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Wheat Sensitivity to Nitrogen Supply under Different Climatic Conditions

Veres Szilvia, Ondrasek Gabrijel and Zsombik László

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Abstract

With the projection of the Earth's population reaching eight billion in coming years and nine billion by 2050 which means increasing demand for food. Wheat (*Triticum aestivum* L.) is the main important and strategic cereal crop for feeding the majority of world's populations. Scientific forecasts predict that wheat production in the future will be affected by climate change and will decrease on the global level. To reduce these risks, the impact of climate change mitigation strategies and management systems for crop adaptation to climate change conditions should be considered. Demand for increases in food production will have to occur on less available arable land, which can only be accomplished by intensifying production. Chemical fertilisers are responsible for 40–60% of the world's food production. Because nonlegume plants generally require 20–50 g of nitrogen to produce 1 kg dry biomass, the natural supply of soil nitrogen usually restricts plants yield in most agricultural cropping system. The goal of ecological intensification is to increase yield per unit of land, intensify production, while meeting acceptable standards of environmental quality. This chapter discusses some aspects of connection between nitrogen supply and different abiotic conditions.

Keywords: wheat, nitrogen, drought, salinisation, climate

1. Introduction

The global wheat consumption has escalated at a faster rate than all other cereals. This growth is accounted for by the increase in developing countries, mainly in China and India, and based on the future projection, the growth of wheat consumption will continue [1]. In these two countries, the use of production inputs, primarily nitrogen fertiliser and irrigation water, has risen dramatically as well. Wheat is an important staple crop, providing 20% of all calories

consumed by people worldwide. It is the leading source of non-animal protein in human food and also makes a significant contribution to animal feed. Increasing global demand for wheat is also based on the ability to make several food products and the increasing consumption of these with industrialisation. In particular, the properties of the gluten protein fraction allow the processing of wheat to produce bread, other baked goods, noodles and pasta, and a range of functional ingredients [2].

Beside the food demand sustainable nutrient supply and climatic effect on plant productivity are two crucial topics of agricultural development. Applying adequate amount of nutrients based on genotype requirements is hard under potential conditions, especially under different abiotic loads. Nitrogen (N) is an important nutrient, which determines the amount of yield and throughout the proteins the quality as well. The increased crop productivity has been associated with a 20-fold increase in the global use of nitrogen fertiliser during the 50 years [3], and this is expected to increase by threefold by the year 2050 [4]. Inadequate application of N—deficiency and excess—can cause environmental and ecological problems. Climatic factors can improve and deteriorate crop nutrient use efficiency and yield. Drought occurs in all climatic regions and drought-induced crop yield reduction is among the greatest losses in agriculture. About 32% of wheat production areas in developing countries experience serious drought stress in different growth stages [5]. Lobell et al. [6] published that climate trends were large enough in some countries to offset a significant portion of the increases in average yields that arose from technology, fertilisation, and other improving factors. High and low temperature [7–9], irrigation [10–12], salinisation [13, 14], agrotechnology [15–17], and other nutrients [18] also have an effect on N use of wheat. These effects are depending on the adaptation and acclimatisation strategies of different wheat genotypes, the current climatic conditions and its combinations and biotic effects as well [19]. To know more about and improve nitrogen use efficiency of wheat means a way towards the sustainability. Wheat being the basic food plant and the global demand for qualitative perfect food is increasing we have no other alternatives, than step forward to smart-wheat, which will be able to survive unfavourable conditions.

2. Nitrogen requirement and NUE

Nitrogen is one of the nutrients plants need in high quantity [20], as it is a core constituent of a plant's nucleic acid, proteins, enzymes, and cell wall and pigment system [21]. The availability of nitrogen for plants is complex, and depending on different processes in connection with nitrogen cycle in the environment (**Figure 1**). Through the different way of nutrition supply and agrotechnology processes, the agriculture has a main impact on global and local nitrogen cycle. Plants also can have an effect on your own nitrogen supply by connecting different bacteria or releasing different extracts, like nitrification inhibitors. Biological nitrification inhibition (BNI) is the natural ability of certain plant species to release nitrification inhibitors from their roots that suppress nitrifier activity, thus reducing soil nitrification and N_2O emission (**Figure 1**). Among the tropical pasture grasses, the BNI function is the strongest in *Brachiaria* sp. [22].

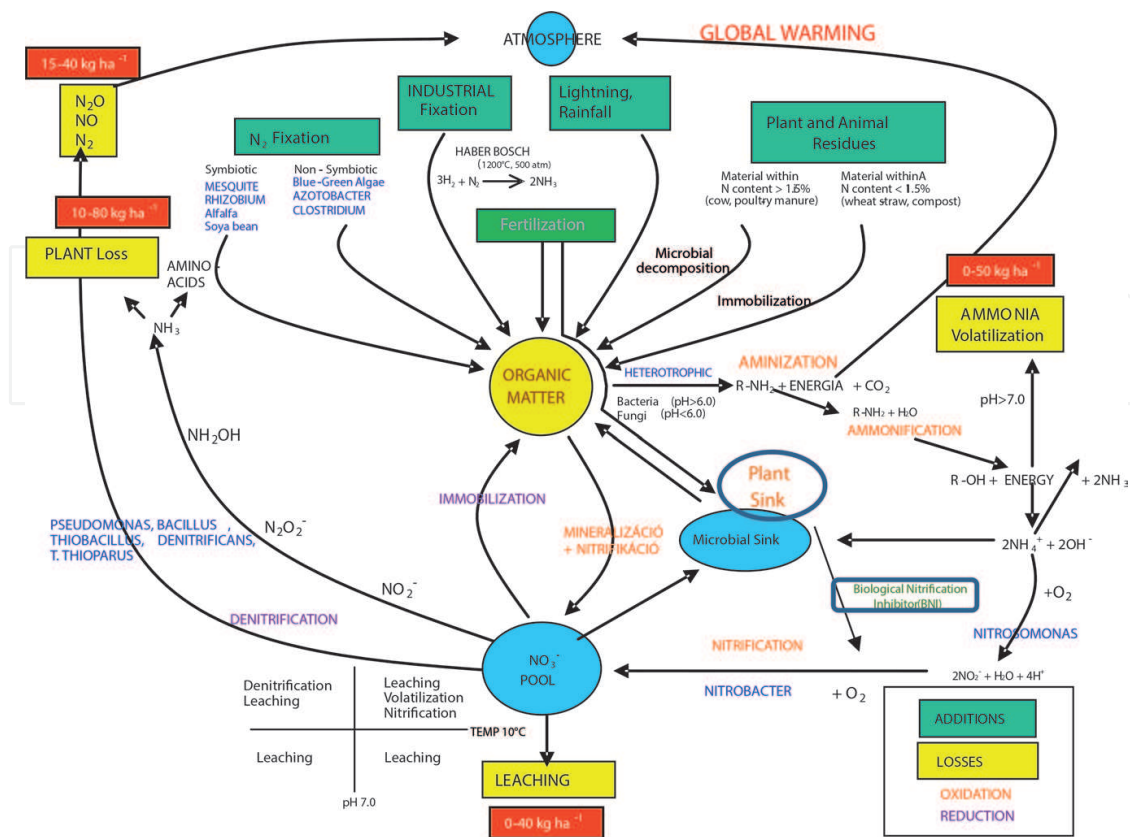


Figure 1. Nitrogen cycle (adapted according to LaRuffa et al. [23]).

Nitrogen availability and using capacity are crucial in plant life. The chlorophyll content of wheat leaves and leaf N is closely related as the photosynthetic machinery accounts for more than half of the N in a leaf [24]. Nitrogen influences carbohydrate source size by leaf growth and leaf area duration and also the photosynthetic rate per unit leaf area and thereby source activity. The availability of N is of agricultural concern because plant metabolism is differently affected by excess, optimal and deficient levels [25]. The concept of nitrogen-use efficiency (NUE) has been widely used to characterise plant responses to different levels of N availability. Moll et al. [26] defined the most use of NUE, at least among breeders, which computes the grain dry mass divided by the total N available to a plant. It is divided into two components: $NUE = NUpE \times NUtE$, where NUpE is the N-uptake efficiency calculated as the total amount of N in above-ground plant at harvest divided by the available N in soil, and NUtE is the utilisation efficiency calculated as the grain dry mass divided by the total amount of N in above-ground plant at harvest. Based on several authors, establishment N remobilisation efficiency (NRE) is also a main component of NUE [27]. The NRE—the proportion of N in the crop or crop component at anthesis which is not present in the crop or crop component at harvest—is the ability of plants to translocate the N after anthesis from the shoot to the grains. Nitrogen is the most limiting nutrient for the production of wheat [28]. Cultivars with higher NRE tend to accelerate the senescence process and increase N levels in grains [29]. It is widely understood that N accumulated before anthesis provides the major source of grain N. In wheat, around 50–95% of the grain N at harvest comes from the remobilisation of N stored in shoots and roots before anthesis [30–32]. In wheat between anthesis and maturity, the leaves had a higher

NRE than the stem and the roots [33]. About 70–80% of nitrogen, which is needed for grain development in cereals, is gained from vegetative organs before flowering stage [34]. Nitrogen use efficiency (NUE) plays a fundamental role in sustainable grain production [35, 36]. Based on several physiological parameters of doubled-haploid mapping wheat populations can lead to identification of specific loci that might be useful in marker-assisted breeding for increased N-use efficiency [35, 37, 38].

3. Temperature influence on nitrogen nutrition

Wheat growth can be impaired by heat stress at any developmental stage, and modelling scenarios predict even warmer temperatures in the future [39]. Production of wheat is affected markedly by high temperature [40, 41]. Elevated temperature alters uptake and allocation of N, thus intensifying N deficiency in plants [42]. Wheat shows enormous diversity in canopy architecture, and it has long been proposed that optimised light distribution could improve radiation use efficiency as well as light interception [43]. In heat tolerance, the activity of enzymes has crucial role. Rubisco's affinity for CO₂ decreases with temperatures [44]. Therefore, increasing affinity would simultaneously improve adaptation to warmer conditions, the proof of concept coming from C₄ species, in which it is achieved by concentrating CO₂ [45]. High temperature not only degrades Rubisco but also accelerates its inactivation by addition of inhibitory sugars to its active site. Moreover, Rubisco has a relatively low turnover number as compared with the other Calvin cycle enzymes. Activity of Rubisco is mainly regulated by a catalytic chaperone—Rubisco activase—which catalyses removal of inhibitory sugars from its active site, switching the enzyme to active mode [46]. Among cereals wheat's Rubisco has one of the best CO₂ affinities. Models where wheat's substrate specificity factor of Rubisco is replaced from *L. gibertii* predicted increases of 12% in net assimilation [47]. Combined stress of high temperature and low nitrogen affected both the abundance and mode of regulation of Rubisco, which catalyses CO₂ fixation and is one of the primary determinants of photosynthetic rate [48].

4. Effect of drought on wheat nutrition

According to the most recent assessment report of the Inter-governmental Panel on Climate Change, published in 2014, levels of anthropogenic emissions of greenhouse gases are now at their highest in history [49]. Agricultural production and its effect on land use are major sources of these emissions by sharing methane and nitrous oxide gases. Greenhouse gases causing air temperatures increase, thus more moisture evaporates from land and water bodies. Warmer temperatures also increase evaporation and evapotranspiration in plants, soils, and on other hand, they will also escalate the water stress frequency and intensity with a rise from 1 to 30% in acute drought land area by 2100 [50].

Under dry conditions in the field, 75–100% of the grain yield could be attributed to stored assimilates, compared with 37–39% under high-rainfall conditions. Drought stress severely

influenced plant water status by reducing the water potential and the relative water content in wheat [51]. Optimal nutrition levels have also alleviated drought stress damage by sustaining metabolic activities under reduced tissue water potential [52]. Nitrogen supply also has a crucial role in combating drought [53]. Efficiency of nitrogen supply declined with increasing of drought stress [54]. Morgan [55], Arun et al. [56] and Binghua et al. [57] who showed that with an application of nitrogen, plants show positive influence in terms of growth and development under drought stress. Although Li et al. [58] mentioned that different grass species under drought stress did not modify physiological functions under varying N application. Water limitation reduces diffusive conductivity which in turn affects other physiological process such as energy and N metabolism. It is concluded that N uptake and its diffusion depend on environmental condition especially to water supply as also indicated by Abreau et al. [59]. Under water deficiency, roots are unable to get optimal amounts of nitrogen from soil, which has general negative effects on plant metabolisms [60]. The main effect of water restriction is certainly a reduction in N demand due to the marked sensitivity of leaf area expansion [61]. Fewer results have about light reaction affected by genotypic and nitrogen supply variations, mainly under stress conditions. By measuring the yield of chlorophyll fluorescence (Chl-fl), information about changes in the efficiency of photochemistry and heat dissipation can be obtained [62]. Under extreme drought stress when the stomatal resistance just around $0.1 \text{ mol H}_2\text{O m}^{-2} \text{ s}^{-1}$, poor performance of photosystem II (F_v/F_m) and downregulated activities of CO_2 assimilating enzymes such as Rubisco become the dominant limitations to reduced photosynthesis [63]. The optimal photochemical activity (F_v/F_m) values were sensitive for the investigated two environmental factors, and genotype differences were established in tolerance [64]. Chl-fl parameter's sensitivity for detecting nitrogen deficiency is different, but some of them are really applicable for describing nitrogen lack [65]. Previous drought stress studies have reported that photosynthetic rate of the leaf under drought stress is closely related to the leaf chlorophyll contents, N concentrations and stay-green characteristics of the leaf, which in turn increases the grain yield by increasing the photosynthetic process [66]. Palta et al. [67] and Hosenlou et al. [54] reported induction of N remobilisation under drought stress. Application of the high amounts of N under drought resulted to the lowest NUE [68]. Critical, sufficient concentration of nitrogen in leaf is $15\text{--}40 \text{ mg g}^{-1} \text{ DM}$ [69]. Based on Pepó [16] and Zsombik and Seres [70] results, the dry weight production was mainly influenced by environmental factors and modified by fertilisers and genotypes. Water deprivation means higher strain than nitrogen lack with genotype difference based on dry weight value [65]. Plant responses to drought stress vary at different growth stages of the crop [71]. In wheat, tillering capacity of the crop is a major constituent of the final grain yield [72], but has been reported to be highly vulnerable to drought stress [73].

5. Salinisation and impact to wheat production

Salinisation or increased concentration of dissolved cations/anions in soil solution and/or water resources (e.g. capillary rising of saline groundwater, salinised waters used for irrigation) [74] across the (agro)ecosystems is the principal cause of most widespread abiotic constraint to glycophytes (i.e. the majority of cultivated crops, including wheat) known as salt

stress. Salt stress encompasses wide range of physiological dysfunctions as a consequence of primary salinity effects, that is, osmotic and ionic disorder. Primary salinity effects, depending on the salinity level/duration, crop/genotype type, development stage, and so on, very often cause different secondary salinity-induced effects such as reduced cell expansion and assimilate production (i.e. growth and yield reduction), production of reactive oxygen metabolites and even plant mortality [75]. The general salinity effects are quite visible and assume reduce biomass growth (shoot/root height and weight, leaf area) and changes in root and shoots colour (e.g. presence of leaf tip burns, scorching/firing of leaves) [76]. The extent to which growth and yield will be reduced under salt stress mostly depends on the salinity level and plant (crop) species (**Figure 2**).

Electrical conductivity (EC) is commonly used as an expression of the total dissolved salt concentration in an aqueous sample (e.g. water, soil solution) and usually express soil salinity level based on measured EC of saturated soil paste extracts (EC_e) (e.g. Rhoades et al. [77]). Therefore, EC_e threshold level (i.e. EC_t), as a numeric value at which crop growth and yield start to decline (more or less intensive under certain slope) can be very useful for categorisation of plants from salt tolerant (halophytes) to salt-sensitive (glycophytes) (**Figure 2**). In general, wheat is categorised as moderately tolerant to soil salinity (e.g. a threshold EC of 6.0 dS/m) [78] although existing significant differences among genotypes that it is difficult to make a categorical statement [79]. The relative effects of salt stress on wheat vegetative

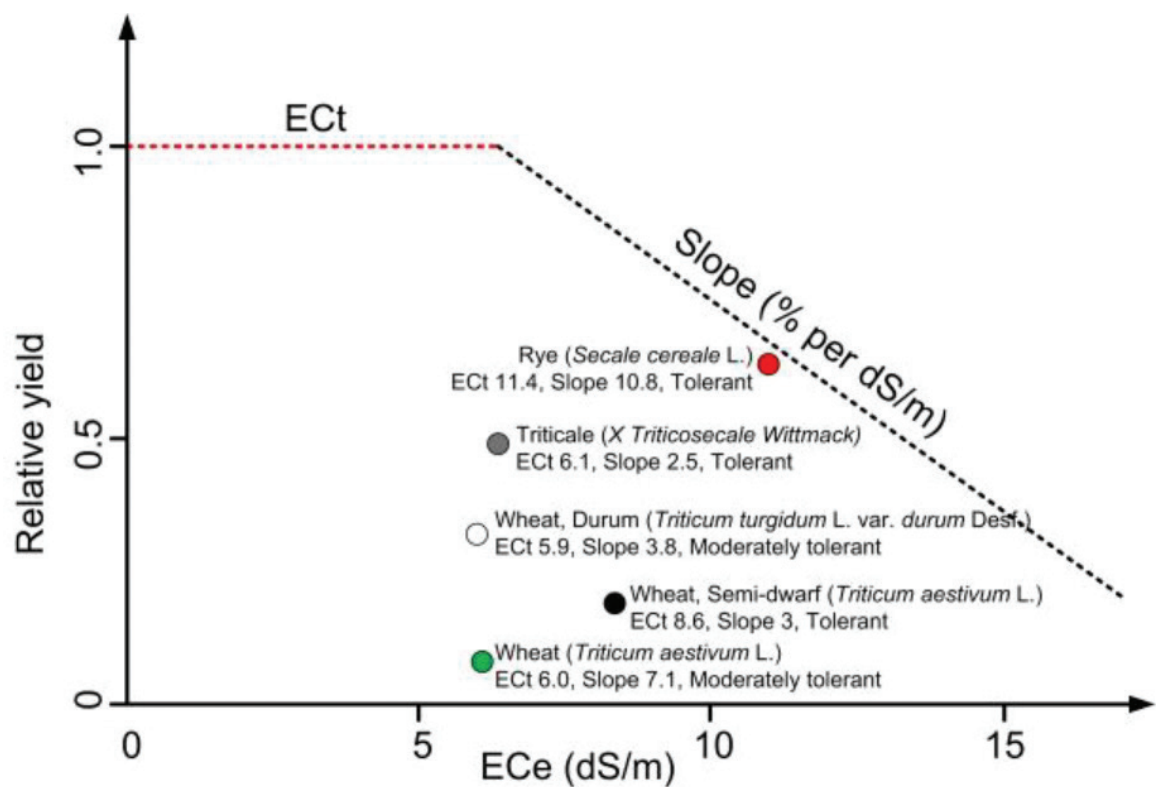


Figure 2. Simplified presence of salt tolerance in some cereals (adapted according to Maas [81]). EC_t represents the threshold in soil EC that is expected to cause the initial significant reduction in the maximum expected yield, whereas the slope is the percentage of yield expected to be reduced for each soil salinity unit above the EC_t [82].

growth parameters and grain yield can vary significantly among genotypes (**Figure 2**) and with the developmental stage at which salt stress occurs [75] as well under specific environmental conditions given that the interaction of crop (genotype) and environment is not completely understood but is likely to be significant [80].

5.1. Salinisation and wider (agro)ecological impact

Environmental salinisation process represents an increasing environmental issue especially in intensive agroecosystems such as (fert)irrigated areas [83] but also in less intensive rain feed (semi)arid regions [84]. Salt-affected areas are often overlapping with numerous other physical, chemical and/or biological pedosphere constraints such as sandy soils with low water retention capacity, non-structured/dispersed (waterlogged) soils, organically depleted soils with diminished microbial activity/diversity and excessive alkalinity, specific ionic (Al, B) toxicity, and many other [84, 85] (**Figure 2**). Saline or alkaline (sodic) soils due to increased concentration of particular salts (Na^+ , Cl^- , Ca^{2+} , Mg^{2+} etc) and ionic interrelations (e.g. $\text{Na}^+/\text{Ca}^{2+}$; $\text{Na}^+/\text{Mg}^{2+}$) can be recognised and visually by crystallised (precipitated) salts on the soil surface (forming a brighter salt forms on the soil surface; **Figure 3a**) or at later (developed) stages by topsoil crusting, as a consequence of dispersed clay minerals and soil aggregates (**Figure 3b**).

A constitute of structurally dispersed soils (e.g. clay particles, minerals, organics) undergo leaching through the soil profile, accumulating and blocking deeper macro/micro pores, especially in textured-heavier soil layers, and finally causing waterlogging (e.g. Burrow et al. [86]. Thus, salt-affected soils (profiles) depleted in adsorption matrices (organic matter and clay content notably) might be more prone to mobility and transfer of certain pollutants (e.g. toxic trace elements) on the soil/crop/groundwater routes, although certain genotypic differences have to be considered.

For instance, it was shown that raised soil solution salinity can significantly impact mobility of toxic Cd in the rhizosphere and enhance its uptake and root/shoot accumulation in different wheat cultivars [87, 88]. Also, sublimating the results of studies conducted by Norvell et al. [89], Khoshgoftarmanesh et al. [88] and Ozkutlu et al. [90] their outcomes suggest that

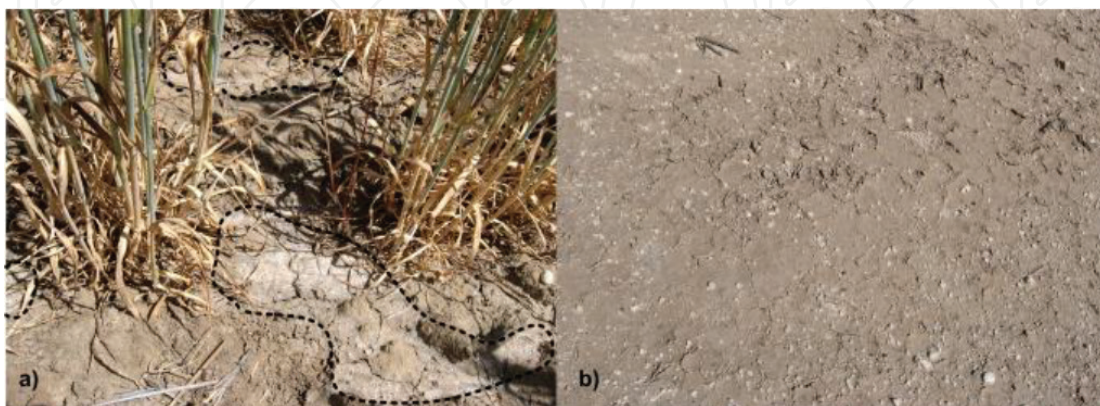


Figure 3. Topsoil (a) crystallisation of soluble salts (dotted brighter areas) in a wheat paddock, depleted with soil organic matter, and (b) crusting in an adjacent saline plot with disturbed soil structure (Esperance area, Western Australia).

durum vs. bread wheat genotypes could be more effective, not only in Cd root extraction, but also in Cd root to shoot (leaf/grain) translocation and deposition under excessive Cl salinity. Such genotypic differences should be considered also in wheat breeding programs related to salt resistance (next section).

5.2. Sustainable management practices and perspectives for wheat cropping under salinised conditions

Some of the widely used and most promising perspectives and strategies against soil salinity are listed in **Table 1**, and some of them are explained in the next section in more detail. Beside excessive E_{Ce} in saline soils, it is of great importance and interrelated concentrations of particular ions (notably portion of exchangeable Na⁺; ESP) as well as soil pH reaction. According to some of chemical parameters, salt-affected soils generally can be categorised as: saline (E_{Ce} > 4 dS/m, ESP < 15 and pH <8.5), saline-sodic (E_{Ce} > 4 dS/m, ESP > 15 and pH <8.5) and sodic/alkaline (E_{Ce} >4 dS/m, ESP >15 and pH >8.5), and usually require specific strategy for reclamation often with low benefit/cost ratio for crops (Ondrasek et al. [85] and references therein). Sustainable agricultural management in saline/sodic conditions usually is combination of certain preventive actions (aiming to control salinity/alkalinity level) and/or remediate of saline/alkaline areas. For instance, saline soils might be easier for reclamation than sodic soils because the former often requires only salt leaching while the latter requires addition and certain Ca-/Mg-based soil amendments (e.g. gypsum) to replace excess ESP in addition to leaching (e.g. [91]).

Perspective	Description
Species/varieties selection	Cropping of more salt resistant wheat varieties (genotypes), although genotypic differences related to efficiency of mineral uptake and accumulation (e.g. trace elements) should be considered (explained above)
Amelioration of soil water management	Implementation of subsurface drainage system may be useful approach for: (i) prevention of salt accumulation in sub/surface horizons as a consequence of seasonal sea water intrusion and/or capillary rising and/or (ii) salt leaching from the surface soil layers (e.g. [109]). Implementation of irrigation can decline vegetative growth of wheat cropped on salt-affected soils but without evident yield reductions (e.g. [75])
Soil amelioration by microbes	It was shown that exploitation of certain microbial populations can be a promising alternative to alleviate crops stress under excessive root zone salinity [96]. Thus for instance, inoculation of wheat seeds prior sowing by salt-tolerant microbe colonies might be beneficial strategy for wheat cropping in salt-affected environment (e.g. [97])
Application of inorganic amendments	Addition of natural or synthetic Ca-/Mg-/Zn based sources can ameliorate soil salinity/sodicity [110] and related pedosphere constrains (e.g. Zn-deficiency; see above)
Conservation and increasing of soil organic matter	Over conservation land management (e.g. reduced/minimal/no tillage) is possible to preserve and/or enhance soil-plant water relations, soil organic matter content and rhizosphere biodiversity across the saline paddocks (e.g. [85])
Genetic improvement	Genetic improvement of wheat genomes for salt-tolerance has a great potential of acquiring some halophytic traits such as Na ⁺ and/or Cl ⁻ exclusion by crossing cultivars of <i>Triticum aestivum</i> L. with genetically related (non)halophytes (e.g. [80])

Table 1. Some perspectives for improving wheat cropping in salt-affected agroecosystems.

Application of (in)organic soil amendments, such as mineral/organic fertilisers, lime, gypsum phospho-gypsum, and so on to salt-affected pedosphere has multi-beneficial impact [75]. Introduction of Ca-/Mg-enriched amendments enhances to maintain soil micro-aggregate structure in the soil profile, and consequently improves physical pedovariabiles such as improved flocculation, reduced spontaneous dispersion (air-dry aggregates) and dispersion of remoulded aggregates, increased hydraulic conductivity and soil aeration [92]. Furthermore, it was confirmed that soil salinity/alkalinity is frequently associated with microelement Zn deficiency, and that under such conditions, application of certain inorganic Zn-based fertilisers is able to improve salt tolerance but also and nutritional value of wheat. Namely, ~40% of the soils used for wheat production in Iran are Zn-deficient [93] and comparing to some other widely cropped cereals, wheat genotypes are especially very sensitive to Zn deficiency which markedly reduce wheat grain yield [94]. However, one of the biggest issues with soil amendments (Ca-/Mg-/Zn-based) application and their beneficial impact to crops in saline conditions is often lacking of their dissolution (i.e. phytoavailability of specific element/substance) due to (semi)arid conditions and/or not implemented irrigation practice.

Another promising strategy to enhance wheat salt tolerance might be introduction of salt more tolerant root-associated microbes that enhance plant growth under excessive salinity. Namely, it was widely discussed how spatial rhizosphere adaptation of plants is also driven by genetic differentiation in closely associated microbe populations such as: (i) arbuscular mycorrhizal fungi (whose hyphal networks ramify throughout the soil and within the plant cells) then (ii) ectomycorrhizal fungi (over a fungal layer around the root system and root inter-cellular spaces) and (iii) root-associated plant growth-promoting rhizobacteria (see reviews by Rodriguez and Redman [95]; Dodd and Perez-Alfocea [96]). Alleviation of salt stress on yield and mineral nutrition (e.g. increased K/Na ratio) exploiting the arbuscular mycorrhizal fungi was confirmed in certain wheat varieties under field saline conditions [97]. For instance, the mycorrhizal colonisation enhanced grain wheat yield up to >31% in Kavir (spring cultivar), up to >32% in Roshan (spring and semi-early maturing cultivar) and even up to >38% in Tabasi (mutated salt tolerant line) [97]. Furthermore, Sadeghi et al. [76] applying the isolate of *Streptomyces* in cultivated soil with wheat (cul. Chamran) observed: (i) increased the growth/development and shoot concentration of N, P, Fe and Mn in both saline and non-saline conditions and (ii) significant increases in germination rate, percentage and uniformity, shoot length and dry weight of salt-exposed plant (*vs.* non saline control). Also, studying the effect of inoculation of the five halotolerant bacterial strains in alleviation of NaCl-induced stress (80–320 mM) in wheat (var. HD 2733) Ramadoss et al. [98] observed an increase in root elongation (by >90%) and root dry weight (by >17%) in comparison with control (uninoculated) plants. Such beneficial effects of salt-tolerant microbes to (wheat) crops exposed to salinity are explained by improved plant water relations (e.g. due to enhanced accumulation of specific osmolytes), then regulating plant homeostasis and improved phytonutrients (e.g. N, P, K, Zn, Cu, Mn, Fe) uptake as well by enhanced germination rate [96, 97, 99].

Breeding programs to salt tolerance (as relatively long-term approach) are expecting that might have crucial role in (wheat) cropping under saline conditions in the near future (see down). Relatively little work has been done on breeding programs of wheat cultivars for saline conditions [80] given on polygenic character of salt tolerance, but continuous progress

is evident. Namely, hexaploid bread wheat (*Triticum aestivum* L.) has one of the most complex (ABD) genomes (e.g. six copies of each chromosome, numerous of near-identical sequences scattered throughout, overall haploid size of >15 billion bases) [100], thus making wheat highly challenging for genome sequencing and detection of salt-tolerant genes and quantitative trait loci. Also, the huge amount of repetitive sequences poses a big challenge for sequencing the wheat genome [101]. For instance, first assembly of the wheat genome from 2012 was represented by only ~33% (5.42 billion bases) [102], another assembly from 2014 by ~66% (10.2 billion bases) [103] whereas assemblies from 2017 were extended to 78% (12.7 billion bases) [104] and recent assembly was almost completed with >15.3 billion bases [100]. Hence, the genomic complexity and its uncomplete assembly makes the wheat crop additionally extremely difficult for improvement to salt tolerance over conventional (e.g. traditional breeding) and/or modern genetic (e.g. molecular and transgenic breeding) approaches.

Genetic improvement of wheat for salt-tolerance has also a great potential of acquiring some halophytic traits (genes) such as Na^+/Cl^- exclusion and/or compartmentation by crossing wheat genotypes with genetically related halophytic plant species (e.g. *Lophopyrum elongatum*) [105]. In wheat salt resistance is associated with low rates of the root-to-shoot transport of Na^+ with high selectivity for K^+ over Na^+ [106]. Bread wheat genotypes have a low rate of Na^+ accumulation and enhanced K^+/Na^+ discrimination which is controlled by a locus (Kna1) on chromosome 4D [107]. Contrary, durum wheat (tetraploid, AB genomes) have higher rates of Na^+ accumulation and weaker K^+/Na^+ discrimination [80] and is consequently less salt resistant *vs.* bread wheat (**Figure 2**). It was confirmed that salt-/draught-tolerant genes and quantitative trait loci identified in *T. dicoccoides* and *H. spontaneum* have great potential in wheat improvement also [108]. Finally, improvement in salt resistance of modern wheat genotypes will be generated from introducing new gene(s) by (i) crossing with new donor germplasm or (ii) transformation with single genes, and after the progeny has to be back-crossed into adapted cultivars before the donor genes are ready for cultivation [80].

6. Conclusion

Sustainable plant production has three main goals: environmental health, economic profitability, and social and economic equity. It needs to achieve higher and higher amount of quality food by using less stock and energy under actual environmental conditions. Nitrogen is one of the most important nutrients for plants because of the yield quality and quantity as well. Applying adequate amount of nutrients based on genotype requirements is hard under potential conditions, especially under different abiotic loads. About 70% of all fertilisers are used on wheat and rice. Wheat is an important staple crop and crucial source of non-animal protein in human food and also makes a significant contribution to animal feed. The problem is that the utilisation efficiency of nitrogenous fertilisers under field conditions is relatively low, thus the production may become dangerous for the environment, economically inadequate and can result in poor quality. Finding of 'smart' wheat genotypes with high NUE does not mean a solution for the problem of being sustainable. Several environmental conditions have effect on NUE and/or the components of NUE, thus we need more knowledge to locate the final answer our global challenge.

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Conflict of interest

We have no conflict of interest declare.

Author details

Veres Szilvia^{1*}, Ondrasek Gabrijel² and Zsombik László³

*Address all correspondence to: szveres@agr.unideb.hu

1 Faculty of Agricultural and Food Sciences and Environmental Management, Department of Agriculture Botany, Crop Physiology and Biotechnology, Institute of Crop Sciences, University of Debrecen, Debrecen, Hungary

2 Faculty of Agriculture, Department of Soil Amelioration, University of Zagreb, Zagreb, Croatia

3 Institutes for Agricultural Research and Educational Farm, Research Institute of Nyíregyháza, University of Debrecen, Nyíregyháza, Hungary

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