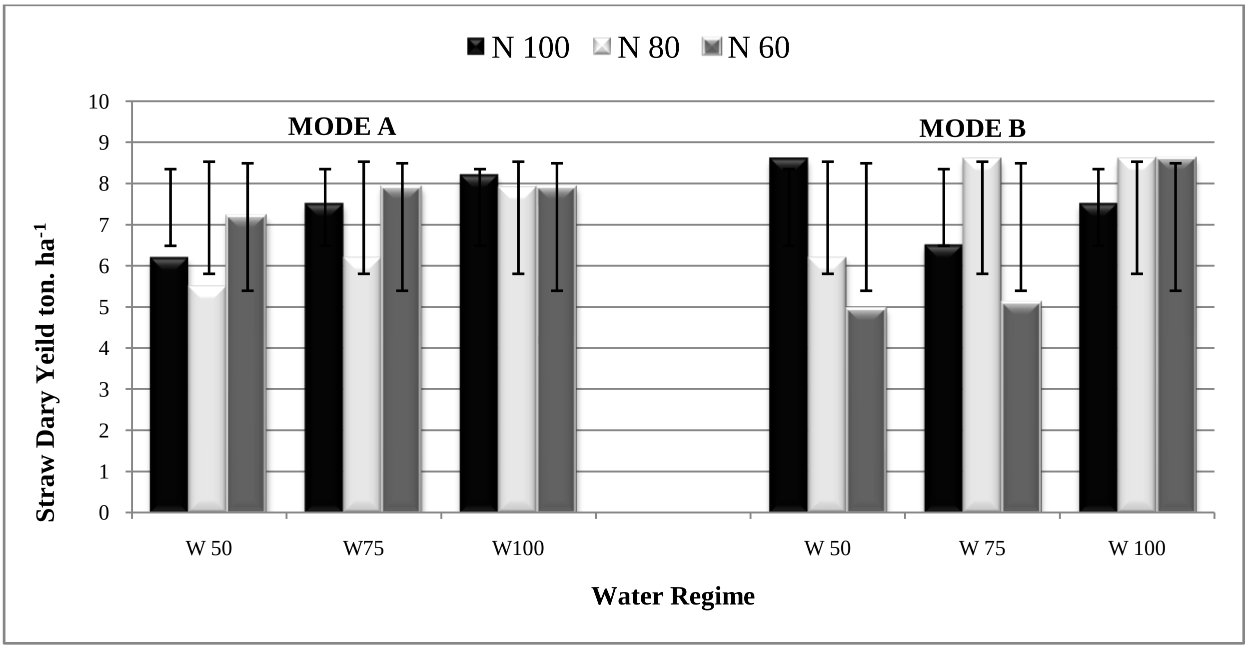


Figure (20): Effect of nitrogen fertilizer application strategy and irrigation water regime on straw dry yield (t.ha^{-1}) of wheat grown on sand soil

4. Grain yield t. ha^{-1}

The grain yield depends on number of tillers surviving up to maturity, spike length, fertile spikelet, seed per ear and grain size (1000-grain weight). In the present study the dry grain yield of wheat crop affected by nitrogen fertilization practices and irrigation water regime is presented in**Table (18),** and illustrated graphically by **Figure (21),**It is clearly evident that increasing nitrogen rate with best water supply had been resulted the highest grain yield of wheat. In this regard, the best value (6.65 t.ha^{-1}) was observed when the 75% of water regime was applied along with 100% of recommended nitrogen rate under mode B. This is might be inconsistent to both Sharif (1999) and Musaddique *et al.*(2000) who reported that "greater than 400 tillers/m^2 were obtained in wheat in control treatment in which maximum number of irrigation was applied" and also to Matsunaka *et al.* (1992) and Ghazal *et al.* (1998) both reported that “number of spikes/m^2 increased as irrigation increased”. Also, Akhter *et al.*, (2008), reported that “.The water stress decreased biomass yield (BY) in all genotypes and was largely associated with decrease in number of tillers (NT) and plant height (PH)”.

Similar trends were noticed under 80% and 60% of recommended nitrogen rate with the same superiority of mode B.

At 100% water regime there was significant difference between mode A and B in all nitrogen rates, with a slight exception in 80% of recommended rate of nitrogen. Reversible trend was noticed with 50% of water regime whereas there was no significant difference between two modes.

It is worthy mentioned that the result obtained with 75% of water regime in combined with either 100% or 80% of recommended nitrogen rate under mode B showed the highest values (6.65 and 5.90 t.ha^{-1}), respectively, among all the interactions.

Overall means of grain yield as affected by interaction of N fertilizer rates and mode of application as well as water regime indicated the superiority of 100% and 80% N recommended rate, respectively, and mode B of application overall the treatments. Concerning water regime, the best values of wheat grain yield were obtained when 75 % was applied.

Since there was no big significant difference between 100% and 80% nitrogen dose under mode B using 75% water regime, we can conclude that the 80% nitrogen dose in combination with 75% water regime could be accepted as suitable treatment that gave the economical yield. In other turn, 20% of nitrogen fertilizer and 25% of water requirements could be saved without significant reduction of grain yield. These findings are supported by Kang et al., and Arabi et al. (2002), Pirdashti et al. (2004), Mesbah (2009), and Akram (2011). Giunta et al. (1993). Pannu et al. (1996) also obtained the same results.

Table (18): Effect of nitrogen fertilizer application strategy and irrigation water regime on grain yield (t. ha^{-1}) of wheat grown on sand soil.

N Level %	N Mode	Water Regime			Mean
		50	75	100	
100	A	4.39	3.17	1.37	**2.98**
	B	4.58	6.65	2.64	**4.62**
Mean		**4.49**	**4.91**	**2.01**	**3.80**
80	A	3.97	2.70	3.78	**3.48**
	B	3.45	5.90	4.19	**4.27**
Mean		**3.71**	**3.93**	**3.98**	**3.88**
60	A	3.12	4.02	1.32	**2.82**
	B	3.82	4.64	3.91	**4.13**
Mean		**3.47**	**4.33**	**2.62**	**3.47**
A		**3.83**	**3.30**	**2.16**	**3.09**
B		**3.95**	**5.48**	**3.58**	**4.34**
Mean		**3.89**	**4.39**	**2.87**	**3.72**

LSD value $_{0.05}$ **A**: 0.8 **B**: 0.28 **C**: sig. **AB**: 0.49 **AC**: 0.74 **BC** 0.74 **ABC**: 1.28

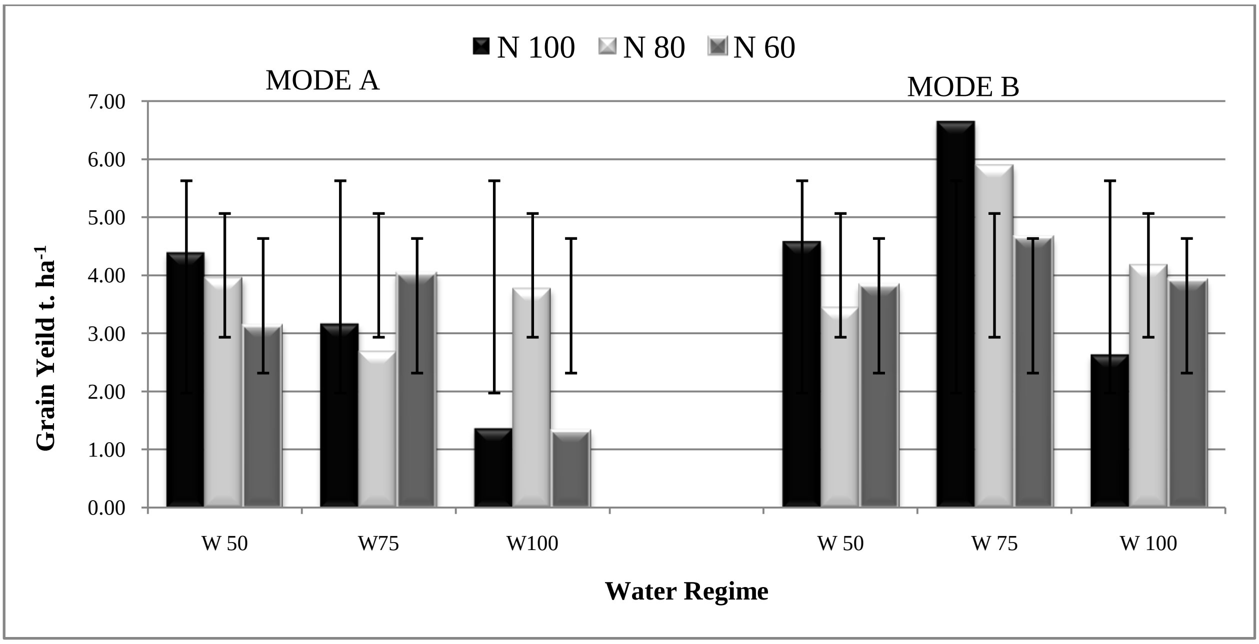


Figure (21): Effect of nitrogen fertilizer application strategy and irrigation water regime on grain yield (t.ha^{-1}) of wheat grown on sand soil.

5. Thousand-Seed-Weight (TSW gram)

The Thousand-Seed-Weight of wheat crop affected by nitrogen fertilization practices and irrigation water regime is presented in**Table (19),** and graphically illustrated by**Figure (22).**Thousand-Seed-Weight fluctuated under all studied attributes. However, it is tended to increase with reducing the water regime to 75%. This holds true when 100% N recommended rate was applied using mode B, which recorded the highest value (47.8g) of TSW among all the treatments. That is might be supported by Mesbah, (2009), who found that " the highest values of 100-grain-weight obtained under I_2 (1600 m^3/ fed). While these observations could be inconsistent with some researchers who found a negative correlation effects of water stress on 1000-grain weight (Qadir *et al.*, 1999; Shehzadi, 1999 ; Dencic *et al.*, 2000 and Akram 2011). These findings are supported by Kang *et al.* (2002) and Pirdasti *et al.* (2004) who reported a positive correlation between spiktets per ear and 1000-grain weight and grain yield.

In case of 100% and 50% water regime, application of 100% N rate, there was no significant difference of Thousand-Seed-Weight in both modes A & B (37.8 & 37.4 g) and (45.8 & 44.8 g), respectively.

At 80% of recommended nitrogen rate in combination with either 75% or 50% of water regime the mode A tends to show the superiority against mode B. Opposite trend was observed with 100% of water regime whereas the mode B recorded a higher value than in mode A. In the same time, the observed data at 60% of recommended nitrogen rate followed the same direction tendency of 80% of recommended nitrogen rate overall unites whereas the mode A showed surpass against mode B, without any exceptions.

A little bit difference in value (46.9 & 46.5 g), was noticed at 80% of recommended rate of nitrogen using 75% and 50% of water regime, respectively. This holds true when the mode A is used as a method application.

Comparing the values that obtained in both above-mentioned water regimes in mode A with that value (47.8 g) obtained in 100% of recommended nitrogen rate with mode B using 75% of water regime, we can clearly notice that there was no big significant different. Hence, the using of 80% of recommended nitrogen rate in combination with either 75% or 50% of water regime could be the preferable strategy that gave the acceptable TSW, and in the other hand the beneficial effect of using less amount of water could be explained by enhancing plant growth and protecting soil fertility in the long run, that can be achieved through maintaining good soil water-air relation for mechanism of nutrients uptake by plant root.

Table (19): Effect of nitrogen fertilizer application strategy and irrigation water regime on Thousand-Seed-Weight (g) of wheat grown on sand soil.

N Level%	**N Mode**	**Water Regime**			**Mean**
		50	**75**	**100**	
100	**A**	45.77	44.94	37.80	**42.84**
	B	44.84	47.83	37.43	**43.37**
Mean		45.**31**	**46.39**	**37.62**	**43.10**
80	**A**	46.51	46.88	40.54	**44.64**
	B	43.92	42.92	44.72	**43.85**
Mean		**45.22**	**44.90**	**42.63**	**44.25**
60	**A**	43.48	44.27	47.21	**44.99**
	B	41.40	40.46	40.00	**40.62**
Mean		**42.44**	**42.37**	**43.61**	**42.80**
A		45.25	45.36	41.85	**44.16**
B		43.39	43.74	40.72	**42.61**
Mean		**44.32**	**44.55**	**41.28**	**43.38**

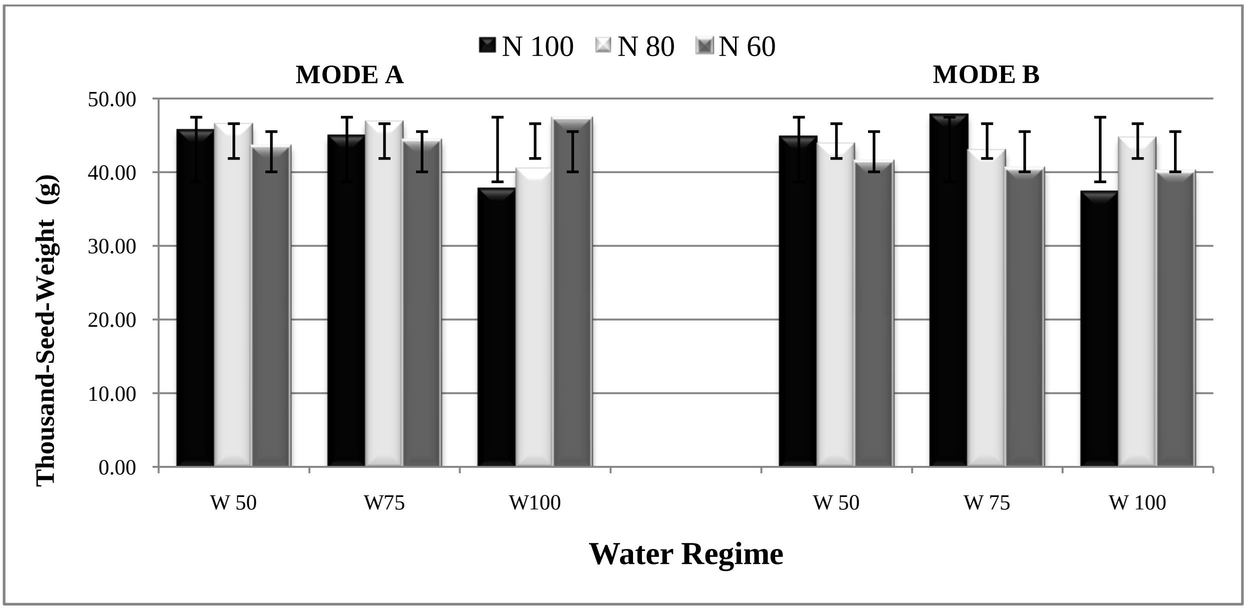


Figure (22): Effect of nitrogen fertilizer application strategy and irrigation water regime on Thousand-Seed-Weight (g) of wheat grown on sand soil.

6. Harvest Index (HI)

The harvest index of wheat crop affected by nitrogen fertilization practices and irrigation water regime is presented in**Table (20)**, and graphically illustrated by**Figure (23),** the harvest index tends to be with highest values using 75% of water regime, regardless the mode of application, overall the attributes. Considering the mode of nitrogen application, it is evidence that mode A has surpass over mode B; it is holds true using any treated nitrogen rate. Similar trends have been observed using 100% of water regime with somewhat exception where 80% of recommended rate of nitrogen was applied.

At 50% of water regime the values didn't follow any tendency of above-mentioned; whereas, mode B shows a higher value against mode A using 100% of recommended rate of nitrogen, and reveal results obtained using 60% of recommended nitrogen, whilst there was no difference between modes using 80%.

Overall means showed that the superiority of 80% of recommended rate of nitrogen along with 75% of water regime is the best combination that could increase the HI of what yield. These could be agreed with the findings of Mesbah (2009) that "application of 1600(I_2) or 1850 (I_1) m^3/fed irrigation water increased significantly grain yield/fed in both seasons, while the harvest index was significantly increased in the first season only".Also, overall means showed semi-concrete increased of HI using mode A over mode B.

However, among all the attributed studies there was no big significant difference between water regime, nitrogen rate and nitrogen application methods. This conclusion is supported by Akram (2011) reported that "Harvest index (HI) was significantly influenced between cultivars. Different moisture stress treatments exhibited non-significant effects on HI and it ranged from 26.90 to 30.11% among different water stress treatments".

Table (20): Effect of nitrogen fertilizer application strategy and irrigation water regime on harvest index (HI) of wheat grown on sand soil.

N Level %	N Mode	Water Regime			Mean
		50	75	100	
100	A	0.42	0.47	0.24	**0.38**
	B	0.34	0.33	0.15	**0.27**
Mean		**0.38**	**0.40**	**0.20**	**0.33**
80	A	0.39	0.39	0.35	**0.37**
	B	0.39	0.24	0.31	**0.31**
Mean		**0.39**	**0.31**	**0.33**	**0.34**
60	A	0.35	0.37	0.39	**0.37**
	B	0.39	0.44	0.13	**0.32**
Mean		**0.37**	**0.41**	**0.26**	**0.35**
A		**0.39**	**0.41**	**0.33**	**0.37**
B		**0.37**	**0.34**	**0.20**	**0.30**
Mean		**0.38**	**0.37**	**0.26**	**0.34**

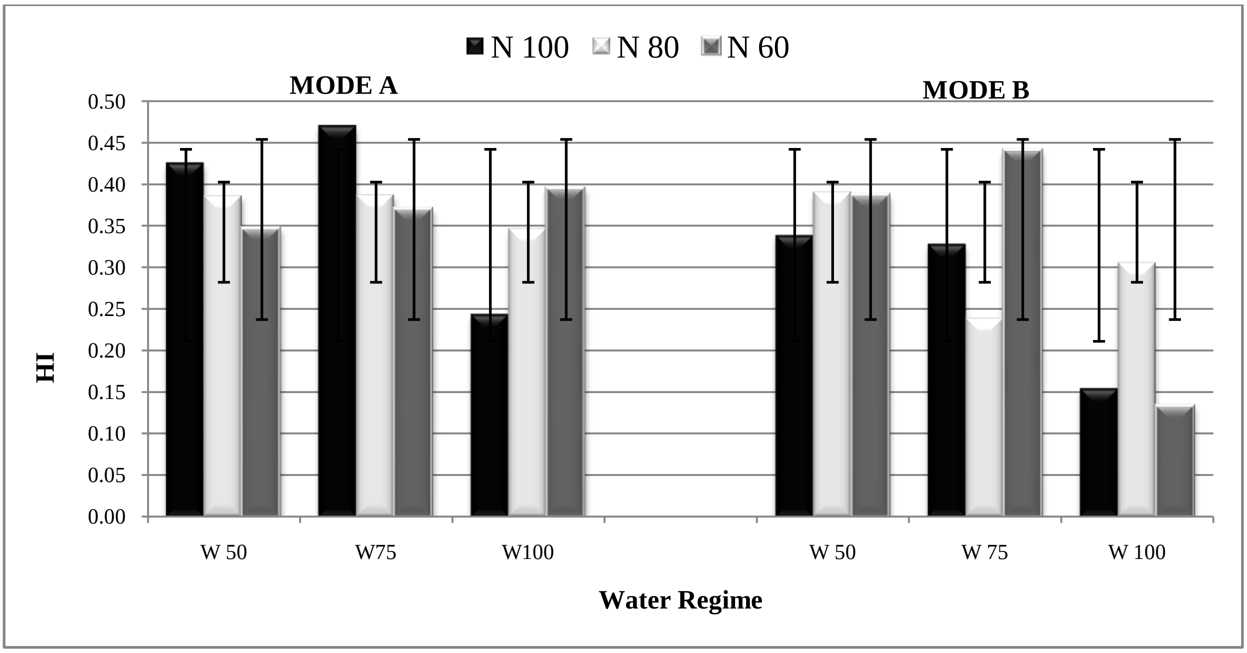


Figure (23): Effect of nitrogen fertilizer application strategy and irrigation water regime on harvest index (HI) of wheat grown on sand soil

Nitrogen Nutrient

A. Clay Soil

1. Total Nitrogen Uptake kg/ha in

a. Total Nitrogen Uptake in Straw yield

Nitrogen uptake by straw as affected by fertilizer-N application strategy (levels and modes) and water regime is presented in **Table (21)**, and graphically illustrated by **Figure (24).** Plants fertilized with 100% recommended N applied with mode A showed higher N uptake when combined with 50% water regime, than those recorded with 75 and 100% water regime where the results did not reflects significant difference between the last two water regimes. When mode B was applied, nitrogen uptake by straw tended to decrease as compared to mode A. this holds true under all water regimes. In other turn, the means indicated the superiority of mode A over mode B (262.7 vs 182.7 kg ha^{-1}). Overall means of water regime indicated gradual decrease of N uptake with 75% regime increased again with 100% regime but both of them were lower than those of 50% water regime.

In case of 80% N application, nitrogen uptake by straw has the same trend but to somewhat low extent, like those recorded with 100% N application rate. Means of nitrogen application mode indicated a little bet difference between A and B modes.

Another view was detected with 60% nitrogen application where N uptake by straw tended to increase with increasing water regime. The highest values of N uptake by straw were occurred with 100% water regime. There was no significant difference between means od A and B modes.

In general, the average of N uptake by straw indicated the superiority of mode A over mode B. significant increases in N uptake were occurred with 100% water regime. It tends to decrease with reducing nitrogen application rates.

Table (21): Effect of nitrogen fertilizer application strategy and irrigation water regime on total Nitrogen Uptake in straw (kg ha^{-1}).

N Level %	N Mode	Water Regime			Mean
		50	75	100	
100	A	312.0	235.0	241.0	**262.7**
	B	190.0	146.0	212.0	**182.7**
Mean		**251.0**	**190.5**	**226.5**	**222.7**
80	A	194.0	213.0	147.0	**184.7**
	B	190.0	148.0	190.0	**176.0**
Mean		**192.0**	**180.5**	**168.5**	**180.3**
60	A	162.0	193.0	275.0	**210.0**
	B	156.0	244.0	211.0	**203.7**
Mean		**159.0**	**218.5**	**243.0**	**206.8**
A		**222.67**	**213.67**	**221.00**	**219.11**
B		**178.67**	**179.33**	**204.33**	**187.44**
Mean		**200.67**	**196.50**	**212.67**	**203.28**

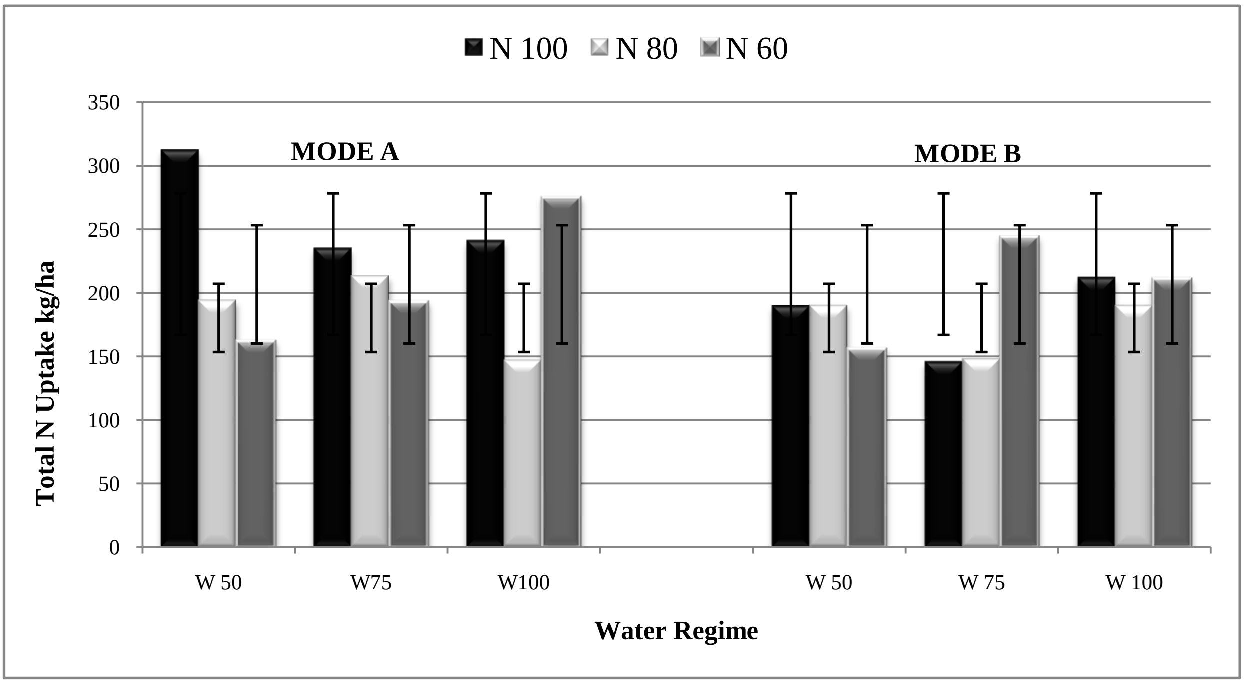


Figure (24): Effect of nitrogen fertilizer application strategy and irrigation water regime on total Nitrogen Uptake in straw(kg ha^{-1}).

b. Total Nitrogen Uptake in Grain yield

As shown in **Table (22), and Figure (25),** nitrogen uptake by grain was significantly declined by raising water regime up to 100% in combination with 100% nitrogen rate applied by mode A. Opposite direction was noticed with mode B where N uptake by grain was significantly and gradually increased with increasing water regime. Comparison held between the two modes of applications indicated that mode B surpassed mode A. Mean average of 100% N rate interacting with different water regimes, despite of application modes, showed gradual increase of N uptake by grain with 75% water regime (**331.6** kg ha^{-1}) then tended to decrease with 100% water regime (**297.7** kg ha^{-1}).

Application of 80% N rate applied with mode A resulted in lower values of N uptake by grain than those of 100% N rate when 50% and 75% water regimes (258.4 and 237.6 kg ha^{-1},respectively) were concerned, while it tends to increase with 100% water regime (309.3 kg ha^{-1}). When mode B was followed, N uptake was higher than those recorded for the same mode under 100% N rate. This holds true with 50% water regime while it tends to decrease with 75% and 100% water regimes.

Average of N uptake values as affected by application mode were to somewhat higher in case of mode A than those recorded with mode B. on the other hand, average of N uptake as affected by water regimes indicated that there was no big significant difference between 50% and 75% water regimes while jf tends to increase with 100% water regime.

Addition of 60% of recommended N rate resulted in severe reduction in N uptake by grain as compared to other rates either applied with mode A or mode B. in this respect, mode B, as indicated by average, was superior over mode A when N uptake by grain was concerned.

Considering the average of water regimes, N uptake was nearly the same for 50% and 100% but a little bit decreased with 75% water regime.The overall averages of N uptake by grain indicated the superiority of mode B, 50% and 100% water regime and nearly equality of 100% and 80% N fertilizer rates.

Table (22): Effect of nitrogen fertilizer application strategy and irrigation water regime on total Nitrogen Uptake in Grain(kg ha^{-1}).

N Level %	N Mode	Water Regime			Mean
		50	75	100	
100	A	311.29	299.3	221.2	**277.3**
	B	327.21	363.8	374.2	**355.1**
Mean		**319.3**	**331.6**	**297.7**	**316.2**
80	A	258.4	237.6	309.3	**268.4**
	B	345.3	356.1	351.1	**350.8**
Mean		**301.9**	**296.9**	**330.2**	**309.6**
60	A	242.2	217.2	180.7	**213.4**
	B	228.16	208.6	295.1	**244.0**
Mean		**235.2**	**212.9**	**237.9**	**228.7**
A		**270.63**	**251.37**	**237.07**	**253.02**
B		**300.22**	**309.50**	**340.13**	**316.62**
Mean		**285.43**	**280.43**	**288.60**	**284.82**

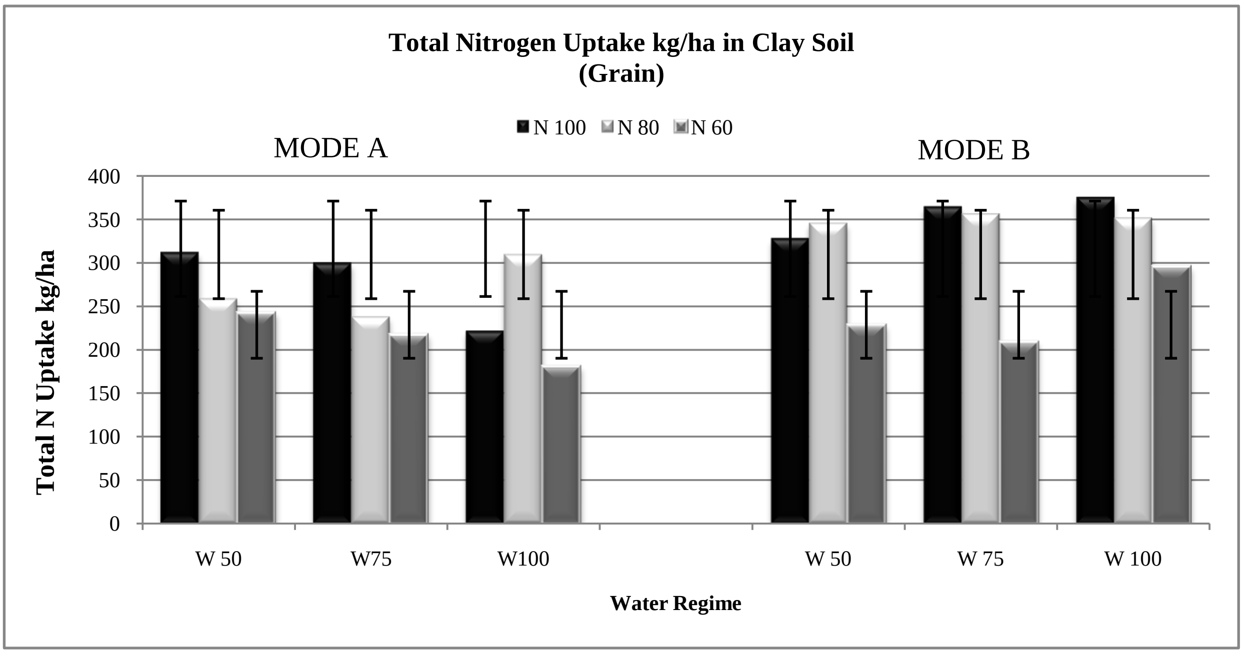


Figure (25): Effect of nitrogen fertilizer application strategy and irrigation water regime on total Nitrogen Uptake (kg.ha^{-1}) in Grain

2. Nitrogen Derived From Fertilizer (Ndff)

a. Nitrogen Derived from Fertilizer in Straw yield

Nitrogen derived by straw from the fertilizer (Ndff) portion as affected by nitrogen fertilizer rates and mode of application as well as water regimes is presented in **Table (23)** and graphically illustrated by **Figure (26)**. Application of 100% recommended rate resulted in 70.2, 54.1 and 57.8 kg ha^{-1} for W50 W75 and W100 respectively when mode

A was applied while with mode B values of Ndff were 43.7 34.3 and 53.0 kg ha^{-1} for the same sequence. It means that the absolute values of N derived from fertilizer by straw were significantly higher when mode A (60.7 kg ha^{-1}) was applied than those of mode B (43.7 kg ha^{-1}). In the same time these values showed a little bit decrease with increasing water regime up to 75 and 100%.

In case of 80% N rate the data of Ndff doesn't reflect any significant difference between the two modes of application as indicated by the average mean (39.4 and 40.8 kg ha^{-1}). Similar trend was noticed with the average of water regime where it was 41.3 39.9 39.1 kg ha^{-1} for W50 W75 W100 respectively.

The mean average of Ndff as affected by water regime interacted with the rate of 80% N reflected to somewhat extent low Ndff values comparing to those obtained with the rate of 100% N fertilizer.

Nitrogen derived from fertilizer by straw of wheat fertilized with 60% N rate didn't significantly change as affected by mode of fertilizer-N application (average 43.7 and 42.2 kg ha^{-1} for mode A and B respectively). Reversible trend was observed with increasing water regime where the values of Ndff tended to increase as indicated by the mean average which were 32.6, 43.6, and 52.8 kg ha^{-1} for W50 W 75 and W100 respectively.

The overall means of Ndff resulted from the interaction between nitrogen rate mode and water regimes indicated that there was no significant difference between mode A and B whereas it tended to increase by increasing water regime up to 100%. Ndff values were a little bit decreased by reduction of N fertilizer rates to either 80% or 60% N rates.

Table (23): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Derived from Fertilizer in straw(kg ha^{-1}).

N Level %	N Mode	Water Regime						Mean
		50		75		100		
		%	kg.ha^{-1}	%	kg.ha^{-1}	%	kg.ha^{-1}	
100	A	22.5	70.2	23.0	54.1	24.0	57.8	**60.7**
	B	23.0	43.7	23.5	34.3	25.0	53.0	**43.7**
Mean		**22.8**	**57.0**	**23.3**	**44.2**	**24.5**	**55.4**	**52.2**
80	A	21.0	40.7	21.5	45.8	21.5	31.6	**39.4**
	B	22.0	41.8	23.0	34.0	24.5	46.6	**40.8**
Mean		**21.5**	**41.3**	**22.3**	**39.9**	**23.0**	**39.1**	**40.1**
60	A	20.0	32.4	20.5	39.6	21.5	59.1	**43.7**
	B	21.0	32.7	19.5	47.6	22.0	46.4	**42.2**
Mean		**20.5**	**32.6**	**20.0**	**43.6**	**21.8**	**52.8**	**43.0**
A		**21.17**	**47.77**	**21.67**	**46.50**	**22.33**	**49.50**	**39.44**
B		**22.00**	**39.40**	**22.00**	**38.63**	**23.83**	**48.67**	**37.04**
Mean		**21.58**	**43.58**	**21.83**	**42.57**	**23.08**	**49.08**	**38.24**

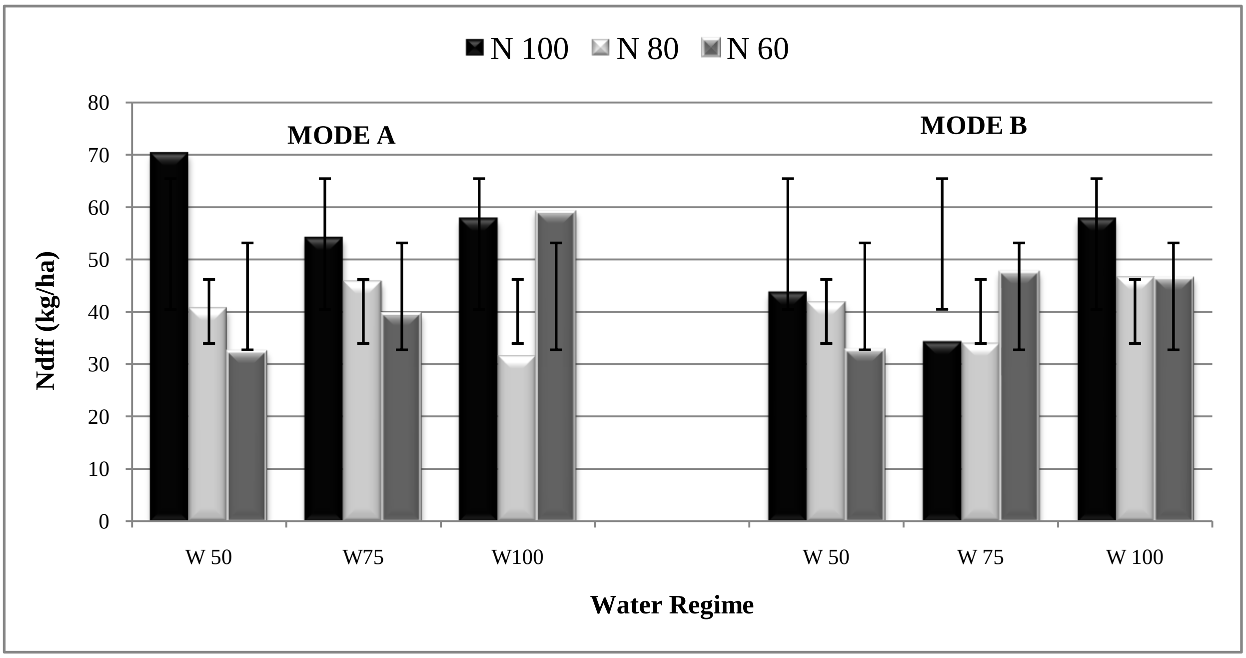


Figure (26): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Derived from Fertilizers (kg.ha^{-1}) in Straw

b. Nitrogen Derived from Fertilizer in Grain yield

Nitrogen yield derived from fertilizer by grain of wheat fertilized with 100% N rate was significantly affected by water regime and mode of fertilizer application as presented in **Table (24)** and **Figure (27).** In case of N application with mode A, values of Ndff tended to increase with raising water regime up to 75% then declined with 100%

although its %Ndff was higher than those of 50% and nearly closed to those of 75% water regimes. Opposite direction was noticed with application of mode B where values of Ndff continued to increase with increasing water regimes but it was highly significant with 75% water regime as compared to 100% water regime.

Concerning the application mode, values of Ndff were to some extent higher in case of mode B than those of mode A. this was more pronounced with 100% water regime. The mean average of 100% N rate despite of application modes indicated an increment of Ndff values and portion (%Ndff) with 75% water regime comparing to 50%. Although the average of percent of Ndff in case of 100% water regime was higher than 50% water regime, the absolute values of both of them were nearly closed to each other. This seems to be related to individual N uptake as a function of accumulation of dry matter yield of both regimes.

Application of 80% N rate resulted in, but to somewhat low extent, similar trends like those obtained with 100% N rate. This phenomenon was also indicated but lowers than those of 100% and 80% N rates, explaining the superiority of mode B over mode A and suitability of 75% water regime where the optimum %Ndff and absolute value were occurred.

In general, our overall means gave us the chance to conclude that the best values and percent of Ndff by grains were achieved by application of fertilizer-N with mode B rather than mode A, in combination with 75% water regime.

The highest %Ndff and absolute values were recognized with the recommended rate of fertilizer-N followed by those of 80%, the 60% N rates. It is worthy to mention that values of 80% N rate were near to those of 100% N rate which gave us the opportunity to recommend this rate if we looking after the environmental protection against the excessive application of manufactured fertilizers and prevention of pollution of surrounding environment including soil, underground water and air.

Table (24): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Derived from Fertilizer in Grain(kg ha^{-1}).

N Level %	N Mode	Water Regime						Mean
		50		75		100		
		%	kg.ha^{-1}	%	kg.ha^{-1}	%	kg.ha^{-1}	
100	A	35.6	110.8	47.5	142.2	45.0	99.5	**117.5**
	B	35.7	116.8	39.1	142.2	33.8	126.5	**128.5**
Mean		**35.7**	**113.8**	**43.3**	**142.2**	**39.4**	**113.0**	**123.0**
80	A	30.0	77.5	43.7	103.8	29.1	90.0	**90.5**
	B	25.1	86.7	32.1	114.3	27.7	97.3	**99.4**
Mean		**27.6**	**82.1**	**37.9**	**109.1**	**28.4**	**93.6**	**94.9**
60	A	30.0	72.7	39.0	84.7	34.9	63.1	**73.5**
	B	30.2	68.9	39.9	83.2	25.2	74.4	**75.5**
Mean		**30.1**	**70.8**	**39.5**	**84.0**	**30.1**	**68.7**	**74.5**
A		**31.87**	**87.00**	**43.40**	**110.24**	**36.33**	**84.20**	**76.92**
B		**30.33**	**90.80**	**37.03**	**113.26**	**28.90**	**99.37**	**80.51**
Mean		**31.10**	**88.90**	**40.22**	**111.75**	**32.62**	**91.79**	**78.72**

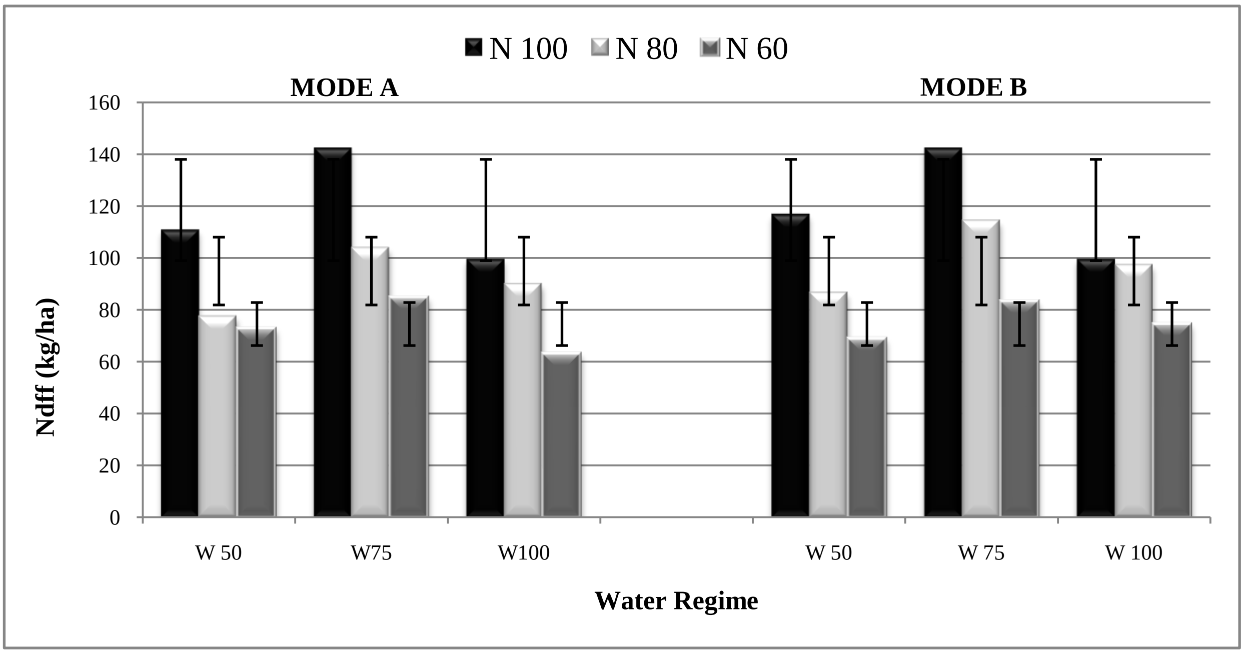


Figure (27): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Derived from Fertilizers (kg.ha^{-1}) in Grain

3. Nitrogen Derived From Soil (Ndfs)

a. Nitrogen Derived from Soil in Straw yield

Nitrogen derived from soil (Ndfs) by wheat straw as affected by fertilizer N rates, mode of application and water regime was presented in **Table (25)**, and graphically illustrated by **Figure (28)**. There was no significant difference between percentages of N derived from soil as affected by mode of application and/or water regimes when 100% N rate was applied. In contrast, the absolute values of Ndfs were declined with increasing water regime up to 75% and 100% water regimes under mode A. In this respect, there was no significant difference between 50% and 100% water regimes.

On the other hand, mode B interacted with different water regimes resulted in decreases of Ndfs values with increasing water regime up to 75% then increased again with 100% water regime. Despite of water regimes mean average of Ndfs of 100% N rate indicated the superiority of mode A over mode B.

Application of 80% N rate with mode A resulted in slight increase in Ndfs as interacted with 75% water regime comparing to 50% water regime then severely reduced with 100% water regime. Reversible trend was observed when mode B was applied where Ndfs values were reduced with 75% water regime then tended to increase again, but still lower than 50% regime, with 100% water regime. In general, values of Ndfs were lower than those recorded with 100% N fertilizer rate. Application mode A is still better than mode B. Ndfs values, in averages, were declined gradually with increasing water regime.

Table (25): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Derived from Soil in straw(kg ha^{-1}).

N Level %	N Mode	Water Regime						Mean
		50		75		100		
		%	kg.ha^{-1}	%	kg.ha^{-1}	%	kg.ha^{-1}	
100	A	77.5	241.8	77.0	181.0	76.0	183.2	**202.0**
	B	77.0	146.3	76.5	111.7	75.0	159.0	**139.0**
Mean		**77.3**	**194.1**	**76.8**	**146.3**	**75.5**	**171.1**	**170.5**
80	A	79.0	153.3	78.5	167.2	78.5	115.4	**145.3**
	B	78.0	148.2	77.0	114.0	75.5	143.5	**135.2**
Mean		**78.5**	**150.7**	**77.8**	**140.6**	**77.0**	**129.4**	**140.2**
60	A	80.0	129.6	79.5	153.4	78.5	215.9	**166.3**
	B	79.0	123.2	80.5	196.4	78.0	164.6	**161.4**
Mean		**79.5**	**126.4**	**80.0**	**174.9**	**78.3**	**190.2**	**163.9**
A		**78.83**	**174.89**	**78.33**	**167.20**	**77.67**	**171.48**	**138.78**
B		**78.00**	**139.25**	**78.00**	**140.69**	**76.17**	**155.68**	**124.18**
Mean		**78.42**	**157.07**	**78.17**	**153.94**	**76.92**	**163.58**	**131.48**

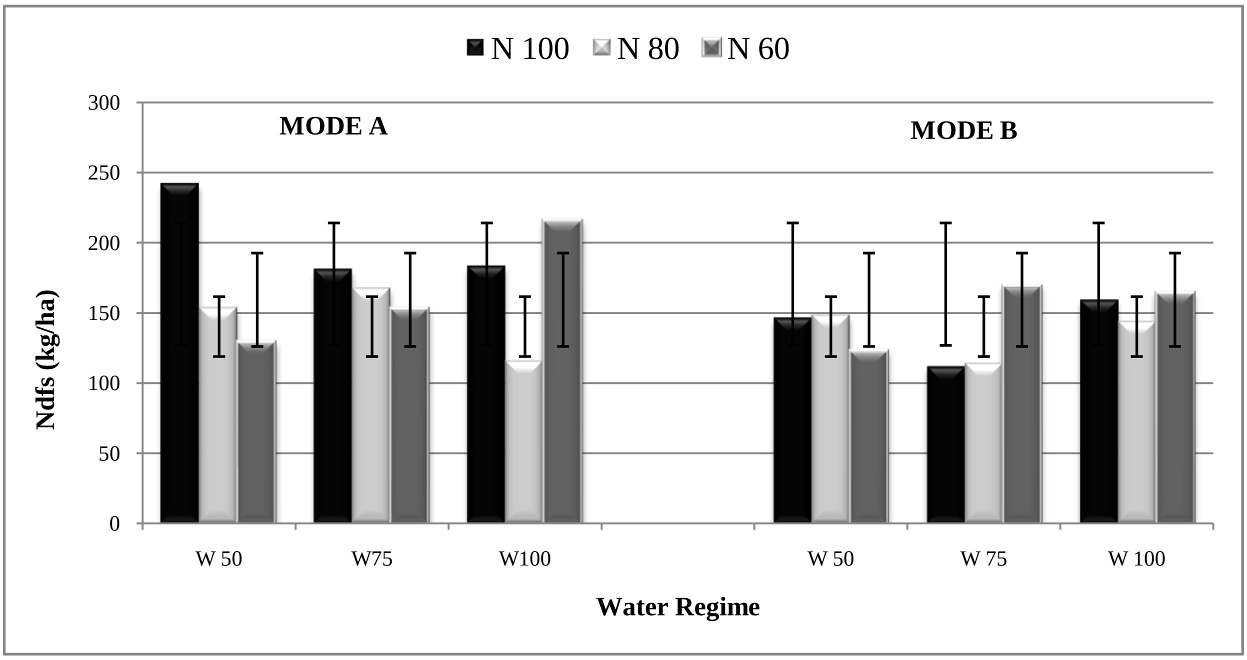


Figure (28): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Derived from Soil (kg.ha^{-1}) in Straw

Another view was drawn with application of 60% N rate at mode A where values of Ndfs were dramatically increased with increasing water regime up to 75% and 100% of water requirements. When mode B was applied, Ndfs values were significantly increased with 75% regime as compared to 50% regime then declined, but still higher than 50% regime, with 100% water regime.

Averages of ndfs showed alittle bit difference between Modes of applications. Concerning water regime effects, the averages noted that Ndfs values tended to gradual increase with increasing water regime.

Overall means of Ndfs values as affected by water regimes, N fertilizer rates and mode of application indicated the superiority of 100% and 60% N rates, Mode A over 80% N rate and mode B, respectively. There was no big significant difference between the three water regimes when Ndfs average values were concerned.

b. Nitrogen Derived from Soil in Grain yield

Nitrogen derived from soil by wheat grain as affected by nitrogen fertilizer rate, mode of application and water regimes is presented in **Table (26),** and graphically illustrated by **Figure (29).** It seems that both %Ndfs and absolute values were negatively affected by increasing water regimes gradually from 50% to 100% regime in combination with 100% N rate applied at mode A. in this respect, relative declines were accounted for 21.6%, 39.3% for 75% and 100% water regimes, respectively. Reversible trend was detected when fertilizer N was applied using mode B where Ndfs by grains tended to increase by increasing water regimes up to 75% and 100%. Relatively, increments were accounted for 5.3% and 17.7% for 50% and 100% water regimes, respectively. The average of Ndfs under this rate indicated the superiority of mode B over mode A. the average of water regimes revealed that absolute values of N derived from soil by grains tended to decrease gradually with increasing water regimes.

Application of 80% N fertilizer rate with mode A induced some decrease in Ndfs by grains when water regime increased to 75%, while it tends to increase again with 100% water regime. This holds true with the percentages of N derived from soil.

Similar trend, but to some extent high, was observed when mode B was applied. Mean average of application modes indicated the superiority of mode B over mode A. in this regard, the relative increase of Ndfs was accounted for 41.2% for mode B over mode A. average of Ndfs as affected by water regimes indicted significant decrease with 75% regime and significant increase with 100% water regime in relation to those of 50% water regime. Relatively, it accounts for 14.5% decrease and 7.6% increase for 75% and 100% regime, respectively.

Generally, values of Ndfs by grains of wheat treated with 80% N rate, despite of application mode, were higher than those of 100% fertilizer-N rate.

Table (26): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Derived from Soil in Grain(kg ha^{-1}).

N Level %	N Mode	Water Regime						Mean
		50		75		100		
		%	kg.ha^{-1}	%	kg.ha^{-1}	%	kg.ha^{-1}	
100	A	64.4	200.5	52.5	157.1	55.0	121.7	**159.8**
	B	64.3	210.4	60.9	221.6	66.2	247.7	**226.6**
Mean		**64.4**	**205.4**	**56.7**	**189.3**	**60.6**	**184.7**	**193.2**
80	A	70.0	180.9	56.3	133.8	70.9	219.3	**178.0**
	B	74.9	258.6	67.9	241.8	72.3	253.8	**251.4**
Mean		**72.5**	**219.8**	**62.1**	**187.8**	**71.6**	**236.6**	**214.7**
60	A	70.0	169.5	61.0	132.5	65.1	117.6	**139.9**
	B	69.8	159.3	60.1	125.4	74.8	220.7	**168.5**
Mean		**69.9**	**164.4**	**60.6**	**128.9**	**70.0**	**169.2**	**154.2**
A		68.13	183.63	56.60	141.13	63.67	152.86	119.22
B		69.67	209.43	62.97	196.24	71.10	240.77	169.37
Mean		**68.90**	**196.53**	**59.78**	**168.68**	**67.38**	**196.81**	**144.29**

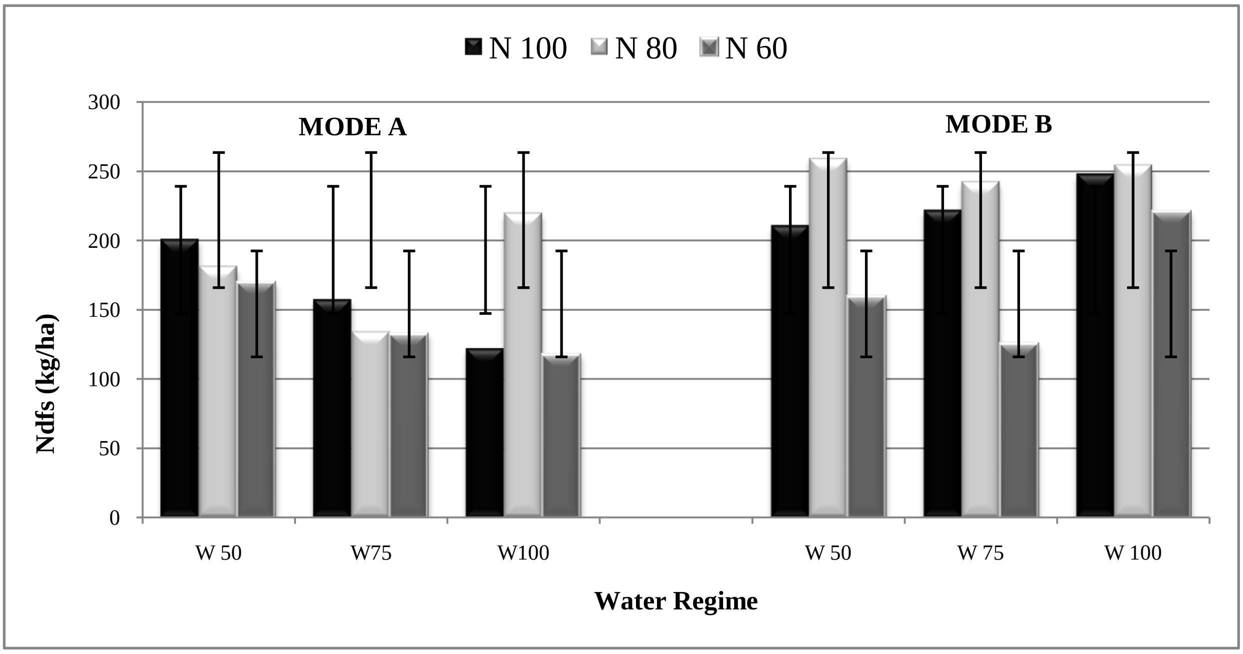


Figure (29): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Derived from Soil (kg.ha^{-1}) in Grain

Similar trends, with some exceptions, were noticed with application of 60% N rate. As indicated by mean average values of Ndfs as affected by mode B were superior over those of mode A. in this respect, the relative increase was accounted for 20.4%. Concerning water regimes, average indicated severe reduction in Ndfs values with increasing water regime up to 75%. Relatively, it accounts for 21.6% lesser than 50%

water regime while there was no significant difference between 50% and 100% water regimes.

4. Nitrogen Use Efficiency (NUE) %

a. In Straw Yield

Efficient use of mineral fertilizer by straw yield as affected by fertilizer-N rate and application mode as well as different water regimes is presented in **Table (27)**, and graphically illustrated by **Figure (30)** .In case of 100% N rate, %NUE was gradually decreased with increasing water regimes. High reduction in %NUE was detected with 75% water regime as compared to 100% water regime when mode A was applied. In this respect, %NUE could be ranked as following: W50% (39.4%) > W100% (32.5%)> W75% (30.7%). In case of mode B, similar trend, but to somewhat low extent, was recorded. Severe reduction in NUE was indicated in the treatment of W75%. It could be ranked as follow: W100% (29.8%)> W50% (24.6%) > W75% (19.3%). Mean average indicated the superiority of mode A over mode B. Reduced NUE was pronounced with W 75%. In the same time, there was no big significant difference between W50% and W 100%. It means that 25% or 50% of water requirement could be saved without adverse effect on efficient use of mineral fertilizer applied at 100% recommended rate with mode A.

Application of 80% N recommended rate induced lower %NUE when mode A was applied and compared to the same mode of 100% N rate. This percentage of NUE slightly increased with increasing water regime up to 75% then decreased with 100% water regime. Reversible trend was noticed with mode B where %NUE slightly decreased with W75% then significantly increased with W100 %. Nitrogen use efficiency as affected by water regime could be arranged as follow: W75 (32.3%) > W50 (28.7%) > W100 (22.3%); W100 (32.8%) > W50 (29.3%) > W75 (23.9%) for mode A and mode B, respectively. Mean average of both water regimes and N application mode doesn't reflected significant variations between modes of application or water regimes.

Application of 60% N recommended rate resulted in highly significant %NUE as compared to other two rates. Addition of this rate with mode A resulted in 55.2%, 37.1 and 30.3% for W100, W75 and W50; 44.5%, 43.4% and 30.6% for W75, W100 and W50, for mode A and mode B, respectively. Average indicated that there was no significant difference between modes of N applications. Concerning the water regimes, mean average of 60% N rate showed significant increase of %NUE with 100% water regime (**49.3%**) followed by 75% (**40.8**%) then 50% water regime (**30.4%**).

Overall means indicated a little bit high %NUE for mode A over mode B, and in the same time gradual increase in %NUE with increasing water regime up to 100% where the highest NUE was recorded. It is worthy to mention that the best %NUE were obtained with application of 60% of N recommended rate applied with mode A and combined with 100% water regime (55.2%).

Table (27): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Use Efficiency in Straw(%).

N Level %	N Mode	Water Regime			Mean
		50	75	100	
100	A	39.4	30.7	32.5	**34.2**
	B	24.6	19.3	29.8	**24.5**
Mean		**32.0**	**25.0**	**31.1**	**29.4**
80	A	28.7	32.3	22.3	**27.7**
	B	29.3	23.9	32.8	**28.7**
Mean		**29.0**	**28.1**	**27.5**	**28.2**
60	A	30.3	37.1	55.2	**40.9**
	B	30.6	44.5	43.4	**39.5**
Mean		**30.4**	**40.8**	**49.3**	**40.2**
A		**32.79**	**33.35**	**36.66**	**34.27**
B		**28.15**	**29.24**	**35.32**	**30.90**
Mean		**30.47**	**31.29**	**35.99**	**32.58**

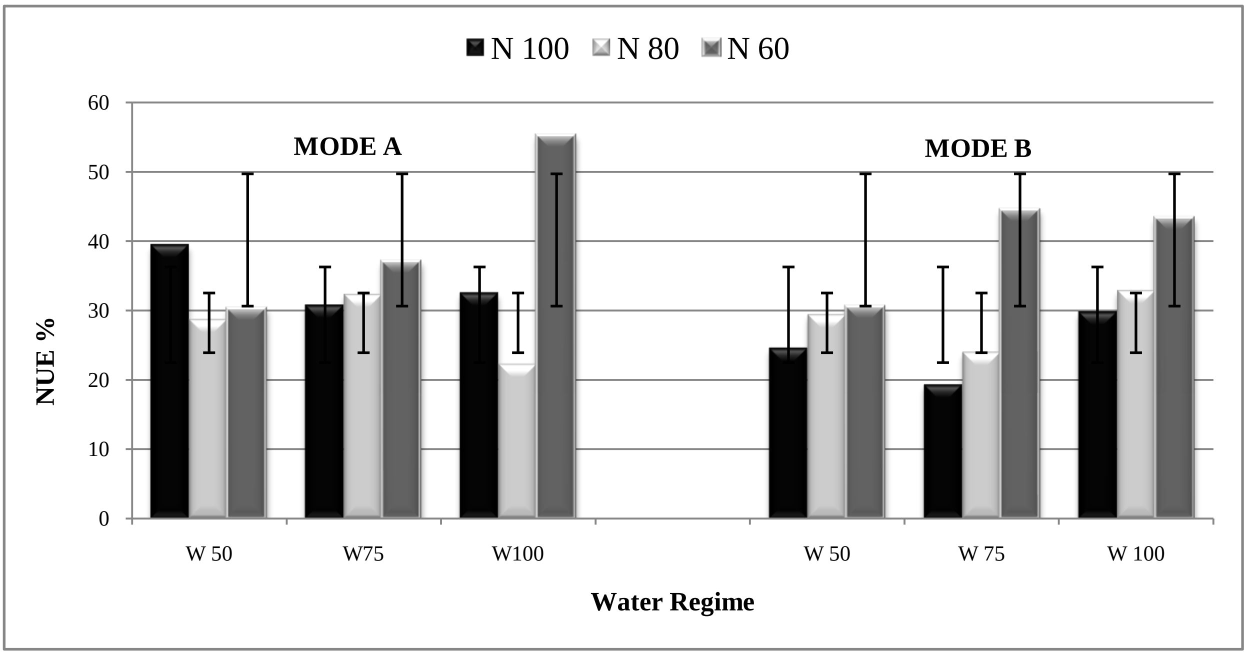


Figure (30): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Use Efficiency (%) in Straw

b. In Grain Yield

As shown by **Figure(31),** and presented in **Table (28),** the application of100% of N recommended rate with mode A induced in combination with 75% water regime induced highly significant efficient use (NUE) of mineral nitrogen by grains which accounted for 79.9% followed by those 50% water regime (62.3%), then those of 100% water regime (55.9%). These percentages of NUE were significantly increased when mode B of N application was used. This holds true under all water regimes. it accounts for 65^%, 79.9% and 71.1% for W50, W75 and W100, respectively. It is obvious that the best %NUE was obtained when 100% N rate, either applied with mode A or B, combined with 75% water regime. The mean average indicated the superiority of mode B over mode A and in the same time the superiority of W75 over the other two regimes. it means that 25% of water requirement could be saved without adverse effects on efficient use of mineral fertilizer.

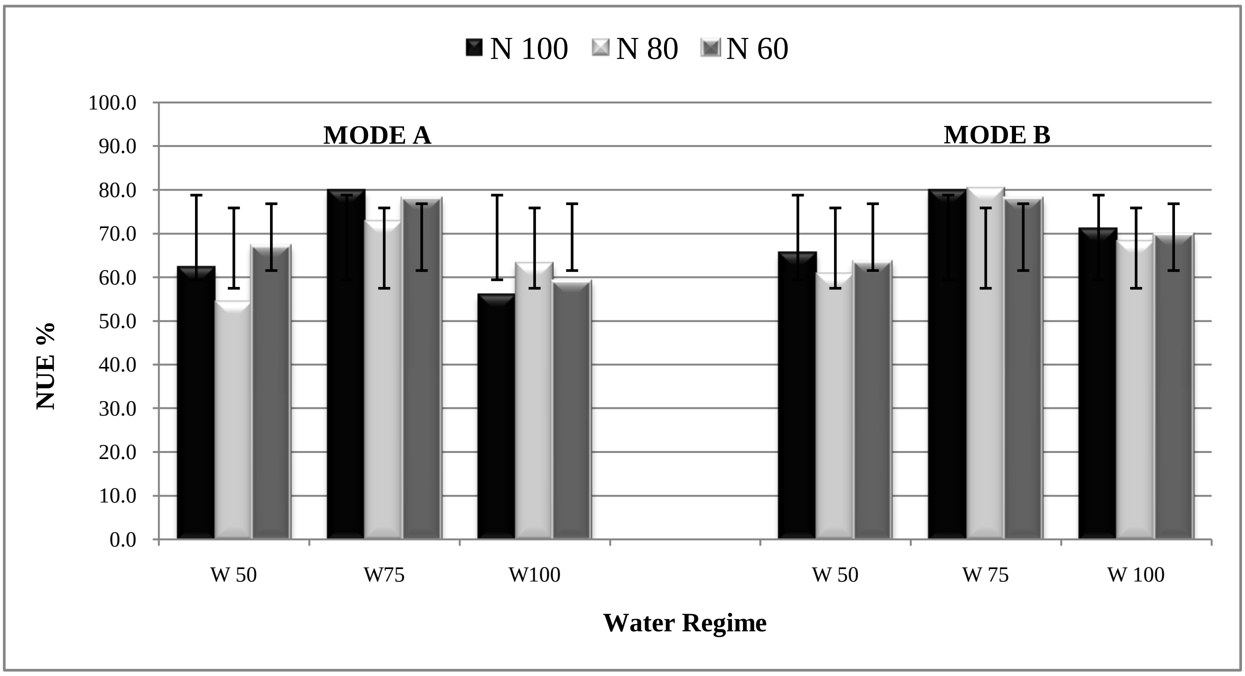
Similar trends, but to somewhat lower extent, were noticed with application of 80% of N recommended rate, where mode B still superior over mode A and the highest %NUE were achieved by combination of this rate with 75% water regime. In this regard, the highest and best %NUE was detected in case of 80% N rate applied with mode B (80.3%) and interacted with 75% water regime.

It is the same case when 80% of N recommended dose was applied. The highest NUE still occurred with combined treatment of N rate either applied with mode A or B and 75% water regime. It accounts for 79.3% and 77.9% for mode A and mode B, respectively. It means that mode B is still better than mode A.

In conclusion, the best %NUE of grains was achieved by application of 80% of N recommended rate applied with mode B and combined with 75% water regime. It means that 20% of N rate and 25% of water requirement could be saved without negative effects on fertilizer use efficiency. It is obvious that fertilizer nitrogen was more efficiently used by grains as compared to those used by straw yield.

Table (28): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Use Efficiency in Grain (%)

N Level %	N Mode	Water Regime			Mean
		50	75	100	
100	A	62.3	79.9	55.9	**66.0**
	B	65.6	79.9	71.1	**72.2**
Mean		**63.9**	**79.9**	**63.5**	**69.1**
80	A	54.4	72.9	63.2	**63.5**
	B	60.9	80.3	68.3	**69.8**
Mean		**57.7**	**76.6**	**65.8**	**66.7**
60	A	68.0	79.3	59.0	**68.8**
	B	64.5	77.9	69.6	**70.7**
Mean		**66.3**	**78.6**	**64.3**	**69.7**
A		**61.58**	**77.37**	**59.39**	**66.11**
B		**63.67**	**79.37**	**69.66**	**70.90**
Mean		**62.62**	**78.37**	**64.53**	**68.51**



Figure(31): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Use Efficiency (%) in Grain

5. ^{15}N Recovery

a. By Straw

Yield of ^{15}N recovered by straw as affected by fertilizer-N rates, mode of application and water regime is presented in **Table (29),** and graphically illustrated by **Figure (32).** In case of 100% N rate applied with mode A, ^{15}N recovered by straw yield tended to decrease with increasing water regime. With mode B, ^{15}N recovery firstly decreased with 75% water regime then tended to increase with 100% water regime. The average indicated that Mode A was superior over mode B. on the other hand, average of water regime indicated some reduction in ^{15}N recovery when water regime increased to 75% then slightly increased with 100% water regime but both of them were lower than those of 50% water regime. It is obvious that the best ^{15}N recovered by straw was achieved by application of 100% N rate combined with 50% water regime using mode A of N application.

In case of 80% N rate applied with mode A, ^{15}N recovery doesn't significantly varied between 50% and 75% water regimes but to some extent decreased with 100% water regime. Application of N with mode B resulted in different picture where ^{15}N recovery decreased with 75% water regime then tended to increase again with 100% water regime. Mean average indicated that mode B was a little bit higher than mode A in contrast with those noticed with 100% N rate. Concerning the average of water regimes, ^{15}N recovery doesn't reflect significant variations between them.

In case of 60% N rate, ^{15}N recovery tended to gradual increase with increasing water regime. This holds true either fertilizer nitrogen was applied with mode A or B. in this respect, the highest values of ^{15}N recovered by straw yield were obtained by combination of 100% water regime and 60 % N rate either applied with mode A or B. in this regard, mode A was superior over mode B. Concerning the average of water regime, means indicated reversible trend than those of 100% and 75% water regimes where it tends to increase with increasing water regimes.

Table (29): Effect of nitrogen fertilizer application strategy and irrigation water regime on ^{15}N Recovery ($kg.ha^{-1}$) By Straw

N Level %	N Mode	Water Regime			Mean
		50	75	100	
100	A	41.4	33.1	32.6	**35.7**
	B	25.3	19.3	29.0	**24.5**
Mean		**33.4**	**26.2**	**30.8**	**30.1**
80	A	24.4	24.9	18.9	**22.7**
	B	24.2	20.2	27.0	**23.8**
Mean		**24.3**	**22.6**	**22.9**	**23.3**
60	A	19.2	23.8	35.3	**26.1**
	B	20.2	24.2	28.6	**24.3**
Mean		**19.7**	**24.0**	**31.9**	**25.2**
A		**28.32**	**27.28**	**28.94**	**28.18**
B		**23.22**	**21.23**	**28.18**	**24.21**
Mean		**25.77**	**24.26**	**28.56**	**26.20**

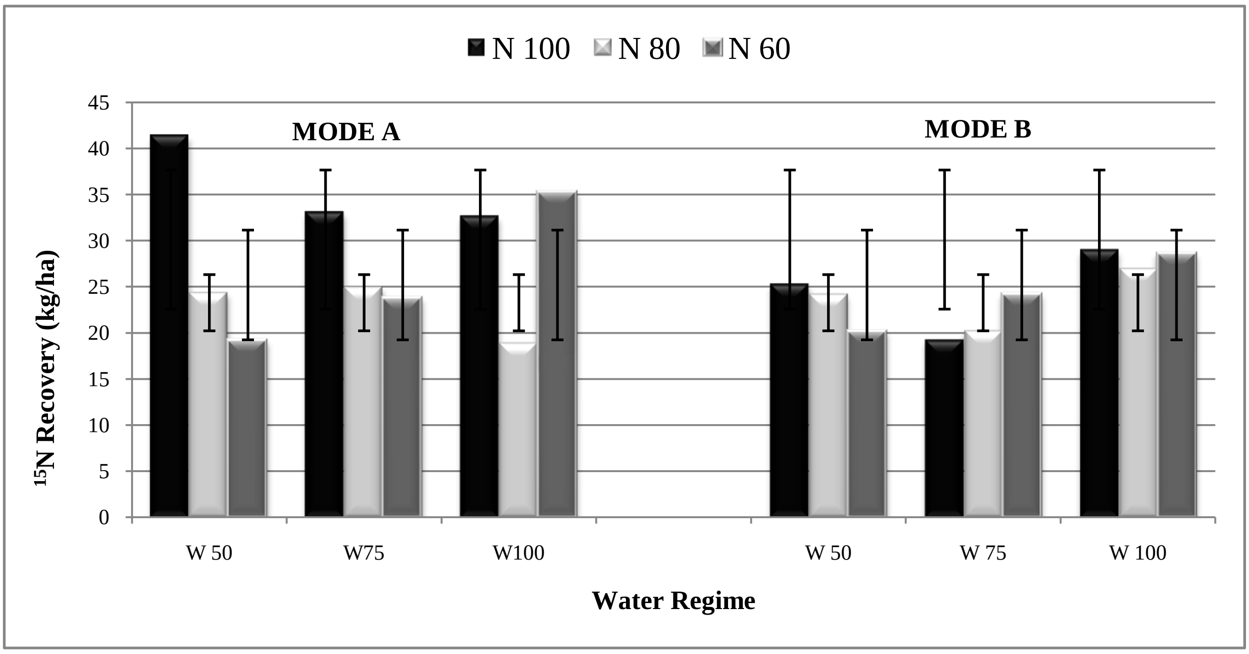


Figure (32): Effect of nitrogen fertilizer application strategy and irrigation water regime on ^{15}N Recovery (kg.ha^{-1}) By Straw

Considering the overall means, ^{15}N recovery was higher in case of 100% N rate followed by 60% N rate then the rate of 80%. Superiority of mode A over B was only more pronounced with 100% N rate. also, the best ^{15}N recovery was occurred with 100% water regime.

b. By Grain

Labeled N recovered by grains as affected by fertilizer N rates and mode of applications and water regimes is presented in **Table (30)** and graphically illustrated by **Figure (33)** ^{15}N recovery was significantly affected by water regimes when fertilizer nitrogen applied at rate of 100% with mode A where it doesn't reflects significant variation between 50% and 75% regimes while it tended to significant increase with 100% water regime.

Similar trend but to high extent was noticed using mode B of N application. It means that ^{15}N fraction was efficiently used by grain when 100% N recommended rate was applied using mode B as compared to mode A under 100% water regime.

In case of 80% of N recommended rate mode A showed similar trend as noticed with rate 100% with a little bit difference. On the other hand use of mode B reflected slight decrease in ^{15}N recovery with increasing water regimes. Mean average of application modes still indicated the superiority of mode B over mode A but in low extent especially mode B comparing to those recorded at b100% N rate.

Another view was drawn with application of 60% N rate using mode A of application where ^{15}N recovery slightly decreased with increasing water regime up to 75% while severe reduction in ^{15}N recovery was detected under 100% water regime. Similar trend was noticed when mode B applied but the reduction only noticed with 75% water regime then tended to increase significantly when water regime raised to 100%.in this regard the mean average of application modes doesn't reflected significant variation between the two modes.

Table (30): Effect of nitrogen fertilizer application strategy and irrigation water regime on ^{15}N Recovery ($kg.ha^{-1}$) By Grain

N Level %	N Mode	Water Regime			Mean
		50	75	100	
100	A	32	30.4	45.1	**35.8**
	B	48.6	49.7	55.3	**51.2**
Mean		**40.3**	**40.1**	**50.2**	**43.5**
80	A	35	34.8	42.8	**37.5**
	B	49.5	45.7	42.1	**45.8**
Mean		**42.3**	**40.3**	**42.5**	**41.7**
60	A	37.5	32.4	23.4	**31.1**
	B	30.1	20.8	36.2	**29.0**
Mean		**33.8**	**26.6**	**29.8**	**30.1**
A		**34.83**	**32.53**	**37.10**	**34.82**
B		**42.73**	**38.73**	**44.53**	**42.00**
Mean		**38.78**	**35.63**	**40.82**	**38.41**

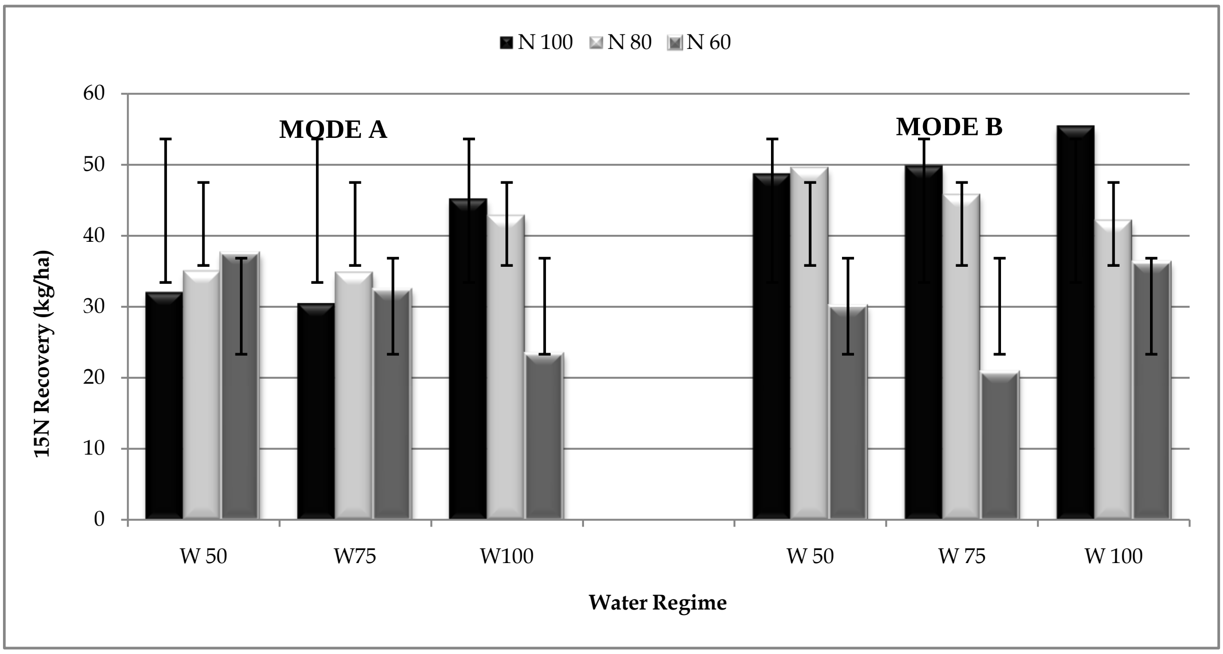


Figure (33): Effect of nitrogen fertilizer application strategy and irrigation water regime on ^{15}N Recovery (kg.ha^{-1}) By Grain

In general the overall averages indicated the superiority of mode B over mode A and the suitability of 100% water regime for moving nitrogen toward the plant roots then enhanced the uptake of element in fraction of ^{15}N molecules. This fraction of nutrient was not significantly varied between 100% and 80% of N recommended rates but significantly decreased with 60% rate which gave us the opportunity to recommend the moderate rate of nitrogen fertilizer combined with 75% water regime using mode B of nitrogen fertilizer application as the best strategy of nitrogen and water regimes. ^{15}N recovered by grains was significantly higher than those recorded with plant straw.

6. Nitrogen Remained In Soil

Nitrogen remained ion soil after wheat harvest as affected by fertilizer N rates and mode of application as well as different water regimes is presented in **Table (31),** and graphically illustrated by **Figure (34).** In case of mode A the percentages of N remained in soil after harvest showed slight decrease with increasing water regimes up to 100%. The absolute values has the same behavior. Similar trends with a little bit difference were noticed when mode B was applied. It means that fertilizer N remained in soil after harvest was mainly affected by water regimes not by fertilizer application modes.

Results And Discussion

When the moderate rate of fertilizer N (80%) was used severe reduction in nitrogen remained in soil was noticed with 100% water regime. Still there was no significant variation between the two modes of N application. Also there was no significant variation in N remained in soil when comparison held between 50% and 75% water regimes. This rate of fertilizer N resulted in to some extent lower figures of N remained in soil than those recorded under 100% fertilizer N rate.

Application of 60% of fertilizer recommended rate induced severe reduction in portion and absolute figures of N remained in soil after harvest but the same pattern of application modes and water regimes was observed. Highly significant reduction in fertilizer nitrogen remained in soil still occurred with 100% water regime.

In conclusion the percent and quantity of fertilizer N remained in soil after wheat harvest were attributed to the fertilizer application rates but not to application modes and in the same time it significantly negatively affected by increasing water regime up to 100%. From the economical and environmental view points if we consider the N fertilizer remained in soil as storage for the next crop in a rotation then we can recommend the moderate rate of fertilizer N either applied using any one of modes in combination with 75% water regime.This strategy could be helpful in keeping soil fertility and in the same time avoid the pollution of surrounding environment including soil ground water and air.

Compared to a conventional application rate of 360 kg N ha^{-1} (N360), a reduced rate of 120 kg N ha^{-1} (N120) led to a significant increase ($P < 0.05$) in wheat yield and no significant differences were found for maize. However, in the 0-100 cm soil profile at harvest, compared with N360, N120 led to significant decreases ($P < 0.05$) of percent residual N and percent unaccounted-for N, which possibly reflected losses from the managed system (Xiao-Tang et al. 2007).

For N120, total soil N balance was negative; however, there was still considerable mineral N (NH_4^+:-N and NO^-_3,-N) in the soil profile after harvest. Therefore, N120 could be considered agronomical acceptable in the short run, but for long-term sustainability, the N rate should be recommended based on a soil mineral N test and a plant tissue nitrate test to maintain the soil fertility.

Meanwhile, the residual N for the first wheat and maize crops in the form of nitrate (NO_3^--N) under the conventional application rate (N360) significantly increased ($P < 0.05$) and accounted for 11.2%-24.4% of the total N applied. This resulted in a high risk of nitrate leaching. Also the unaccounted-for N fraction, which included all losses combined with experimental error (leaching below 100 cm soil as well as gaseous losses), was significantly lower ($P < 0.05$) at N120 compared to that at N360.

Therefore, total N fertilizer losses of N120 and N360 treatments for winter wheat were 12.4 and 94.0 kg N ha^{-1}, respectively, and for summer maize 23.0 and 97.6 kg N ha^{-1}, respectively. Thus, under the experimental conditions, a reduced N application rate of 120 kg N ha^{-1} resulted in a significant increase in fertilizer N recovery of the crops and significantly reduced losses. In considering the total soil N balance **(Table (31))**, for both crops the residual fertilizer N in the soil after harvest at N120 (34.9-54.4 kg N ha^{-1}) was much less than the total crop N uptake derived from other sources (94.8-106.3 kg N ha^{-1}). Even including inputs from dry and wet deposition, the total soil N balance was still negative, which seemed to suggest that the soil N pools could be depleted over time.

However, considering the high Nmin (NH_4-N^+ NO_3-N) after harvesting each crop (indicating the relatively high N mineralization potential in this fertile soil), in the short run the recommended 120 kg N ha^{-1} could be considered an acceptable N rate for both yield production and environmental protection. However, for long-term sustainability, fertilizer N recommendation rates should be recommended according to a soil Nmin test and a plant tissue nitrate test (Chen, 2003; Liu et al., 2003).

Contrary to the results obtained in N120, the residual fertilizer N in soil after harvest under conventional N rate (N360) was much higher than crop N uptake derived from soil in both crops, which resulted in large amounts of residual soil Nmin after harvesting.

Table (31): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Remained in Soil

N Level %	N Mode	Water Regime						Mean
		50		75		100		
		%	kg.ha^{-1}	%	kg.ha^{-1}	%	kg.ha^{-1}	
100	A	13.5	24.0	11.5	20.5	10.5	18.7	**21.1**
	B	14.0	24.9	13.0	23.1	11.0	19.6	**22.5**
Mean		**13.8**	**24.5**	**12.3**	**21.8**	**10.8**	**19.2**	**21.8**
80	A	11.0	15.7	11.5	16.4	9.5	13.5	**15.2**
	B	11.0	15.7	12.5	17.8	4.5	6.4	**13.3**
Mean		**11.0**	**15.7**	**12.0**	**17.1**	**7.0**	**10.0**	**14.3**
60	A	10.0	10.7	9.5	10.1	4.0	4.3	**8.4**
	B	9.5	10.1	8.5	9.1	3.5	3.7	**7.6**
Mean		**9.8**	**10.4**	**9.0**	**9.6**	**3.8**	**4.0**	**8.0**
A		**11.50**	**16.80**	**10.83**	**15.67**	**8.00**	**12.17**	**11.94**
B		**11.50**	**16.90**	**11.33**	**16.67**	**6.33**	**9.90**	**10.97**
Mean		**11.50**	**16.85**	**11.08**	**16.17**	**7.17**	**11.03**	**11.46**

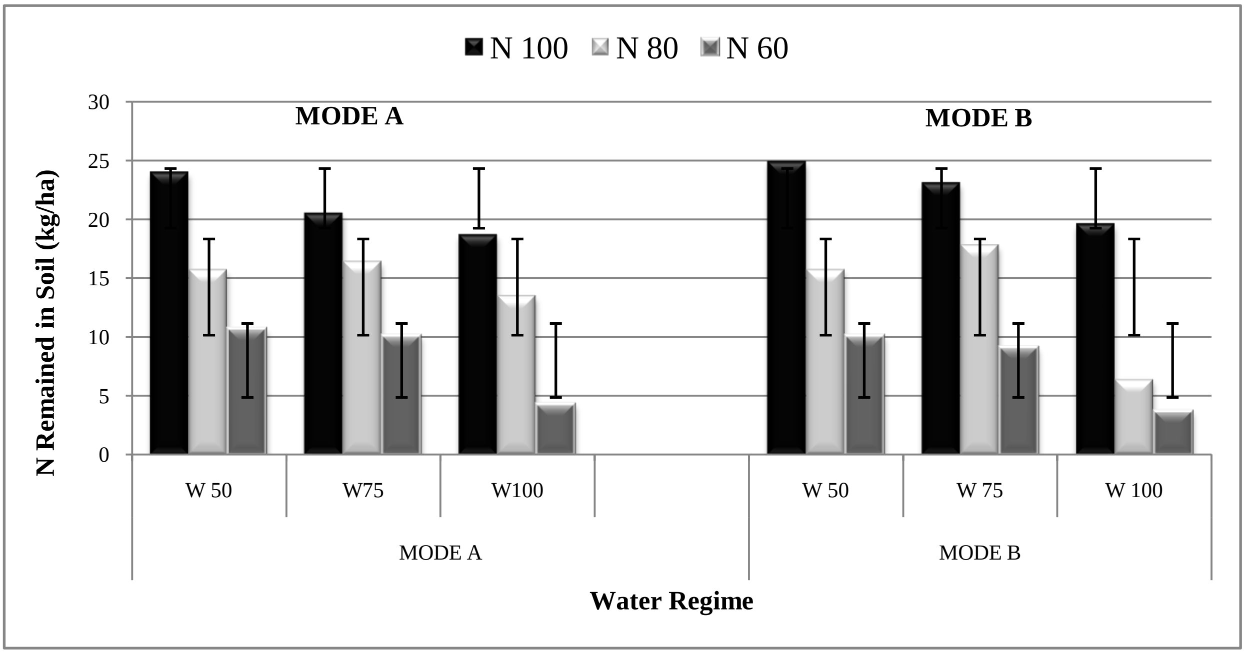


Figure (34): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Remained in Soil (kg.ha^{-1})

7. Nitrogen Losses after harvest as affected by nitrogen fertilizer application strategy and irrigation water regime

Nitrogen losses from soil medium were significantly affected by water regime and mode of fertilizer N application **(Table (32)** and **Figure (35))**. In case of 100% N application rate using mode A, losses were higher with 50% and 100% water regimes while remarkable and sever reduction in N losses was detected with 75% water regime.

Similar trend, but to somewhat lower extent, was noticed when mode B was applied. It seems that moderate water regime was profitable and preferable for saving fertilizer N. In the same direction, mode B of application was effective on reducing nitrogen losses as compared to mode A.

Average of N losses as affected by 75% water regime, were relatively reduced by about 64.8% and 69.5% of W50 and W100, respectively. Regarding mode of N application, mode B had reduced fertilizer N losses by about 31.5% of those induced by mode A.

Similar trend was noticed with application of 80% fertilizer N rate. In this respect, losses values were nearly closed to those of 100% N rate. it means that we can consider this rate instead of 100% N rate to be used in combination with 75% water regime.

Remarkable reduction in fertilizer nitrogen losses were recorded with application of 60% fertilizer N rate as compared to either 100% or 80% N rates. This phenomenon was more pronounced with mode B of N application.

Comparison between the three N rates indicated that fertilizer N losses were significantly reduced linearly with reduction of fertilizer N rate. it seems that combined treatment of moderate N rate x mode B of application x 75% water regime is the best strategy that compensate remarkable quantities of nitrogen nutrient without adverse effect on plant growth and yield. Consequently, it reduces, to somewhat extent, N fertilizer losses and compensate reasonable amount of both fertilizer and water requirement.

Table (32): Fertilizer-N Losses (kg.ha^{-1}) after harvest of wheat Grain yield as affected by nitrogen application strategy and water regime

N Level %	N Mode	Water Regime			Mean
		50	75	100	
100	A	43.2	15.3	59.8	**39.4**
	B	36.3	12.7	31.9	**27.0**
Mean		**39.8**	**14.0**	**45.9**	**33.2**
80	A	49.2	22.2	38.9	**36.8**
	B	40	10.3	38.7	**29.7**
Mean		**44.6**	**16.3**	**38.8**	**33.2**
60	A	23.4	12	39.4	**24.9**
	B	27.8	14.5	28.7	**23.7**
Mean		**25.6**	**13.3**	**34.1**	**24.3**
A		**38.60**	**16.50**	**46.03**	**33.71**
B		**34.70**	**12.50**	**33.10**	**26.77**
Mean		**36.65**	**14.50**	**39.57**	**30.24**

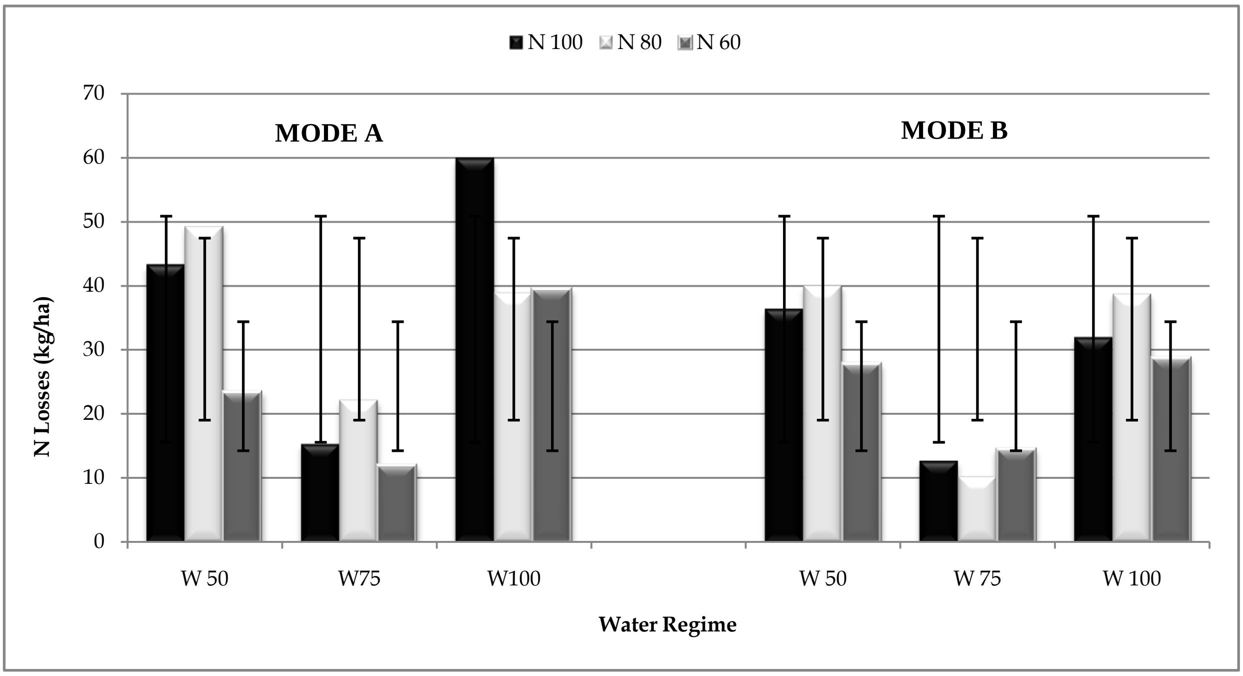


Figure (35): Fertilizer-N Losses (kg.ha^{-1}) after harvest of wheat Grain yield as affected by nitrogen application strategy and water regime

8. Fertilizer-N balance (kg.ha^{-1}) after harvest of wheat Grain yield as affected by nitrogen application strategy and water regime under Clay Soil

The abovementioned results of nitrogen nutrient, i.e. uptake by plant, remained in soil and losses as affected by fertilizer application rate and modes and water regime could be summarized in the following **Table (33),** and illustrated by **Figure (36)**.

Results And Discussion

Average of water regimes combined with 100% N rate showed higher uptake by plants (142.21 kg ha^{-1}) when 75% water regime applied that those of other regimes. N remained in soil were nearly the same in different water regimes.

N losses highly significantly reduced by application of 75% water regime. Both plant uptake and fertilizer N remained in soil were not varied according to mode of N application while mode B was effective on reducing N losses as compared to mode A.

Similar trends were noticed, but to somewhat lower extent, with the other two fertilizer N rates.

Generally, fertilizer nitrogen balance showed that the N losses accounted for 28.7%, 8.5% and 34.5% in relation to sum of N uptake and n remained in soil for W50, W75 and W100, respectively under 100% N application rate. It accounts for 45.6%, 12.9% and 34.2%; 31.6%, 14.2% and 46.9% for the sequence under 80% and 60% N application rates, respectively. Both N uptake by plants and N remained in soil after harvest tended to decline with reducing the rate of fertilizer N application rate. On the other hand, fertilizer N losses slightly decreased with reduced fertilizer N rate. This was more pronounced with application of 75% water regime.

Crop yields do not linearly respond to inputs of N fertilizer (e.g., Cassman et al. 2002; Syswerda et al. 2012). As closer N supply approaches optimum fertilization rates and specifically if N supply exceeds the optimum N supply, environmental losses of N such as in form of N_2O or NH_3 will increase exponentially (Van Groenigen et al. 2010; Sutton et al. 2011).

In converse to crop yields, analysis of Zhou and Butterbach-Bahl (2014) revealed a linear relationship between NO_3^-leaching loss and N application rates for both maize and wheat cropping systems. Moreover, their meta-analysis showed that across different studies with their specific site features such as soil characteristics and agricultural management or climatic conditions, 25 % and 13 % of applied N were lost by NO_3^-leaching to the hydrosphere from maize and wheat systems, respectively. They demonstrated that crop nitrogen use efficiency (NUE) ranged from 14.2%to 74.6% (mean value: 50.9 %) for wheat system. The highest average crop NUE for wheat (66.7 %) system was obtained with the corresponding average N application rates of 234.2 kg

N ha^{-1}(ranging from 200 to 300 kg N ha^{-1}) and 174.6 kg N ha^{-1} (ranging from 150 to 200 kg N ha^{-1}).

In consistent, López-Bellido et al. (2008) demonstrated that wheat types showed a significant increase of straw N uptake with N rate. Also, grain N uptake rose with increasing N rate in both wheat types. They also indicated that all N efficiency indices , i.e. N use efficiency (NUE), N uptake efficiency (NUE) and N utilization efficiency (NUE), apparent N recovery fraction (NRF) were declined with rising N fertilizer rates in both wheat, a finding also reported by Ehdaie et al (1999, 2001).

Table (33): Fertilizer-N balance (kg.ha^{-1}) after harvest of wheat Grain yield as affected by nitrogen application strategy and water regime under Clay Soil

N Level %	N Mode	Water Regime								
		50			75			100		
		N_{plant} Kg/ha	N_{soil} Kg/ha	N_{Losses} Kg/ha	N_{plant} Kg/ha	N_{soil} Kg/ha	N_{Losses} Kg/ha	N_{plant} Kg/ha	N_{soil} Kg/ha	N_{Losses} Kg/ha
100	**A**	110.82	24.00	**43.18**	142.17	20.50	**15.33**	99.54	18.70	**59.76**
	B	116.81	24.90	**36.29**	142.25	23.10	**12.65**	126.48	19.60	**31.92**
Mean		**113.82**	**24.45**	**39.73**	**142.21**	**21.80**	**13.99**	**113.01**	**19.15**	**45.84**
80	**A**	77.52	15.70	**49.18**	103.83	16.40	**22.17**	90.01	13.50	**38.89**
	B	86.67	15.70	**40.03**	114.31	17.80	**10.29**	97.25	6.40	**38.75**
Mean		**82.10**	**15.70**	**44.60**	**109.07**	**17.10**	**16.23**	**93.63**	**9.95**	**38.82**
60	**A**	72.66	10.70	**23.44**	84.71	10.10	**11.99**	63.06	4.30	**39.44**
	B	68.90	10.10	**27.80**	83.23	9.10	**14.47**	74.37	3.70	**28.73**
Mean		**70.78**	**10.40**	**25.62**	**83.97**	**9.60**	**13.23**	**68.71**	**4.00**	**34.09**
A		87.00	16.80	**38.60**	110.24	15.67	**16.50**	84.20	12.17	**46.03**
B		90.80	16.90	**34.70**	113.26	16.67	**12.47**	99.37	9.90	**33.13**
Mean		**88.90**	**16.85**	**36.65**	**111.75**	**16.17**	**14.48**	**91.79**	**11.03**	**39.58**

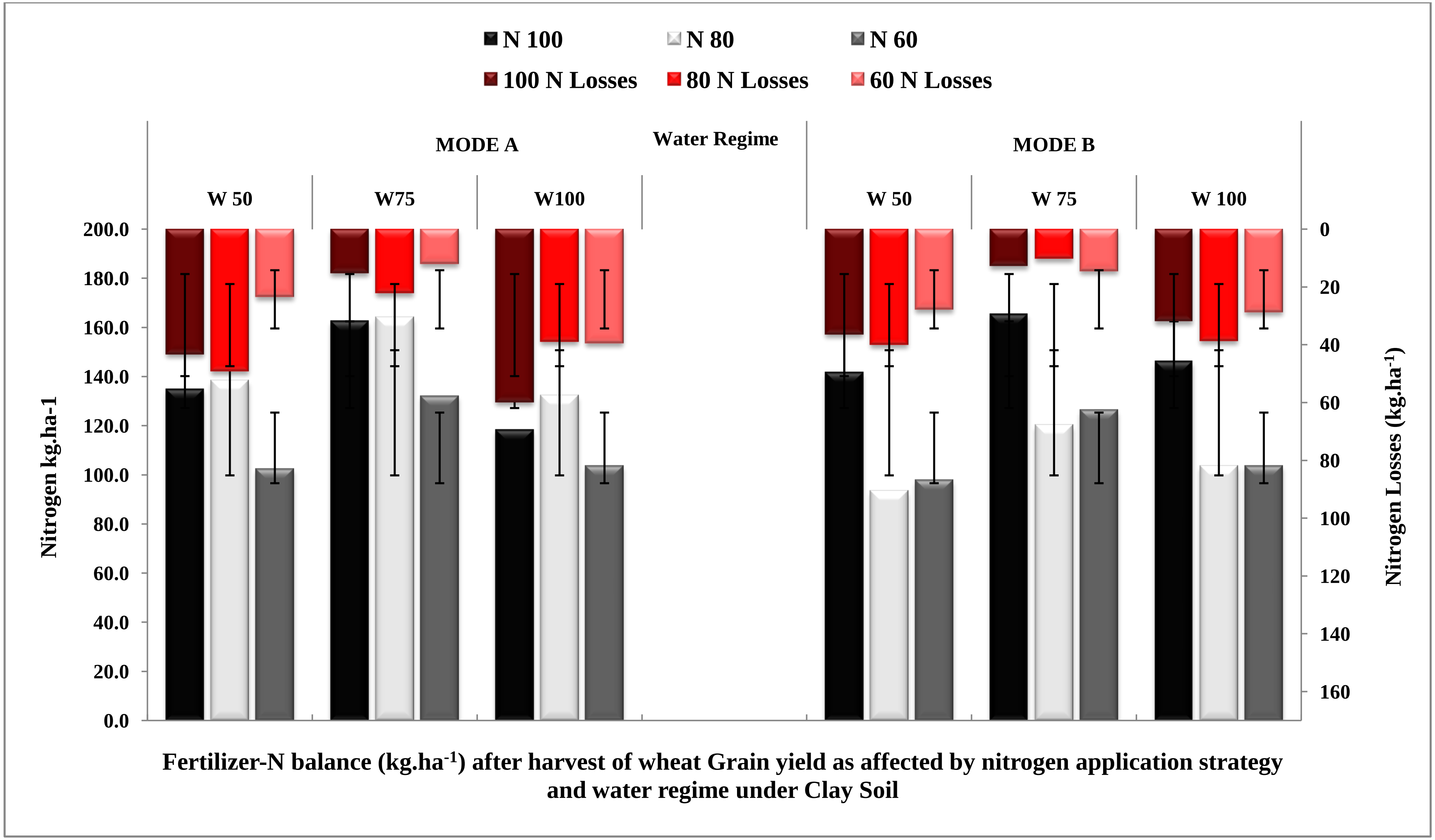


Figure (36): Fertilizer-N balance (kg.ha^{-1}) after harvest of wheat Grain yield as affected by nitrogen application strategy and water regime under Clay Soil

B. Sand Soil

1. Total Nitrogen Uptake kg/ha in

a. Total Nitrogen Uptake in Straw yield

Nitrogen uptake by straw yield of wheat fertilized with 100% N rate slightly increased with increasing water regime up to 100%. It was also slightly increased using mode B of N application **(Table (34)** and **Figure (37)).** Application of 80% N rate resulted in nearly closed values of N uptake by straw to those recorded with 100% N rate. Average of N uptake as affected by water regime indicated highly significant increase with increasing water regime. In this regard, both N uptake averages of W75 and W100 were nearly closed to each other. Mode B of N application still superior over mode A. Similar trends, but to somewhat low extent, were detected with 60% N rate. in this respect, reversible ranking of application modes was noticed where the average of N uptake of mode A surpass those of mode B.

In conclusion, significant increases in N uptake by straw were occurred with 100% and 80% N rates, which nearly closed to each other, using mode B of application and combined with 100% water regime.

Table (34): Effect of nitrogen fertilizer application strategy and irrigation water regime on total Nitrogen Uptake in straw(kg ha^{-1}).

N Level %	N Mode	Water Regime			Mean
		50	75	100	
100	A	130.8	161.3	174.7	**155.60**
	B	185.8	146.3	161.3	**164.47**
Mean		**158.3**	**153.8**	**168.0**	**160.03**
80	A	113.3	140.1	169.9	**141.10**
	B	145.7	203	203.8	**184.17**
Mean		**129.5**	**171.6**	**186.9**	**162.63**
60	A	149	165.1	163.5	**159.20**
	B	99	108.6	176.3	**127.97**
Mean		**124.0**	**136.9**	**169.9**	**143.58**
A		**131.03**	**155.50**	**169.37**	**151.97**
B		**143.50**	**152.63**	**180.47**	**158.87**
Mean		**137.27**	**154.07**	**174.92**	**155.42**

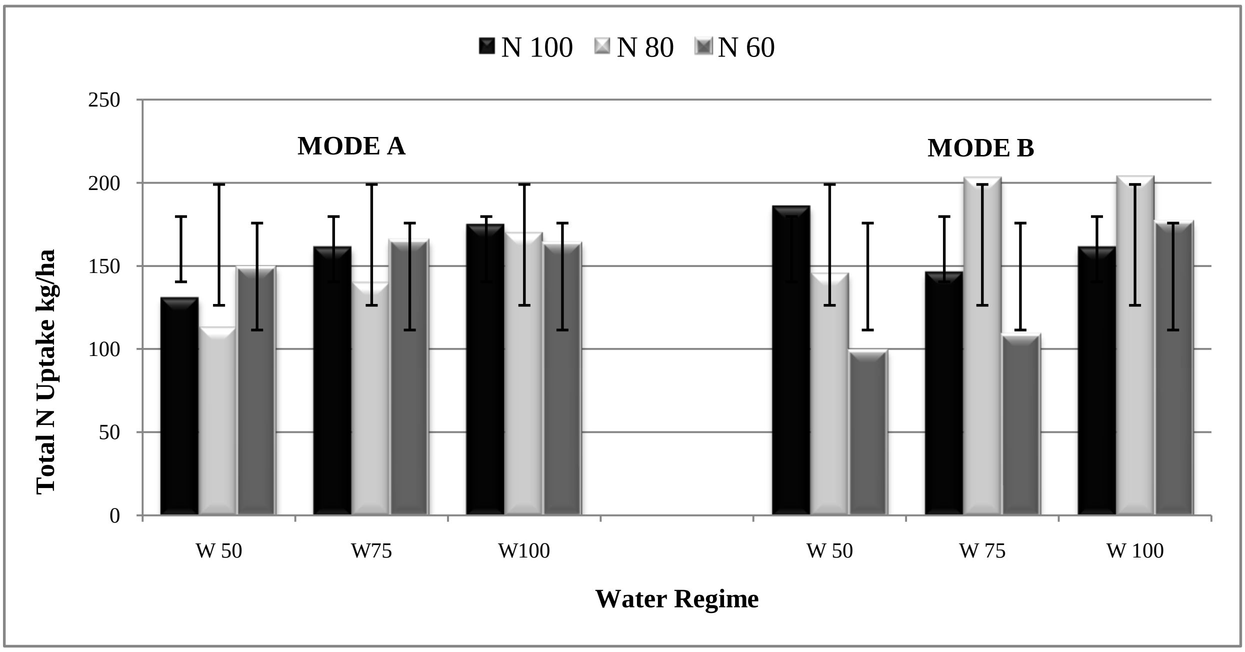


Figure (37): Effect of nitrogen fertilizer application strategy and irrigation water regime on total Nitrogen Uptake in straw(kg ha^{-1}).

b. Total Nitrogen Uptake in Grain yield

It is obvious; in general, that N uptake by grains is higher than those recorded with those of straw **Table (35)** and **Figure (38).** Average of N uptake by grains under 100% N rate as affected by water regime showed highly significant increase with W75 comparable to those of W50 and W100. Severe decrease in N uptake by grain was detected at W100. The significant increase in N uptake was induced by following the mode B of N application. Application of 80% N rate resulted in higher N uptake than those of 100% N rate especially when combined with W75 and W100. In this regard, W75 is still the best treatment among water regimes. average of N uptake under this rate was nearly closed to those of 100% N rate. Therefore, we recommend this moderate rate of fertilizer N that caused remarkable values of N uptake by grain. This may save 20% of fertilizer N rate. similar trend, but to somewhat low extent, was recorded with application of 60% N rate.

From the abovementioned results, we can conclude that 80% N rate applied using mode a in combination with W75 is the best practice that induced the best average of N uptake by wheat grain.

Table (35): Effect of nitrogen fertilizer application strategy and irrigation water regime on total Nitrogen Uptake in Grain(kg ha^{-1}).

N Level %	N Mode	Water Regime			Mean
		50	75	100	
100	A	245.7	268	194.6	**236.10**
	B	246	360.2	164.6	**256.93**
Mean		**245.9**	**314.1**	**179.6**	**246.52**
80	A	221.4	318.8	221.4	**253.87**
	B	194	328.1	205.9	**242.67**
Mean		**207.7**	**323.5**	**213.7**	**248.27**
60	A	192.1	316	114.5	**207.53**
	B	192.9	259.2	278.7	**243.60**
Mean		**192.5**	**287.6**	**196.6**	**225.57**
A		219.73	300.93	176.83	**232.50**
B		210.97	315.83	216.40	**247.73**
Mean		**215.35**	**308.38**	**196.62**	**240.12**

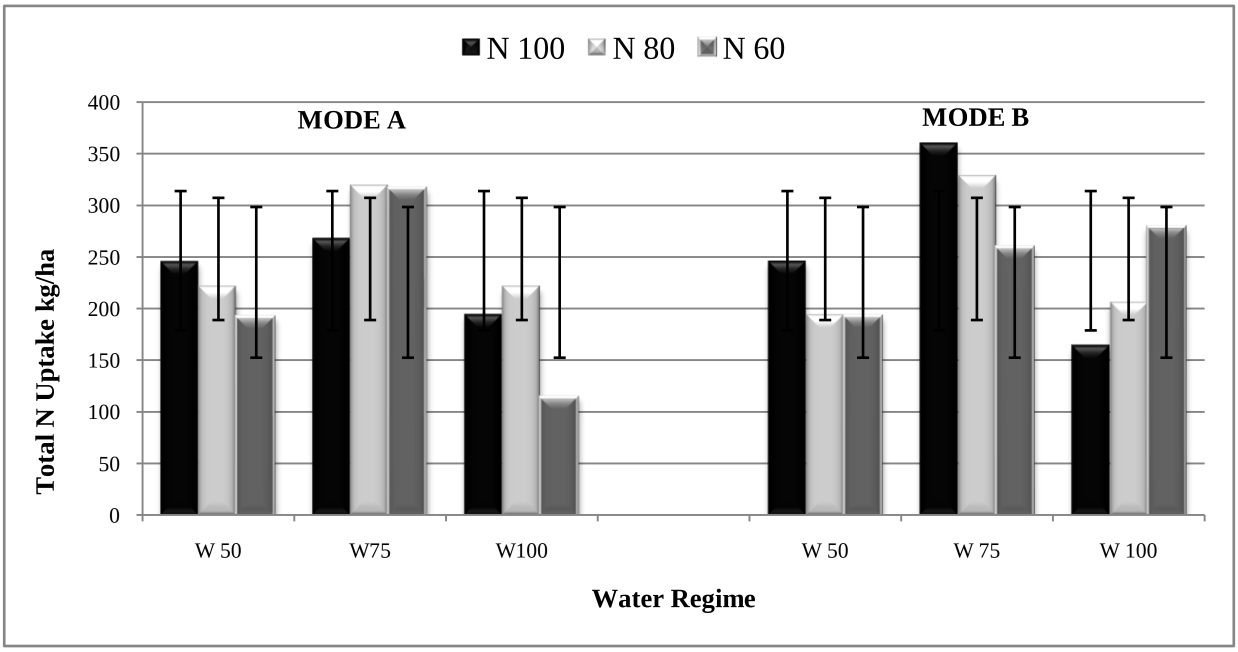


Figure (38): Effect of nitrogen fertilizer application strategy and irrigation water regime on total Nitrogen Uptake in Grain(kg ha^{-1}).

2. Nitrogen Derived From Fertilizer (Ndff)

a. Nitrogen Derived from Fertilizer in Straw yield

Considering the average of absolute values of N uptake from fertilizer by straw, it was slightly increased with increasing water regime combined with 100% N rate **(Table (36)** and **Figure (39)).** In this regard, there was no big significant difference between the fertilizer N application modes. Similar trends, but to some low extent, were noticed with application of 80% N rate. Average of this N rate didn't significantly vary than those of 100% N rate. In addition, mode B was to some extent superior over mode A of fertilizer N application. In case of 60% N rate, values of Ndff by straw, in average, were declined with 75% water regime then raised again with 100% water regime. Average of the N rate indicated a little bit low Ndff as compared to other N rates.

From the overall averages of Ndff values, we can conclude that the best Ndff values were obtained with the rate of 100% or 80%. These values tended to increase slightly with increasing water regime up to 100%. There was no significant difference between the two modes of fertilizer N applications.

Table (36): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Derived from Fertilizer in straw(kg ha^{-1}).

N Level %	**N Mode**	**Water Regime**						**Mean**
		50		**75**		**100**		
		%	**Kg·ha^{-1}**	**%**	**kg·ha^{-1}**	**%**	**kg·ha^{-1}**	
100	**A**	31.1	40.7	33.6	54.2	34.45	60.2	49,62
	B	32.2	59.8	32.9	48.1	34.95	56.4	46.48
Mean		**31.7**	**50.3**	**33.3**	**51.2**	**34.7**	**58.3**	48.05
80	**A**	30.25	34.3	31.05	44.9	31.65	53.8	43.45
	B	30.5	44.4	31.2	63.3	31.85	64.9	53.35
Mean		**30.4**	**39.4**	**31.1**	**54.1**	**31.8**	**59.4**	48.40
60	**A**	29.3	43.7	29.5	48.7	34.75	56.8	46.75
	B	29.95	57.5	30.1	32.7	30	52.9	38.53
Mean		**29.6**	**50.6**	**29.8**	**40.7**	**32.4**	**54.9**	42.64
A		30.22	39.57	31.38	49.27	33.62	56.93	46.61
B		30.88	53.90	31.40	48.03	32.27	58.07	46.12
Mean		30.55	46.73	31.39	48.65	32.94	57.50	46.36

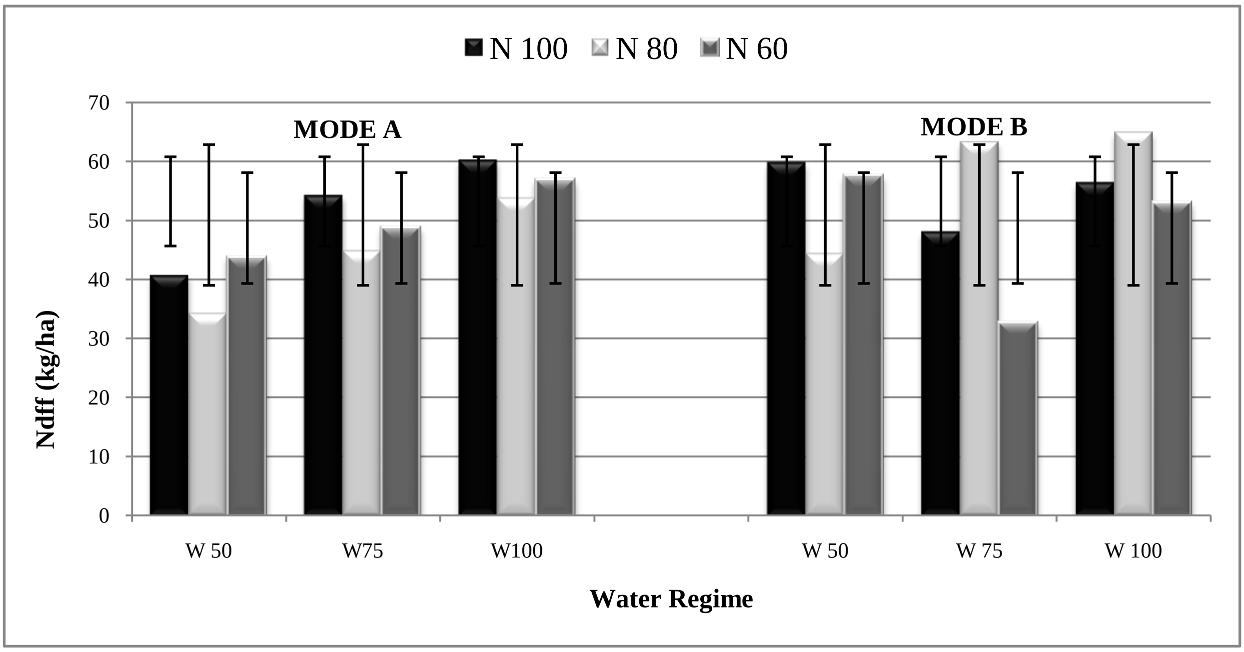


Figure (39): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Derived from Fertilizers (kg.ha^{-1}) in Straw

b. Nitrogen Derived from Fertilizer in Grain yield

Nitrogen derived from fertilizer by grains was significantly increased by increasing water regime to 75% comparing to W50 combined with 100% N rate. This was more pronounced with application of mode B as compared to mode A **(Table (37)** and **Figure (40)).** As indicated by mean average, Ndff induced by mode B was superior over those of mode A. similar trend, but to somewhat low extent was noticed with application of 100% N rate. likewise 100% N rate, there was no significant difference in Ndff average between modes of N application. Comparison held between these two N rates indicated no significant difference in Ndff values. Remarkable decrease in Ndff values was induced by application of 60% N rate. this holds true under all water regimes. High reduction in Ndff was detected with W100. In average, Ndff resulted from application of mode B was higher than those of mode A.

From the overall averages of Ndff values, we can conclude that the best Ndff values gained by grain were obtained with the rate of 100% or 80%. These values tended to decrease severely with increasing water regime up to 100%. Mode B was superior over mode A when Ndff was concerned.

Table (37): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Derived from Fertilizer in Grain(kg ha^{-1}).

N Level %	N Mode	Water Regime						Mean
		50		75		100		
		%	kg.ha^{-1}	%	kg.ha^{-1}	%	kg.ha^{-1}	
100	A	46.6	114.5	44.6	119.5	47.9	93.2	86.88
	B	48.25	118.7	47.75	172.0	49.4	81.3	100.90
Mean		**47.4**	**116.6**	**46.2**	**145.8**	**48.7**	**87.3**	93.89
80	A	43.75	96.9	44.35	141.4	44.4	98.3	94.70
	B	42.8	83.0	42.7	140.1	44.55	91.7	92.13
Mean		**43.3**	**89.9**	**43.5**	**140.7**	**44.5**	**95.0**	93.41
60	A	39.95	76.7	39.3	124.2	39.4	45.1	69.57
	B	39.9	77.0	40.1	103.9	40.75	113.6	86.09
Mean		**39.9**	**76.9**	**39.7**	**114.1**	**40.1**	**79.3**	77.83
A		43.43	96.03	42.75	128.37	43.90	78.88	83.71
B		43.65	92.90	43.52	138.68	44.90	95.54	93.04
Mean		43.54	94.47	43.13	133.52	44.40	87.21	88.38

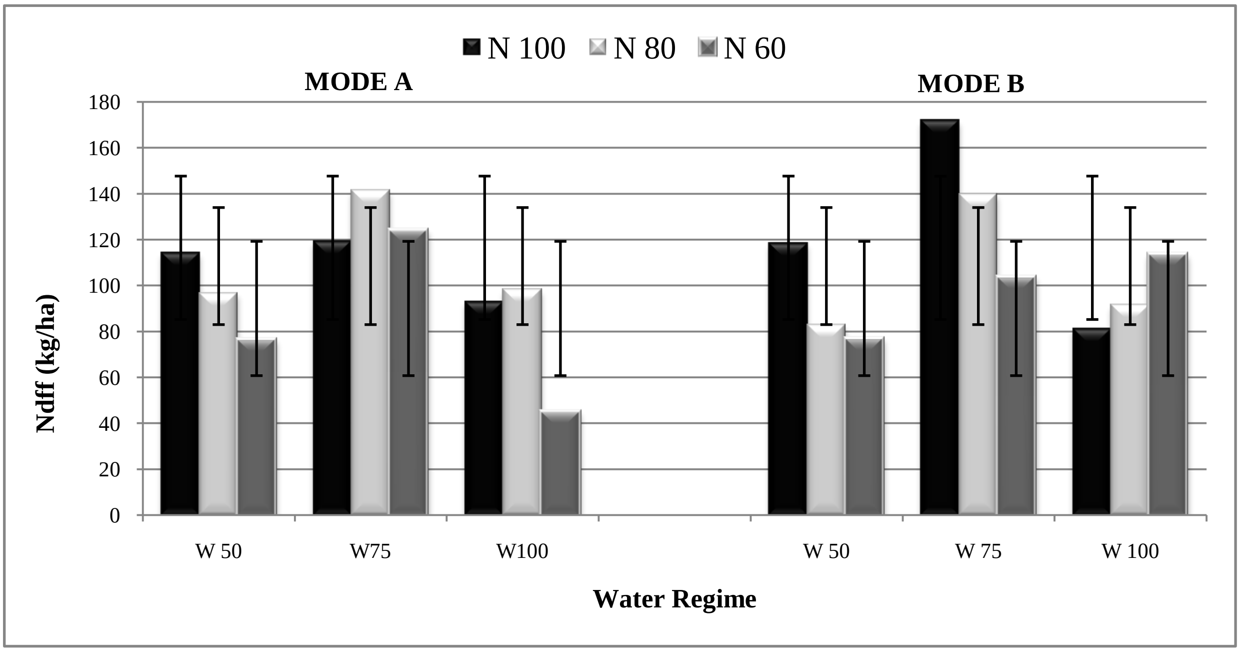


Figure (40): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Derived from Fertilizers (kg.ha^{-1}) in Grain

3. Nitrogen Derived From Soil (Ndfs)

a. Nitrogen Derived from Soil in Straw yield

Nitrogen derived from soil by wheat straw didn't reflect any significant variations as affected by water regimes under 100% N rate. Mode of fertilizer application followed the same behavior where it doesn't show significant variations in Ndfs values **(Table (38)** and **Figure (41)).** Reversible trend was observed with 80% N rate whereas Ndfs tended to increase slightly and gradually with raising the water regimes as indicated by mean averages. Under this N rate Ndfs (mean value) was to some extent higher when mode B was followed than those of mode A. It was a little bit vary than those recorded at 100% N rate. Similar trend but to some low extent was noticed with 60% N rate.

Overall mean averages gave us the chance to conclude that best values of Ndfs were obtained W100. This holds true with all N rates. In this regards, fertilizer N rates hasn't significant effect on N derived from soil. In addition, there was no significant variation between the two modes of fertilizer application.

Table (38): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Derived from Soil in straw(kg ha^{-1}).

N Level %	N Mode	Water Regime						Mean
		50		75		100		
		%	kg.ha^{-1}	%	kg.ha^{-1}	%	kg.ha^{-1}	
100	A	68.9	90.1	66.4	107.1	65.55	114.5	95.72
	B	67.8	126.0	67.1	98.2	65.05	104.9	89.38
Mean		**68.4**	**108.0**	**66.8**	**102.6**	**65.3**	**109.7**	92.55
80	A	69.75	79.0	68.95	96.6	68.35	116.1	93.69
	B	69.5	101.3	68.8	139.7	68.15	138.9	115.57
Mean		**69.6**	**90.1**	**68.9**	**118.1**	**68.3**	**127.5**	104.63
60	A	70.7	105.3	70.5	116.4	65.25	106.7	96.11
	B	70.05	69.3	69.9	75.9	70	123.4	89.77
Mean		**70.4**	**87.3**	**70.2**	**96.2**	**67.6**	**115.0**	92.94
A		69.78	91.50	68.62	106.70	66.38	112.44	95.17
B		69.12	98.86	68.60	104.58	67.73	122.41	98.24
Mean		69.45	95.18	68.61	105.64	67.06	117.43	96.71

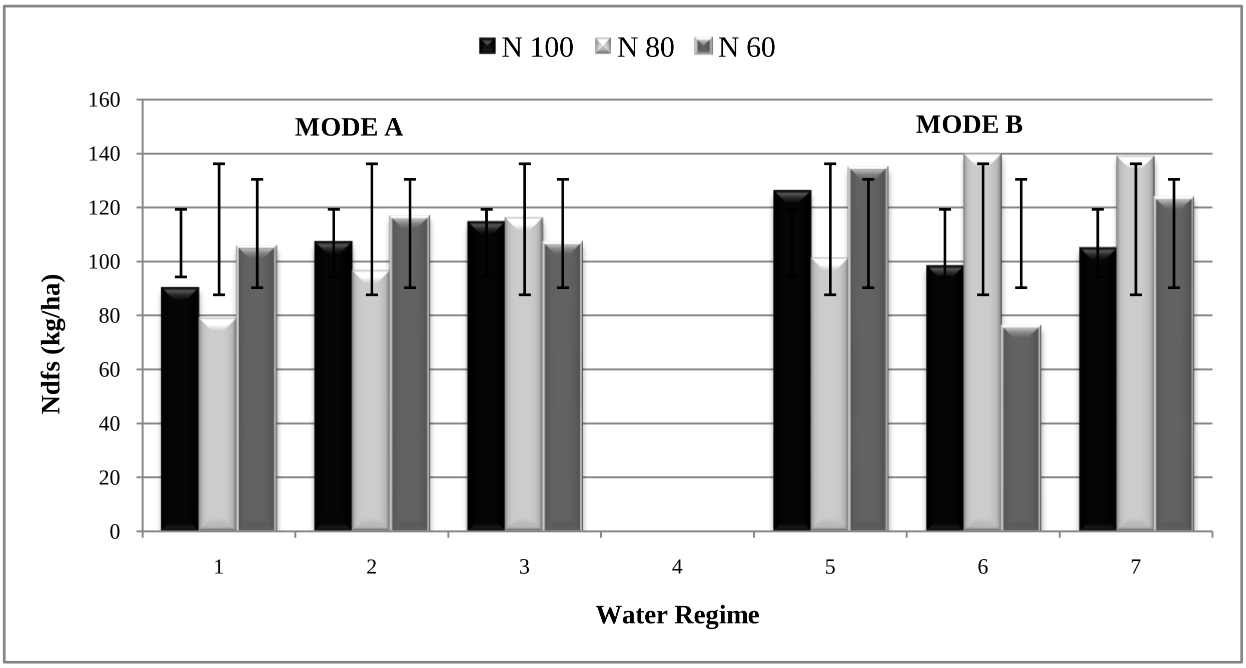


Figure (41): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Derived from Soil (kg.ha^{-1}) in Straw

b. Nitrogen Derived from Soil in Grain yield

In case of 100% N rate, Ndfs by grains tended to increase with increasing water regime from 50% to 75% then decreased when water regime reached 100%. A little but not significant variations between modes of fertilizer N application was noticed **(Table (39)** and **Figure (42)).** Application of 80% N rate caused a little bit higher Ndfs than those of 100% N rate. The best value of Ndfs was detected with 75% water regime. There was no significant difference between the two modes of N application. Similar trend with no big variations was noticed with 60% N rate.

It seems that Ndfs by grains was a little bit higher than those of straw. In contrast to straw, Ndfs by grains was higher W75. Mode B of fertilizer N application seems to be a little higher than those of mode A

Table (39): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Derived from Soil in Grain(kg ha^{-1}).

N Level %	N Mode	Water Regime						Mean
		50		75		100		
		%	kg.ha^{-1}	%	kg.ha^{-1}	%	kg.ha^{-1}	
100	A	53.4	131.2	55.4	148.5	52.1	101.4	**100.65**
	B	51.75	127.3	52.25	188.2	50.6	83.3	**107.36**
Mean		**52.6**	**129.3**	**53.8**	**168.3**	**51.4**	**92.3**	**104.01**
80	A	56.25	124.5	55.65	177.4	55.6	123.1	**118.70**
	B	57.2	111.0	57.3	188.0	55.45	114.2	**119.21**
Mean		**56.7**	**117.8**	**56.5**	**182.7**	**55.5**	**118.6**	**118.96**
60	A	60.05	115.4	60.7	191.8	60.6	69.4	**107.27**
	B	60.1	115.9	59.9	155.3	59.25	165.1	**126.55**
Mean		**60.1**	**115.6**	**60.3**	**173.5**	**59.9**	**117.3**	**116.91**
A		**56.57**	**123.70**	**57.25**	**172.57**	**56.10**	**97.96**	**108.87**
B		**56.35**	**118.07**	**56.48**	**177.16**	**55.10**	**120.86**	**117.71**
Mean		**56.46**	**120.88**	**56.87**	**174.86**	**55.60**	**109.41**	**113.29**

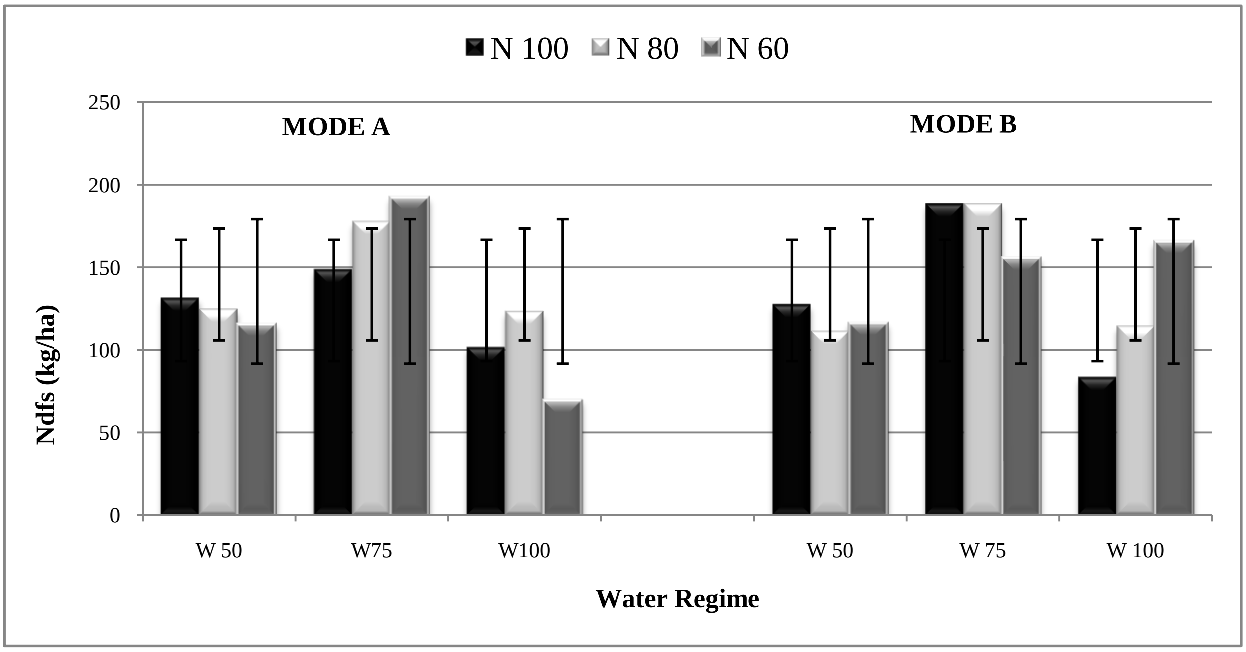


Figure (42): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Derived from Soil (kg.ha^{-1}) in Grain

4. Nitrogen Use Efficiency (NUE) %

a. In Straw Yield

It is clear that nitrogen use efficiency of wheat straw amended with 100% N rate slightly enhanced by increasing water regime. This figure didn't affected, in significant, by mode of application **(Table (40)** and **Figure (43)).** It tends to increase with application of 80% N rate comparable to 100% N rate especially under W75 and W100. In this respect, mode B showed high %NUE as compared to mode A. similar trend but to somewhat high extent, was observed with application of 60% N rate. In this regard, the highest %NUE was detected under 100% water regime. There was no significant difference between modes of fertilizer N application.

In conclusion, %NUE of straw was positively significantly affected by increasing water regime up to 100%. Although, %NUE was higher with moderate N rates (80% and 60%) than 100% N rate it was not varied as affected by fertilizer N mode of application. In other turn, %NUE was mainly affected by fertilizer N rates rather than the mode of application.

Table (40): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Use Efficiency (%) in Straw

N Level %	N Mode	Water Regime			Mean
		50	75	100	
100	A	16.8	22.6	25.1	21.50
	B	24.9	20	23.5	22.80
Mean		**20.9**	**21.3**	**24.3**	22.15
80	A	17.9	23.4	28	23.10
	B	23.1	33	33.8	29.97
Mean		**20.5**	**28.2**	**30.9**	26.53
60	A	30.3	33.8	39.4	34.50
	B	39.9	22.7	36.7	33.10
Mean		**35.1**	**28.3**	**38.1**	33.80
A		21.67	26.60	30.83	26.37
B		29.30	25.23	31.33	28.62
Mean		25.48	25.92	31.08	27.49

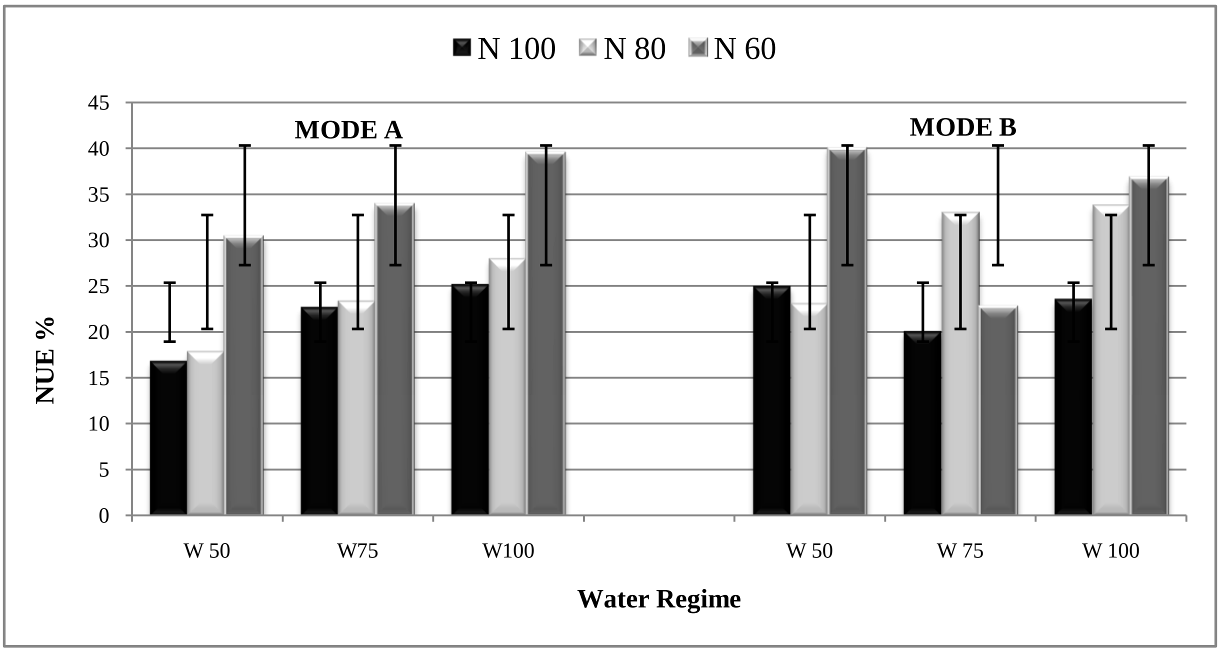


Figure (43): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Use Efficiency (%) in Straw

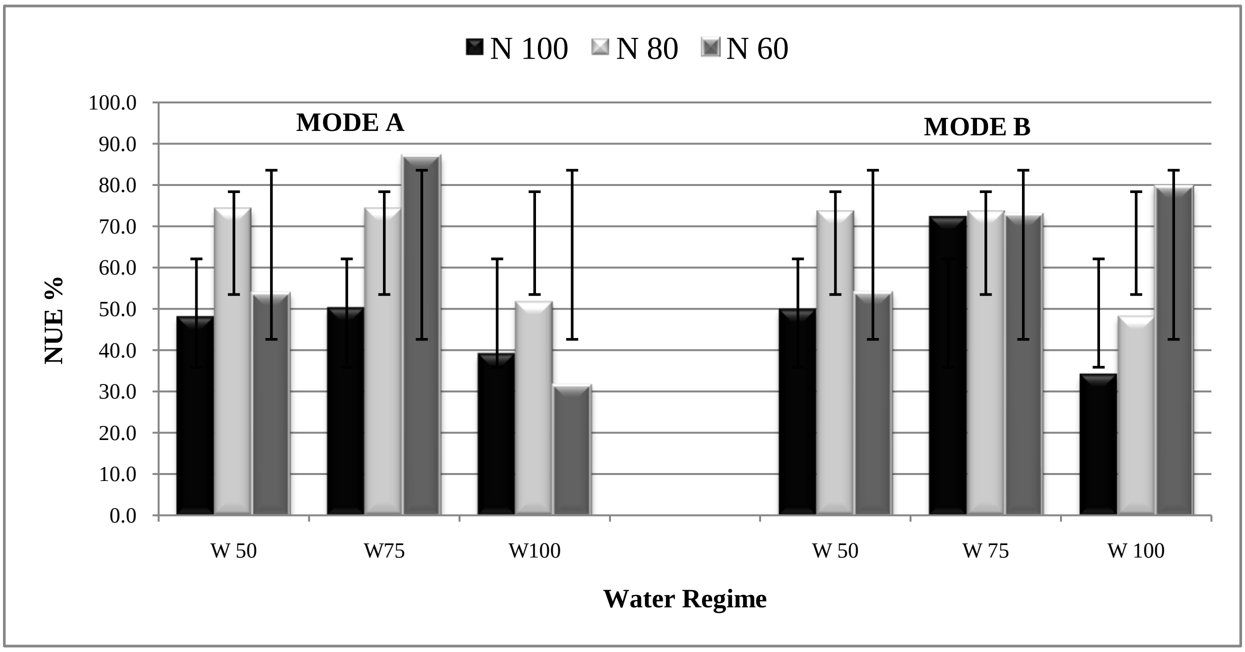
b. In Grain Yield

Fertilizer N was efficiently used by grains as compared to those of straw. This figure was significantly affected by changes in water regimes. in this respect, opposite direction to those of straw was noticed where %NUE tended to decrease with increasing water regime up to 100%. The best average of %NUE was detected with W75. Concerning the application modes, data showed superiority of mode B over mode A especially under W75 **(Table (**41**)** and **Figure(44)).** Similar trends, but to high extent, were noticed with both 80% and 60% N rates. In this regard, the average of the moderate N rates seems to be nearly closed to each other. In average, mode B was to some extent effective than mode A.

Finally, it seems that the highest %NUE by grains were achieved by W75 and the lowest was at W100. Moderate rates of fertilizer N were more efficiently used by grain as compared to rate of 100% N. Mode B, despite of low variation, has an effective role in enhancing %NUE comparable to mode A.

Table (41): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Use Efficiency (%) in Grain

N Level %	N Mode	Water Regime			Mean
		50	75	100	
100	A	48.1	50.2	39.2	**45.83**
	B	49.9	72.3	34.2	**52.10**
Mean		**49.0**	**61.2**	**36.7**	**48.97**
80	A	74.3	74.3	51.6	**66.72**
	B	73.6	73.6	48.2	**65.11**
Mean		**73.9**	**73.9**	**49.9**	**65.91**
60	A	53.7	87.0	31.6	**57.43**
	B	53.9	72.8	79.5	**68.74**
Mean		**53.8**	**79.9**	**55.6**	**63.09**
A		**58.70**	**70.48**	**40.80**	**56.66**
B		**59.12**	**72.88**	**53.96**	**61.98**
Mean		**58.91**	**71.68**	**47.38**	**59.32**



Figure(44): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Use Efficiency (%) in Grain

5. ^{15}N Recovery

a. *By Straw*

^{15}N recovered by straw recoded high average at rate of 100% fertilizer N either applied using mode A or B combined with 100% water regime **(Table (42)** and **Figure (45)).** In this regard, the average of application modes didn't shows significant difference between them. Similar trend and nearly closed values to those of 100% N rate were detected with 80% N rate. Application of 60% N rate resulted in reduction in ^{15}N recovery when combined with 75% water regime but tended to increase again with increasing water regime up to 100%.

Changes in ^{15}N recovery were mainly attributed to rate of fertilizer N rate and high water regime rather than mode of application. High rate of fertilizer nitrogen and water regime induced high values of ^{15}N recovered by straw.

Table (42): Effect of nitrogen fertilizer application strategy and irrigation water regime on ^{15}N Recovery (kg.ha^{-1}) By Straw

N Level %	N Mode	Water Regime			Mean
		50	75	100	
100	A	38.6	50.4	56.5	48.50
	B	55.4	42.8	52.4	50.20
Mean		**47.0**	**46.6**	**54.5**	49.35
80	A	33.3	38.5	50	40.60
	B	37.8	53.6	54.8	48.73
Mean		**35.6**	**46.1**	**52.4**	44.67
60	A	42.2	46.6	54.9	47.90
	B	57.5	30.7	51.6	46.60
Mean		**49.9**	**38.7**	**53.3**	**47.25**
A		38.03	45.17	53.80	45.67
B		50.23	42.37	52.93	48.51
Mean		**44.13**	**43.77**	**53.37**	**47.09**

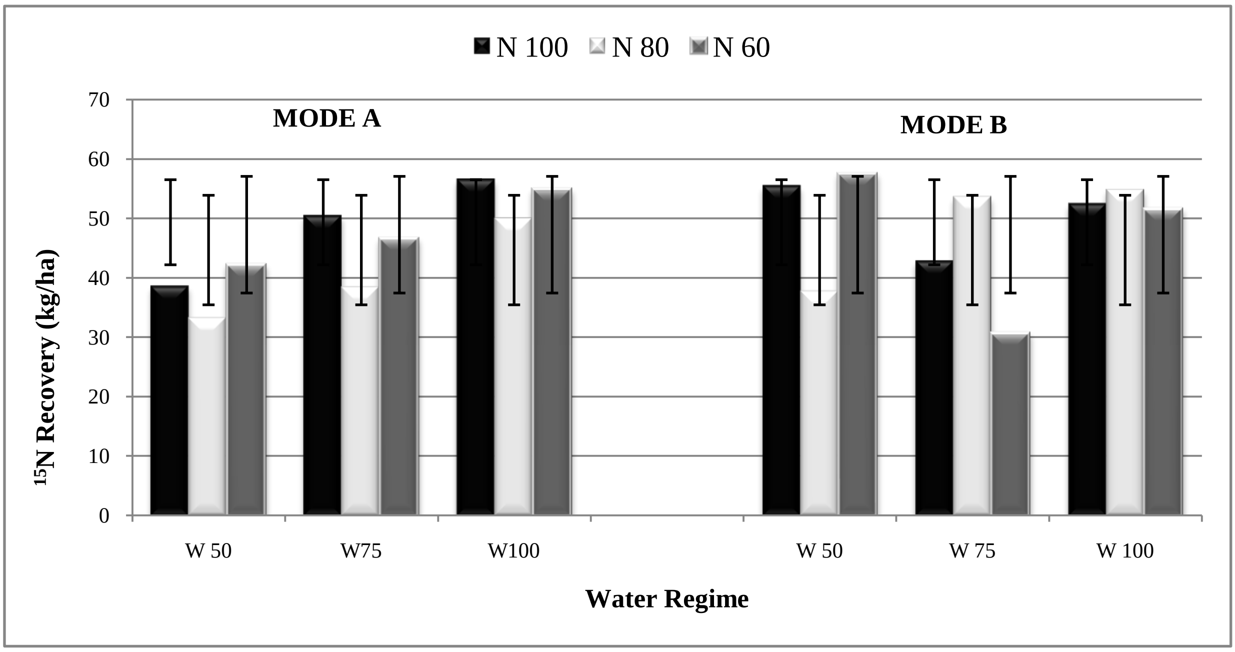


Figure (45): Effect of nitrogen fertilizer application strategy and irrigation water regime on ^{15}N Recovery (kg.ha^{-1}) By Straw

b. By Grain

^{15}N recovered by grain was higher than those recovered by straw. This was true with all tested factors **(Table (43)** and **Figure (46)**. Under 100% N rate, the highest value of ^{15}N average recovered by grain was recorded with W75.and the lowest was detected with W100. It is obvious that mode A of application is superior over mode B. Rate of 80% showed ^{15}N recovery values nearly closed tto those of 100% N rate especially at W75. Similar trends, but to somewhat low extent were noticed with 60% N rate.

As indicated by the overall average, the highest value of ^{15}N recovery was detected with W75. Mode A was superior over mode B. there was no significant difference between 100% and 80% N rates. This, from economical and environmental viewpoints, give us the chance to recommend the rate of 80% N since it gives nearly closed ^{15}N recovery to those of 100% N rate. in the same time, 25% of required water could be saved.

Table (43): Effect of nitrogen fertilizer application strategy and irrigation water regime on ^{15}N Recovery (kg.ha^{-1}) By Straw

N Level %	N Mode	Water Regime			Mean
		50	75	100	
100	A	63.7	96.5	44	68.07
	B	66.5	70.2	25.2	53.97
Mean		**65.1**	**83.4**	**34.6**	61.02
80	A	50.1	89.8	57.9	65.93
	B	54.9	82.5	57.2	64.87
Mean		**52.5**	**86.2**	**57.6**	65.40
60	A	45.1	57.7	62.2	55.00
	B	42.7	65.8	24.9	44.47
Mean		**43.9**	**61.8**	**43.6**	49.73
A		52.97	81.33	54.70	63.00
B		54.70	72.83	35.77	54.43
Mean		53.83	77.08	45.23	58.72

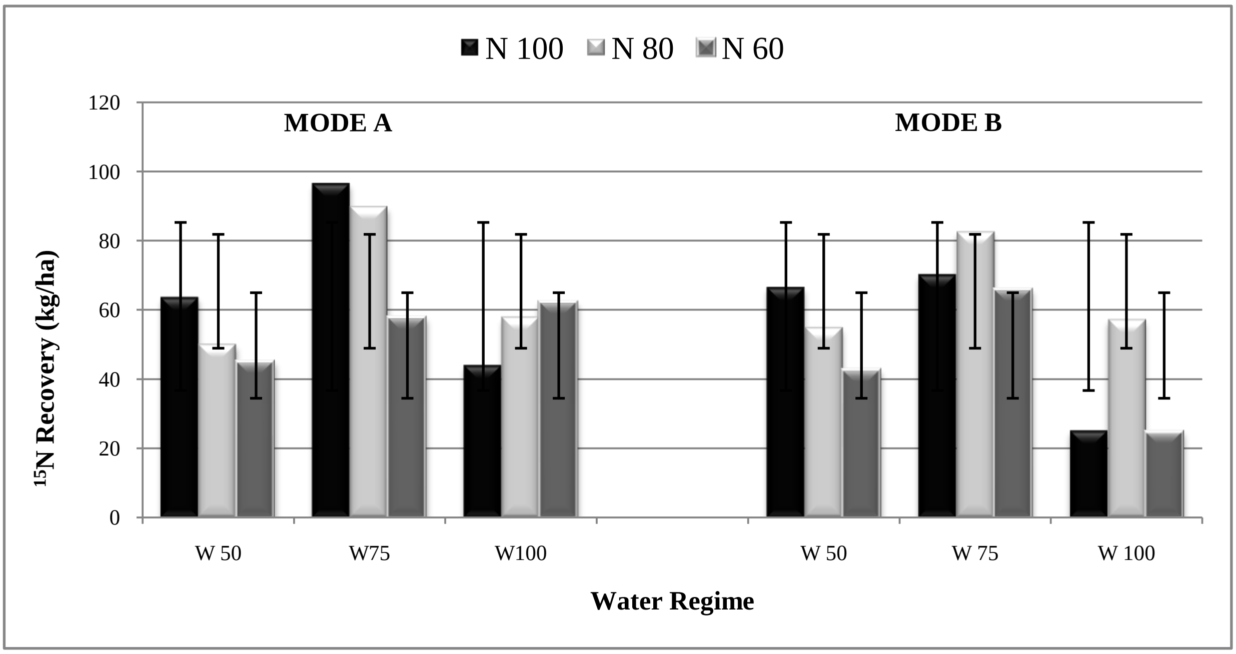


Figure (46): Effect of nitrogen fertilizer application strategy and irrigation water regime on ^{15}N Recovery (kg.ha^{-1}) By Grain

6. Nitrogen Remained In Soil

Nitrogen remained in soil after harvest seems to be lower than those recorded with clay soil. The obtained values less affected by fertilizer N rates where a little bit changes were detected **(Table (44)** and **Figure (47)).** In case of 100% N rate, a little decrease in N remained in soil was observed with W100 as compared to other regimes. in spite of water regime, values tended to slight decrease with application of either 80% or 60% fertilizer N rates. It is clear that fertilizer n application modes has no significant variations between them as indicated through the overall mean averages of N remained in sand soil after harvest.

Table (44): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Remained in Soil

N Level %	N Mode	Water Regime						Mean
		50		75		100		
		%	kg.ha^{-1}	%	kg.ha^{-1}	%	kg.ha^{-1}	
100	A	2.6	6.2	2.6	6.2	2.45	5.8	4.82
	B	2.85	6.8	2.9	6.9	2.45	5.8	5.05
Mean		**2.7**	**6.5**	**2.8**	**6.6**	**2.5**	**5.8**	4.93
80	A	2.25	5.4	2.2	5.2	2.15	5.1	4.15
	B	2.05	4.9	2.2	5.2	2.35	5.6	4.38
Mean		**2.2**	**5.2**	**2.2**	**5.2**	**2.3**	**5.4**	4.27
60	A	1.9	4.5	1.95	4.6	2.1	5	3.90
	B	1.95	4.6	2.1	5	2.25	5.4	4.22
Mean		**1.9**	**4.6**	**2.0**	**4.8**	**2.2**	**5.2**	4.06
A		2.25	5.37	2.25	5.33	2.23	5.30	4.29
B		2.28	5.43	2.40	5.70	2.35	5.60	4.55
Mean		2.27	5.40	2.33	5.52	2.29	5.45	4.42

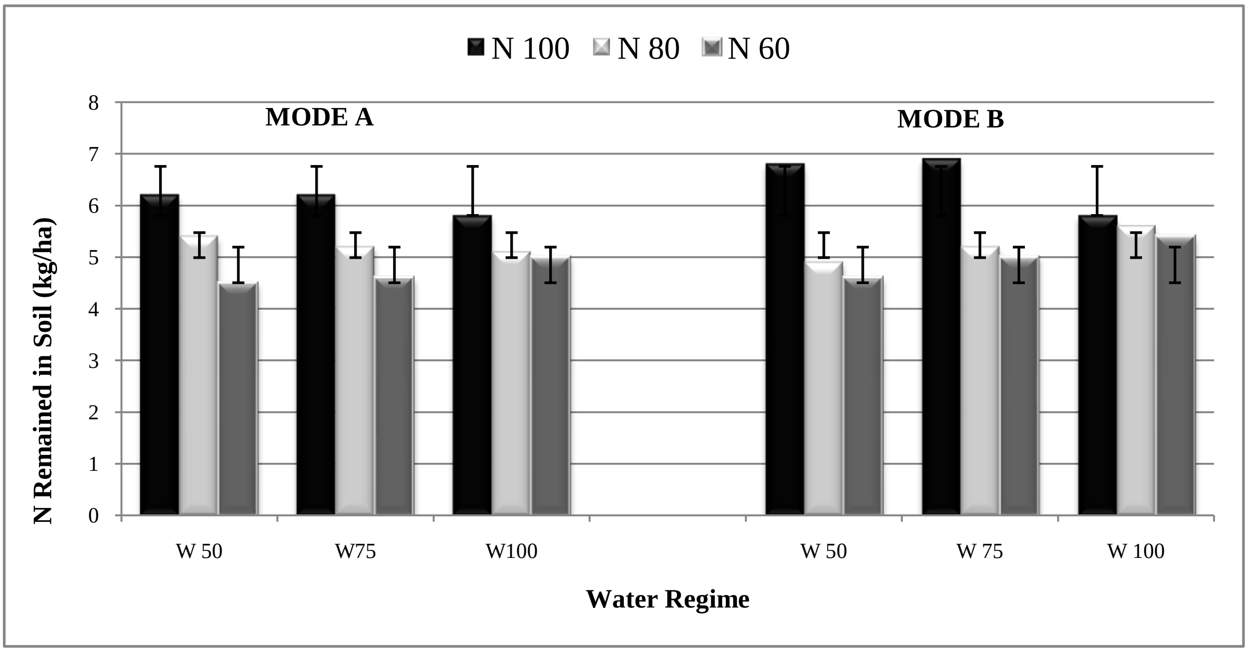


Figure (47): Effect of nitrogen fertilizer application strategy and irrigation water regime on Nitrogen Remained in Soil (kg.ha^{-1})

7. Nitrogen Losses after harvest as affected by nitrogen fertilizer application strategy and irrigation water regime

Fertilizer nitrogen lost from sand media, in general were higher than those recorded for clay soil. These values were decreased with decreasing the rate of fertilizer addition **(Table (45)** and **Figure (48)).** In average, higher losses were detected with W100 than W75 and W50, respectively. Similar trend, but to some lower extent, with some exceptions were detected with 80% and 60% N rates. These losses were to some extent, high in case of mode A as compared to mode B. this holds true under all n rates. The lowest values of fertilizer N losses were induced by application of W75. It seems that N losses were mainly correlated to water quantities and could be reduced through management of irrigation water.

In agreement with Jia et al. (2011), our results are nearly closed to their results where they found that the total N uptake by wheat ranged from 186 to 238 kg ha^{-1} and the fertilizer-derived N (Ndff), were about 34–55%. The Ndff from labeled basal-^{15}N urea and from labeled topdress-^{15}N were about 15–22% and 16–40%, respectively. The nitrogen recovery efficiency (NRE) (measured either as recovery in grain or as the total N recovery in the plant) was higher with three irrigations I3 (39–41 or 47–49%) than with two irrigations I2 (35–40 or 42–47%), showing maximum NRE in grain of about 40% both at N210 with I2 and at N150 with I3 treatment.

The NRE by the first wheat crop (in grain or the total N recovery in plant) was higher with labeled topdress-^{15}N (39–48 or 45–56%) as compared to that with labeled basal-^{15}N (30–37 or 36–45%), while the unaccounted N losses were lower with labeled basal-^{15}N (14–22%) relative to labeled topdress-^{15}N (14–35%). Higher residual N in soils was found with labeled basal-^{15}N (41–51%), as compared to labeled topdress-^{15}N (18–35%). Residual N in the 0- to 150-cm soil depth ranged from 26 to 44% while the unaccounted N losses ranged from 14 to 30%. Recovery of residual N by the 2nd and 3rd crops in the rotation was 5–10% in the maize crop and a further 1.7–3.5% in the subsequent wheat crop. The accumulated N recovery and the unaccounted N losses in continuous wheat–maize–wheat rotations derived from labeled topdress-^{15}N were 54–64% and 16–37%, respectively while they were 47–53% and 16–28%, respectively from labeled basal-^{15}N. This study also suggested that an N rate of 210 kg ha^{-1}(with a ratio of basal-N to topdress-N of 1:1.3) with two irrigation applications could optimize wheat grain yields and NRE, under the water limited conditions.

In this regard, Jia et al demonstrated the fate of labeled urea-^{15}N affected by irrigation times(or total rates) and they found that the total N uptake by wheat derived from urea fertilizer N (Ndff (kg ha^{-1})) was significantly higher with treatment three irrigations I3 (75–126 kg ha^{-1}) than with treatment two irrigations I2 (63–116 kg ha^{-1}), showing that increased irrigation could increase N uptake from fertilizer-N and NRE. The highest grain yield of wheat was 8,629 kg ha^{-1} at N210 under treatment I2 and 9,670 kg ha^{-1}at N270 under treatment I3, indicating that both yield potential and the N level required to optimize grain yield increased when the moisture regime was improved with higher irrigation.

In the same time, they studied the Fate of labeled urea-^{15}N affected by N application rate and timing where the total plant N derived from basal-^{15}N and topdress-^{15}N applications ranged from 15 to 22% and from 16 to 40%, respectively, while the N derived from soil ranged from 44 to 66%. The higher N taken up from the soils in our study may be associated with the lower losses of N from the column because the technique led to reduced leakage of the previously applied fertilizer-N downward to the deep layers and outside the column.

There may also have been increased deepsoil N uptake by wheat roots in late growing stages. They concluded that under their experimental conditions, an N rate of 210 kg ha^{-1} was optimal for a wheat crop grown with two irrigation applications. The total N uptake by wheat (186–238 kg ha^{-1}) was related to both irrigation management and N application rate, while the N uptake per kg of grain yield of wheat (23–25 g kg^{-1}) was not affected by irrigation or N rates.

The total amount of wheat plant N derived from fertilizer-N (Ndff) and from soils (Ndfs) ranged from 34 to 55% and 44 to 66%, respectively. The Ndff derived from basal-^{15}N and labeled topdress-^{15}N applications was 15–22% and 16–40%, respectively. The average NRE by wheat grain (35–41%) or the total N recoveries in plants (42–49%) decreased with increasing N rate. The residual N in the 0–150 cm depth of soil ranged from 26 to 44% and the unaccounted N losses ranged from 14 to 30%. The NRE in grain or the total N recovery in plants was higher with three irrigation applications (39–41 or 47–49%) than with two irrigation applications (35–40 or 42–47%), showing a maximum recovery of about 40% at N210 under I2 and at N150 under I3. The NRE by the first wheat crop was higher with labeled topdress-^{15}N (39–48 or 45–56%) as compared to that with labeled basal-^{15}N (30–37 or 36–45%), while the unaccounted N losses were lower with labeled basal-^{15}N (14–22%) relative to labeled topdress-^{15}N (14–35%). Residual N in soils was greater with labeled basal-^{15}N (41–51%) than with labeled topdress-^{15}N (18–35%).

Fan et al. (2007) in the ^{15}N experiment, found considerable accumulation of mineral N after the wheat harvest (125 kg ha^{-1}), of which 69% was subsequently lost after 13 days of flooding. Results from their study indicate the importance of N management in the wheat-growing season, which affects N dynamics and N losses significantly in the following rice season. Integrated N management should be adopted for rice–wheat rotations in order to achieve a better N recovery efficiency and lower N loss.

Table (45): Fertilizer-N Losses (kg.ha^{-1}) after harvest of wheat Grain yield as affected by nitrogen application strategy and water regime

N Level %	N Mode	Water Regime			Mean
		50	75	100	
100	A	117.3	112.3	139	122.87
	B	112.5	59.1	150.9	107.50
Mean		**114.9**	**85.7**	**145.0**	115.18
80	A	88.1	43.8	87	72.97
	B	102.5	45.1	93.1	80.23
Mean		**95.3**	**44.5**	**90.1**	76.60
60	A	61.6	14	92.7	56.10
	B	61.2	33.9	23.8	39.63
Mean		**61.4**	**24.0**	**58.3**	47.87
A		89.00	56.70	106.23	83.98
B		92.07	46.03	89.27	75.79
Mean		90.53	51.37	97.75	79.88

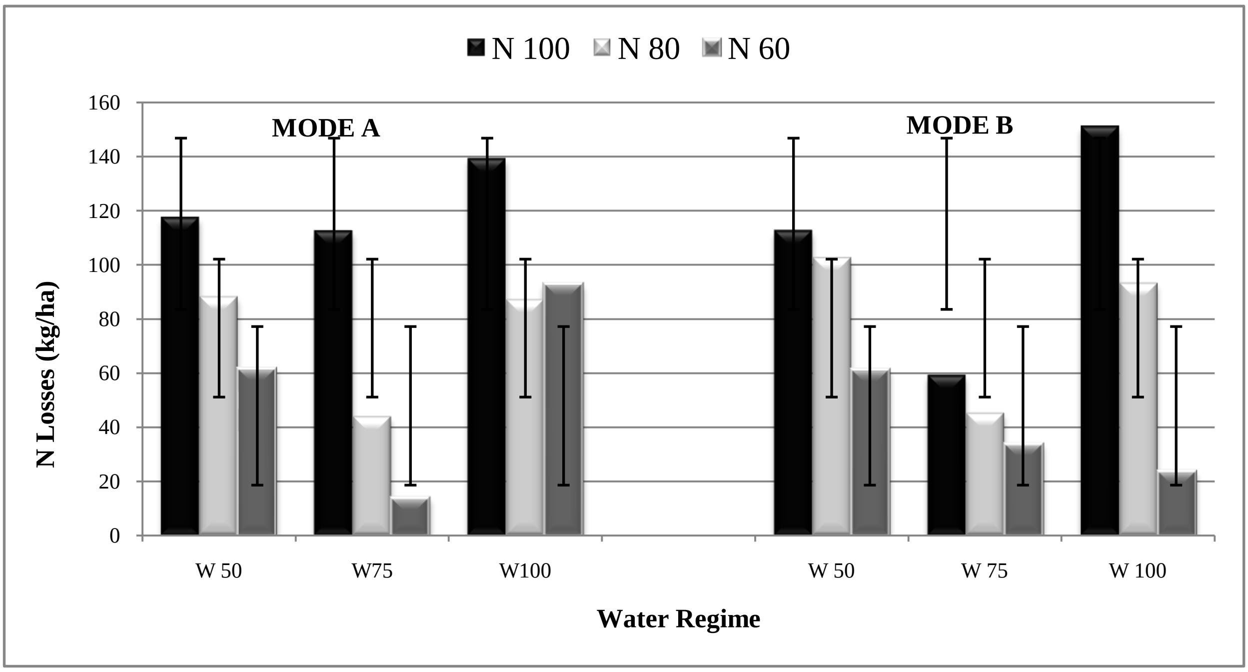


Figure (48): Fertilizer-N Losses (kg.ha^{-1}) after harvest of wheat Grain yield as affected by nitrogen application strategy and water regime

8. Fertilizer-N balance (kg.ha^{-1}) after harvest of wheat Grain yield as affected by nitrogen application strategy and water regime under Sand Soil

Fertilizer nitrogen balance indicated that N losses values nearly closed to those uptaken by the plant under 50% and 75% water regimes while it increases by 1.5 fold over N uptake at 100% water regime. In this respect, there was no significant difference between modes of fertilizer N application **(Table (46)** and **Figure (49))**. This phenomenon takes place with all fertilizer N rates with different pattern. The obtained results, in general confirm that the behavior of fertilizer N is mainly attributed to water regime and mode of fertilizer N application. The combined effect was more pronounced at 100% N rate.

In sand soil, high N losses in addition to a very low N remained in soil proved the low N use efficiency as compared to those of clay one.

Table (46): Fertilizer-N balance (kg.ha^{-1}) after harvest of wheat Grain yield as affected by nitrogen application strategy and water regime under Sand Soil

N Level %	N Mode	Water Regime								
		50			75			100		
		N_{plant} Kg/ha	N_{soil} Kg/ha	N_{Losses} Kg/ha	N_{plant} Kg/ha	N_{soil} Kg/ha	N_{Losses} Kg/ha	N_{plant} Kg/ha	N_{soil} Kg/ha	N_{Losses} Kg/ha
100	**A**	114.5	6.2	**117.30**	119.5	6.2	**112.27**	93.2	5.8	**138.99**
	B	118.7	6.8	**112.51**	172.0	6.9	**59.10**	81.3	5.8	**150.89**
Mean		**116.6**	**6.5**	**114.90**	**145.8**	**6.6**	**85.69**	**87.3**	**5.8**	**144.94**
80	**A**	96.9	5.4	**88.14**	141.4	5.2	**43.81**	98.3	5.1	**87.00**
	B	83.0	4.9	**102.47**	140.1	5.2	**45.10**	91.7	5.6	**93.07**
Mean		**89.9**	**5.2**	**95.30**	**140.7**	**5.2**	**44.46**	**95.0**	**5.4**	**90.03**
60	**A**	76.7	4.5	**61.56**	124.2	4.6	**14.01**	45.1	5.0	**92.69**
	B	77.0	4.6	**61.23**	103.9	5.0	**33.86**	113.6	5.4	**23.83**
Mean		**76.9**	**4.6**	**61.39**	**114.1**	**4.8**	**23.94**	**79.3**	**5.2**	**58.26**
A		96.03	5.37	**89.00**	128.37	5.33	**56.70**	78.88	5.30	**106.22**
B		92.90	5.43	**92.07**	138.68	5.70	**46.02**	95.54	5.60	**89.26**
Mean		**94.47**	**5.40**	**90.53**	**133.52**	**5.52**	**51.36**	**87.21**	**5.45**	**97.74**

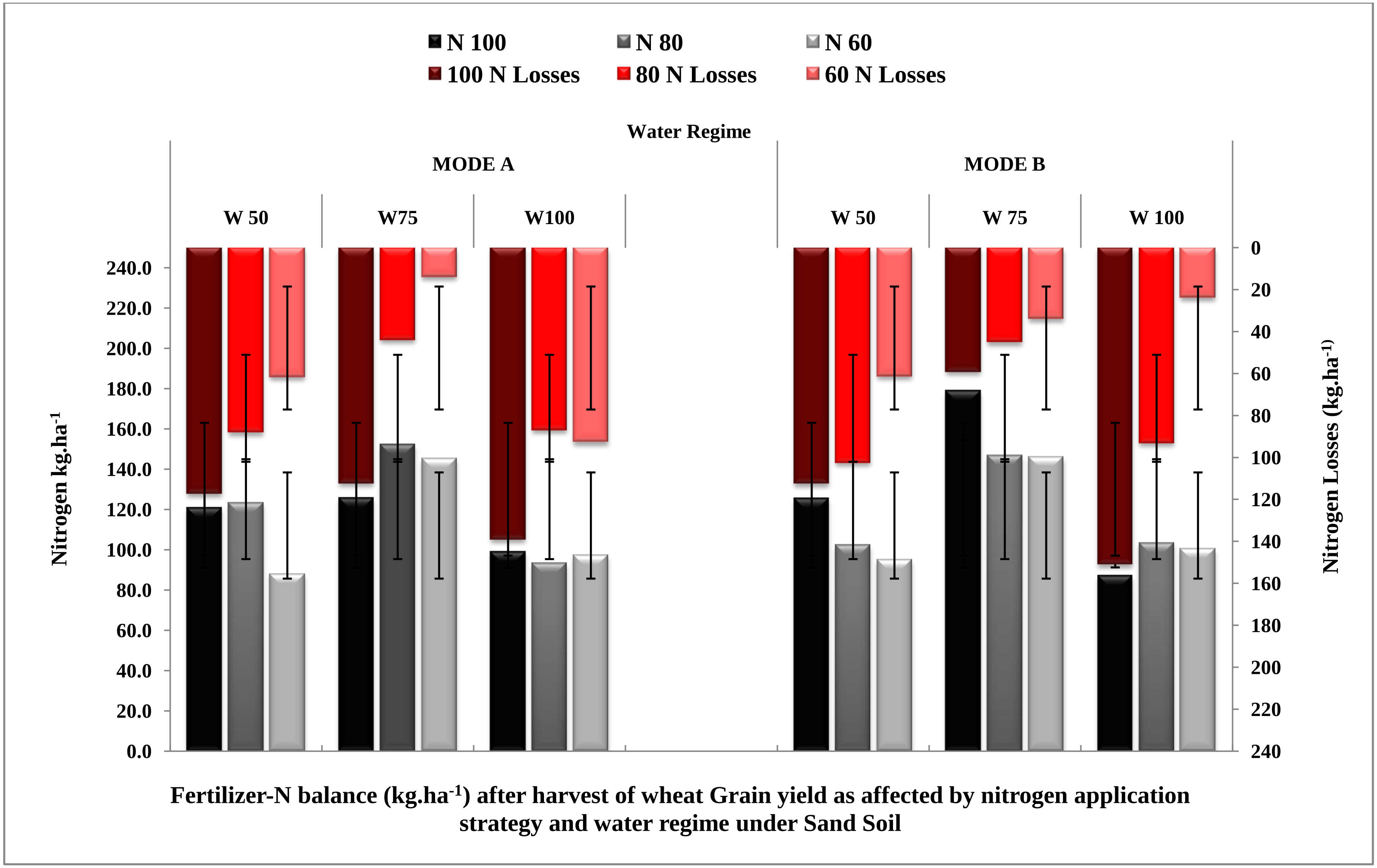


Figure (49): Fertilizer-N balance (kg.ha^{-1}) after harvest of wheat Grain yield as affected by nitrogen application strategy and water regime under Sand Soil

SUMMARY AND CONCLUSIONS

Chapter 6

Summary

1. Comparison of some vegetation parameters behavior in the soils above mentioned

This part will shed light on behaviour of some vegetative growth parameters of wheat plants grown on different soils;

1.1. Grain yield

The comparison of plant production tendency of wheat crop affected by nitrogen fertilization practices and irrigation water regime under different soils is presented in **Table (47),** and graphically illustrated by **Figure (50),** the grain yield seems to be significantly affected by soil type where it was higher in clay soil than sand soil, despite of mode of applications, when soils irrigated with 50% and 100% water regime while the reverse trend was detected with 75% water regime under fertilization with 100% of the recommended rates. In this respect, comparison between modes of applications indicated surpass of mode B over mode A under all water regimes. Means of grain yield of plants fertilized with 80% of the recommended rate showed higher increases in yield of clay soil than those recorded with sand one. This holds true under all water treatments. In this regard, the highest grain yield was induced in clay soil by application of mode B (8.39 t ha^{-1}). Mode B still superior over mode A with some exception in both clay (W 100%) and sand (W 50%) soils where the reversible trend was observed.

Concerning the application of 60% nitrogen from the recommended rate, mean data indicated the increase of grain yield of plants grown on clay soil as compared to sand soil especially with 50% and 100% water regime while 75% water regime doesn't reflect any significant difference between them. Focusing on mode of application under this rate of N, the grain yields as affected by soil types were fluctuated in relation to water regimes.

Finally, we can conclude that grain yield, in general, was higher in clay soil than sand soil. Similarly, mode B of N application was superior over mode A. interaction of nitrogen rates x water regimes resulted in fluctuated grain yields. In this regard, the best value of grain yield (4.91 t ha^{-1}) of plants grown on sand soil was achieved by application of 100% N rated interacted with 75% water regime. In case of clay soil; the best value of grain yield (7.03 t ha^{-1}) was detected when nitrogen was applied at 80% of recommended rate interacted with 50% water regime.

Table (47) Effect of Soil type on Grain yield ($t.ha^{-1}$)

N Level %	**N Mode**	**Water Regime**					
		50		**75**		**100**	
		Sand	**Clay**	**Sand**	**Clay**	**Sand**	**Clay**
100	**A**	4,39	4,00	3,17	2,72	1,37	5,00
	B	4,58	7,05	6,65	6,30	2,64	6,48
Mean		4,49	5,53	4,91	4,51	2,01	5,74
80	**A**	3,97	5,67	2,70	5,42	3,78	7,04
	B	3,45	8,39	5,16	8,01	4,19	6,90
Mean		3,71	7,03	3,93	6,72	3,98	6,97
60	**A**	3,12	6,78	4,02	5,71	1,32	3,40
	B	3,82	5,00	4,64	2,65	3,91	6,34
Mean		3,47	5,89	4,33	4,18	2,62	4,87
A		3,83	5,48	3,30	4,62	2,16	5,15
B		3,95	6,82	5,48	5,65	3,58	6,57
Mean		3,89	6,15	4,39	5,14	2,87	5,86

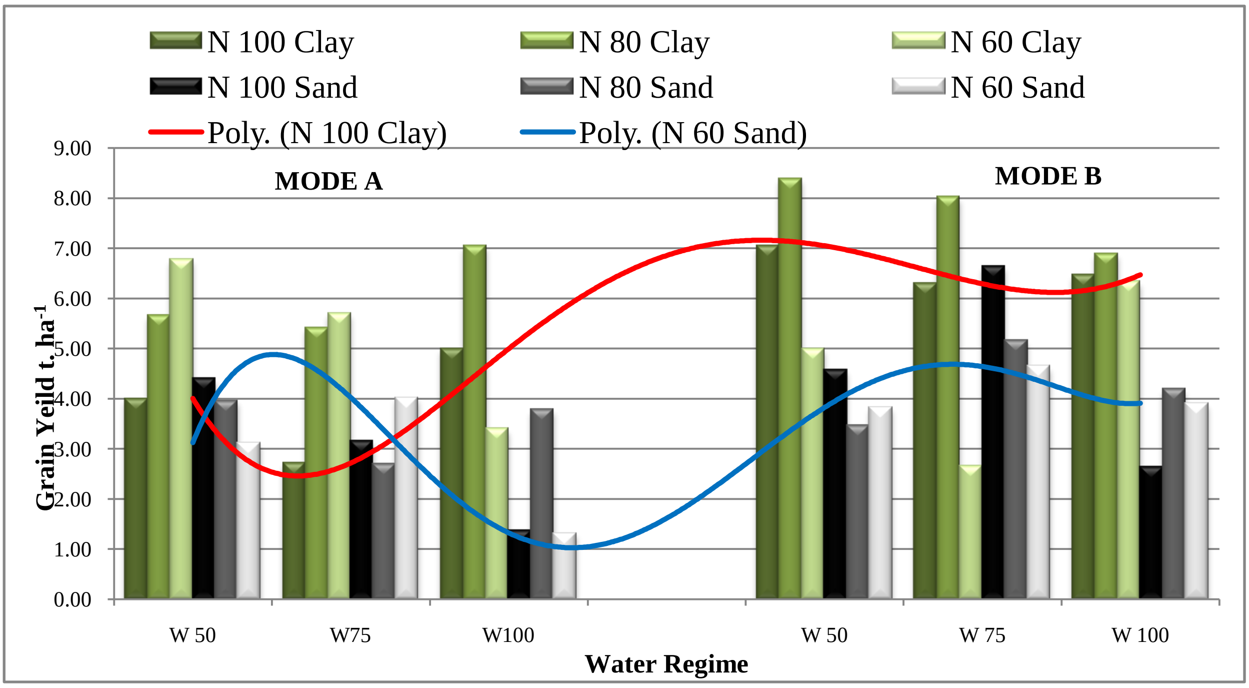


Figure (50) Effect of Soil type on grain yield ($t.ha^{-1}$)

1.2. Straw yield

Straw yield of wheat plants was dramatically affected by water regime when 100% N applied with both modes of application **(Table (48)** and **Figure (51)).** In this respect, straw yield doesn't reflect any significant difference between two soils with 50% water regime while sand soil recorded a little bit high straw yield as compared to clay soil with75% and 100% water regimes. In the same rate of N application, mode A recorded higher straw yield than mode B except those recorded in sand soil at 50% water regime where mode B surpass mode A.

Nitrogen applied at 80% rate of recommended dose resulted in similar trend when soil types were concerned. In most cases, means of straw yield indicated that application of 80% N rate resulted in, to somewhat extent, lower values than those recorded with 100% N rate. In the same time, at rate of 80% N comparison between modes of application showed that mode B was superior in sand soil while reverse was detected in clay soil only with 50% and 75% water regimes.

At rate of 60% N, straw yield in sand soil, in general, nearly closed to those of 80% N rate. In this regard, clay soil showed fluctuated values of straw yield attributable to water regime where it was to some extent lower than those of 80% N in combination with 50% water regime. Reversible trend was noticed with 75% and 100% water regimes where straw yield was higher than those of 80% N rate.

Generally, we can conclude that straw yield was significantly varied according to soil type. It was significantly higher in case of sand soil than clay one. Concerning the mode of application, data reflected no significant difference between them in sand soil while in case of clay soil mode A induced to some extent, higher straw yield than mode B.

From economic and environment point of view, values of straw yield as affected by N rates lead us to prefer the moderate rates of 80 and 60% since the difference between them and 100% N rate was not that hiegh.

Finally, the best value of straw yield (8.25 t ha^{-1}) in sand soil was resulted from combined treatment of 80% N applied with mode B and 100% water regime. In case of clay soil, the best value of straw yield was achieved by application of 60% N applied with A in combination with 100% water regime.

Table (48) Effect of Soil type on Straw yield (t.ha^{-1})

N Level %	N Mode	Water Regime					
		50		75		100	
		Sand	Clay	Sand	Clay	Sand	Clay
100	A	6,20	9,20	7,50	7,20	8,20	6,80
	B	8,60	5,50	6,50	4,10	7,50	5,80
Mean		7,40	7,35	7,00	5,65	7,85	6,30
80	A	5,50	5,80	6,20	5,80	7,90	4,40
	B	6,20	5,50	8,60	4,40	8,60	5,50
Mean		5,85	5,65	7,40	5,10	8,25	4,95
60	A	7,20	4,80	7,90	5,80	7,90	8,20
	B	4,95	4,80	5,10	6,20	8,60	6,50
Mean		6,08	4,80	6,50	6,00	8,25	7,35
A		6,30	6,60	7,20	6,27	8,00	6,47
B		6,58	5,27	6,73	4,90	8,23	5,93
Mean		6,44	5,93	6,97	5,58	8,12	6,20

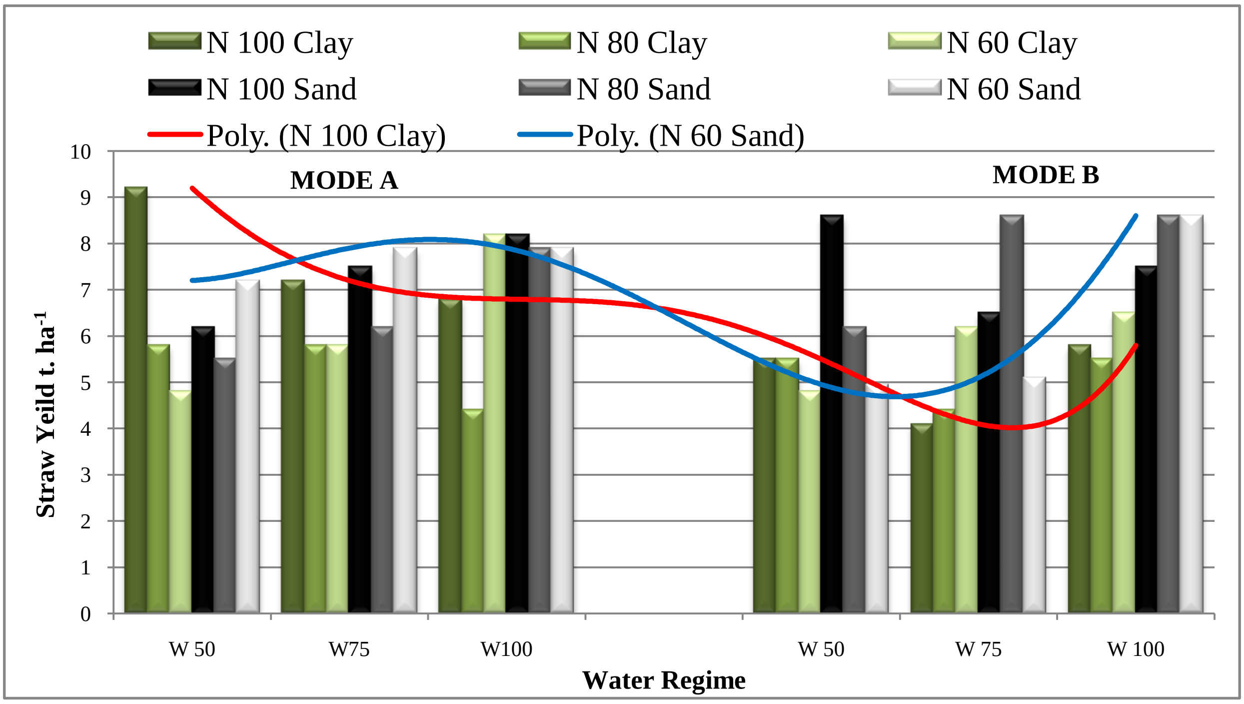


Figure (51) Effect of Soil type on straw yield (t.ha^{-1})

1.3. Harvest Index (HI)

Addition of 100% N rate resulted in different HI in relation to water regime and mode of application **(Table (49), Figure (52))**. Also, it was affected by soil types. Sand soil recorded 0.42, 0.47 and 0.24 HI for 50%, 75% and 100% water regime respectively while clay soil recorded 0.30, 0.0.27 and 0.42 for the same sequence when mode A was followed.

It is obvious that harvest index estimated for sand soil with mode B were lower than those of mode A while reversible trend was noticed with clay soil. In this respect, means of HI of sand soil tended to increase with increasing water regime up to 75% then severely decreased at 100% water regime. On the other hand, HI of clay soil slightly increased with increasing water up to 100% water regime. In the same time, HI of clay soil was to somewhat higher than those recorded for sand soil. This is true with all water regimes despite of mode of N applications.

In case of 80% N rate applied with mode A, HI was almost steady as affected by different water regimes. On the other hand, clay soil showed highly significant increase of HI with increasing water regime up to 100%. Using mode B, HI were erratic in relation to water regime in sand soil while clay soil showed slight increase of HI with increasing water regime up to 75% then tended to decrease with 100% water regime.

There was no big significant difference between modes of N applications when sand soil was concerned. In this respect, clay soil showed significant increases in HI with 50% and 75% water regime when mode B was considered while it was slightly decreased at 100% water regime. Despite of mode of application, the overall means of HI at 80% N rate reflected the superiority of clay soil over sand one. In the same time, HI of sand soil as affected by water regime was nearly closed to each other. Similar trend was noticed with clay soil.

At 60% N rate, harvest index of sand soil was almost steady under all water regimes when mode A was used and values nearly closed to those obtained at 80% N rate. When mode B used, HI of sand soil tended to a little bit increase with increasing water regime up to 75% then severely dropped down with 100% water regime.

Harvest index of clay soil reflected gradual decreases with increasing water regime either with mode A or B. in this regard, high HI was noticed at 50% water regime where it was 0.59 and 0.51 for mode A and mode B respectively.

The overall means of HI under 60% N rate indicated increases with increasing water regime up to 75% then decreased when sand soil concerned. Concerning clay soil, HI tended to decrease with increasing water regime. Comparison held between the two modes of application noted the superiority of mode A over mode B when sand soil was considered. Reversible trend was observed with clay soil where mode B surpass mode

In conclusion, sand soil doesn't reflect significant differences between N rates when HI was considered. This holds true with all water regimes. On the other hand, HI of clay soil tended to slight increase with the moderate rates of nitrogen fertilizer. Clay soil indicated higher HI than sand soil.

Regarding water regime, the best HI in both sand and clay soils was indicated at 50% and 75% water regimes. Generally, the best HI was recorded for sand soil (0.41) with combined treatment of 75% water regime and 60% N rate. For clay soil, the best HI was recorded when 100% water regime combined with 80% N rate. Mode A was preferable in sand soil while mode B was the best for clay soil.

Table (49) Effect of Soil type on Straw yield (t.ha^{-1})

N Level %	**N Mode**	**Water Regime**					
		50		**75**		**100**	
		Sand	**Clay**	**Sand**	**Clay**	**Sand**	**Clay**
100	**A**	0,42	0,30	0,47	0,27	0,24	0,42
	B	0,34	0,56	0,33	0,61	0,15	0,53
Mean		0,38	0,43	0,40	0,44	0,20	0,48
80	**A**	0,39	0,49	0,39	0,48	0,35	0,62
	B	0,39	0,60	0,24	0,65	0,31	0,56
Mean		0,39	0,55	0,31	0,56	0,33	0,59
60	**A**	0,35	0,59	0,37	0,50	0,39	0,29
	B	0,39	0,51	0,44	0,30	0,13	0,49
Mean		0,37	0,55	0,41	0,40	0,26	0,39
A		0,39	0,46	0,41	0,42	0,33	0,44
B		0,37	0,56	0,34	0,52	0,20	0,53
Mean		0,38	0,51	0,37	0,47	0,26	0,48

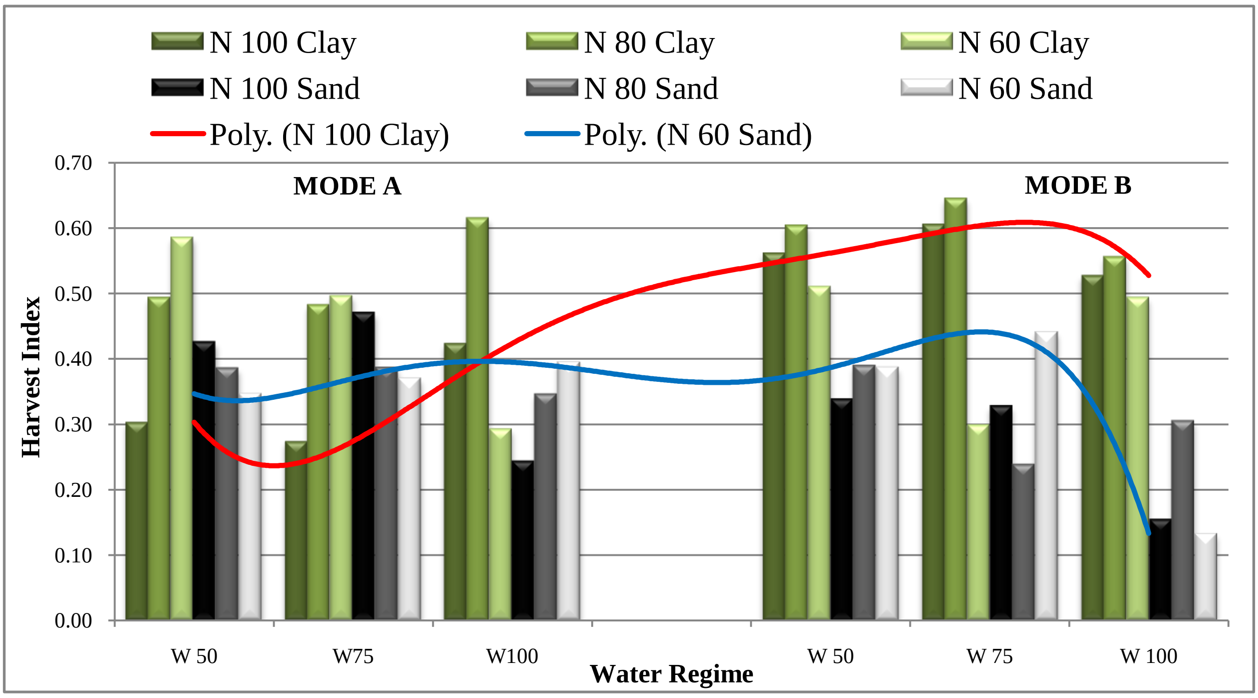


Figure (52) Effect of Soil type on Harvest index

2. Comparison of some of above-mentioned Nitrogen portions

2.1. Nitrogen Use Efficiency by Straw

As shown in **Table (50),** and graphically illustrated by **Figure (53)** efficient use of fertilizer N by straw tended to increase with raising water regime up to 100% when 100% N rate was applied using mode A in sand soil. Reversible trend was noticed with clay soil where N efficiency slightly decreased with increasing water regime.

This mode of N application indicated that %NUE under clay soil condition was significantly higher than those recorded for sand one. Application of fertilizer N using mode B, reflected a little bit reduction in %NUE as compared to those of mode A under sand soil. Similar trend was noticed with clay soil. In general, mode A seems to be better than mode B when efficient use of fertilizer N was concerned.

The best %NUE for sand soil fertilized with 100% N rate applied using mode A accounted for 25.1% under W100, while it was 24.9% under W50 combined with mode B. Reversible trend was noticed with clay soil where the best %NUE were 39.4% and 29.8% under W50 and W100 for mode A and mode B, respectively. Generally, despite of water regimes the %NUE of clay soil was significantly higher than sand soil.

In case of 80% N rate, %NUE of sand soil doesn't significantly varied than those recorded with 100% N rate for the same soil and mode A. Application of mode B indicated high increase in %NUE of sand soil especially with W75 and W100 as compared to 100% N rate.

Clay soil reflected significant decrease in %NUE under W50 and W100 as compared to the same water regimes under 100% N rate and mode A. Reversible trend was noticed with Mode B where %NUE were higher than those of 100% N rate under all water regimes. Clay soil showed somewhat high %NUE especially with W50 and W75 under mode A as compared to sand soil. Fluctuated data were observed with mode B.

The third rate of N application (60%), resulted in higher %NUE than those of 80% and 100% N rates. This holds true with both soils, N application modes and water regimes. In most cases the %NUE of clay soil still higher than those of sand soil.

From the above-mentioned results, we can conclude that fertilizer nitrogen applied at rate of 60% of the recommended dose either using mode A or mode B was efficiently used by wheat straw as compared to other N rates. The best and higher %NUE was occurred for both soils with W100 despite of application modes. In this respect, mode A was better than mode B.

Table (50): Nitrogen use efficiency (%) by wheat straw as affected by fertilizer N rate, mode of application, soil type and water regime

N Level %	**Soil Type**	**MODE A**				**MODE B**		
		W 50	**W75**	**W100**		**W 50**	**W 75**	**W 100**
N 100	**Sand**	16.8	22.6	25.1		24.9	20.0	23.5
	Clay	39.4	30.7	32.5		24.6	19.3	29.8
N 80	**Sand**	17.9	23.4	28.0		23.1	33.0	33.8
	Clay	28.7	32.3	22.3		29.3	23.9	32.8
N 60	**Sand**	30.3	33.8	39.4		39.9	22.7	36.7
	Clay	30.3	37.1	55.2		30.6	44.5	43.4

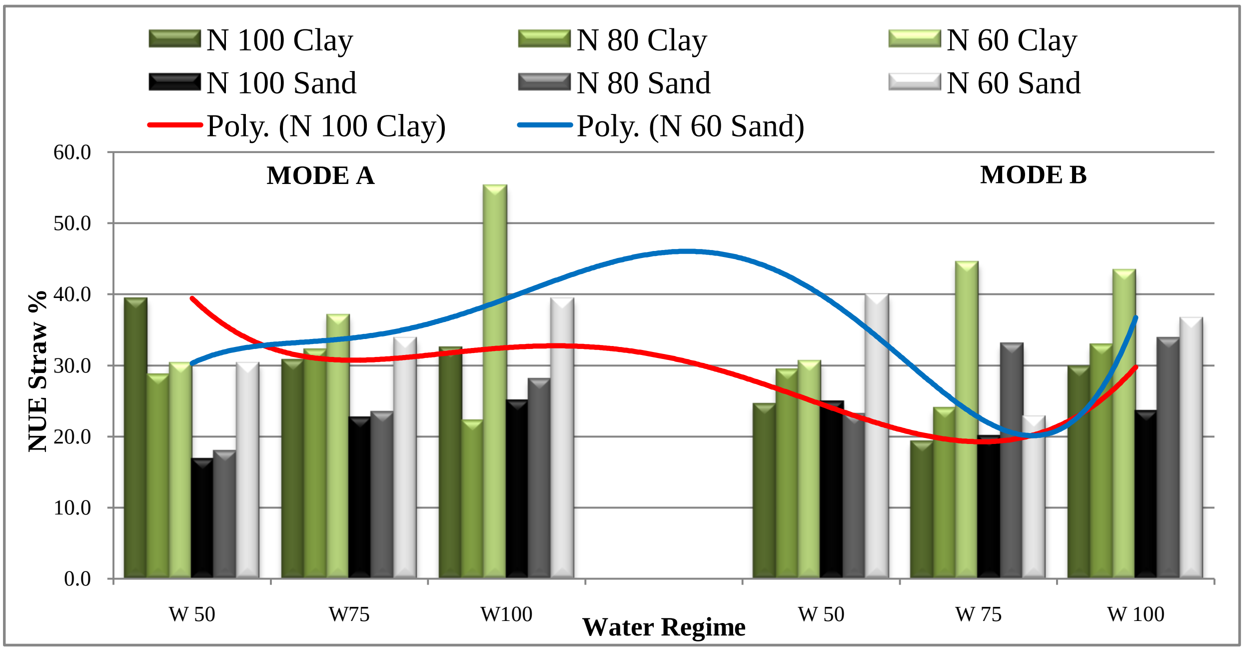


Figure (53): Nitrogen use efficiency (%) by wheat straw as affected by fertilizer N rate, mode of application, soil type and water regime

2.2. Nitrogen Use Efficiency by Grain

Fertilizer-N used by grains of wheat grown on different soils was remarkably varied between the two soils as affected by tested factors **Table (51)**, and **Figure (54)**. As recognized with straw. %NUE by grains was slightly increased when sand soil fertilized with 100% N rate applied using mode A combined with 75% water regime. Similar trend, but to high extent was noticed when mode B was applied. Regarding the clay soil, %NUE behaves the same way like sand soil but to highly significant extent. Application of 80% N rate resulted in higher %NUE of sand soil than those recorded with 100% N rate. this holds true with all water regimes applied under mode A of nitrogen application. Similar trend and nearly closed %NUE was detected with mode B of N application. Clay soil showed lower %NUE than those of sand soil under 50% and 755 water regimes while reversible trend was noticed under 100% water regime applied in combination with mode A. in this respect, %NUE was lower than those of 100% N rate for 50% and 75% water regimes.

Similar trends were observed with mode B. At 60% N rate, sand soil reflected lower %NUE than those of 80% but higher than those of 100% N rate under 50% water regime.

With 75% water regime, sand soil reflected higher %NUE than those of 60% and 100% N rates. Reverible trend was noticed with 100% water regime under mode A. similar trend was noticed with mode B except W100 where %NUE was significantly higher than those of 80% and 100% N rates.

In conclusion, nitrogen fertilizer was efficiently used by grain of wheat grown on clay soil in higher extent, in general, than those of sand soil. Application of both 80% and 60% N rates reflected, to some extent, higher %NUE than those of 100% N rate especially in sand soil. It was obvious that the most efficient use of fertilizer N by grains was occurred under W75 comparable to other water regimes. in this respect, there was no big significant difference between the two modes of N application.

Therefore, we can suggest the combined practice of moderate rates of fertilizer N (80%) and moderate quantities of water requirement (W75) as the best treatment that gave the most efficient use of applied nitrogen by wheat grains. This practice is still proper either fertilizer nitrogen applied at three splitting doses, i.e. 25% at seedling, 25% at tillering, 50% at jointing (mode A); or at two splitting doses as 35% at seedling, 65% at tillering (mode B).

They demonstrated that crop nitrogen use efficiency (NUE) ranged from 14.2%to 74.6% (mean value: 50.9 %) for wheat system. The highest average crop NUE for wheat (66.7 %) system was obtained with the corresponding average N application rates of 234.2 kg N ha^{-1} (ranging from 200 to 300 kg N ha^{-1}) and 174.6 kg N ha^{-1} (ranging from 150 to 200 kg N ha^{-1}). (Zhou and Butterbach-Bahl 2014)

Table (51) Nitrogen use efficiency (%) by wheat grain as affected by fertilizer N rate, mode of application, soil type and water regime

N Level %	Soil Type	MODE A				MODE B		
		W 50	W75	W100		W 50	W 75	W 100
100	**Sand**	48.1	50.2	39.2		49.9	72.3	34.2
	Clay	62.3	79.9	55.9		65.6	79.9	71.1
80	**Sand**	74.3	74.3	51.6		73.6	73.6	48.2
	Clay	54.4	72.9	63.2		60.9	80.3	68.3
60	**Sand**	53.7	86.9	31.6		53.9	72.8	79.5
	Clay	68.0	79.3	59.0		64.5	77.9	69.6

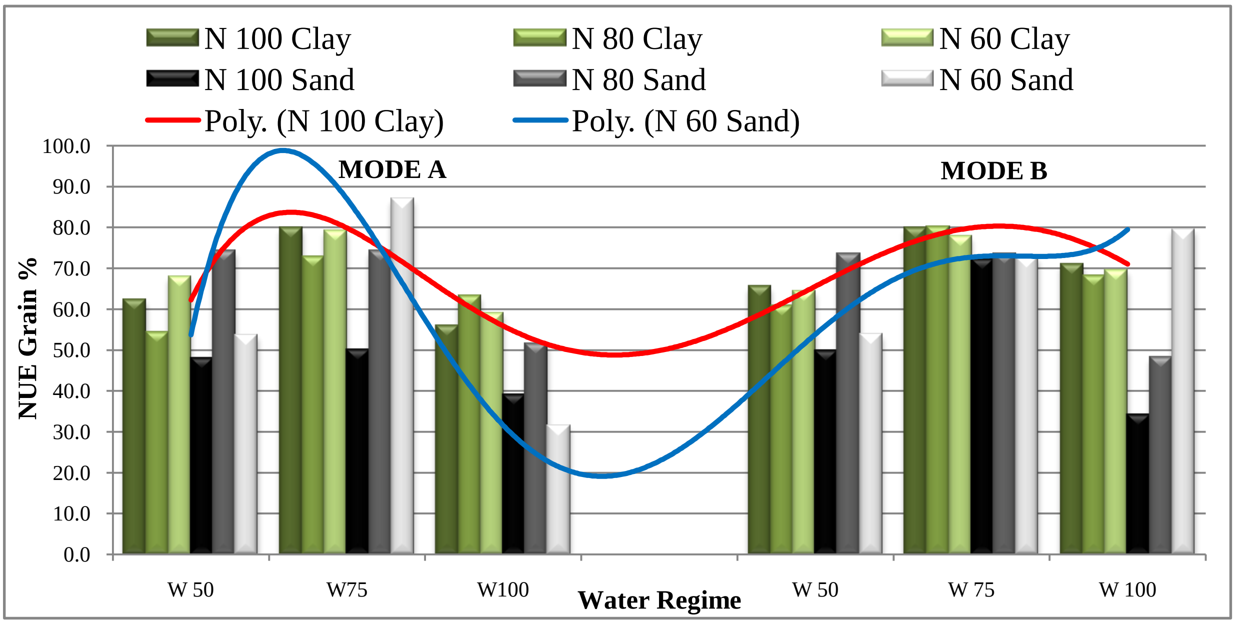


Figure (54): Nitrogen use efficiency (%) by wheat grain as affected by fertilizer N rate, mode of application, soil type and water regime

2.3. Fertilizer Nitrogen Losses

Fertilizer nitrogen lost from the two experimental soils was highly significantly correlated to soil types, fertilizer practices and water regimes **(Table (52)** and **Figure (55)**. It seems that application of 100% N rate caused higher N losses than those recorded with other two fertilizer N rates. This holds true for both soils. Generally, nitrogen losses from clay soil were lower than those recorded for sand soil. This holds true under all fertilizer N rates, water regimes and mode of N application. Regarding the water regimes, data showed gradual increases in fertilizer N losses with increasing water regimes up to 100% which induces, in most cases, the highest N losses. Jn most practices of fertilizer N rates combined with different water regimes, N losses were to some extent, higher when mode A of application was followed than those recorded for mode B except those of 100% N rate in combination with 100% water regime in sand soil which resulted in the highest value of fertilizer N losses.

In conclusion, N losses were reduced by application of moderate rates of fertilizer N combined with moderate quantities of water requirement. In this respect, the lowest values of N losses were induced by application of W75 for both soils under all management practices with some exceptions. It means that N losses was mainly correlated to water regime and varied in quantities according to rate of fertilizer N applied to both soils. In average, values of N losses doesn't big significantly varied when modes of N application was concerned.

In converse to crop yields, analysis of Zhou and Butterbach-Bahl (2014) revealed a linear relationship between NO_3^- leaching loss and N application rates for both maize and wheat cropping systems. Moreover, their meta-analysis showed that across different studies with their specific site features such as soil characteristics and agricultural management or climatic conditions, 25 % and 13 % of applied N were lost by NO_3^- leaching to the hydrosphere from maize and wheat systems, respectively.

Table (52): Fertilizer nitrogen losses as affected by soil type, fertilizer practices and water regimes(kg ha^{-1}).

N Level %	Soil Type	MODE A			MODE B		
		W 50	W75	W100	W 50	W 75	W 100
100	Sand	117.3	112.3	139.0	112.5	59.1	150.9
	Clay	43.2	15.3	59.8	36.3	12.7	31.9
80	Sand	88.1	43.8	87.0	102.5	45.1	93.1
	Clay	49.2	22.2	38.9	40.0	10.3	38.7
60	Sand	61.6	14.0	92.7	61.2	33.9	23.8
	Clay	23.4	12.0	39.4	27.8	14.5	28.7

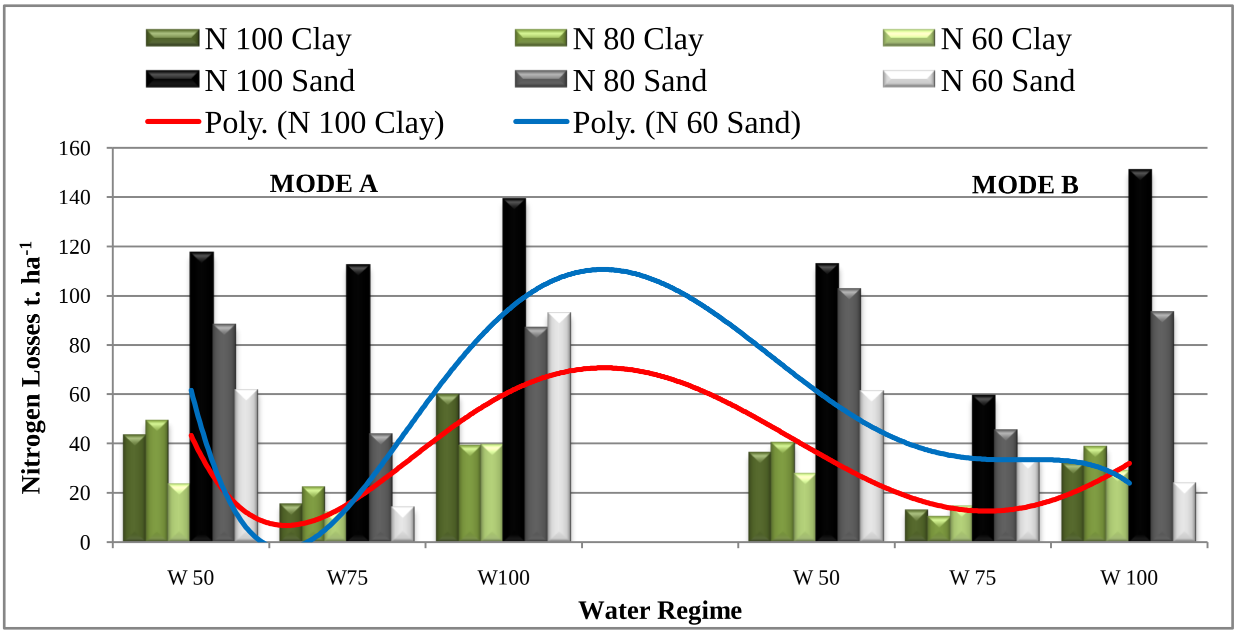


Figure (55): Fertilizer nitrogen losses as affected by soil type, fertilizer practices and water regimes(kgha^{-1}).

REMARKED CONCLUSIONS

Chapter 7

Remarked Conclusions

The interaction effect of "Soil type, Soil water regime, Nitrogen fertilizer application Rates and Timing" on Nitrogen balance in soil were studied; in terms of nitrogen gained by plant portions, remained in soil, and losses through different ways under wheat (*Triticum aestivum L. Giza 168*), in order to identify the most proper and effective combinations of above-studied variables that provides a satisfactory grain wheat yield and minimizes the use of chemical nitrogen fertilizers, to save the surrounding environment and to achieve good water saving.

Two field experiments were carried out during November and December –April 2012-13, under Egyptian conditions represents two different textured soils, i.e clay and sand soils as growth media of wheat (*Triticum aestivum* L. Giza 168) crop. The application methods of Nitrogen rates, 100, 80 and 60% of recommended rates, were applied as **Mode A**, 25% at seedling, 25% at tillering, 50% at jointing ; **Mode B**, 35% at seedling, 65% at tillering. Drip irrigation system was used. Crop water requirements were applied at three regimes, 100%, 75% and 50% of estimated requirements of wheat. ^{15}N isotope dilution technique was followed to recognize the different nitrogen portions as well as estimation of fertilizer use efficiency and fertilizer-N balance.

The main objective of this study aims to explore the next items:

- Tracing the effect of water regime and Nitrogen applications mode on N nutrition.
- Determine the long-term nitrogen mass losses from the soil under existing irrigation and fertilizer application rates.
- Drawing the relationship could exist between the water regime, nitrogen distribution, attributable to produce large crop yield without excessive losses.
- Develop strategies that would minimize the potential of nitrogen losses that pollute the surrounding environment.
- Educate the proper rate of Nitrogen fertilizer could keep optimum yield and minimize the environmental risks.

- Evaluation of the output of studied management practices on the environmental conditions.

- **Concluding remarks released from the present work could be summarized as follow:**

- Grain yield, in general, was higher in clay soil than sand soil. Similarly, mode B of N application was superior over mode A. interaction of nitrogen rates x water regimes resulted in fluctuated grain yields. In this regard, the best value of grain yield (4.91 t ha^{-1}) of plants grown on sand soil was achieved by application of 100% N rated interacted with 75% water regime. In case of clay soil, the best value of grain yield (7.03 t ha^{-1}) was detected when nitrogen was applied at 80% of recommended rate interacted with 50% water regime.

- Straw yield was significantly varied according to soil type. It was significantly higher in case of sand soil than clay one. Concerning the mode of application, data reflected no significant difference between them in sand soil while in case of clay soil mode A induced to some extent, higher straw yield than mode B. From economic and environment view point, values of straw yield as affected by N rates lead us to prefer the moderate rates of 80 and 60% since the difference between them and 100% N rate was not so big. Finally, the best value of straw yield (8.25 t ha^{-1}) in sand soil was resulted from combined treatment of 80% N applied with mode B and 100% water regime. In case of clay soil, the best value of straw yield was achieved by application of 60% N applied with A in combination with 100% water regime.

- In conclusion, sand soil doesn't reflect significant differences between N rates when HI was considered. This holds true with all water regimes. On the other hand, HI of clay soil tended to slight increase with the moderate rates of nitrogen fertilizer. Clay soil indicated higher HI than sand soil. Regarding water regime, the best HI in both sand and clay soils was indicated at 50% and 75% water regimes. Generally, the best HI was recorded for sand soil (0.41) with combined treatment of 75% water regime and 60% N rate. For clay soil, the best HI was recorded when 100% water regime combined with 80% N rate. Mode A was preferable in sand soil while mode B was the best for clay soil.

- Fertilizer nitrogen applied at rate of 60% of the recommended dose either using mode A or mode B was efficiently used by wheat straw as compared to other N rates. The best and higher %NUE was occurred for both soils with W100 despite of application modes. In this respect, mode A was better than mode B.

- Nitrogen fertilizer was efficiently used by grain of wheat grown on clay soil in higher extent, in general, than those of sand soil. Application of both 80% and 60% N rates reflected, to some extent, higher %NUE than those of 100% N rate especially in sand soil. It was obvious that the most efficient use of fertilizer N by grains was occurred under W75 comparable to other water regimes. In this respect, there was no big significant difference between the two modes of N application. Therefore, we can suggest the combined practice of moderate rates of fertilizer N (80%) and moderate quantities of water requirement (W75) as the best treatment that gave the most efficient use of applied nitrogen by wheat grains. This practice is still proper either fertilizer nitrogen applied at three splitting doses, i.e. 25% at seedling, 25% at tillering, 50% at jointing (mode A); or at two splitting doses as 35% at seedling, 65% at tillering (mode B).

- In conclusion, N losses were reduced by application of moderate rates of fertilizer N combined with moderate quantities of water requirement. In this respect, the lowest values of N losses were induced by application of W75 for both soils under all management practices with some exceptions. It means that N losses was mainly correlated to water regime and varied in quantities according to rate of fertilizer N applied to both soils. In average, values of N losses doesn't big significantly varied when modes of N application was concerned.

CONCLUDING REMARKS

- Practical work proved that grain yield was significantly affected by soil type, mode of fertilizer application and water regimes. Definitely, it was significantly higher in clay soil than sand one. Grain yield was also varied according to soil type whereas the best yield has been achieved by different combination of fertilizer N rate and water regimes. Generally, W75 was the best in both soils that gave the highest yield when fertilizer applied at 35% at seedling, 65% at tillering (Mode B).

- Fertilizer nitrogen was efficiently used by grains when applied at moderate rates in combination with W75 either N applied at three splitting doses, i.e. 25% at seedling, 25% at tillering, 50% at jointing (mode A); or at two splitting doses as 35% at seedling, 65% at tillering (mode B). It was higher in clay soil than sand soil.

- Fertilizer nitrogen lost from the soil media was mainly correlated to water regimes and N rates. Modes of N applications don't reflect significant variations in %NUE. Losses were to extent higher in sand soil than clay soil.

- From the above-results it is recommended that the moderate rates of fertilizer nitrogen and the moderate regime of water requirements is the best practice that achieved remarkable yield of wheat and efficient use of fertilizer nitrogen with minimum losses.

- From the economical and environmental point of view, this practice could reduce to some extent the nitrogen losses to surrounding environment and in the same time the reduction in rates of fertilizer (20%) and quantities of water requirement (25%) could be translated into profit.

- It should be put into consideration the amount of fertilizer nitrogen that remained in soil after harvest which will be helpful in drawing the fertility map of soil and necessary for management of successive crop in a rotation.

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Chapter 8

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