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Water-Nutrients Interaction: Exploring the Effects of Water as a Central Role for Availability & Use Efficiency of Nutrients by Shallow Rooted Vegetable Crops - A Review

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Abstract: Shallow rooted crops are very sensitive to both nutrients and water stresses; thus, they have to be frequently irrigated and fertilized with balanced nutrients or the two materials together as fertigation especially in semi-arid and arid areas of agriculture. So, this paper was reviewed with the objective of evaluating the effects of soil water and nutrients interaction on the yields and nutrients use efficiency of shallow rooted vegetable crops. Many research activities have been done regarding the interactions of water and nutrients and their use efficiency in different vegetable crops under different agro-ecological conditions. Short supply of fresh water and fertilizer pollution has promoted many investigations into the interaction effects of water and nutrients on crop yield and nutrient and water use efficiency of crops, and some achievements have been made. The value of soil nutrients in plant growth and agricultural output is closely related to water availability and also the agricultural water productivity is in larger part determined by nutrient supplies. Yield or crop productivity is more or less closely correlated with water and nutrients utilization. Nutrient and water application can destabilize the soil nutrient balance and have long-term negative impacts on crop growth and harvest then on the final productivity of the crop. To overcome these problems it requires different mechanisms to be adopted in areas where nutrients and water stresses are a serious problem. Thus, it is possible to increase crop productivity through utilization of an opportunity of selecting improved variety and balanced nutrients application or application of organic fertilizers for dry areas. In conclusion, integrated nutrient and water management is an important issue to minimize the negative impacts of water and nutrients stresses and to increase both yield potential and quality of shallow rooted crops for producers.

Keywords: Availability of water; Nutrient stresses; Nutrient use efficiency; Shallow rooted crops; Water-nutrients interaction.

1. Introduction

The vast semiarid and sub-humid regions referred to as dry land areas are stressed by two major constraints for crop production: shortage of water supply and deficiency of nutrients in soils. Low precipitation and its uneven distribution have resulted in soil water, surface water and groundwater deficit, and made crops being under water stress in most cases [1]. The value of soil nutrients in plant growth and agricultural output is closely related to water availability. Likewise, agricultural water productivity is in large part determined by nutrient supplies. The main goal of agricultural research traditionally has been to increase crop productivity. However, there are currently increased concerns about environmental sustainability of crop production systems (biodiversity) as well as the environmental problems caused by the enhanced use of nutrient fertilizers to increase productivity, which goes along with decreased efficiency of fertilizer use [2]. In this context, the nutrient use efficiency of crops has acquired great relevance [3, 4].

In general, the nutrient use efficiency considers the processes of carbon gain and loss in relation to the processes associated with the gain and loss of the major growth-limiting nutrients. Nitrogen(N) and phosphorus(P) are the nutrients that most frequently limit plant growth, although growth conditions (e.g.temperature) and other resources (e.g.water) might often greatly alter the nutrient limitation [5]. The strong interaction between water and the availability of nutrients to crops arises from the various effects of water on, (i) the release of nutrients from unavailable to available forms; (ii) the transport of nutrients to plant roots; and (iii) loss processes in the soil [6].

In semi-arid environments, available water and/or nutrients are typically the most limiting factors for dry land crop production. Whereas N fertilizer can be applied to supplement soil N, water availability depends on growing season rainfall and stored soil moisture. In the Canadian prairie, high inter-seasonal variation in growing season precipitation can influence crop response to N and result in major variations in N uptake by crops, and thus influence N use efficiency. Low soil moisture availability has been shown to limit N uptake after anthesis [7]. Understanding what drives N fluxes in crops such as N uptake and redistribution is essential to advance N use efficiency. The influence of water availability during the growth period on NUE and its components, and on N translocation, was typically greater than that of N supply or tillage system [7].

Many reviews of semi-arid production systems have shown that the efficiency of N and P fertilizers depends on the rainfall received by the crop (Christianson & Vlek, 1991 cited in Gregory, *et al.* [6]) and that the response to N, in particular, is very limited in dry years. Similarly, studies in the Sahel have concluded that soil fertility is often a more important factor in rangeland and crop productivity than rainfall, so that effective management of water cannot be achieved without also correcting soil fertility constraints particularly N and P. The result is that the limiting factors to crop growth during any particular season could be either water or nutrient availability or both [6]). Deficiency of N can be found everywhere and that of P occurs at least in one third of the arable lands, this leading to low productivity. However, the limited water resources have not been fully used and the nutrient use efficiency by crops is very low, both having a certain potential for use and a large room for improvement. Management of water and nutrients are extremely important not only for crop production, but for environmental concern in these areas [1].

The increase in yield and improving bulb quality of garlic is usually dependent on many factors that influence the plant growth throughout the growth period, improving agricultural treatments especially application of optimal source of potassium fertilizer and the amount of available soil moisture especially the problem now is finding ways by which available water could be economically utilized. Many investigators found a direct relationship between yield and its components of bulb crops and available moisture at the time of irrigation [8-11]. Thus, the objective of this review paper is to assess the effects of soil water and nutrients interaction on the yields and nutrients use efficiency of shallow rooted vegetable crops.

2. Interactions between Soil-Water and Nutrients and Their Effects on Crop Yield

Water and nutrients have great interactions that may gain either positive or negative effects on crop production, depending on crop growth stages, amounts, combinations and balance. In the dry land areas specially, the effect of nutrients and that of water are often limited to each other. Remarkable variations in precipitation from year to year significantly influence soil water and nutrient status, and so do the nutrient input effect. Nutrient input may obtain a good harvest in one year while a poor harvest in another. Considering the precipitation changes and taking effective measures to regulate nutrient supply, crops may not suffer from water limitation in a dry year and from nutrient deficiency in a wet year, and in this way we cannot lose the opportunity to obtain good harvest in both dry and wet year [1, 12].

Yield is more or less closely correlated with water and nutrients use. It is often claimed that the water use–biomass function is changed by fertility and that the efficiency of water use can be increased by fertilizer application. The combined effect of the growth factors, water and plant nutrients, on yield formation are discussed using an irrigation and nitrogen fertilizer experiment. When water supply is plentiful, yield is increased at all N levels to a greater extent than when water is short. Even without any N addition (N_0), yield is greater with ample water supply. At high soil moisture levels, larger amounts of N are available to the plant and are used in the production of a higher yield compared to that when soil moisture is limiting. It is likely that larger quantities of plant available N are formed by stimulated mineralization of soil-borne N, the large pool of N bound in organic matter. But in addition to mineralization, the uptake of mineralized N ($Nmin = NO_3^- + NH_4^+$) by plants may have been enhanced at greater soil moisture values, supporting nutrient flux towards roots by mass flow and diffusion [1].

Reduced soil moisture will probably not just decrease the nutrient flux from the soil reserves towards the roots, i.e. the nutrient availability. This term describes the ‘source’ of nutrients or – in other words the capability of the soil to supply a nutrient. In addition, reduced soil moisture will also decrease the ‘sink’ of nutrients, i.e. the nutrient uptake by a plant – the plants’ ability for nutrient acquisition [12]. Deficiencies in water and nutrient supply limit the growth of shoot and root in such a way that specific plant properties, important for nutrient acquisition, remain insufficiently developed. For instance, these properties are represented by the density and depth of the root system, the number and length of root hairs and the physiological activity of roots. The activity may be related to the excretion of acids or chelating agents, by which ‘insoluble’ chemical compounds of the soil nutrient stock are made soluble and consequently available to plants. But a restricted sink also pertains to poor emergence and shoot development, defective shoot and leaf formation as well as to limitations in the formation of reproductive plant organs [1].

The effect of N fertilization on yield depends on the water supply, and the effect of water depends on the N doses. When all the growth factors involved are at optimum level, maximum yield will be attained. The shared effect of water and nitrogen supply on crop yield can formally be treated as an interaction, a concept from statistics: the effect of nitrogen on yield depends on water supply, and vice versa; the effect of water (irrigation water, soil moisture) on yield formation is shaped by the N supply [13]. According to Ehlers and Goss [13] it is quite surprising that in the irrigated treatment the total yield and the grain yield were nearly doubled by N fertilization. Of the various field crops, sugar beet and Lucerne with three cuts used the greatest amount of water, while sugar beet was highest yielding and they suggested that by optimizing nutrient supply with fertilizer additions, the water use efficiency (WUE) can be increased noticeably. This is true for WUE based on total shoot mass and for the agronomic WUE; and a relatively small value of WUE is obtained when a plentiful water supply is combined with the omission of fertilizers.

One part of the explanation stems from the assumption that the leaf area index (LAI) and the leaf area duration (LAD) of the crop stand are increased by fertilization when water supply is abundant relative to the potential atmospheric demand. Increased LAI and LAD will increase the daily amount of intercepted radiation, depending on leaf inclination and the duration of radiation interception. Fertilizer addition will also alter the leaf color from pale green (nutrient deficient) to dark green, lowering reflection and increasing absorption of radiation. These effects on the canopy will improve the crop growth rate and the accumulation of biomass [1].

The greater the crop density and the LAI developed as a consequence of a sufficient nutrient supply, the smaller will be the amount of radiation reaching the soil surface, the less the contribution of evaporation(E) to evapotranspiration(ET) and the smaller is the clothesline effect responsible for unproductive transpiration. Plants suffering from nutrient deficiency with a small LAI, a thin crop density and short in height will allow a greater E and a smaller T, because a greater percentage of radiation reaches the soil surface. When the soil surface dries as a consequence of evaporation (also due to root water extraction from the soil below the surface), sensible heat is formed between the sparsely leafed plants. The heated air is carried to the plants in the form of advective energy, as a result of which the plant transpiration is enhanced [13].

Water stress is one of the main problems of agriculture in arid and semiarid areas [14]; since water plays a very important role among environmental factors [15]. Lack of water influences on most of plant physiological processes such as photosynthesis, physiological materials transmission to seeds, cleavage and cellular development, coalescence and transmission of nutrients in plants are vital [16].

On the other hand, the lettuce planted in pots filled with perlite and irrigated daily with a constant volume of nutrient solution at different frequencies, showed at high fertigation frequency induced a significant increase in yield, mainly at low nutrients concentration level. Yield improvement was primarily related to enhancement of nutrient uptake, especially P. It was suggested that the yield reduction obtained at low frequency resulted from nutrient deficiency, rather than water shortage and that high irrigation frequency can compensate for nutrient deficiency. Frequent fertigation improved the uptake of nutrients through two main mechanisms: continuous replenishment of nutrients in the depletion zone at the vicinity of root interface and enhanced transport of dissolved nutrients by mass flow, due to the higher averaged water content in the medium. As such, an increase in fertigation frequency enables to reduce the concentrations of immobile elements such as P, K and trace metals in irrigation water, and to lessen the environment pollution by discharge [17]. Yield gain can be primarily related to increased nutrients availability and effects on plant growth, of water content and of the unsaturated hydraulic conductivity in the substrate.

3. The Roles of Water in Crops Production

Although water is the most abundant molecule on the Earth’s surface, the availability of water is the factor that most strongly restricts terrestrial plant production on a global scale. Low water availability limits the productivity of many natural ecosystems, particularly in dry climates. In addition, losses in crop yield due to water stress exceed losses due to all other biotic and environmental factors combined [18].

3.1. Functions and Availability of Water

Increasing population, global climate changes, other non-agricultural water uses, increased demands for irrigation and reduced precipitation have caused pressure on natural resources including water particularly in dry and semi-dry lands. Thus, great emphasis is placed on crop management for dry conditions with the aim of increasing water use efficiency [19]. Drought is one of the most common environmental stresses that limit agricultural production worldwide. Many vegetable crops, including potato, have high water requirements and in most countries, full or supplemental irrigation is necessary for successful vegetable production [20].

Water shortage in soil may affect nutrient availability and absorption by plant roots. Therefore, the combined improvement of water and nutrient use efficiencies under conditions of locally restricted irrigation should be an important research topic [12]. The linkages between soil nutrients and agricultural water use are many but might be best conceptualized by considering their potential for positive and negative reinforcement. On the positive side, water can increase the ability of plants to use soil nutrients and, vice versa, nutrients can increase the ability of plants to convert water into crop output. For example, water is a prerequisite for soil-supplied nutrient uptake by plants, and soil water content is the single most important factor controlling nutrient uptake rates as well as other chemical and biological processes such as mineralization [21].

Likewise, water can only be used by plants if nutrient availability is sufficient. Work in Africa’s Sahel region highlights this point. There has been shown that often only 10 to 15% of rainwater is used for plant growth. The rest is “lost” through runoff, evaporation and drainage, largely because crops cannot use it due to lack of nutrients for sufficient (root) growth [21].

3.2. Effects of Soil-Water Supply on Nutrient Utilization

According to Alizadeh and Nadian [22] treatments of irrigation levels affected at 1% probability on absorption of all elements of nitrogen, phosphorus, zinc, copper, iron and manganese with an increase of water stress intensity nitrogen, phosphorus and manganese absorption was decreased. But potassium, iron, copper and zinc absorption was increased in similar water stress and mycorrhizae treatment showed an increment in relative absorption of nitrogen, phosphorus, potassium, copper and zinc. With increase of nitrogen in mycorrhizae and nonmycorrhizae treatments, absorption of nitrogen, phosphorus, manganese and a little potassium increased but iron decreased and it has not any certain process about other elements. The results of this study clarify properly that mycorrhizae can increase absorption of some nutrients in plants in the drought stress conditions and moderates impacts of the stress. Most of these materials are elements having low motion power and less solubility in soil and drought stress conditions can restrict their absorption [22].

The vast majority of studies investigating soil resource patterns in dry land ecosystems have focused on soil–water relations [23]. Comparatively little is known about dynamics and plant acquisition of mineral nutrients in dry lands despite recognition that the nutrient status of soils can affect the structure and functioning of water-limited ecosystems [24, 25]. Soil-moisture status and nutrient uptake are not independent [26, 27], and effects of low soil moisture on nutrient availability to plants may be as significant as direct effects of water stress on plant performance [28].

3.3. Water as a Nutrients Medium

Nutrient–water interactions on plant traits and, consequently, crops growth, are likely to be based on the physiology of nutrient transport into the plant. Mineral nutrients are delivered from the root to the shoot along the transpirational stream, and therefore soil water deficits can limit nutrient transport simply by reducing the volume of water that moves into the plant [29]. The movement of minerals into the root does not occur passively, but requires a considerable investment of energy to overcome steep electrochemical gradients [27]. Soil water content can potentially influence nutrient uptake by disrupting the function of ATP-dependent membrane transport systems. For example, flooding reduces respiration in the root, which decreases ATP availability for mineral transport (Kozlowski & Pallardy, 1984 cited in Lower and Orians [29]). An additional way in which water stress could influence nutrient uptake is by inducing signals, e.g., a change in pH that may regulate transporters in root membranes [29].

Effective water management can increase nutrient availability, transformation of nutrients in soil or from fertilizers. Mineralization of organic N is proportional to soil water, and the net mineralized nitrate-N is increased with the increase of water content in an adequate range under suitable temperature. A very closely linear relationship has been found between water content and mineralized N. Due mainly to good aeration induced by deficit of water on dry lands, ammonium-N both from soil and fertilizers can be quickly nitrified into nitrate-N. Thus, a large amount of nitrate-N often accumulates in soil profile that has been used as a good index for reflecting soil N-supplying capacity. Adequate water content can promote nitrification of ammonium N while the process is inhibited when moisture content is too high or too low. Water influences mineral nutrient movement from soil to roots and then from roots to aboveground parts of plants. The difference of nitrate N concentrations at different distance points of soil from a plant being greatly declined by adequate irrigation is a typical example showing that some nutrients could be transferred as solute to plant roots with water movement. Adequate soil water content can significantly transfer a large portion of N to aboveground part, and increase N contents in seeds. All in all, water promotes total nutrient uptake by plants and nutrient use efficiency, and affects nutrient composition of plants. It has been reported that N recovery was increased about 20% at any N rate by an adequate supply of water. Water deficit, on the other hand, not only causes water stress to plants, inhibits plant root growth, reduces roots-absorbing area and capacity, increases the viscosity of sap in hadromestome, and thereby decreases nutrient transfer, but also reduces the availability of soil nutrients, nutrient movement in soil, and nutrient uptake and efficiency. Plant growth and crop yield are thus reduced. However, the reduction rate of plant growth is more serious than nutrient uptake, leading to a relative increase in nutrient concentration. Too much supply of water may cause nitrate N leaching and decrease N recovery. Since water supply and nutrient efficiency are closely related, balanced application of nutrients, and determination of their types, ratios, amounts, timing and methods should be based not only on the nutrient-supplying capacity, but also on water status of soil [1].

3.3.1. Nutrient Movement

Water and nutrients acquisition by plants, and the formation of a depleted zone in the immediate vicinity of the roots are the driving forces for solute movement towards the roots. Nutrient transport from the soil solution to the root surface takes place by two simultaneous processes: convection in the water flow (mass flow) and diffusion along the concentration gradient [26]. Soil properties, crop characteristics and growing conditions affect the relative importance of each mechanism, but the general situation is that the mobile NO_3 ion supply is taken up mainly through mass flow, while for less mobile elements such as P and K, diffusion is the governing mechanism [17, 26]. Consequently, on a time scale of days or weeks, nutrient transport from soil solution to the root interface took place mainly by diffusion. In modern agricultural systems, especially under arid or semi-arid conditions, or in greenhouses where artificial substrates are used, water and nutrient are supplied simultaneously (fertigation), mainly by drip irrigation devices. The general wish to increase crop yields has led to frequent fertigation and, therefore, the time scale between successive fertigation events has diminished to hours, or even less. Under these circumstances, the mechanism of nutrients movement towards the roots may differ from that considered in the traditional approach.

In addition to transport limitation, the precipitation of insoluble compounds, electrostatic adsorption reactions and microbial activities may further reduce nutrient concentrations in the rhizosphere. In general agricultural practice, nutrients deficiency is prevented by increasing their concentrations in the irrigation water to levels that ensure optimal uptake by plants. Thus, as the period between successive irrigation events becomes longer, the nutrient concentrations in the rhizosphere may be high or even excessive immediately after irrigation and may fall to deficit levels as time proceeds. Reducing the time interval between successive irrigations in order to maintain constant, optimal water content in the root zone may reduce the variations in nutrient concentration, thereby increasing their availability to plants and reducing their leaching beneath the root zone [17].

3.4. Negative Effects of Water stress on Availability and Supply of Nutrients to Plants

Nutrient and water application can destabilize the soil nutrient balance and have long-term negative impacts on crop growth and harvest. Over-fertilization can limit the ability of water to contribute to crop growth by causing salinization and damage to soil structure. Likewise, irrigation can cause nutrient depletion through leaching. Further, while irrigation can increase yields in part by making soil nutrients plant-available in the short-term, it can indirectly contribute to soil fertility decline in the long term through the increased harvest removals made possible by higher production. These nutrient losses can only be compensated for by increases in nutrient inputs [21].

Rational combinative supply of water and nutrients can increase efficiency of both and produce good interaction. When available water supply is less than a certain range, crops may have little response to fertilizers at any rate, and with sufficient supply of water, nutrient efficiency is increased. An intense interaction exists between available water and fertilizer, and one being changed will likewise lead to the change of the other. The interaction of water and fertilizer is time dependant, and application of water and fertilizer at different stages of plant growth may produce different interaction effects. Over supply of either or both may delay crop maturation by encouraging excessive vegetative growth, while deficit of water may result in high nutrient concentration in soil, making it difficult for crops to take up and use both water and nutrients, and in a worst case, plants may die resulting in “haying off” effect. The different results obtained for the optimal time of application of water and fertilizer may relate to soil water and nutrient supply at different time. For promotion of water and nutrient fully playing their role and realization of maximum yield, high quality and high efficiency, while protection of the environment from fertilizer ill impact, one important thing is to fully understand and utilize their positive interaction, and attention should be paid not only to input of water and nutrients, but to their rational combination. That is, for addition of water, one should consider nutrient supply, and for addition of nutrients, one should consider water coordination, so that limited nutrient and water can produce optimum effect [1].

Nutrients used for plant growth and biomass productions generally come from the internal cycling of reserve materials which require water for their solubilization and translocation. Nutrient absorption is governed by the interaction occurring at the soil-root interface, including (a) root morphology and growth rate, (b) nutrient absorption kinetics of the root; and (c) soil nutrient supply [30]. Decrease in soil water availability affects the rate of diffusion of many plant nutrients and finally the composition and concentration of soil solution. Over a period of water stress a marked decrease in nutrient uptake is reported through decreased transfer of ions to the root. Thus, it will be of significant use to quantify the level of water stress above which the mobilization and absorption of nutrients are adversely affected [31, 32].

Total nutrient uptake followed the pattern of biomass accumulation. Total nutrients content of all the mineral elements decreased with increasing water stress. Decrease in Zn, Cu, Fe and Mn uptake in leaf, stem and root under soil water stress might be due to decrease in total biomass from 20mm to 8mm treatments as evidenced by negative correlations of total mineral nutrients uptake with water stress [32].

4. Soil Fertility and Nutrients for Vegetable Crops Production

Soil fertility refers to the ability of the soil to supply the nutrients needed by the plants. According to Martin [33] the study of soil fertility involves examining the forms in which plant nutrients occur in the soil, how these become available to the plant, and factors that influence their uptake. This in turn leads to a study of the measures that can be taken to improve soil fertility and crop yields by supplying nutrients to the soil-plant system. This is usually done by adding fertilizers, manures and amendments to the soil but sometimes by supplying nutrients directly to the leaves and other plant parts by means of sprays, particularly through leaf stomata [33].

Mineral nutrition- along with availability of water and cultivar; control of diseases, insects, and weeds; and socioeconomic conditions of the farmer-plays an important role in increasing crop productivity. Nutrient concentrations in soil solution have been of interest for many decades as indicators of soil fertility in agriculture. Mineral nutrition refers to the supply, availability, absorption, translocation, and utilization of inorganically formed elements for growth and development of crop plants [34]. The importance of soil fertility and plant nutrition to health and survival of all life cannot be understated as human population continue to increase, human disturbance of earth's ecosystem to produce food and fibre will place greater demand on soils to supply essential nutrients. Therefore, it is critical that we increase our understanding of the chemical, biological and physical properties and relationships in the soil-plant atmosphere continuum that control nutrient availability [35].

The evidence is clear that the soils native ability to supply sufficient nutrients has decreased with the plant productivity levels as human demand for food increased. One of the greatest challenges for our generation will be to develop and implement soil, water and nutrient management technologies that enhance the quality of soil, water and air with improving and sustaining the productive capacity of our fragile soil, and continuing to support the food and fibre demand of our growing population [35]. On the other hand, today’s doubts about the increasing use of agricultural chemicals and annual consumption of millions of tons of fertilizers are the one imposing challenges on natural ecosystems [33].

4.1. Nutrients Requirements of Crop

The supply of adequate plant nutrients are essential for producing sufficient and healthy food for the world`s expanding population [36]. However, degradation of soils’ biological, chemical, and physical properties have resulted in depletion of soil nutrients, soil organic matter and soil depth of extensive area worldwide thereby affecting crop productivity [37]. The overall soil condition in the cultivated land is deteriorating and getting below the condition of the soils under the native forest as well as the grazing lands [38]. The irreversible loss of good quality agricultural soil influences the capacity of the farmer to produce sufficient food. Thus, soil degradation is a fundamental impediment to agricultural growth and sustainability and a major reason for slow growth in food production especially in Sub-Saharan Africa [38, 39].

Fertilizer requirements of a crop vary with fertility status of the soil, availability of soil moisture, variety of the crop, purpose for which the crop is grown, etc. The major factors determining the level of soil fertility are organic matter content, availability of macro- and micro- nutrients, soil reaction and physical soil characteristics such as texture, structure, depth and nature of the soil profile [35]. Increasing crop yield is basically dependent on the fertility status of the soils. Both organic and inorganic fertilizers are applied to increase the supply of plant nutrients in the soil to ensure that crops can produce yields up to their full genetic potential under varying environmental conditions in which they are grown [40]. The three major essential plant nutrients, N, P and K are increasingly in short supply in the soils of Eastern, Western and Southern Africa [41] because of the large quantities taken up from the soil relative to the other essential nutrients [27]. Particularly N and P are deficient in many soils of tropical Africa, which are true also for many Ethiopian soils [42, 43].

Bulb crops are high value crops and their improved yield and quality are important economic considerations. Sullivan, *et al.* [44] reported that nutrients supply interacted with other management practices, pest and climatic factors affect quality and yield of onion. The Allium species have low nutrient extraction capacity than most crop plants because of their shallow and un-branched root system. Hence, they require and often respond well to additional fertilizers [45]. Garlic has a moderate to high fertilizer requirement, depending on the nutrient status of the soil, with banding being a preferable application method [46]. Soils with high organic matter content are preferred due to their increased moisture and nutrient-holding capacity, and less prone to crusting and compaction. Very heavy soil types hinder bulb expansion, especially if allowed to dry out, resulting in rough and irregular shaped bulbs. Intensive soil management practices are required on light sandy soils due to their low moisture-holding capacity [47].

Both manure and chemical fertilizers have a potential role on the growth and development of crops. Mineral fertilizers of balanced dozes increased the leaf area, photosynthetic productivity and yield of garlic. Manure supplies all the essential nutrients as well as improves physical, chemical and biological properties of the soil and helps in boosting up production of garlic [48]. Combined S and K fertilization resulted in substantial increases in crop production. Fertilization of the soils of 12 trials with Chinese cabbage, garlic, scallion, chili, green turnips and carrot with NPK, adding 60-120 kg/ha S, increased yields by 16.0-36.4% with a large value/cost ratio of 12.3-28.7, and high vegetable quality and in nutrient management, S combined with other nutrients has to become a common fertilizer practice to guarantee optimal crop production [49].

Nitrogen is the most frequently deficient of all nutrients and is a vitally important raw material required for the growth of plants as it is an essential constituent of metabolically active compounds such as amino acids, proteins, enzymes, coenzymes and some non-proteinous compounds [50, 51]. Kakara, *et al.* [52] reported that nitrogen accounts for a higher percentage of variation in plants height, leaf area, leaf count, and fresh and dry plant mass when it was increased from 50 to 200 kg/ha. Therefore, use of nitrogen fertilizer is necessary for ensuring successful vegetative growth of garlic crop. On the other hand Brewster and Butler [53] reported that high levels of N nutrition prevented or delayed flowering in onion crops, and Stork, *et al.* [54] reported that the application of N with additional S at an early vegetative (sprouting) stage is useful for the promotion of strong vegetative growth before cold winter months.

Phosphorus is the second most important nutrient limiting plant growth [35]. It is known to be involved in several physiological and biochemical processes of plants being components of membranes, chloroplasts and mitochondria and constituent of sugar phosphates, viz. adenosine diphosphate (ADP), adenosine triphosphate (ATP), nucleic acid, etc. Phosphorus also plays a crucial role in energy transfer reactions and metabolic processes in plant maturity, fruit setting and seed production [55]. Phosphorus is an essential nutrient both as a part of several key plant structure compounds and as a catalyst in the conversion of numerous key biochemical reactions in plants. It is noted especially for its role in capturing and converting the sun's energy into useful plant compounds [56]. Phosphorus is part of plant nucleoprotein and hence important in plant heredity and also plays a role in cell division, stimulates root growth, and hastens plant maturity and also physiologically notable in the storage and transfer bonds of ATP. The need for phosphorus is critical during the early stage of growth when normal meristem development and rapid vine growth are necessary for a high yield [35].

4.1.1. Role of Nutrient in Plant Growth and Development

In intensive horticulture, the management of mineral nutrition is a key factor determining the yield and nutritional quality of vegetable crops [57, 58]. In practice, excessive supplies of mineral nutrients often occur because growers seem to believe that high fertilizer inputs can result in high crop yields [59]. However, excessive fertilizer inputs can cause nutrient salt accumulation in growing media. Too high salinity in growing media can inhibit the growth of vegetable crops and decrease the nutritional quality. Nutrients have numerous roles in crops production and productivity.

4.1.2. Root growth

Nutrient input is the key for crop production. Roots are essential for taking up water and nutrients to support crop growth, and the significance of roots becomes even more important on dry lands, since the topsoil is often dry and nutrients are often unavailable, and plants need to extend their roots into deep layer to obtain available nutrients in the moist soil. It has been found that in most cases, crop yield is highly correlated with crop root mass almost in a linear shape [1]. Water supply to roots is essential for plant life. To sustain the root water uptake, a continuous liquid phase has to be maintained at the interface between soil and roots. Gaps between soil and roots may interrupt the liquid phase continuity across the soil-root interface, acting as capillary barriers for the water flow. Additionally, due to the radial geometry of the flow to roots and the non-linearity of the soil hydraulic conductivity, a drop in water potential and consequently of water content is expected to occur next to the roots, in particular when soil dries and transpiration demand is high. Such a drop in water content may limit water and nutrient uptake by roots [60].

Root surfaces represent one of the most important phase boundaries in nature since most mineral nutrients essential for life enter the biosphere and the food chains of the animal world through the roots of higher plants [61]. Similarly, root water and nutrient uptake is one of the most important processes considered in numerical models simulating water content and fluxes in the subsurface, thus controlling water flow (recharge) and nutrient transport (leaching) to the groundwater, and exerting a major influence on predictions of climate change impacts (Feddes & Raats, 2004 cited in Carminati and Moradi [60]) on terrestrial ecological systems, driving new research at understanding roots and their functioning [62].

Addition of organic fertilizers can enhance soil organic matter, raise soil water storage capacity, reduce soil bulk density, and therefore create good conditions for root penetration into deep layer. Both organic and chemical fertilizer can provide nutrients for forming strong root system and for roots having a higher capacity to absorb nutrients and water, improve root activities such as raising the root synthetic ability of amino acids by rational N fertilization. Different nutrients have different functions on root growth and its distribution. Nutrient input is also essential for improvement of plant physiological activities. Regulating plant water status and osmotic pressure, increasing the activity of nitrate reductase in plant leaves and raising photosynthesis and transpiration intensity whereas decreasing evaporation constitute some important aspects. All these benefit plants in optimization of the use efficiency of water and nutrients [1].

Experimental results show that the osmotic regulation effect is higher with fertilization. The increase of N-supply level reduces disorder of N metabolism in plants deficient in water and increases plant resistance to drought. Under water stress, rational N supply could make crops leaves to have high activity of nitrate reductase, high levels of proteins, and better water status. Bleeding sap amount increase per plant by N fertilization provides evidence that water intake by plants is increased. Addition of K can make leaf stomata quickly closed under dry and hot wind conditions. With normal water supply, transpiration rate is increased by fertilization while reduced in a water deficit case. Due to vigorous growth, rapid leaf emergency, large leaf area and high coverage rate of plants on the ground with fertilization, soil surface evaporation is reduced and more water is used by transpiration. It has been found that by rational N fertilization, the ratio of water lost by transpiration to that by evapotranspiration was increased from 0.32 to 0.65, and water loss by evaporation was decreased by 1/3, the water use efficiency (WUE) for both grain and dry matter production being increased. Addition of nutrients, particularly K, can increase chlorophyll, protect the photosynthetic organs from dryness and make the photosynthetic organs fully played their role, and therefore increase the photosynthesis that is regarded as the main cause for crop yield reduction under dry conditions. All these have made the dry land crop production increased [1].

4.1.3. Photosynthesis

In addition to roots growth, nutrients have great roles in plant physiological activities like photosynthesis, as it was observed in an overall increase in microbial N immobilization under elevated CO_2. Carbon sequestration in both plants and soils under elevated CO_2 can only be sustained when additional nutrients are supplied. This conclusion supports the theory of progressive nitrogen limitation postulated by Luo, *et al.* [63]. In corroboration with this theory a recent study on plant production under long term elevated CO_2 and different N fertilization rates, also stresses the importance of nutrient additions to grassland systems for sustaining increased plant growth under elevated CO_2 [64].

In the short term, progressive nitrogen limitation can be alleviated or delayed by a number of ecosystem responses. Such responses probably explain the 10% increase in aboveground plant production under elevated CO_2 and low N availability in the analysis. Firstly, priming has been observed to supply systems with sufficient nutrients to sustain increased plant growth under elevated CO_2 [65]. Priming has been shown to occur in nutrient poor soils [66], as a mechanism to supply N needed to sustain plant growth under elevated CO_2 [67]. This mechanism, however, does not contribute to a net gain of ecosystem N, but rather causes redistribution of available N. Redistribution of N under elevated CO_2 is expected to have a limited effect on N availability and soil C sequestration in the long term [65]. Secondly, the efficiency of plant N uptake under elevated CO_2 has been observed to increase due to increased fine root production [68], or increased mycorrhizal colonization of roots. However, further increases in plant growth and soil C input resulting from these adaptations, will increase competition for N between plants and microbes. Thus, CO_2-induced mechanisms that increase plant N uptake without a net ecosystem gain of N are selflimiting [65]. Finally, progressive nitrogen limitation may be alleviated by the additional supply of N to the soil through N_2 fixation by leguminous plants. However, Luo, *et al.* [63] analysis revealed that symbiotic N_2 fixation only increased (50.8%) under longer-term elevated CO_2 when additional non-N nutrients were added. Thus, these results suggest that in unfertilized systems, symbiotic N_2 fixation will have a limited effect on preventing progressive nitrogen limitation under increased levels of atmospheric CO_2, and that yet again nutrient availability determines the potential for C sequestration under elevated CO_2.

In conclusion, we expect that any rapid increases in plant production under elevated CO_2 in unfertilized systems are transient and that the potential for mitigating atmospheric CO_2 through additional soil C sequestration in such systems is minimal. In contrast, when additional nutrients are supplied we do expect a potential for C sequestration. The amount of C sequestered, however, seems limited as the increased C inputs are partially counterbalanced by increased C outputs through mineralization. Furthermore, many systems receiving additional nutrients are managed for production of agricultural products. Soil disturbance in these systems may cause a majority of the recently accumulated C to be re-released into the atmosphere [69].

4.1.4. Soil Water Storage

Different soil management practices especially nutrients can affect soil water storage by altering the available water in the profile, and the exchange rate of water between the soil and atmosphere [70] with tillage and residue management as the most widely researched tools for affecting soil water. Other practices for dry land systems include minimizing fallow periods or switching to crop intensification with various cropping systems [71].

4.1.5. Reduction of Water Loss by Evaporation and Increase of Water Transpiration

Optimizing nutrients use can adjust water use efficiency of crops as water is the major factor limiting agricultural productivity. Given that lack of water generally limits crop yields all the concerned groups should benefit from better understanding the relationship between plants and soil water. This relationship is an integration of three interfaces: water movement in the soil, water absorption and circulation into plant tissues and the release of water to the atmosphere [72].

4.1.6. Improving Water Use Efficiency

Optimal nutrient levels in the soil have been found to increase water use efficiency (WUE) by maintaining plant growth, health and yield. Nutrient levels affect crop photosynthetic rates, root development, biomass yield and quality. Valuable information regarding macronutrients in relationship to WUE is available, while little information is available on the micronutrients. If water is available and N is limiting, the addition of N fertilizer will likely increase yield and WUE up to a certain application rate, after which both yield and WUE decline [73]. At the optimum N rate, crops have efficiently used all the water and nutrients they can absorb and any excess is detrimental to growth, yield and WUE.

Efficient water use by crops can be affected by soil P levels. A Montana study on the addition of P to malt barley under both well watered conditions and water stressed conditions, found higher WUE and yield in soils with medium Olsen P levels compared to soils with low Olsen P levels [74, 75]. When the plants were water stressed, WUE was 50% higher with 50 lbs P_2O_5/ac than when no P was added. Therefore adequate P nutrition may help offset effects of drought.

4.1.7. Soil Erosion Control

Wise input of fertilizer and manure may do more to prevent soil erosion than some of the more obvious mechanical means of control, since the growing of bumper crops by fertilization not only gives a maximum ground cover but supplies sufficient organic matter to aid in the maintenance of all important soil constituents; and the increase of soil permeability to water under such conditions is certainly a factor of major importance **[1]**.

4.2. Nutrient Use Efficiency of Vegetable Crops

Many agricultural soils of the world are deficient in one or more of the essential nutrients needed to support healthy plants. Acidity, alkalinity, salinity, anthropogenic processes, nature of farming, and erosion can lead to soil degradation. Additions of fertilizers and/or amendments are essential for a proper nutrient supply and maximum yields. Estimates of overall efficiency of applied fertilizer have been reported to be about or lower than 50% for N, less than 10% for P, and about 40% for K [76].

In the 21st century, nutrient efficient plants will play a major role in increasing crop yields compared to the 20th century, mainly due to limited land and water resources available for crop production, higher cost of inorganic fertilizer inputs, declining trends in crop yields globally, and increasing environmental concerns. Furthermore, at least 60% of the world's arable lands have mineral deficiencies or elemental toxicity problems, and on such soils fertilizers and lime amendments are essential for achieving improved crop yields. Fertilizer inputs are increasing cost of production of farmers, and there is a major concern for environmental pollution due to excess fertilizer inputs. Higher demands for food and fiber by increasing world populations further enhance the importance of nutrient efficient cultivars that are also higher producers. Nutrient efficient plants are defined as those plants, which produce higher yields per unit of nutrient, applied or absorbed than other plants (standards) under similar agro-ecological conditions [3].

Inter- and intra-specific variation for plant growth and mineral nutrient use efficiency (NUE) are known to be under genetic and physiological control and are modified by plant interactions with environmental variables. There is need for breeding programs to focus on developing cultivars with high NUE. Identification of traits such as nutrient absorption, transport, utilization, and mobilization in plant cultivars should greatly enhance fertilizer use efficiency. The development of new cultivars with higher NUE, coupled with best management practices will contribute to sustainable agricultural systems that protect and promote soil, water and air quality [76].

Differential capacity of different plant genotypes to acquire and utilize nutrients has encouraged researchers to study nutrient efficiency as influenced by both, nutrient absorption by roots and utilization in plants. The relative importance of these strategies depends on specific element and on plant species [77]. Gahoonia and Nielsen [78] demonstrated that from plants nutrition point of view, a genotype efficient in P absorption is the one which can both dissolve soil P and absorb it efficiently.

The evaluation of NUE is useful to differentiate plant species, genotypes and cultivars for their ability to absorb and utilize nutrients for maximum yields. The NUE is based on (a) uptake efficiency (acquire from soil, influx rate into roots, influx kinetics, radial transport in roots are based on root parameters per weight or length and uptake is also related to the amounts of the particular nutrient applied or present in soil), (b) incorporation efficiency (transports to shoot and leaves are based on shoot parameters) and (c) utilization efficiency (based on remobilization, whole plant *i.e.* root and shoot parameters) [76]. Absorption tests of nutriments in red and white garlic were conducted in the edaphoclimatic conditions of La Consulta, Mendoza, Argentina. For a red garlic yield of 10 t/ha and a density of 17 plants/m^2, it was determined that 180 kg/ha of N, 20 kg/ha of P and 115 kg/ha of K were extracted from garlic. For a yield of 12 t/ha of white garlic, 160 kg/ha N and similar amounts of P and K were extracted for the same plant density [79].

The use of fertilizers to obtain high yield and good quality are important features in today’s garlic production. Both of these features can be improved through nitrogen (N) and sulfur (S) application strategies as influenced by the source of N and S nutrients as well as rates and times of application [80]. An increase in S supply is related to an increase in alliin content of leaves and bulbs of garlic crop, where as nitrogen fertilization has only a minor influence on crop quality [81]. Application of N, K and S significantly increased yield and yield attributes. The maximum plant height (41.8cm), length of bulb (4.49cm) and diameter of bulb (3.85cm), single bulb weight (41.4g/ha), fresh yield (10.33 t/ha) and gross return (Tk.1,23,960/ha) were obtained with the treatment $N_{125}K_{175}S_{24}$ kg/ha. The maximum number of leaves (7.67/plant) were obtained from $N_{175}K_{100}S_{24}$, and this indicated that excessive nitrogen caused high leaves growth and leads to rapid deterioration and weight loss of bulbs during storage at ambient temperature [82].

Phosphorus (P) is an essential plant nutrient. Its peculiar behavior, both in calcareous soils (high Ca^{2+}) and in acidic soils (high Al^{3+} and/or Fe^{3+}), requires regular annual applications of this element to maintain optimum crop yield. The annual consumption of P fertilizer is more than 39 million tons [83], ranking second after nitrogen. Because of the complexity of P chemistry in soil, only about 20% of the total amount of P fertilizer is utilized by the first crop and the remaining 80% is fixed in soil in an unavailable form [84]. Excessive P accumulation in soils results in low productivity and low seed protein because of interaction with other nutrients especially micronutrients. Also, transport of soil particles loaded with P into lakes and surface waters cause eutrophication [85]. Hence, various approaches that can increase utilization of P fertilizer in the soil-plant system have been considered, including selection of genotypes with increased P acquisition and utilization efficiency [27]. Potassium and phosphorus are very important nutrients for increasing garlic yields. Proper application rates and timing are critical for generating a yield or quality response. As crop yields increase, the amount of P and K required also increases, along with all other nutrients. The amount applied ranges from 50 to 120 kg P_2O_5/ha, and 60 to 150 kg K_2O/ha, respectively, depending on the soil P and K levels, crop yield goal, and the site’s soil characteristics [86].

4.2.1. Factors Affecting Nutrients Requirement and Use Efficiency of Crops

Increased NUE in plants is vital to enhance the yield and quality of crops, reduces nutrient input cost and rate of nutrient losses and improve soil, water and air quality. The NUE of plants can be affected by many factors and need to be clearly defined to control each of them during the production of crops. Much can be achieved by selecting nutrient efficient genotypes and to incorporate these in breeding programs. However, the poorly developed state of nutritional genetics of plants and its response to environmental variables and management practices and the difficulty of identifying nutrient efficiency traits by rapid and reliable techniques have contributed to a lack of progress and success in breeding plant cultivars with high NUE.

Genetic, morphological, and physiological plant traits and their interactions with external factors such as soil moisture and temperature, light, best management practices, soil biological, and fertilizer materials, have profound effects on their abilities to absorb and utilize nutrients which need to be more thoroughly evaluated to improve the NUE in plants [76]. Plants interaction with environmental factors such as solar radiation, rainfall, temperature and their response to diseases, insects and allelophathy and root microbes have a great influence on NUE in plants [76]. According to Raun and Johnson [87] report N recovery efficiency in annual crops averages only about 42% and 29% in developed and developing countries, respectively. Similarly, Fageria and Baligar [88] reported that N recovery efficiency in crop plants is usually less than 50% worldwide. This is associated with loss of applied nutrients through leaching, volatilization, denitrification, and soil erosion; and use of inadequate crop management practices, biotic and abiotic stresses are also responsible for low nutrient use efficiency [88].

Production potential of many soils in the world is affected by the low supply of nutrients due to adverse soil physical and chemical constraints [89-91]. In tropical regions the main soil problems in rain fed systems that affect crop production are low soil fertility, salinity, alkalinity, acidity, and Fe toxicity, and P and Zn deficiencies. Physical constrains such as high bulk density layers, poor structure and texture, surface sealing and crusting, high or low water holding capacity, water logging and extreme drying or poor aeration can also reduce NUE [92, 93]. Also fertilizer use efficiency is affected by several factors such as soil properties, efficiency of crops, climate, and chemical species of the fertilizer used (eg. Urea, NH_4^- -N or NO_3^--N), mycorhiza, and others [94, 95]. The availability and recovery efficiencies of fertilizers are greatly affected by amendments such as lime, organic materials and others, due to their effects in nutrient dynamics [89, 96, 97].

Genetic variability has been reported to explain the differences in NUE and the parameters of nutrient uptake. Such differences in growth and NUE in plants have been related to differences in absorption, translocation, shoot demand, dry matter production per unit of nutrient absorbed, and environmental interactions [98]. The potential for breeding improved cultivars for high tolerance to low levels of nutrients supply and biotic and abiotic constraints with superior NUE largely depends upon: (i) the genetic variability present in the species/cultivar for that particular trait(s) that govern NUE and, (ii) development of methodology to accurately quantify the physiological parameters that reflect efficient NUE [76]. Fageria and Baligar [99] have grouped genotypes into four classes based on grain yield response index (GI Eq. 1). The genotypes were grouped as (a) non-efficient and non-responsive (NENR), (b) non-efficient and responsive (NER), (c) efficient and responsive (ER), and (d) efficient and nonresponsive (ENR). Genotypes falling into the ER group would be most desirable because they can produce high yields at low as well as high levels of nutrient availability. Cultivars in the ENR group would also be desirable because they produce high yields at low nutrient availability.

$$\mathrm{GI} = \frac{(\text{Yield in non P stress soil}) - (\text{Yield in P stress soil}) \quad \text{kg/kg}}{\text{Differences in applied P levels between non}-\text{stress and stress}} \qquad \text{(Eq. 1)}$$

In general, an improved NUE in plants can be achieved by careful manipulation of plant, soil, fertilizer, biological, environmental factors and best management practices. There is great need for a well coordinated, multi-disciplinary, team effort of plant geneticists and breeders, physiologists, biologists, agronomists, soil scientists, and chemists among other disciplines, to formulate an effective system to overcome the internal and external constraints that are contributing to lower nutrient use efficiencies and to make increased NUE in plants a reality.

4. 2.2. Mechanisms Involved In Improving Nutrient Requirement and Use by Crops

Nutrient efficient plants as well as nutrient use efficiency in plants is improved by different mechanisms. The difference in nutrient uptake and utilization may be associated with better root geometry, ability of plants to take up sufficient nutrients from lower or subsoil concentrations, plants ability to solubilize nutrients in the rhizosphere, better transport, distribution and utilization within plants and balanced source-sink relationships [3].

Plants, having vigorous and extensive root systems, can explore large soil volumes and absorb more water and nutrients under nutrient stress conditions and can increase crop yield and nutrient use efficiency. The quantity of nutrient taken up by plants is largely influenced by root radius, mean root hair density and length of root [26].

Capacity of some plant species or genotypes within species to absorb nutrients at higher rate at low nutrient concentration of the growth medium is one of the mechanisms responsible for efficient nutrient use by plants. At lower rhizosphere nutrient concentrations the genotype will have higher uptake rates and more efficient in nutrient utilization than the one that have higher concentrations although they have similar maximum nutrient uptake rate [3].

Several chemical changes occur in the rhizosphere, due to plant roots and soil environmental interactions. Among these changes, pH, oxidation potential, rhizodeposition, root exudates and nutrient concentrations are prominent. These chemical changes in the rhizosphere significantly influence nutrient solubility and uptake by plants and improving soil pH is one of the most important chemical properties, influencing nutrient solubility, and hence availability to plants. Also it is well known that acidification of the rhizosphere can solubilize several low soluble macronutrients and micronutrients.

Better distribution of dry matter and nutrients in plant parts (root, shoot and grain/bulbs) reflects their use efficiency. Higher accumulation of N and P in grain improves yield and consequently leads to higher use efficiency of these nutrients which is defined by the proportion of total plant nutrient (N/P) partitioned to grain called nutrient harvest index (NHI). NHI is defined as nutrient uptake in grain divided by nutrient uptake in grain plus straw and dry matter distribution is measured by grain harvest index. Amounts of N/P remobilization from storage tissues influence grain N/P use efficiency and partitioning of assimilate are under genetic control although, it is influenced by environmental factors [3].

Balanced source and sink relationships were vital for higher yields and, consequently, higher nutrient use efficiency in crop plants. Most plants have the ability to buffer any imbalance between sources and sink activity by storing carbohydrate during periods of excess production and mobilization of these reserves when the demands of growth exceed the supply of carbohydrate available through current photosynthesis. Even though, the antagonistic (uptake of one nutrient is restricted by another nutrient) and synergistic (uptake of one nutrient is enhanced by other nutrient) effects of nutrients on nutrient use efficiency among various plant species and cultivars within species have not been well explored; the application of different nutrients in balanced amounts can influence the yield and then, the nutrients use efficiency of crops [3]. Interactions occur when supply of one nutrient affects the absorption, distribution, or function of another nutrient [33].

Nitrogen promotes P uptake by plants by increasing top and root growth, altering plant metabolism and increasing the solubility and availability of P, decreasing soil pH as the result of absorption of NH_4^+ and thus increasing solubility of fertilizer P [100, 101]. Responses to both N and P are small at low levels of the other nutrients, but increase markedly for combination of N and P at higher rates of N and P. The contents of N and P in leaves followed the same pattern and one stimulates the uptake of the other. Because increased growth requires more nutrients to maintain tissue composition within acceptable limits, mutually synergistic effect of N and P promotes growth even more [102, 103].

4.3. Negative Effects of Nutrients Stresses

A lot of agronomic studies have been carried out to study the effect of nitrogen on onions in the field in relation to time and rate of application, but most of these results on yield and other parameters have been difficult to interpret and use because of the failure to quantify the original level of N in the soil and its changes throughout the growing season [104]. Nitrogen is known to be most essential during the initial stages of plant growth. A deficiency of this element at this stage causes stunted growth, general yellowing, and weak plants. On the other hand, excess nitrogen results in succulent growth and robust plants. Low nitrogen levels have been associated with early bulb formation in onion. Under sub-optimal supply of N, onions and shallots can be severely stunted, with bulb size and marketable yields reduced. Also when the levels of nitrogen applied to shallot crop decreases its leaves become light green and older leaves die, showing bleached yellow color, and the diameter of the leaves goes to short and small, and its growth is looks like stiff and upright. Phosphorus deficiency decrease the yield and productivity of shallot by causing older leaves become wilt, die back of tips, by mottling green areas of the crop, turning black dead leaves, slowing growth, delaying maturity, and a high proportion of thick-necked bulbs [105].

By contrast, too much nitrogen can result in excessive vegetative growth, delayed maturity, increased susceptibility to diseases, increased double centres in onions, reduced dry matter contents and storability and, thus, result in reduced yield and quality of marketable bulbs [45, 106]. According to Tamirat [107] report increased P uptake and its concentration in the plant reduced the time taken for bolting, flowering and maturation of onion which agreed with the physiological aspect of the nutrient imposed on plant growth and development [27]. Narang and Dastane [108] reported that onion bulbs grown under low nitrogen and moisture regime, which were small in size and less in dry matter content, were liable to dry-out earlier than those grown under adequate moisture and nutrition. They showed that the loss in storage up to five months was mainly due to drying of bulbs. On the other hand, studies show that application of N reduces postharvest loss. Dankhar and Singh [109] reported that weight loss of bulbs increased with the increase in the nitrogen level. Some cultivars lose the skin of the bulb relatively easily through cracking. The loss of skins detracts the appearance of bulbs and lowers their commercial value [110].

Also bulbs form plants with higher tissue nitrogen levels often are of poor quality and do not store well for longer periods [111]. In India, [109] found that increasing the rate of applied nitrogen from 50 to 150 kg/ha led to significant increase in storage loss on onion during 4-5 months under ambient conditions. High dose of nitrogen produced quick sprouting of thick-necked bulbs during storage. Moreover, greater percentage of open thick-necked bulbs resulted with increased sprouting due to increased access of oxygen and moisture to the central growing point [109]. According to Dankhar and Singh [109] sprouting percentage of onion bulbs was increased with the increase in the N application. Similarly, Bhalekar, *et al.* [112] reported 6.7, 11.6, and 13.1% sprouting in onion plants fertilized with 0, 75, and 150 kg N/ha, respectively, during periods under common storage condition and excessive N fertilization and late irrigation resulted in higher levels of neck rot (*Botrytis allii*) in onion. The effect of N and late irrigation were attributed to an increase in the succulence and diameter of the onion necks which made them more difficult to dry. Bhalekar, *et al.* [112] showed that total loss (sprouting + rotting) on number bases was 9.7%, 15.4% and 18.5% at 0, 75, and 150 kg N/ha, respectively.

Increasing biological and chemical fertilizers concentration from 300 to 450g/block and 75 to 100g/block, respectively, had no significant effect on shallot growth and yield instead it enhances leaf growth Sopit [113] and Wiedenfeld [114] found that no additional yields benefit from applying N rates higher than 84kg/ha and average N uptake efficiency less than 10%. Report by Celestino [115] shows nitrogen application increased rotting of bulbs under both common and cold storages. The timing and source of N application can also have significant impact on storability of onion bulb. Bacterial storage rots were found to be more severe with late N applications [116]. In Georgia, splitting the N application between early and late growth periods reduced bulb rots of cv. 'Granex 33'. Bulb decay was highest with ammonium nitrate and lowest with calcium and sodium nitrate use [117].

4.3.1. Reducing the Impacts of Nutrients Stresses

Nutrient acquisitions under stress conditions are increased by techniques especially through the use of mycorrhizal activity: First, external mycelia of these fungi spreads in soil and penetrates small soil porosity in which there is no possibility for enter of hairs to absorb water and absorb nutrients through it and transfer to the host plant [118, 119]. Second, they influence on the hormone surfaces of plant especially, ABA and cytokinin and stomatal conductivity (Druge & Schonbeck, 1993 cited in Caravaca, *et al.* [120]). Third, they influence on turgor pressure and increase it through decrease of the leaf osmotic potential [119]. One of the most important reasons of micorrhizae protection in drought stress conditions from the most host plant is increase of nutrients absorption in soil and better feeding of plants. Phosphorus and nitrogen are the most important elements absorbed by micorrhizae plants. This absorption increase can be seen in mycorrhizae plants hypha have ability to absorb the soil nitrogen and transfer it to plants roots [120]. External balanced applications of different nutrients depending upon soil and plants nutrients status analysis is above all to overcome nutrients stresses and crop yield reductions.

5. Summary and Conclusion

Many research activities have been done regarding the interactions of water and nutrients and their use efficiency in different vegetable crops under different agro-ecological conditions. Short supply of fresh water and fertilizer pollution has promoted investigations into the interaction effects of water and nutrients on crop yield and nutrient efficiency and WUE, and some achievements have been made. However, there still exist a large number of issues that need further studies in the future. Delineating dry lands into different regions and determining the priority issue in each region, determination of most efficient time or growth stage for input of nutrients and water to different crops, and interaction mechanism of water and nutrients are some important aspects to be considered. Water shortage in soil may affect nutrient availability and absorption by plant roots especially for shallow rooted crops. Therefore, the combined improvement of water and nutrient use efficiencies with varietal selection strategy under conditions of locally restricted irrigation should be an important research topic that should be investigated and resolved.

The interaction between soil nutrients and water is not only a biophysical one; it is also an economic and has obvious implications for farm economics and sustainability, analysis of alternative agricultural management options and investments, water productivity and decision-making on water allocation. Despite their interrelationship, research projects and agricultural management interventions in which nutrient and water balances are jointly considered are rare. This may partly be due to the fact that tools for valuing soil nutrients—the focus of the remainder of this review—received relatively little attention.

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