CHAPTER 2

REVIEW OF LITERATURE

The following review deals with the effect of water harvesting system, (mineral nitrogen and biofertilization) and the interaction between them on growth, yield, yield attributes, water use efficiency, some chemical composition and economic evaluation of barley.

2.1. Effect of Water Harvesting System (Catchment): Cultivated Area:

Singh (1977) reported that, the increasing in biological yield due to increasing in crop growth rate (CGR), higher crop growth rate with liberal irrigation could be due to beneficial effect of water on cell turgidity and cell elongation.

Christiansen (1982) Reported that, in rainfed agriculture, yield production was permanently dependent on the amount and distribution of rainfall. Seasonal rainfall is the most important factor effecting yields in the rainfed areas of West Asia and North Africa, up to 82 percent of the variation in grain yield was found to be determined by seasonal rainfall.

Hadjichristodoulou (1982) investigated the effect of annual precipitation and its distribution on grain yield of dry land cereals. He reported that, the percentage of the variation in grain yield explained by annual precipitation varied with variety and species (5-13% in barley and 31-79% in wheat). The distribution of precipitating was the major factor effecting grain yield, although it varied with variety and explained 72-92% of the variation in barley and from 75-98% in wheat. He added that, barley yield response to seasonal rainfall of 8.12 kg/ha/mm across 34 environments with seasonal rainfull average (307 mm) for wheat growing in slightly water environments, the response ranged from 6.42 to 16.42 kg/ha/mm.

Gardner *et al.* (1985) pointed out that, a mature seed has four components significant both physiologically and ecologically, these features also provide the seed with protective mechanism to withstand harsh environments while in a quiescent state.

Nakhtore and Kewat (1989) showed that, the increase in irrigation frequencies showed decreasing trend in wheat protein content.

Rees *et al.* (1989) reported that, the maximum water requirement for wheat grain production was about 300 mm. The chances of getting more than this amount varies from 10 to 50 %.

Verma and Sarma (1990) found that, total cost of tank per unit of capacity decreased with increasing tank capacity. Tanks designed on the basis of seasonal runoff and used for pre sowing irrigation of wheat, are the most beneficial with a benefit-cost ratio ranging from 1.6 to 4.56 for catchment area varying from one to 100 ha.

Ben-Hur (1991) reported that, wheat yield was very low, and was not harvested due to low precipitation (128.5 mm) and the poor distribution of this rain during the winter. Yield for seeded areas in the strip system were higher than for the common system. The wheat higher yield in the strip system was probably due to the additional water flowing from the contributed to the collector are in the strip system. The significantly higher yield was apparently due to increase of runoff from the CONA treat with STP.

Carter and Miller (1991) reported that, water harvesting improved sorghum grain yield two- to three fold during seasons where rainfall was low or poorly distributed. Larger yields were associated with higher pre-planting soil moisture, higher profile soil moisture, higher water use, and a larger and deeper root system. Storms with a minimum of 20 mm daily rainfall were associated with runoff volume exceeding 1000 msuperscript 3. The probability of receiving such a storm annually during the growing season was greater than 80%.

Abd El-Aleem *et al.* (1992) found that, wheat grain yield was significantly increased with increasing the ratios of catchment area to cultivated area as compared with control.

Laryea (1992) studied the Micro-Catchment-Water-Harvesting method involved the collection of surface runoff from a catchment area over a distance of less than 100 m and storing it in the soil profile of a basin located downstream. The primary objective of soil water conservation was to optimize the soil physical attributes in the field so as to minimize runoff and erosion so that sufficient water was stored in the soil profile for crop production. Management systems that conserve soil water either involved construction of earthen bunds that traverse the landscape and shortened the length of slope of the terrain, or inter-terrace management. Collection, storage and use of excess runoff to supplement rainfall in these areas would also help to control erosion.

Van and Acevedo (1993) compared the grain yield of two barley cultivars, i.e. Harmal and Arabia under rainfall and temperature variations in Northern Syria. They found that, total seasonal rainfall was strongly correlated factor with the grain yield, a counting for 62.5% of the variance. They added that, the overall yield response to seasonal rainfall was 11.89 kg/ha/mm for Harmal and 8.57 kg/ha/mm for Arabia variety.

Yoshinaga *et al.* (1993) showed that, the water poundage system was most efficient when scheduled for several years than for 1 year because of the reduction in reservoir capacity. But as reservoir decreases in size the sensitivity to the unit of water balance greatly increases, it therefore was considered that operating small-scale reservoirs on a daily basis was preferable to operating them on a 5 day, 10 day or monthly basis. They added that, the relationship between the reservoir capacity and catchment area was affected by rainfall and storm water runoff characters and the method of irrigation. As values for the quantity of rainfall, the runoff coefficient of storm water and the volume of water saving irrigation increased for a given catchment area, the capacity of the reservoir decreased. The level of this dependence was inversely proportional to the catchment area involved.

Mounir *et al.* (1994) found that, the water harvesting at gentle slope, is an alternative to increase available soil moisture content in the cultivated area.

Musick *et al.* (1994) pointed out that, the average water use efficiency (WUE) values for dry land wheat was 0.41 kg/m^3, or half/ the average 0.82 kg/m^3 from irrigated testes. The association of high WUE values with high yield has important implications for both dry land and irrigation management for attaining efficient use of water recourses in the semi arid climatic environment of the southern high plains. It emphasizes the importance of limiting duration and severity of plant water stress and attaining relative high yields when limited irrigation management is practiced.

Cohen *et al.* (1995) reported that, the efficiency of the water harvesting systems is strongly associated with its cost and therefore, risk assessment should be an integral part of any project involving water harvesting systems. The methodologies that have been used for assessing risk in small scale water harvesting systems are reviewed. A simulation-modeling stochastic approach is discussed highlighting the concept of risk behavior.

Rodriguez *et al.* (1995) found that, wheat grown in a 1:1 ratio of cropped to catchment area can increase farmers' income and decrease its variation. For barley, farmers are better off using their traditional management practice than giving up part of their cropped area to create water catchments.

Abelardo (1996) maintained that, water harvesting can increase the soil moisture content by holding more run-off water from catchments area for the cropped area which was reflected on increasing plant growth due to increasing in sink capacity.

Riki *et al.* (1996) reported that, wheat grain yield ranged from 316 to 456 gm^{-2} under rainfed conditions and from 95 to 658 gm^{-2} under irrigated conditions. Above ground biomass production ranged from 1036 to 1273 gm^{-2} under rainfed conditions and from 1778 to 1949 gm^{-2} under irrigated conditions. Harvest index differed significantly between cultivars ranged from 0.29 to 0.38 under rainfed conditions and from 0.36 under irrigated conditions. Time to heading was on average 3.5 days shorter in rainfed treatments. They added that, water use efficiency in the production of biomass for all cultivars was significantly higher under irrigated conditions than under rainfed conditions. Water was used more efficiency for biomass production, and equally efficiently for grain production under irrigated as compared with rainfed conditions. Under rainfed conditions crop water use efficiency was higher for cultivars developed for rainfed environments than for those developed for high rainfall or irrigated environments.

Sawarkar and Goydani (1996) recorded that, the yield of rainfed wheat was mush lower not only due to less moisture availability in soil but also on account of poor nutrient management.

Hassan *et al.* (1998) showed that, soil moisture content increased with increasing soil depth and/or catchment area to cultivated area ratios up to 3 : 1, 2 : 1 and 1 : 1 at the 1st, 2nd and 3rd samples, respectively, this will reflect on increasing wheat yields while, the plant height, No. of spikes/m^2, No. of grains/spike. 1000 grain weight, spike weight, tillering index grain yield, biological yield and harvest index were significantly increased with increasing ratio of catchment area to cultivated area as compared with the control (without leaving catchment area).

Zhang *et al.* (1998) reported that, water use efficiency was increased by 29 % for wheat grain yield under rainfed conditions and 57 % under irrigated conditions**.**

Li *et al.* (2000) reported that, micro catchment water harvesting can improve soil moisture storage, prolong the period of moisture availability, and enhance growth of field, horticultural and forest crops.

Prinz and Singh (2000) reported that, rainfed agricultural water management including water conservation and water harvesting, water for sustainable food production and rural development depends on efficient water use and conservation practices that consist primarily of irrigation technologies development and management, water management for rainfed areas, and water for aquatic and terrestrial ecosystems, due to rising water demand in the agricultural sector. They added that, improving rainfed production through water harvesting: increasing the productivity of rainfed agriculture which still supplies some 60% world food and occupies almost 75% of agricultural yields depends strongly on rainfall pattern and its distribution. In dry areas, rain water harvesting can both reduce risk and increase yield.

Rockstrom *et al.* (2002) reported that, small-holder farmers often work with infertile soils, or soils where nutrients are gradually depleted by a process of nutrient mining which means that initial increases in cereals crop yields may be unsustainable in the long-term, yet this is often overlooked (FAO, 2003). Soil characteristics including high infiltration rate, low water holding capacity.

Shangguan *et al.* (2002) studied micro catchment for water harvesting and conservation to increase fallow efficiency in rainy season. Using the stored runoff water to irrigate the mulched winter wheat, significant yield increasing and water use efficiency improvements have been achieved**.**

Shaozhong *et al.* (2002) reported that, water use efficiency (WUE) for winter wheat ranged from 0.73 to .93 kg/m^3 under rainfed conditions and from 0.77 to 1.46 under the irrigated treatments. The harvest index was 0.24 – 0.29 under rainfed conditions and 0,25 – 0.45 under irrigated conditions, in different growing periods, evapotranspiration, grain yield, biomass,(WUE) and harvest index depended on the controlled ranges of soil water content. Grain yield response to irrigation varied considerably due to differences in soil moisture contents and irrigation scheduling between seasons.

Xiao and Dong (2002) reported that, the ridge: furrow ratio had a significant effect on crop yield and yield compounds. They added that, 120: 60 cm ridge and furrow (120 cm wide ridge and 60 cm wide furrow) system increased yield by 27.9%, seed weight per head by 14.8%, seed number per head by 7.4% and 1000 seed weight by 4.7% compared with 60: 60 cm ridge and furrow (60 cm wide ridge and 60 cm wide furrow) system, no differences in WUE were obtained between the two ratio systems.

Slah *et al.* (2004) reported that, water harvesting system significantly reduced peaks of surface runoff within the catchment, which also reduced erosion hazards. The cultivated area of approximately 5% of the total catchment could be supplied by a harvested water amount corresponding to about seven times the amount of each rainfall event larger than 20 mm.

Attia (2005) studied the effect of size strip of water harvesting system on growth, yield, yield components, water use efficiency, chemical composition and economic evaluation of wheat in flood plain of Wadi Medour, El-Qasr Region, at 14 km West Matrouh, Marsa Matrouh Governorate, North Western Coast of Egypt, He reported that, the strip water harvesting system had a significant effect on growth characters i.e. plant height, number of tillers per plant, the fresh and dry weight of stem per plant, total chlorophyll (SPAD), flag leaf area and crop and its components i.e. number of spike per m^2, number of grains and spikelets per spike, spike length, 1000 grains weight, grain, straw and biological yield, crop, harvest and tillering index, water use efficiency, protein percentage and protein yield. The lowest values were obtained by control treatment, the maximum values were obtained by using the largest catchment area (five times of cultivated area), He added that, improvement of wheat production through the use of water harvesting techniques shows attractive return to investment and the economic impact of water harvesting methods varies significantly, and therefore cost benefit analysis should be carried out to determine the best one to be used.

Al-Razqi *et al.* (2006) indicated that, the growth of the Australian atriplex in namely the contour ridges and the Negarim Basins Techniques was superior than those planted outside the water harvesting system (control). They added that, the overall efficiency of each technique was different depending on technique used and the size of the catchment area, with contour ridges technique and the size of the catchment area has the largest effect on the plant growth.

Oweis and Hachum (2006) showed that, there was an opinion that in some areas rainfall is simply to erratic for rain water harvesting agriculture to sustain crop yields successfully, particularly when not distributed in line with the crop-growing seasons.

Ali *et al.* (2007) In North-West Egypt reported that, water harvesting in the dry lands is a viable option to improve productivity and conserve natural resources, if it is appropriately implemented. Nevertheless, the size of the water harvesting system and the spatial scale at which it is to be implemented determine the options for water harvesting.

Kumar *et al.* (2008) reported that, high potential evaporation in arid and semi arid areas reduces the ability of rain water harvesting agriculture systems to increase productivity.

Barron (2009) reported that, rain water harvest (RWH) is thought to be particularly suited to the application of supplemental irrigation in arid and semi arid areas where yield losses are high due to moisture stress. In these areas, the high variability of rainfall presents the greatest challenge to crop production.

Pachpute *et al.* (2009) reported that, the availability of resources such as finances, land and labor are widely cited as constraining factors to the adoption of rain water harvesting (RWH) systems by farmers.

Reddy and Bhagirath (2009) pointed out that, net present value of returns turned out to be positive in all the three rehabilitated tanks. Interestingly, net returns are not proportional to size of the tank, which indicates that the high per unit costs in the case of small tanks is more than upset by the higher incremental returns from wheat crops, which is facilitated by double cropping. The economic viability of tank restoration is also reflected in the cash flow measures, which are often used to take investment decisions. Benefit-cost ratios are quite high in both scenarios for all the three tanks. Net present value of the benefits is positive for all the three tanks. And internal rate of return is quite high for all the tanks. Large size tanks seem to perform better with regard to all these measures.

Bunclark and Lankford (2010) indicated that, the suitability of rain water harvesting for increasing crop production and reducing poverty in developing countries depends on factors related to climate and ecology, farming practices, availability of assets, livelihood strategies, national governance and community and catchment institutions.

Nijhof *et al.* (2010) reported that, never the less, institutions can play a primary role in learning and knowledge exchange, development of best practices, farmer support and the management of rain water harvesting systems and may help provide the poorest households with resources needed for the adoption of the technology.

Singh (2011) on wheat crop found that, rainwater harvesting refers to the collection and storing of rainwater for human related activities. The popularity of rainwater harvesting and utilization is its decentralized nature located in proximity to and supply of good quality water to the end user.

Younis and El-Sheikh (2011) reported that, the implementation of the tears water harvesting catchment basin, conveyance device, storage facility and cultivated field type of water harvesting system as well as direct run-off system using indigenous micro-catchment basins (teras).

Al-Ali and Mahmoud (2012) showed that, a smaller catchment area is capable of providing sufficient harvested water to meet crop growth requirements.

Ghimire *et al.* (2012) recommended that, full cost pricing for rainwater harvesting is important for the promotion of sustainable practices and life cycle based system design is critical to make rain water harvesting systems economically attractive.

Hadadin *et al.* (2012) reported that, rainwater harvesting could make water available during dry periods and its capture can also reduce soil erosion from runoff during wet periods.

Tallal *et al.* (2012) demonstrated that, rain water harvesting systems were shown to be a relatively low cost option for improving a households' geographical and temporal access to a water source, increasing convenience and decreasing collection times.

Gammoh (2013) reported that, using micro-catchment technique [Wide Furrow with Back-placed transplanting area (WFB)], and employing 1-2-month old atriplex transplants facilitate mechanized transplanting and/or seed drilling for mixed cropping as well as mechanized maintenance of the micro-catchments, which will presumably encourage large-scale implementation and improve the sustainability of the water harvesting structures.

Teka *et al.* (2013) illustrated that, an integrated assessment of the hydrological response in the catchment is necessary for an adequate design of water harvesting systems because the high losses of water through seepage and evaporation substantially decreased the irrigation capacity by up to 33%. They added that, an integrated assessment of the hydrological response in the catchment is necessary for an adequate design of water harvesting systems.

2.2. Effect of Mineral Nitrogen and Biofertilization:

Nitrogen is essential for plant growth and for higher productivity and it plays an import activates, formation and functions of protoplasm, which consequently increase the plant growth.

Misra and Sen (1981) pointed out that, the higher WUE with 120 kg N/ha. indicated proportionately much more photosynthetic areas of wheat plants than water loss resulting in higher WUE.

Ishac *et al.* (1984) showed that, inoculation of wheat grains with Azoospirillum brasilense significantly enhanced the growth and the yield was increased.

Fayez (1989) studied the possible association with the flowering microorganisms *Azotobacter chroococcum* and *Azospirillum brasilense with* wheat and barley. He found that, inoculation of single inoculums of each of the N2-fixing bacteria had no significant influence on plant growth.

EL-Khawas (1990) found that, biofertilization promote the production of barley grains. Once roots emerge at seed germination and are colonized by N2- fixing bacteria, energetic pathways such as glycolysis and conversion of conjugate IAA to active IAA are stimulated. Also, the mineral nitrogen fixing bacteria may increase the synthesis of the endogenous phytohormones i.e. indole acetic acid (IAA), Gibbrelic acids (GAS) and cytokinones (CKS) which plays an important role in formation of a big active root system, that allow more nutrients uptake and hence may promote photosynthesis and translocation as well as accumulation of dry matter within deferent plants parts and hence increased number of spikes/m^2 and number of grains/spike.

Gomma (1992) pointed out that, the high mineral nitrogen levels improved barley grain yield.

Barsoum (1994) showed that, application of 80 kg N/fed. gave highest barley, straw yield, yield components and chemical composition of grains.

Dubey and Sharma (1996) reported that, the increase in tillering index may be due to increasing in vegetative growth of wheat plant vigorous and N supply of photosynthetic formation of production tiller and spike and the increasing in number of spikes/m^2.

El-Sayed *et al.* (1999) found that, the biofertilizer (*Nitrobein* and *cerealin*) caused an increase in harvest index of barley which reached about (62.8% for biofertilization), (40.3% for *nitrobein*) and (19.7% for *cerrealine*) compared to the non inoculation.

El-Toukhy and Abdel-Azeem (2000) under the conditions of calcareous desert soil, found that, significant increase in the yield of leaves, stems, spikes, leaf: stem ratio and whole barley yield (fresh and dry) were recorded in biofertilizer application treatments as compared with inorganic nitrogen also, biofertilizer application improved plant growth characters such as plant height, number of tillers, number of leaves and leaf area. The highest plant yield and the best plant growth characters had been achieved when using the immobilized biofertilizers and half rate of mineral nitrogen fertilizer.

Sanjay and Megh (2001) reported that, the application of 90 kg N/ha. (fertilizer costs of Rs 684.0/ha) to barley plants recorded the highest return of Rs 22218.0/ha.

Spaner *et al.* (2001) indicated that, increasing nitrogen fertilization from 0 to 60 kg N/ha. increased spike density/m^2 at harvest, resulting in linear increases in barley grain yield in all years.

Tolstopyatova (2002) illustrated that, increase in the mineral nitrogen input did not increase barley yield and crude protein content, but lead to an increase in straw weight and nitrogen content.

Ali *et al.* (2003) found that, grain inoculation with *Azospirillum brasilense* Sp 246 significantly affected yield and yield components, both in wheat and barley. On average of years and N doses, inoculation with *Azospirillum brasilense* Sp246 increased spike number per m^2, grain number per spike, grain yield, and crude protein content by 7.2, 5.9, 14.7, and 4.1% in wheat and by 6.6, 8.1, 17.5, and 5.1% in barley, respectively, as compared to control. Inoculation with *Bacillus sp.* OSU-142 significantly increased kernel number per spike in wheat, but no significant effect was determined in the other characters. Grain yields and yield components were also higher at all levels of nitrogen fertilizer in the inoculated plots as compared to the control. However, these increases diminished at high fertilizer levels. These results suggest that application of the growth promoting bacteria *Azospirillum brasilense* Sp246 may have the potential to be used as a biofertilizer for spring wheat and barley cultivation in organic and low-N input agriculture.

Moreno *et al.* (2003) found that, no significant differences in barley yield were found between 100 and 150 kg N/ha., but yield was significantly reduced by applying 200 kg N/ha.

Turk *et al.* (2003) showed that, the highest barley grain yield (2112.5 kg/ha.), grain weight per plant (5.4 g), number of grains per spike (56.3), spikes per m^2 (537.5), spikes per plant (4.8), plant height (75.5 cm) and spike length (7.5 cm), were obtained with 120 kg N/ha. and the highest 100-grain weight (41.1 g) was recorded for 40 kg N/ha.

Ummed *et al.* (2003) reported that, increasing levels of N up to 75 kg/ha. improved all barley growth and yield attributes, but remained at par with that of 100 kg N/ha. Nitrogen fertilizer up to 75 kg/ha increased grain and straw yields, with 18.3, 8.9 and 2.9 q/ha increase over 0, 25 and 50 kg N/ha, respectively. The highest N rate had no advantage over 75 kg N/ha. Inoculation with *Azotobacter chroococcum* + *Azospirillum brasilense* resulted in the highest grain and straw yields. With the *Azotobacter chroococcum* + *Azospirillum brasilense* treatment, grain yield was 31.2, 6.9 and 10.8% higher than that of the control, *Azotobacter chroococcum and Azospirillum brasilense* inoculations, respectively. Individual inoculations with *Azotobacter chroococcum* and *Azospirillum brasilense* were at par with each other and recorded higher grain and straw yields than the control. The relative performance of these inoculations was in the order: *Azotobacter chroococcum + Azospirillum brasilense>Azotobacter chroococcum>Azospirillum brasilense.*

Kumawat and Jat (2005) reported that, nitrogen fertilizer at a rat of 40 or 60 kg/ha. recorded the highest values for barley yield attributes and net returns, also these treatments recorded the highest uptake of N, P and K.

Kumawat *et al.* (2006) reported that, application of 40 kg N/ha. gave higher grain (5.59 t/ha) and straw yield (7.06 t/ha) of barley and N fertilizer at a rate of 60 kg N/ha. gave the highest net returns (Rs 30 543/ha).

Satyajeet *et al.* (2006) reported that, increasing nitrogen levels up to 60 kg/ha. to barley plants increased grain yield significantly over the preceding levels, the recorded increases with N 80, over N 0, N 20, N 40 and N 60 were 116, 49, 18 and 5 respectively, maximum grain yield was recorded with dual inoculation followed by *Azotobacter*, *Azospirillum* and control. Application of 40 kg N/ha significantly increased the protein content in grain over preceding levels but every successive N dose beyond 40 kg N/ha did not cause significant increase in protein content on the other side the malt yield of barley decreased significantly with the successive increase in N. They added that, barley grain yield, net return and B: C ratio increased significantly up to 60 kg N/ha. and the economic optimum dose of nitrogen was worked out to be 59.6, 51.1, 51.0 and 51.1 kg ha. with control, *Azotobacter, Azospirillum* and *Azotobacter + Azospirillum*, respectively.

Mustafa *et al.* (2007) showed that, all the inoculated bacteria contributed to the amount of mineral nitrogen. Grains inoculation significantly increased the count of bacteria and fungi. Data suggest that grains inoculation of barley with PGPR strains increased root weight by 9–12.2%, and shoot weight by 29.7–43.3% compared with control. The N, NP and P application, however, increased root weight up to 18.2, 25.0 and 7.4% and shoot weight by 31.6, 43.4 and 26.4%, respectively. Also, data show that PGPR stimulate barley growth and could be used as an alternative to chemical fertilizer. Soil compaction hampers the beneficial plant growth promoting properties of PGPR and should be avoided.

Nishant *et al.* (2007) obtained, positive and significant results obtained by different biofertilizer treatments as compared to their respective controls. Application of *Azotobacter* showed significant increase in total nitrogen, crude protein, carbohydrate and lipid contents of barley grains, whereas *Azospirillum* significantly increased calcium and iron contents of grains. Combined treatment (*Azotobacter+Azospirillum+phosphate solubilizing bacteria*) also increased seed's total nitrogen, crude protein, iron, calcium and phosphorus contents as compared with the control.

Stipesevic *et al.* (2007) found that, winter barley yield increase was not significantly higher after application of 90 kg N ha.

Asadi *et al.* (2008) showed that, the highest rates of nitrogen fertilizer application (150 kg N/ha.) gave the greatest yield of total dry matter and digestibility of organic matter of barley crop.

Candrakova (2008) showed that, there were positive influence of bio-fertilizer by *Azotobacter chrococcum* on yield components and grain yield of spring barley.

Krcek *et al.* (2008) reported that, nitrogen fertilization alleviated adverse effects of drought stress on the yields of barley grain; the rate of 1 g N per pot increased the grain yield of plants stressed during tillering 3.73 times compared to unfertilized and stressed treatment.

Mikhailouskaya and Bogdevitch (2009) reported that, *Azobacterin* applications positively influenced crop production and protein contents of spring barley grains.

Biberdzic *et al.* (2010) showed that, the highest values of 1000 grain mass, hectoliter mass and grain yield of barley were reached with nitrogen dose of 80 kg N/ha.

Broumand *et al.* (2010) found that, nitrogen fertilizer at a rate of 250 kg/ha. on barley had a significant effect on the number of spikes per m^2, number of grains in spike, grain yield, 1000-grain weight, stem height, percentage of lodging, straw yield and chlorophyll content.

El-Metwally *et al.* (2010) reported that, application of nitrogen fertilizer at a rate of 60 kg N/fed. to barley plants recorded the highest value of flag leaf area, plant height, spike length, number of grains/spike, grains weight/spike, spikes number/m^2, straw and grain yields as well as grains protein and total carbohydrates percentage.

Dadnia *et al.* (2010 a) showed that, the practical significant differences among bacterial treatments showed that, yield components affected by these treatments such as *Azospirillum lipcferum* x P. utida, P. utida x *Azotobacter chrococcum* and *Azospirillum lipcferum* x *Azotobacter chrococcum* increased barley yield 27.5, 21.7 and 17.8% at N applied, respectively.

Dadnia *et al.* (2010 b) reported that, barley yield increased 24.5% with *A. brasilense*, 12.7% with *A. lipcferum* at 75 and 100% nitrogen application than control treatments. They added that, the chemical composition of the three *Azospirillum* species notably influenced the soil properties and therefore the barley yield parameters.

Amanullah *et al.* (2011) reported that, average barley plant height (PH), grain yield (GY), and straw yield (SY) were significantly influenced by the main effect of N application. The highest grain yield (103%) was obtained with 120 kg N per ha. compared to the control.

Gigel (2011) showed that, after nitrogen application, the winter wheat and barley yields increased significantly up to the 150 kg per ha. nitrogen/ha dose, at higher rates decreased the yield level, so it is recommended that, mineral nitrogen doses of less than 150 kg per ha. should be applied under the given climate and soil conditions.

Jankovic *et al.* (2011) showed that, nitrogen significantly increased barley grain yield (2219 to 2987 kg/ha.), grain quality was decreased by increasing nitrogen rates (1.24 to 2.13%). Apart from nitrogen rates, the genotype also affected the yield. Premijum variety gave the highest grain yield and the lowest protein content. The optimal plant nutrition was achieved by applying 50 kg N ha. by further increasing nitrogen amounts, the grain yield increased from 380 to 769 kg ha., but the differences were not significant. Different nitrogen rates showed a significant effect on the absolute grain weight (3.00 to 5.76 g) and volume grain weight (2.22 to 5.28 kg ha.

Mousavi and Seghatoleslami (2011) found that, bio-fertilizer treatment provided more suitable condition to bio activities of soil as compared with chemical treatment and they resulted in increasing 1000-grain weight and uptake of nutrients by root of barley plants.

Bashirzadeh *et al.* (2012) illustrated that, the maximum seed yield of barley was observed with *Azospirillum lipcferum* inoculation and highest mineral nitrogen level, and the minimum was with non-inoculation and without mineral nitrogen application.

Dubis *et al.* (2012) reported that, high grain yield of barley was obtained at fertilization rates of 40-60 kg N/ha.

Farrag *et al.* (2012) reported that, *bacillus amendment* enhanced the length of wheat and barley plants in both non-contaminated and contaminated soils.

Riley *et al.* (2012) found that, the optimum nitrogen fertilizer level for barley was found to increase by 8.3 kg N/ha.

Azimi *et al.* (2013) found that, application of biofertilizer to barley grains had the highest grain yield (7.6 ton/ha) and uninoculation treatment had the lowest grain yield (6.3 ton/ha).

Berhanu *et al.* (2013) reported that, highest grain yield (103%) of barley was obtained by using 120 kg N/ha. compared with the control.

Rahim *et al.* (2013) showed that, there was a significant effect on yield and related characters by using chemical fertilizer. The effect was significant on grain yield, harvest index, biological yield, plant height as well as protein content by using bio-fertilizer. The traits of consumer interest such as highest grain yield, harvest index, biological yield and plant height were obtained with the application of (*Azotobacter* + *Pseudomonas*) as compared with non-inoculation treatment. The traits such as grain yield, harvest index, biological and plant height were affected by interaction effects of both chemical and bio-fertilizers. The highest grain yield was thus due to the use of chemical fertilizer with *Azotobacter Pseudomonas*. Thus, we can accept grain yield of barley by using 75% chemical fertilizer and inoculation with (*Azotobacter* + *Pseudomonas*). In general, the result of this investigation showed that the use of 75% chemical fertilizer along with dual inoculation (*Azotobacter* + *Pseudomonas*) could produce satisfactory yield of barley.

Tarun (2013) detected that, nitrogen fertilizer at a rate of 80 kg/ha. with both (*Azotobacter* + *Azospirillum*) inoculations was found to be the most responsive, with significant increase in the growth parameters i.e. plant height, maximum number of tillers and grain yield of barley.

Valkama *et al.* (2013) indicated that, with increasing N rates, protein content increased to a larger extent in spring barley.

2.3. The Interaction between Water Harvesting System (Catchment): Cultivated Area and (Mineral Nitrogen and Biofertilization):

Panda *et al.* (1988) found that, number of productive tillers/m^2 and plant height increased significantly with increasing irrigation frequency and increasing levels of nitrogen.

Kumar *et al.* (1990) maintained that, the interaction between catchment area ratio and mineral and biofertilization is important to produce constant and economically attractive yield and the water use efficiency increased remarkably with increasing nitrogen level due to the higher grain yield and the favorably affected plant height.

Rai and Sinha (1994) reported that, except for wheat under rainfed conditions plant density decreased between 12.7 and 76.3% under rainfed conditions and by between 16.1 and 46.4% under irrigated conditions. Wheat and barley grain yields were increased with fertilizer application under both rainfed and irrigated conditions.

Karczmarczyk *et al.* (1997) reported that, application of irrigation combined with high doses of nitrogen fertilizer caused yield increases in barley of 114 %. The productivity of irrigation was enhanced in variants treated with high fertilizer rates and the effectiveness of nitrogen was many-fold higher on irrigated plots, the yield increases were associated with better tillering, increased number of stalks and spikes per m^2 and increased 1000-grain weight.

Garabet *et al.* (1998) pointed out that, yields of winter wheat were increased by irrigation and nitrogen fertilizer, with a greater response to nitrogen and to irrigation under the relatively drier conditions.

Singh and Bhan (1998) found that, No. of spikes/m row length, grain weight/spike and grain yield weight were favorably affected by increasing water supply and nitrogen levels.

Koszanski, *et al.* (1999) showed that, in natural rain conditions the highest effects on barley yield were obtained when plants were fertilized with 150 kg N/ha. Whereas, with irrigation the best fertilizer rate was 300 kg N/ha. They added that, irrigation significantly increased the productivity of fertilizers and mineral nitrogen fertilizer enhanced the effects of supplemental irrigation.

Wu-Dong *et al.* (2001) recommended that, the relationship between the amount fertilizer and the wheat yield was parabolic when the amount of water supply was constant. The amount of nitrogen and water content had a positively alternative effect, fertilizer application can improve water efficiency and increase wheat yield. The amount of increase in wheat yield by fertilizer can be arranged as follow: with high rainfall year larger than year with medium rainfall larger than year with low rainfall. In different rainfall years (355 mm/a, 411mm/a and 523 mm/a) when wheat yield is highest.

Du-Yao and Liu (2003) reported that, insufficient water supply was the most important factor affecting yield of spring wheat. They added that, the effect of N and water on increasing yield was statistically significant and coincided with the low of diminishing return, a positive interaction existed between N and water and the highest N could increase yield.

Attia (2005) recommended that, adding the strip size of strip water harvesting system (5: 1) (contributed area five times of cultivated area) + mineral and biofertilizer (50 kg N/fed. with microbein) gave the highest grain yield and enhanced most of plant characters, yield, its components, water use efficiency and chemical compositions for winter wheat under rainfed conditions, besides to the increase of cost/benefit analysis.

Karam *et al.* (2009) pointed out that, optimum wheat yield was produced at 50% of soil water deficit as supplemental irrigation and nitrogen rate of 150 kg N/ha. However, harvest index (HI) and water use efficiency (WUE) were not significantly affected neither by supplemental irrigation nor by nitrogen rate.

Ryan *et al.* (2009) at West Asia-North Africa region, which is characterized by a typical Mediterranean climate, showed that, there were considerable differences between crop years, with significantly higher yields in the second growing season when rainfall was heavy at the critical tillering and stem-elongation growth stages. Nitrogen consistently increased dry matter and grain yields in either year, generally being significant up to 80 kg N/ha. There were significant differences observed among varieties, as well as interactions of varieties with years. The six-row variety Arig-8 was consistently the best while the two-row Asni, was the lowest yielding variety. Where an economic analysis was done on yield data (Year 1), N fertilization up to at least 80 kg N/ha. was considered as profitable. Crop N uptake varied with varieties and increased with increasing fertilizer. N recovery was variable and generally less than 50%. In contrast to many other fertilizer trials with barley in the region, this trial from central Morocco showed highly significant yield increases in response to applied N for barley varieties, most of which performed similarly. Therefore, N fertilization of barley in Morocco's semi arid cereal-producing Zone on shallow soils, where root growth and moisture-holding capacity are limited, should be promoted.

Montazar and Azadegan (2012) reported that, consequently, when limited irrigation water is combined with N fertilizer appropriate management, wheat water productivity can be substantially and consistently increased in arid regions.