REVIEW OF LITERATURE
The wheat (*Triticum aestivum* L.) is extremely well adopted to endure in eastern past of Uttar Pradesh in both irrigated and dryland areas. In the dryland areas, productivity and stability of wheat production is exceeded only by barley. This areas sequence of crops is often found with wheat as the dominant crop. The challenges for the agronomist in the dryland environments is to apply knowledge of climatic, edaphic, biological and economic factors to devise a system that optimizes grain yield, yield stability and long term viability.

It is often assumed that most limiting factor in dryland wheat crops is water. In the absolute sense, this is true but in practices many factors limit the efficient use of water in crop production. The idea that water use efficiency is the key to yield improvement in dryland agriculture clearly valid, but the ratio of grain yield to water used (evaporation + transpiration) is most affected more by yield obtained than by water used. In other words, any treatment that increases yield while using the same, or a similar, amount of water will have a higher water use efficiency. This is clear when it is observed that low-yielding crops use about as such water as high-yielding crops in dryland environments (Fischer and Kohn, 1966b; Cooper *et. al.*, 1983; Anderson, 1992).

The dependence of water-use efficiency on correcting the limiting factors other than water supply has been elegantly demonstrated under Southern Australian conditions by French and Schultz (1984a, 1984b). applying the principle that grain yield is linearly proportional to water used so long as other factors are not
limiting, they showed that wheat yields and water-use efficiency were often restricted by crop nutrition. It has further been controlled by inappropriate sowing time and inadequate crop nutrition. It has further been demonstrated that dryland wheat crops in Western Australia can approach or equal the rainfall-limited potential yield given the appropriate combination of agronomic practices.

2.1. Effect of moisture regimes on moisture use and moisture use efficiency:

Moisture use efficiency is the function of grain produced per unit of water utilized by the plant. Water use efficiency decreased with more frequent irrigations.

The highest water use efficiency was under irrigation at 20 percent ASM (Rathore and Singh, 1976) and lowest under 80 percent ASM. This was due to comparatively lesser increase in wheat crop yield with each additional unit of consumptive use of water due to the rapid rate of evapotranspiration under wet conditions at 80 percent ASM. Singh and Kumar (1976) recorded maximum water use efficiency of 19.1 kg grain mm\(^{-1}\) water in barley with three irrigations at pre sowing, crown root initiation and jointing stage. However, Slatyer (1960) was of the view that the efficiency of moisture use can be measured in many ways, but the total production of dry matter should be the principal criteria. For crop grown under dry land conditions, the quantity of water stored in the profile or that received from rainfall remains constant. Under these condition, therefore, it would be expected that the water use efficiency (WUE) of crop will be highest at higher plant population. Parihar et. al., (1981) reported that mustard crop utilized 7.2 to 18.9cm. water (23 to 76 percent of the total water used) from the profile depending
upon irrigation, rain, atmospheric evaporation and other features like irrigation timing. They found that profile water extraction generally showed an inverse relationship with the amount of irrigation water applied, with a maximum average extraction of 16.7 cm with no irrigation closely followed by 15.8 cm for one irrigation three weeks after sowing.

Rao and Bhardwaj (1981) reported that consumptive use of water increased with increase in moisture availability but water is efficiency increased with decreased soil moisture availability because of decrease in yield per unit water used relative to other irrigation levels but not due to any decrease in absolute yield.

The response and optimum doses of nitrogen and sulphur, however would depend on the amount of available moisture particularly during the active growth period of crop through, the crop. is mostly growth under rainfed conditions it responds favourably to supplemented irrigation (Singh et. al., 1985).

Garai et. al., (1989) reported that under rainfed conditions, water use efficiency in mustard increased with increasing rates of nitrogen upto 80 KgNha^{-1}. Vyas et. al., (1995) also reported that nitrogen significantly enhanced the soil moisture extraction and water use efficiency.

2.1.2. Effect of soil moisture stress on growth, physiological development and dry matter accumulations:

Soil moisture stress affects every aspect of plant growth such as plant height, leaf area, number of leaves and tillers, dry matter accumulation in various plant components and translocation of dry matter especially for grain formation. It changes the physiological
developments by virtue of which the quality and yield of final product is affected. Such type of changes depend upon intensity and duration of moisture stress, crop varieties, previous stress history, stage of crop development where moisture stress occurs and environmental factors.

Aspinal et al., (1964) reported that early moisture stress to barley produced largest number of tillers but reduced the mean tiller length whereas stress at or just before the anthesis reduced the upper internodes length. Day et al. (1978) found significant difference in dry matter weight of various plant components and leaf area between irrigated and non-irrigated barley. Legg et al. (1979) reported that the moisture stress reduced the grain yield of barley due to significant decrease in leaf area, however, the photosynthesis and stomatal conductance responded least to moisture stress.

Robin and Domingo (1962) found that the moisture stress at jointing stage of wheat reduced the plant height, resulted in more ears and delayed the maturity time, while moisture stress at dough stage did not influence the plant height but hastened the maturity. Day and Thompson (1975) reported the similar results for barley. Campbell and Davidson (1979) reported that high moisture stress from tillering to last leaf visible stage reduced photosynthates area, stem, leaf and root dry matter, but did not affect the plant height, tillers surviving to the maturity and ear dry weight of wheat grown under controlled environmental conditions, whereas moisture stress at booting to anthesis reduced plant height, number of tillers surviving at maturity and dry matter production mainly by reducing stem and ear development. Chaudhary and Kumar (1980) found that
moisture stress from sowing to tillering, tillering to flowering and 
flowing to maturity, reduced the number of tillers, leaf area and 
plant height of wheat, however the effect was more during sowing to 
tillering, but showed recovery of growth and delayed final 
harvesting for 10-12 days.

Legg et. al., (1970) reported that moisture stress significantly 
reduced various plant components of barely but leaf was relatively 
much affected whereas carbon dioxide assimilation per unit leaf area 
and stomatal conductance was little affected by the moisture stress, 
however, these components were much affected when irrigation was 
withheld from sowing to the anthesis or no irrigation during the 
whole growth period. Moisture stress during the early growth period 
decreased the leaf area index by reducing expansion of main stem 
leaves and by decreasing the growth and number of tillers, leaves 
and also by increasing the senescence of leaves, whereas, moisture 
stress during the late growth period reduced the photosynthetic area 
by senescence of leaves, stem and awns, however fully irrigated crop 
produced maximum green area during the entire grain filling periods. 
Similar results were reported by Imtiyaz and Jensen (1981) for 
barley under green house condition. Imtiyaz et. al., (1982) obtained 
marked difference in leaf area, plant height and total above ground 
dry matter between irrigated and non-irrigated wheat and barley 
under field conditions. However, leaf area index and total dry matter 
were more affected than the plant height, but the number of tillers 
per m² were unaffected by the moisture stress. Leaf area index, dry 
matter accumulation and evapotranspiration of non-irrigated crops 
fell bellow the irrigated crops when the soil water deficit within the 
root zone capacity was exceeded 50-60 mm, however, leaf area
index decreased at an earlier stage of drought than did evapotranspiration. Imtiyaz (1983) reported that the productive than the vegetative stages (Jointing and booting) because the production stages has lower stomatal resistance, total water and pressure potential and relative water content in leaves at any given soil metric potential as compared with the vegetative stages.

2.1.3. Effect of soil moisture stress on yield and yield components and water use efficiency:

In these days water is being scarce and expensive throughout the world, so it is essential to manage irrigation water in such a way that optimum yield may be obtained by each unit of water. In arid and semi-arid regions of the world where irrigation water is most limiting factor for crop production, it is not possible to avoid moisture stress in the plant, so we should make planning in such a way that irrigation may be given in proper amount and at proper time to get the economical yield of the crop.

Aspinal et.al. (1964) reported that moisture stress during vegetative growth period reduced the grains per ear but did not affect the grain yield significantly, whereas stress during anthesis and grain filling period reduced mean grain mass and grain yield of barley significantly. Day and Thompson (1975) reported that barley was more sensitive to moisture during flowering and dough stages than jointing stage due to significant reduction in seed set and seed weight. Day et. al., (1978) found a linear relationship between yield and water use of barley without any indication of critical growth period of drought sensitivity while a longer drought during early growth periods showed large effect on yield and water use. Yield and water use efficiency of barley was increased significantly by
irrigation at flowering period, Sepakhah (1978). Mogensen (1980) reported that yield reduction of barley was maximum when drought occurred during jointing and booting periods, but after re-irrigation late tillers were developed, however, the late tillers failed to ripe at the normal harvesting time. Imtiyaz \textit{et al.} (1981) and Lawlor \textit{et al.} (1981) found that drought during early growth period decreased mainly ears per unit area and grains per ear, whereas late drought affected mean grain mass due to significant reduction in photosynthesis area.

Imtiyaz \textit{et al.} (1981) reported that booting was the most sensitive stage of barley to moisture stress due to significant reduction in ears per plant and grains per ear, Imtiyaz \textit{et al.} (1982) found that number of grains per ear were the main cause for the yield reduction in un-irrigated wheat and barley. Moreover, water use efficiency was higher in irrigated than un-irrigated barley. Nassar \textit{et al.} (1980) observed maximum grain yield reduction of wheat in growth chamber when single moisture stress cycle was imposed at anthesis due to significant reduction in mean grain mass, however second stress cycle further decreased grain irrespective of growth stages. Singh (1981) reported that wheat crop during booting and heading period was most sensitive to moisture stress, however sensitivity was reduced when plants were moderately stressed during vegetative period.

Imtiyaz (1983) reported that the late tillers at booting stage maintained reasonably higher positive pressure potential even during the severe stress, because osmotic and total water potential in leaves decreased approximately at the same rate. The late tillers were more
drought resistance as compared with normal tillers as they had higher total water and pressure potentials and relative water content in leaves at the same development stages, even in lower soil metric potential. The moisture stress at jointing, booting, heading and early grain formation stages reduced grain yield in normal tillers, but reduction was maximum at the booting. However, when normal and late tillers were considered together, then the yield losses at jointing and booting were fully compensated but still grain yield of crops stressed at booting, heading and early grain formation stages was considerably lower as compared with fully watered crop. The moisture stress reduced number of ears per plant at jointing, number of ear per plant and mean grain weight at booting, number of ear per unit, number of grains per ear, mean grain weight at booting and heading, and number of grains per ear and mean grain weight at early grain formation stages in normal tillers. However, when normal and late tillers were considered together, then the number of grains per ear and mean grain weight were the components which reduced the grain yield of crop which was stressed at booting heading and early grain formation stages in normal tillers. However, when normal and late tillers were considered together, then the number of grains per ear and mean grain weight were the components which reduced the grain yield of crop which was stressed at booting heading and early grain formation stages. Even mild moisture stress at booting reduced grain yield in normal tillers by reducing the number of grains per ear, however, an increase in severity of stress reduced number of ears per plant, number of grains per ears and mean grain weight, stresses at booting did not reduce the grain yield of late tillers except slightly in severe stress. The
moisture stress at booting, heading and early grain formation stages reduced water use efficiency for grain production but did not influence total water use.

2.1.4. Water use and yield relationship under limited water supply condition:

The relationship between evapo-transpiration and yield has been defined as water production function. In arid and semi-arid regions information regarding water production function is basis to water resources planners of determining capacity of irrigation system, procedure for scheduling irrigation during the entire growing season, means for comparing water use efficiency within and between the crops and means for predicting yield under different water supply regimes etc.

A linear relationship between water use and dry matter yield was reported by Day et al., 1978 and observed that linear relationship did not hold when other growth factors such as soil fertility, temperature and radiation were not optimum.

The concepts of relating relative yield to relative evapo-transpiration have been used by many workers in order to obtain more general and non-dimensional relationship. The objective for relating relative yield to relative evapo-transpiration is to obtain the slope of the line which indicate the effect of each increment of evapo-transpiration on grain yield. Doorenboss and Kasam (1979) gave the following relationship in order to quantify the effect of moisture stress within and between the crop species.

\[(1 - \frac{Y_a}{Y_m}) = K_y (1 - \frac{ET_a}{ET_m})\] 

......................................(2.2)
where,

\[ \text{Ya} = \text{actual harvested yield as influenced by limited soil water availability.} \]
\[ \text{Ym} = \text{maximum harvested yield from fully irrigated crop.} \]
\[ \text{Ky} = \text{yield response factor which is a slope of the line passing through (0, 0).} \]
\[ \text{ETa} = \text{actual evapotranspiration as influenced by limited soil water availability.} \]
\[ \text{ETm} = \text{maximum evapotranspiration from fully irrigated crop.} \]
\[ (1 - \frac{\text{Ya}}{\text{Ym}}) = \text{relative yield decrease} \]
\[ (1 - \frac{\text{ETa}}{\text{ETm}}) = \text{relative evapotranspiration deficit.} \]

Doorenboss and Kassam (1979) reported that such relationship is valid when all the growth factors such as soil fertility, crop variety, cultivation practices and climatic factors other than the water use are provided at the optimum levels. Yield response factor (Ky) is derived on the assumptions that relationship between relative yield (Ya/Ym) to relative evapotranspiration (ETa/ETm) is linear and valid for relative evapotranspiration deficit up to 50%. In arid and semi-arid regime where it is not possible to meet maximum evapotranspiration (ETa/ETm), therefore each increment of evapotranspiration which cannot be met will decrease the grain yield. Imtiyaz (1983) reported that the relative yield decrease per stress day was highest during the jointing to booting stages.
2.2. Performance of cereals in relation to soil moisture and fertility

2.2.1. Soil Moisture and Yield Relationship

Moisture availability is one of the most important factors in crop production under dryland conditions. It assumes special significance in the dry farming areas due to the fact that a slight variation in the normal rainfall or stored soil moisture makes the differences between the success and the failure of the growing crop. Cole and Mathews (1923) concluded that it was possible to forecast the wheat yield from the amount of soil moisture at sowing time, however, the presence of comparatively large amount of moisture at seeding time has not been found to be a reliable basis to predict yield. Yield of dryland crops depends much on the amount and the distribution of seasonal precipitation (Barnes and Hopkins, 1930). They further observed that soil moisture reserve was particularly valuable in sustaining the crop dry spell of summer. Many workers have studies the correlation between crop yield and soil moisture at sowing time and precipitation (Compton, 1943). Apart from the total precipitation, uniform distribution of rainfall is most important under dryland conditions (Jook, 1950; Bennett et. al., 1954; Harris, 1963). Similarly, Bauer et. al. (1965) reported higher correlation coefficient when spring wheat and barley yields were correlated with available moisture at sowing time and seasonal precipitation.

2.2.2. Consumptive use of water, moisture use efficiency and moisture depletion pattern

Under soil moisture stress, plant growth and crop yields are closely related to consumptive use of water, moisture of studies
conducted with cereals, it has been realized that under the conditions of moisture stress, yield as well as morphological growth behaviour of plants are highly correlated with these parameters depending upon soil type, water table and fertility status of the soil.

Weaver et al., (1956), working the influence of nitrogen fertilization on evapo-transpiration of sudan grass, reported that water use efficiency was greatly increased due to the application of nitrogen. A correlation coefficient of 0.77, 0.53 and 0.87 between winter wheat yield and stored soil moisture, seasonal rainfall and stored soil moisture plus seasonal rainfall, respectively, has been observed by Legett (1959). He predicted that 4" of water was needed just to produce wheat crop. He calculated that 4.4 bushels of wheat was produced per acre inch of water without fertilizer and 7.2 bushels with 80 lb N/acre. Coic (1960) found that when water supply was adequate, late application of N after flowering greatly increased the yield. On the other hand, the yield decreased with the limited water supply and late N application did not increase the yield. Application of F.Y.M. resulted in significant reduction transpiration coefficient which was responsible for economic water use (Kantikar et al., 1960) did not find any difference in water use (from 152 cm of soil sayer) by fertilized wheat used 29.5 cm water during the spring summer growing season and 31.0 cm water when fertilized with 179 kg N/ha.

Olson et al. (1960) reported that N fertilization increased yield, Moisture extraction and moisture use efficiency of un-irrigated crops. In case of wheat, N application increased yield from 31 to 77 bushels/acre, water use by 0.9% and water use efficiency by
Where soil becomes very dry at harvest, a significant correlation was observed between the yield and the consumptive use of water by Michalyna and Hedlin (1961).

Warder et al. (1963) observed that total moisture use did not vary much due to fertilizer application. Fertilized crops, however, made also increased. Apart from this, fertilized plots extracted additional moisture from the subsoil and used more moisture from seeding to heading stage.

Olson et al. (1964) found that 45 kg N/ha increased water use by 2.5 cm, water use efficiency by 12% and average grain yield by 377 kg/ha. During the spring-Summer growing season, N fertilized wheat used 35% of plant available water up to a depth of 183 cm while unfertilized crop used only 25% of available water.

Bauer et al. (1965) stated that as the available soil moisture increased, there was an increased demand of N along with P and K. Smika (1970) observed that when the annual precipitation was between 24.6 to 43 cm, N applied at the rate of 45 kg N/ha increased water use efficiency in fall as well as continuous cropped wheat, but the largest increase occurred in case of wheat. Application of N increased vegetative growth and soil water extraction prior to heading which in turn increased the rate of extracting and subsequently created a shortage of water from crop use from heading to harvest. This increase in water total drymatter production from jointing to heading in N fertilized plots was 2-3 times greater than control plots. Extraction from deeper soil depths occurred during the later part of the growing season. The applied N did not increase the
seasonal water use by 14, 14 and 28% in 1967, 1968 and 1969, respectively (Bond et. al., 1971).

Brown (1971) reported that total water use, soil water depletion and grain yield were subsequently increased due to N fertilization. Gupta et. al. (1970) stated that at low moisture levels or in dry years, fertilizer helps the plants to draw moisture from the deeper layers thus helps the plant to escape temporary drought condition.

The idea that water-use efficiency is the key to yield improvement in dryland agriculture is clearly valid, but the grain yield to water used (evaporation plus transpiration) is most often affected more by yield obtained than by water use. In other words, any treatment that increases yield while using the same, or a similar, amount of water will have a higher water-use efficiency. This is clear when it is observed that low-yielding crops use about as much water as high-yielding crops in dryland environments (Cooper et. al., 1983; Anderson, 1992).

Rao and Bhardwaj (1981) reported that increasing rates of nitrogen recorded little higher consumptive use of water while water use efficiency appreciably increased with increasing rates of nitrogen application.

The dependence of water-use efficiency on correcting the limiting factors other than water supply has been elegantly demonstrated under Southern Australian conditions by French and Schultz (1984a, 1984b). Applying the principle that grain yield is linearly proportional to water used so long as other factors are not limiting, they showed that wheat yields and control, inappropriate
sowing time and inadequate crop nutrition. It has further been demonstrated that dryland wheat crops in Western Australia can approach or equal the rainfall-limited potential yield given the appropriate combination of agronomic practices.

Mishra *et al.* (1994) reported that increasing rates of nitrogen up to 90 kg enhanced consumptive use slightly but WHE was appreciably increased, this was mainly because of extraction of more moisture from deeper soil layer that un-fertilized plots. Increase in water use efficiency due to increasing rates of nitrogen have been also reported by Parihar and Tripathi (1990).

Nitrogen typically represents a grower’s largest fertilizer cost input. Current fertilizer N recommendations are based on an average relationship between N requirements (NR) and estimated yield potential \[ NR \text{ (ibs/acre)} = \text{Yield potential (bu/acre)} \times 2.51 \]. The recommendation assumes 2.5 lbs N/acre are needed to produce each bushel of gain. However, in reality, this relation varies with location, growing season, management, yield potential and variety selection. Since yield potential is most closely associated with available water (stored soil water + growing season precipitation), we were interested in determining the affects of available water supply on available N requirements and winter wheat yield potential.

Siddique *et al.* 1998 reported that thought stress effects on photosynthetic rate and leaf gas exchange characteristics of four wheat cultivars were evaluated under semi-controlled conditions. Four cultivars — Kanchan, Sonalika, Kalyansona, and C306, Kalyasona showed the highest photosynthesis rate both at vegetative and at anthesis. Exposure of plants to drought stress less to
noticeable decrease in photosynthesis rate, stomatal conductance and mesophyll conductance and a concomitant increase in intercellular CO₂ concentration. Plants subjected to drought at the early vegetative stage displayed similar physiological characters subsequently under well-watered conditions as compared with control, relationship between them implied that non-stomatal limitations to photosynthesis might have been in operation.

2.3. Nitrogen Nutrition:

Grain yield responses to nitrogen (N), phosphorus (P) and Potassium (K) are common in the dryland, winter-rainfall area. Responses to nitrogen are variable depending on soil type, season and crop rotation (Russell, 1967; McDonald, 1989; Mason et al., 1994). In general, the optimum nitrogen application is greater on coarser textured soils, where losses from leaching can be higher, and less on clay soils, but this can be modified by the use of legumes in the rotation. Control of root diseases through crop rotation can influence wheat yield response to nitrogen (Rowland et al., 1988).

Engel (1993) reported the response of available nitrogen and water in his finding is nitrogen (N) is the most common nutrient limiting yields of wheat and other crops in Montana. Deficiency symptoms are frequently characterized by general chlorosis (yellowing) of leaves and a reduction in overall plant vigor and growth. In winter wheat, deficiency symptoms most often appear in the early to late spring depending on the level of severity. Once present, symptoms become more severe through vegetative growth stages. At flowering, N deficient plants will be shorter, contain
fewer fillers and smaller heads than healthy plants. Ultimately, grain yield is reduced and the grain protein is low.

Mc Neal et al. (1968 and 1972) noted that nitrogen fertilizer significantly increased grain protein percentage and there was a corresponding increase in leaf volume and grain and texture scores. Banking absorption and mixing time decreased slightly with increasing amounts of N.

According to Mishra et al. (1991), moisture extraction and consumptive use of water increased with increasing levels of N up to 120 kg/ha. Moisture use efficiency was increased the moisture use of deeper layers. Adinarayan and Tiwari (1987) also found the similar results.

Shukla et al. (2000) found significantly superior effect of 120 kg N/ha over rest of the nitrogen levels (0, 40 kg N/ha) except 80 kg N/ha.

2.4. Effect of nitrogen application

Raheja and Yawalkar (1956) reviewed several literature on fertilizer use under dryfarming areas and have advocated fertilizer use under these conditions. Dwarf wheat cultivars have been reported to give higher yield than tall varieties even under dryland conditions. Bragga et al. (1970) found that the tall and the semidwarf wheat varieties performed equally well under rainfed conditions.

2.4.1. Effect on growth

Nitrogen seems to augment growth and yield of cereal crops. Increase in shoot height due to nitrogen application was observed by
Watson (1939). Similarly, Mann (1956) observed an increase in plant height due to N application. He further observed that yield response due to N application was a function of number of fillers which was highly correlated with nitrogen application. Hobbs (1953) and McNeal and Davis (1954) also reported that the yield increase due to N application was greatly influenced by the percentage increase in number of culm. Application of nitrogen alone or in combination with phosphorus and potassium increased leaf area and number of culm. Application of nitrogen alone or in combination with phosphorus and potassium increased leaf area and number of shoots per plant which accreted for more drymatter production (Mann, 1957). The effect of treatments were more marked on leaf area than net assimilation rate. Dubetz (1961) found an increase in plant height of wheat due to N application in a loamy sand but not in a loam soil. Charles (1963), however, obtained an increase in plant height and number of culms per plant due to N application irrespective of soil type. Similarly, Warder et. al. (1963) reported an increase in the number of tilliers and average height and number of wheat plants due to the application of nitrogen. Singh et. al. (1968) found that the number of tillers increased with the increasing doses of fertilizers and different methods of their application over no fertilizer treatments. “Brown (1971) reported that the application of 67 kg N/ha increased the total dry matter production and functional life of upper leaves, besides developing more root system as compared to no nitrogen under dryland conditions.

Dechnik and Bendnarer (1989) found that dry matter content and soil NO₃ concentration increased with nitrogen application
compared to other nitrogen forms in soil and in plant parts in varietal evaluation in Poland.

Jadav (1991) reported that tillers plant$^{-1}$ and ears$^{2}$ increased with increasing nitrogen rate upto 120kg N ha$^{-1}$. Similar observations were also recorded by Sinha and Sharma (1976) and Sandhu et al. (1978).

Sood et al. (1993) reported that nitrogen application significantly influenced the plant height, plants/ m row length, green and dry fodder yields, crude-protein content and crude-protein yield in barley. The green-fodder and dry-matter yields increased consistently and significantly up to 40kg N/ha.

Vyas et al. (1995) also reported that nitrogen significantly increased dry matter production.

Kataria and Bassi (1997) stated that the application of 120kg N/ha in 1990-91 and 80 kg N/ha in 1991-92 produced significantly taller plants, more number of effective shoots and dry matter. Heading and maturity were delayed due to increase in N application.

2.4.2. Effect on yield and yield contributing characters

Hunter et. al. (1957) demonstrated that, in general, increase in the rate of nitrogen increased the test weight and grain yield of wheat under rainfed conditions. They obtained the response of nitrogen upto 80 Ib N/acre in low rainfall areas. Warder et. al. (1963) found an increase in the number of plants, number of mature heads and average number of kernels per earhead due to fertilizer application but the test weight decreased. The ratio of grain to total produce was either not affected or slightly reduced. Number of heads
per plant has been reported to increase due to increasing (votes) of nitrogen from 0 to 90% kg N/ha (Dubetz, 1961). Singh et. al. (1968) obtained 30 to 40% increase in wheat yield due to fertilizer application under barani condition. Singh et. al. (1974) have reported an increase in the yield of wheat due to N application because of increase in fertile spikelets and number of grains per ear head. They further stated that the yield increased significantly due to the application of 60 kg N/ha under rainfed conditions.

The average yield response seed to have been proportionate to the amount of nitrogen applied which was true upto 40 lb N/acre and in some instances upto 60 IB N/acre (Raming and Rhoades, 1962).

Fernandez and Laird (1959b) found that the yield of wheat increased from 680 to 4440 kg/ha due to the application of 0 to 150 kg N/ha at optimum moisture level and from 650 to 2410 kg/ha with the driest treatment.

Singh and Das (1961), Singh and Tiwari (1971) and Mahapatra et. al. (1971) observed higher yield of wheat due to the application of 50 lb N/acre over its lower dose. Increase in yield upto 100 lb N/acre ever under low rainfall areas has been reported by Hunter et. al. (1961). Russell (1967) obtained an increase in 3.9 bushels of wheat per acre due to the application of 46 lb N/acre.

Randhawa et. al. (1967) reported that the application of 66 kg N/ha and 33 kg P205/ha increased the grain yield of C286 wheat by 66.3% over unfertilized control. Response of nitrogen was greater than phosphorus under rainfed conditions of submountain region of Punjab. An increase of 25% in the yield of wheat due to the application of 30% kg N/ha and a further increase of 9% between 30
and 60 kg N/ha has been reported by Kushwaha et al. (1970). The yield of Kalyansona wheat increased up to 80 kg N/ha and the yield response obtained at 80 kg N/ha was 37.3 q/ha as against 20.1 q/ha from control plots (Anonymous, 1970). Similarly, the experiments conducted at I.A.R.I., New Delhi under rainfed conditions during 1967-68 indicated that there was a linear response of N up to 80 kg N/ha applied to soil at sowing time (Saxena et al., 1971). From another trial, the same authors concluded that the variety C306 gave the best yield up to 50 kg N/ha but at higher doses (60 and 75 kg N/ha) Kalyansona and S331 proved better.

Seth and Prasad (1971) reported that high level of conserved soil moisture and good winter showers pushed N-response to a level from 40 to 60 kg/ha and P-response was also recorded. The low dose of 20 kg N/ha applied partially through soil and partially through foliage gave significantly higher yield over all N applied at sowing time. It was easier and more profitable to place entire dose of N, P and K at the time of sowing at a depth of 8-10 cm under the surface as compared to its split application.

Colyer and Pohlman (1971) found that both yield and quality of barley were affected by the level of fertilizer used and the effect due to nitrogen was more pronounced.

Singh and Prasad (1972) and Singh et al. (1972) have found that rainfed as well as irrigated barley needs fertilizer application particularly nitrogen for the improvement in grain yield and its attributing traits.

Application of 50 kg N/ha resulted into linear increase in yield of wheat under rainfed conditions (Mahapatra et al., 1973). Singh
and Singh (1972) on the basis of their research trials conducted under rainfed conditions reported that cultivars Kalyansoa, C306 and K65 showed linear response upto 60 kg N/ha. Malik et al. (1972) obtained 56 and 79% increase in yield due to the application of 22.4 kg and 44.8 kg N/ha over control, respectively.

Increased yields with the increasing levels of nitrogen have been obtained by Mehta and Shekhawat (1972). However, the highest and significant returns were obtained due to the application of 100.8 kg N/ha.

Mishra and Alexander (1973) reported that a dose of 90 kg N/ha may be considered as optimum dose under barani conditions of Varanasi. Singh and Agrawal (1973) obtained the maximum yield of wheat at 60 kg N/ha. Meelu et al. (1973) recommended a balance dose of 80 kg N, 40 kg P$_2$O$_5$ and 40 kg K$_2$O per hectare for rainfed wheat and maize. Singh et al. (1974) reported that grain yield of wheat (Kalyansona) significantly increased due to increasing refer of nitrogen upto 60 kg N/ha.

Moodi and Lal (1981) found that increase in yield of rainfed triticale and wheat due to nitrogen application was only upto 25 kg ha$^{-1}$ in the first year (dried season) while both crop responded upto 75kg N ha$^{-1}$ during second year. Application of nitrogen upto 120 kg ha$^{-1}$ improved ear bearing tillers and grain yield significantly (Rao and Bhardwaj 1981). However, the increase in grains/earhead and test weight was recorded only upto 80 kg N ha$^{-1}$.

Singh and Prakash (1981) tested the relative performance of barley and wheat varieties in rainfed condition and observed that nitrogen has significantly increased the grain yield in barley.
varieties as compared to wheat in rainfed condition. However, the response of 20 kg and 40 kg N/ha was similar in both the crops.

Biswa and Singh (1982) observed that Jyoti responded significantly up to 40 kg N/ha whereas, DL 70 and Arjun responded up to 80 kg N/ha. Grain yield was found to be positively correlated with N-uptake and NR (nitrogen-reductase) activity. Arjun and DL 70 were superior to Jyoti in grain and protein yield and positively correlated with N-uptake and NR activity.

According to Mishra et al. (1991), higher grain yield was recorded at 120 kg N/ha being at par with 80 kg N/ha.

Singh (1993) reported that yield-attributes and grain of barley differed significantly due to various treatments. Ear-bearing tillers, ear length and grain/ear were significantly higher at 80 kg N/ha. Increases in these yield attributes resulted significant rise in grain yield and harvest index by 13.88 and 4.9%, respectively at 80 kg N level over 60 kg N/ha.

Campbell et al. (1994) noted that crop yields of wheat and barley increased with increasing nitrogen rate. In the later years wheat response to N appeared to be dampened as soil pH decreased, while barley appeared to withstand better at low pH in long term use of urea and anhydrous ammonia.

Mishra et al. (1994) also obtained significant increase in wheat yield upto kg/ha due to nitrogen application at Ambikapur.

Among four entries of multilocation trial, RD 2552 was found to be superior than all other entries at all levels of nitrogen. 80 kg of
N/ha was found to be optimum dose for maximum production of barley (46.1 q/ha) under irrigated conditions (Anderson et al., 1995).

Kumar et al. (1995) reported significant increase in which yield due to nitrogen application up to 120kg N ha⁻¹ without irrigation, while there was significant increase in yield up to 180 kg ha⁻¹ in irrigated condition.

Singh and Singh (1995) reported that nitrogen response was positively correlated with N-uptake, which in turn was positively correlated with nitrogen-reductase (NR) activity in the plants, N-R activity increased in barley up to 45-60 days after sowing, while in wheat it continued up to 75-90 days and afterward declined. Tall barley responded up to 40 kg N/ha, dwarf barley up to 80 kg N/ha and dwarf wheat up to 120 kg/ha.

Patil et al. (1996) observed that application of fertilizer though increased the values of the important yield attributes and finally the yield, the increase in grain yield was only significant up to the application of 30:30:20 kg NP/ha, indicating that application of fertilizer @ 30:30:20 kg NPK/ha sufficient to harvest sizeable grain and straw yields of cultivated summer wheat.

Singh et al. (1997) found that the wheat varieties responded significantly up to 60 and 90kg N/ha for grain and straw yields, respectively. However, economic dose was worked out to be 113.07 kg/ha, yielding 21.04 q/ha of grain yield. Wheat variety HUW 234 being at par with K 8020 brought out the maximum grain yield (19.3 q/ha).

Increasing nitrogen rates between 80 to 100 kg ha⁻¹ improved number of grains per ear, 1000 grain weight, grain and straw yield
and N uptake. Deor and Pathik (1997) observed that application of 60-80 kg N/ha, remaining at par the each other, gave significantly higher grain and straw yields that 40 kg N/ha. Application of 80 to 120 kg N/ha significantly improved grains per ear, 1000 grain weight, grain and straw yields and total N uptake. Similar finding was reported by Kataria and Bassi, 1997.

Chen et al. (1998) observed that application of urea in combination with hydroquione plus dicyandiamide gave an improved urea-N recovery and grain yield by spring wheat in a pot experiment. The grain yield was 32% higher than in the treatment where urea was applied without nitrication inhibitors.

Azad et al. (1998) reported significant increase in yield traits effective tillers, ear length, grows per ear-head and 1000 grain weight, and finally grain straw yield were obtained due to application to 80kg N, 0kg P2O5 and 40kg K2O per ha. Similar results were obtained by Soni et al. (1989).

Plant height, shoots/plant, leaf: stem ratio, dry matter yield of oats significantly increased with increasing rates of nitrogen upto 120 kg N ha⁻¹, forage yield and crude protein were recorded at 120 kg N/ha (Singh et al., 1999).

Singh et al. (1996) reported the growth i.e. plant height ear length were significantly program. Increased by increasing nitrogen level and was maximum at 80kg M/ha. Where as grain upto 120kg – N/ha. Application-N also increased the uptake of NP & K significantly.

Deor and Pathik (1997) obtained the grain and straw yields of wheat were better during 1991-92 than 1992-93 crop season. However, the application of 60 and 80kg N/ha remained at par with each other gave
significantly higher grain and straw yields than 40kg N/ha during both the seasons, whereas the time of N application did not influence grain yield during both the years, but straw yield was significantly higher when nitrogen was supplied in 2 equal splits compared to full N at sowing during 1991-92. The economic analysis revealed that the highest additional return of Rs 9,163 and Rs 6,135/ha with a profit of Rs 7.3 and Rs. 5.0/rupee investment was obtained over control when 60 kg N/ha was administered in 2 splits during 1991-92 and 1992-93 respectively.

Sushila and Giri (2000) obtained significant increase in plant height, total tiller, spikes per meter up to 90kg N ha\(^{-1}\). However the significant increase in test weight was restricted to 40kg N ha\(^{-1}\) and they further reported significant increase in seed, grain yield, straw yield and harvest index upto 90kg N ha\(^{-1}\).