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Sustainable agriculture in Europe and quality of the products

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ABSTRACT

The world population is expected to reach 8 billion in 2020. Most of this growth in population will occur in developing countries. To feed the population a great improvement in food production must be achieved. Crop production, particularly cereals, has begun to slow down either in developed or developing countries due to set-aside policy, decline in soil fertility, expansion of crop production to marginal lands, cropping with low nutrient input, and climate. European Union became the greatest producer for cereals and presents excessive fresh horticultural products. In Portugal, about 80% of total area is under agriculture and forest, including about 600 Mha of irrigated land. Nevertheless, most Portuguese soils are poor with a moderate to high erosion risk. Annual crops are recommended for flat soils, whereas vineyards, fruit trees and pastures are advised for sloppy soils. Rotations including legumes and soil conservation practices are being encouraged to improve soil fertility and water retention, with reduction of erosion risks. The focus today, under the new Agenda 2000, is no longer to secure the food supply but on how and under what conditions food is produced and on the relationship between economic activity and the natural environment.

Keywords: Fertiliser use efficiency; Food security; Plant nutrition; Soil conservation practices; Soil erosion; Soil productivity.

RESUMO

A população mundial atingirá os 8 biliões em 2020. A maior parte desta população localizar-se-á nos países em desenvolvimento, sendo necessário um aumento da produção alimentar. A produção vegetal, particularmente, de cereais, começou entretanto a diminuir, quer nos países desenvolvidos quer naqueles em desenvolvimento devido à política do "set–aside", ao declíneo da fertilidade dos solos, à expansão da área de cultivo para terras marginais, à produção com fracos 'inputs', ao clima. A União Europeia tornou-se o maior produtor de cereais, sendo, também, excedentária em produtos hortícolas. Em Portugal, cerca de 80% da área total é agrícola e florestal, incluíndo 600 Mha de regadio. Contudo, a maioria dos solos portugueses é pobre, apresentando risco de erosão moderado a elevado. As culturas anuais são recomendadas para os solos planos, enquanto que a vinha, os pomares

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e as pastagens permanentes são aconselháveis para os solos declivosos. Os sistemas de rotação, incluindo leguminosas e as práticas de mobilização de conservação do solo têm sido encorajados, designadamente, para uma melhoria da fertilidade do solo, maior retenção de água e diminuição do risco de erosão. Na nova Agenda 2000, é dada especial atenção ao modo e condições como os alimentos são produzidos e às suas relações com a actividade económica e com o ambiente, relegando para segundo plano, a segurança alimentar.

Palavras-chave: Eficiência do uso dos fertilizantes; Erosão do solo; Nutrição vegetal; Práticas de conservação do solo; Productividade do solo; Segurança alimentar.

1. Introduction

The world population began to increase with the onset of industrial revolution during the 19th century. It is expected to reach 8 billion in 2020 (Figure 1), with an increase of 73 million people every year (rate of 1.3%) (Lægreid *et al.*, 1999). This increase in population will occur mostly in developing countries (95%), where soil, water and other natural resources are under stress.

Malthus, in 1798, expressed his apprehension about human subsistence, because population should increase in geometric ratio whereas food production should increase in arithmetic ratio. A great improvement in food production, by improving productivity and a better quality food, must be achieved to feed such increase in population. For such purpose, Cakmak (2001) reported that the world must produce as much food during the next 50 years on the existing cultivated land as it was produced since 10,000 years ago.

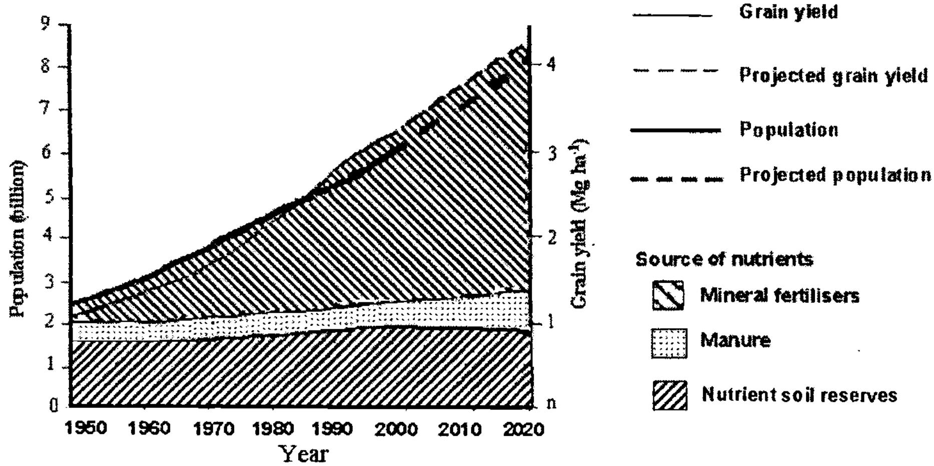
Crop production, particularly cereals (the most important food crops) begun to slow down in developed countries mostly due to set-aside policy to control overproduction in European Union (EU) countries, rural desertification and soils degradation (physical, chemical and biological). About 60% of the present globally cultivated soils have general mineral problems like Al, Mn, and Na toxicities, and N, P, Fe, and Zn deficiencies making research on plant nutrition a major promising research area in meeting the demand for such a large increase in food production for the growing world's population (Cakmak, 2001).

Many environmentalists and agronomists have raised serious concerns about the adverse impact of the green revolution techniques, especially with regard to natural waters pollution, soil contamination, emission of greenhouse gases into the atmosphere, and air pollution. Access to food and clean living environment are two of the most basic human rights, which must be respected for all citizens of the planet earth (Lal, 2001). The answer to both issues of food quality and environmental qualities lies in adopting strategies for sustainable management of soil resources. These strategies rely on the restoration of degraded soils and ecosystems with adoption of recommended agricultural practices to ensure productivity and improve environmental quality. This agriculture (sustainable) should be based on the cultivation of the best soils with the best management practices to produce the optimum sustainable yield, and save marginal lands for nature conservancy. This requires a better and more comprehensive knowledge into ecological crop production processes, especially in the fragile environments.

Agriculture in the EU accounts for only 2% of its total Gross Domestic Product, but accounts for 6% of total employment (Olesen & Bindi, 2002).

Figure 1

Evolution of population growth, grain yield, and N consumption (Adapted from Vos, 1994)



2. Soil productivity

Soil productivity is the ability of the soil to support crop biomass production supplemented by organic and mineral fertilisers to compensate for removal and losses of nutrients to maintain soil reserves. Soil fertility is an expression used in older literature to describe the ability of the soil to support crops through its own nutrient reserves (Lægreid *et al.*, 1999). Both terms are commonly and erroneously used as equivalent.

Soil organic matter plays a key role in building and sustaining soil fertility, affecting physical, chemical and biological soil properties (Olesen & Bindi, 2002). Ploughing and removing the crop residues and weed biomass under extensive agriculture accelerated soil erosion by water and wind on sloppy and flat land. This was particularly important in Mediterranean Basin, after the deforestation (30-70% of agricultural soils are eroded) (Lal, 2001). In EU countries, about 42% of the land is dedicated to agriculture and 27% to forest. About 160 million ha (16% of agricultural land) show different levels of erosion by water, and around 112 million ha (4%) is windy eroded land (Lal, 2001). According to this author (2001), in these European countries, the average rate of soil loss is 17 Mg ha^{-1} $year^{-1}$ that is much greater than the soil formation rate (1 Mg ha^{-1} $year^{-1}$). These degraded soils become less productive. For the past 20-30 years period, C losses by erosion were greater than 50%. Carbon sequestration in the soil at intensive agriculture has the beneficial effect of reducing the rate of increase of atmospheric CO_2 concentration.

In Portugal, about 80% of the total area is under agriculture and forest but most soils (about 90%) are poor, with moderate to high risk of erosion. In Alentejo region, deforestation and tillage in sloppy soils caused a rate of soil loss of about 150 Mg ha^{-1} $year^{-1}$, with a loss of 5% organic matter (Sequeira & Carranca, 1994; Sequeira, 1998). Nevertheless, soil losses by erosion in Portugal are usually not greater than 7.5 kg ha^{-1} $year^{-1}$, but most soils are already unsuitable for intensive crop production, being shallow, stony and poorly structured. To control erosion, annual crops were recommended for flat soils, while vineyards, fruit trees and pastures are advisable for sloppy soils. Also, soil conservation practices have been encouraged.

As consequence, the dominant characteristics of Portuguese soils are acidity, low cation exchangeable capacity and poor organic matter content, being vulnerable to pollution and possible contamination of ground- and surface waters. But the contribution of Portuguese agriculture to environmental problems, compared with other groups is not so important because N input is much lower than in other European countries (average 80 kg N ha^{-1}). For instance, the groundwater contamination with NO_3^- was detected in three areas classified as Vulnerable Zones (Regulation n° 1037/99 from 1 October). Still, the soil contamination by agriculture is restricted to small intensive agricultural zones, where salination, pesticides, and Cu pollution have been reported, namely in Algarve, Ribatejo and Oeste, and in the north where vineyards have been produced for many years using Cu as a fungicide agent (Cakmak, 2001; De Clerq *et al.*, 2001).

In Spain, more than 50% of agricultural land is classified as moderate to highly eroded land (in Andalusia, about 70% agricultural soil is eroded) (Torres, 2002). Italy presents 55% of eroded soils, and France only 29% (Pires, 2000).

Desertification is another serious problem in arid, semi-arid and sub-humid regions and its control is equally important, even for the EU countries.

Restoring degraded soils, enhancing biomass productivity, and C sequestration should globally be done.

3. Plant nutrition

The supply and absorption of chemical compounds needed for growth and metabolism may be defined as "nutrition" and the chemical compounds formed as "nutrients" (Mengel & Kirkby, 1982). These nutrients are converted to cellular material or used for energetic purposes by metabolic processes. Nutrients should be present in sufficient quantity and appropriate form in the right time of greatest crop requirement for its optimum growth and yield.

The main sources of nutrients for the crops are the soil reserves, including soil organic matter, organic (animal and green manures, plant residues, other organic composts) and mineral fertilizers, biological N_2 fixation (symbiotic and asymbiotic), irrigation water, and seeds. In some areas, also aerial deposition is important.

Green manures (catch or cover crops, planted to prevent NO_3^- leaching or soil erosion, and legumes grown in the field) and plant residues added to the soil often supply up to 30% of the total N (in general, the limiting factor) for the next crop, but the amount varies with source of plant material, climate, soil type, and management practices (Peoples *et al.,* 1995). These plant materials must decompose before other crops can use nutrients.

Nitrogen is abundant in the air (78%) in a form that plants cannot utilize it directly. But certain bacteria (e.g., *Rhizobium*) can convert atmospheric N_2 to ammonia for plants (legumes) use as their N source, while plant provides bacteria with energy in the form of organic compounds. The amount of N_2 fixed by this process (symbiosis) varies greatly with crop species, and even cultivars, bacteria strains, soil nutrients, moisture, and temperature, from very low amounts to some hundreds of kg N ha^{-1} $year^{-1}$ (Table 1). Legumes cover about 11% of agricultural land in total earth. Globally, biological N_2 fixation provides about 170 million Mg of N $year^{-1}$. In general, legumes only require a very short amount of N as a starter (exception for legumes such as soybeans and beans that also require N at pod filling) (Lægreid *et al.*, 1999; Carranca, 2000).

4. Recommended agricultural practices

Among the several options to increase food supply and improve food quality with minimum environmental risks there is the increase of productivity on the existing agricultural land, either by increasing crop density or replacing low-yielding by high-yielding cultivars, the use of precision farming to increase fertilizers use efficiency, and the use of soil conservation practices with residue mulching, including rotations or intercropping systems.

Table 1

Symbiotic N_2 fixation by different legumes (Sources: Howieson et al., 1998; Carranca, 2000)

Legume	N_2 fixed	
	%	kg N ha^{-1} $year^{-1}$
Arachis hypogea L.	30-85	-
Cicer arietinum L.	50-80	15-176
Glycine max. L.	5-80	10-192
Lens colinaris Medicus	-	12-84
Lupinus albus L.	50-90	>360
Medicago sativum L.	65-80	29-300
Phaseolus vulgaris L.	5-50	3-125
Pisum sativum L.	30-90	37-185
Trifolium repens L.	- >80	13-109
Trifolium subterraneum L.	25-97	12-200
Vicia faba L.	44-80	160-215

4.1. Soil management practices

To reduce soil erosion and compaction, and increase soil organic matter, conservation practices (no-till or reduced till), already adopted in USA, Brazil, Argentina, Australia and Canada (Table 2) have been very slowly adopted in the EU countries, still occupying less than 5% of agricultural farms. Direct drilling may reduce soil erosion by 90%, while reduced tillage can reduce it by 60% (APOSOLO, 2001). The Common Agricultural Policy (CAP) is developing favourable policies in the EU to increase these uses of conservation practices that are already recommended in the Codes of Good Agricultural Practices and Best Management Practices.

Nevertheless, in certain soils (light soils), NO_3^- leaching in reduced tillage can be greater than under conventional tillage due to the promoting of large channels by-passing the root systems. Also NH_3 and NO_x losses by volatilisation and denitrification can be large, particularly when residues are not incorporated in the soil. Hence, the amount of nutrients supplied by the soil organic matter is less than in soils ploughed where mineralisation rate is faster and greater, depending on plant residues quality and their management in the soil.

Table 2

Total agricultural land using direct drilling and conservation practices (Adapted from APOSOLO, 2001)

Country	Direct drilling area (Mha)	Land under conservation practices (Mha)
USA	21,120	44,120
Brazil	14,330	14,330
Argentina	11,000	11,000
Australia	8,640	8,640
Canada	4,060	4,060
Paraguay	1,100	1,100
Mexico	650	650
Bolivia	350	350
UK	200	200
Spain	150	1,000
Germany	nd	1,300
France	nd	700
Venezuela	150	150
Chile	100	100
Colombia	70	70
Uruguay	50	50
Ghana	30	30
Portugal	9	9
Switzerland	8	9
Other	500	500
TOTAL	62,517	88,367

USA = United States of America; UK = United Kingdom; nd = not determined.

4.2. Fertilizers use efficiency

Europe and other industrialized countries have led to the build-up of soil nutrient stocks resulting in increased nutrient fluxes into the environment due to the excessive use of fertilizers (average 120 kg NPK ha^{-1} $year^{-1}$ in Europe). National balances [total input minus output of N ha^{-1} of Units of Agricultural Area (UAA)] show that N surplus is decreasing in Austria, France and Norway, but it is increasing in Portugal, Spain and Ireland (De Clerq *et al.*, 2001). The mean N inputs in EU over the period 1995-1997 comprised 49% from mineral fertilisers, 31% from livestock manure, and 20% from biological N_2 fixation, atmospheric deposit, and input through seeds and plant residues (De Clerq *et al.*, 2001).

The efficient use of fertilisers aimed at both optimising yield with good crop quality, and reducing environmental pollution is therefore a particularly important issue. The policy for agricultural production, protection of the environment, and the maintenance of the countryside was included in Agenda 2000 for the EU countries (Regulation EC n° 1257/99) in the 2000-2006 periods, where especial attention is being paid to integrated crop management practices.

In Portugal, Carranca *et al.* (1999b) found a fertiliser N use efficiency (FUE) by winter wheat of 48%, corresponding to a N recovery of 57 kg N ha^{-1} for a crop yield of 3.5 Mg ha^{-1} [the average yield for durum wheat in Portugal is 2 Mg ha^{-1} (GPAA, 2000/01)]. In UK, a greater amount of fertiliser N use was recovered (68%) in the winter wheat (AFRC, 1992). In Europe, fertiliser N for winter wheat should be split at affiliation (end of February) and at tillering (end of March), but if necessary a third dose can be later supplied (Carranca *et al.*, 1999b).

Although the few reports, vegetables seem to show FUEs lower than 50%. Spinach cropped in Portugal (Carranca, 2000; 2002) showed 18% FUE, mainly explained by its shallow root system and short growth cycle. Fertilizer N (90 kg N ha^{-1}) should be split twice, 1/3 one week after sowing, and 2/3 in the last month when crop needs are greater.

Perennial crops, such as fruit trees, together with vegetables were considered priority crops by the CAP policy in agreement with Common Market Organisation (CMO). Trees can accumulate nutrient reserves, especially N, in older organs. This internal N is remobilised to the young organs (leaves, twigs, flowers and fruitlets) particularly during the first blooming, flowering and fruit set. Young citrus trees ('Lane Late' x c. 'Carrizo'), grown under fertigation in South of Portugal (Algarve), showed a low 20-30% FUE, mainly due to drop of leaves, flowers, and fruitlets, and any gaseous N losses from the soil or NH_3 volatilisation from the leaves. The young citrus (0-3-years old) should receive a total amount of 180 g N $tree^{-1}$ (unpublished data).

As to apple and pear trees, grown in pots in Israel and Italy, respectively, Klein *et al.* (1989) and Maurizio *et al.* (2002) found in both cases fertiliser N recoveries of about 50% FUE. Data for Portuguese conditions are still coming out.

4.3. Organic farming

General features of organic farming are the removal of weeds by mechanical soil treatment or by the use of flame, the adoption of extensive crop rotation and intercropping using legumes, while monocultures are avoided. The use of synthetic pesticides and genetic engineering are forbidden. Phosphate rock and other natural minerals with low solubility can be used, and soluble potassium sulphate and micronutrients are permitted to avoid their deficiencies in plants and food.

Biological products are increasing significantly (about 20% per year) as a consequence of environmental preservation and a decrease of food quality and nutritive value in some products (Pires, 2000). Since 1992, EU legislation on production and labelling standards for organics products was applied to the sector (FAO, 2000).

In Austria, Denmark, Finland, Italy, and Sweden more than 6% UAA is being used for organic farming, which is a relatively large proportion compared to the EU average (2.7%). In Portugal, organic farms are expanding. Its number increased substantially from 73 in 1993 to 750 farms in 1999. Alentejo is the region with the largest number of organic farms (382), about 48% of total area (De Clerq *et al.*, 2001).

Biological N_2 fixation by legumes should be considered as an important N source to the organic farming, for sustaining productivity of soils.

Legumes included in crop rotations can improve the succeeding crop yield, normally a cereal, either by improving soil aeration, soil microbial activity, pests control, or nutrients availability, particularly N. Carranca *et al.* (1999a) reported that fababeans, with high N_2 fixation rates and high N harvest indices presented a N benefit to the following crops of the order of +19 kg N ha^{-1}. Similarly, chickpea showed a positive N effect to the soil of +5 kg N ha^{-1}. Unlike, peas showed a negative N balance of –20 kg N ha^{-1}. They present C/N ratios of 20-52, with high lignin content that lead to some N immobilization during the first two weeks after residues incorporation in the soil, followed by a slow N release (Nicolardot *et al.*,1996). Lupines show stems with C/N ratios of about 76, but including the fallen leaves, lupines show positive N inputs varying from +40 kg N ha^{-1} in Europe to +53 kg N ha^{-1} in Australia (Howieson *et al.*, 1998). Portuguese data are coming out.

These organic farms need extra labour, ranging from 12% in Germany to almost 100% in Denmark, and may face the same environmental and sustainable problems with crop nutrients as conventional agriculture: NH_3 and NO_x emissions, NO_3^- leaching, energy use, and depletion of natural resources, particularly, phosphate rocks (Lærgreid *et al.*, 1999). Crops can also show greater risks for insects or diseases than conventional agriculture. These problems are more severe with fruit crops. The principal method for pest control in organic farms is the crop rotation. Crops in organic farms may also show smaller N content than under conventional agriculture. Possible risks for humans and animals have no scientific support (Soares, 2001).

Combination of mineral fertilisers with different types of organic materials, including legumes in rotational cropping and intercropping systems and recycling crop residues, and using software for precision agriculture seem to be the best strategies to maintain or improve soil productivity and enhance nutrient use efficiency (integrated crop management practices) (FAO, 1998). These practices should be used under soil conservation tillage.

The land area planted to genetically modified (GM) crops in developed countries is increasing. For example, the cultivated area in USA with GM for insects or herbicides tolerance increased from about 15 to 22 Mha for soybeans, and from 8.5 to about 11 Mha for corn (Lal, 2001). Still there is a consumer resistance in Europe but its long-term future seems positive.

5. Food quality

Food is the first basic human right. The quality of the plant products is not so easily defined and measured as yield. Food quality, under sustainable agriculture, is the biggest challenge in the 21st century, particularly in the developed countries. It implies physical and economic access to balanced diets and safe drinking water to all people (Cakmak, 2001; De Vries, 2001).

Unlike USA, food shortage was a problem in Europe after World War II, and most Western European countries adopted agricultural policies aimed at increasing productivity. Based on this support and technological advancement, farmers were able to invest in and operate their farms at the economic optimum, resulting in increasing productivity. High average yields giving food self-sufficiency in EU were achieved for almost all crops by the 1980s through CAP, and since then EU shifted towards avoidance of overproduction and environmental pollution (Lal, 2001). Europe became one of the world's largest and most productive suppliers of food and fibre. In 1998, the 15-EU countries accounted for 10% of the global cereals, 12% for fruit, 11% for pulses, and 9% for vegetables (Carvalho & Basch, 1996; Olesen & Bindi, 2002). In these countries, food security and quality have been controlled, since 2002, by the European Agency for Food Security. This control respects food production (management practices, environmental conditions, and processing), and its transport and conservation.

Human dietary needs 2000-4000 Kcal day^{-1} depending on weight, age, sex, reproductive status (pregnancy, lactation) and physical activity. A varied diet usually satisfies the need for proteins, minerals and essential components such as vitamins. However, many people eat monotonous diets, and then vitamins and micronutrient deficiencies are common in many countries. Globally, at least 250 million people are vitamin A-deficient (40 million are children, of whom 13 million already have eye damage and some go blind). Iodine deficiency disorders affect around 1.5 billion people in over 90 countries. Iron deficiency occurs in all countries: 3.7 billion people are anaemic (the majority living in Asia) mostly among women, especially pregnant. Soils in the Nordic countries are deficient in Se, a micronutrient essential for humans and animals, but not for plants (Lærgreid *et al.*, 1999; Horst, 2001; Hurrel, 2001).

Plant foods contain macro and micronutrients that are necessary as enzyme co-factors or as essential components of body structures and they contain 11 of the 13 vitamins (exception for vitamins B_{12} and D) which regulate and facilitate chemical reactions such as oxidation, reduction, hydroxylation, methylation, etc., that control our metabolism (Hurrel, 2001).

5.1. Cereals

Cereals are the most important food crops, but their production is decreasing either by controlling overproduction in developed countries (in compulsory set-aside) or by cropping in depleted soils and marginal lands with low nutrients input in developing countries, or to unfavorable climatic conditions at crucial stages of growth cycle (Lærgreid *et al.*, 1999; FAO, 2000).

Maize is grown in more countries than any other cereal. It is planted annually on more than 100 Mha (with 2/3 of the area in developing countries). However, the protein content and nutritional quality is inferior to other cereals. Average grain yields of hybrid maize grown in developed countries is 7-8 Mg ha^{-1}, and 10 Mg ha^{-1} in New Zealand, but yields of more than 18 Mg ha^{-1} have been achieved under ideal conditions (Lærgreid *et al.*, 1999). In the EU, wheat and barley are the main cereals. According to Agenda 2000, the protein content in the winter wheat should be above 11.5% on dry matter. Spring wheat generally yields less than winter wheat but may get premium prices due to its protein content. Barley, for feed purposes should contain 11% protein in dry matter (Olesen & Bindi, 2002). In the Mediterranean region a reduction in wheat area was observed due to reduced yields reflecting mainly water shortage, heat stress and the short duration of the grain filling period (Olesen & Bindi, 2002). But in Portugal, durum and soft wheat production increased (170%) by the increase in cultivated land (three times for durum) and productivity increase (70%). Barley also increased cultivated land by 25%, resulting in 65% production increase Cereals production, in 2000, accounted for 11% of total Portuguese agricultural production (GPAA, 2000/01).

5.2. Vegetables

As to vegetables, their production is more intensive than other arable crops, with a quick succession of crops and general high rates of nutrient input. Irrigation is also common.

Quality of raw and processed vegetable products is probably an elusive factor that may differ from person to person on individual tastes. But consumers want high quality foods (fresh, light, and nutritious) for their diets. The quality of any fresh horticultural product begins with production and selecting a good quality product. Subsequent handling to minimize physical injury, proper sanitation and maintenance of proper temperature and humidity will contribute to the postharvest quality. In Southern Europe, among vegetables, spinach, cauliflowers, cabbage, broccoli, lettuce, tomato, carrots, and potatoes are considered priority crops by the CAP policy. Most are cropped under field conditions. Total production in Portugal (43.4 Mg ha^{-1}) contributed to 32% of final Portuguese agricultural product (GPAA, 2000/01). Spinach yield in Portugal, Italy, France, Germany, and The Netherlands varies from 9 to 25 Mg ha^{-1} (Carranca, 2002).

Leafy vegetables are generally high in organic acids and most minerals, when compared to other vegetables (Table 3). Increase of N supply increases their proteins and vitamin B_1 content, but may decrease ascorbic acid (vitamin C). High levels of K nutrition generally increases th vitamin C content, but also increases the level of oxalic acid which may cause problems to people suffering from calculus in the vesicle and kidney, and also gives a bitter taste (Carranca, 2002). Attention should also be paid to potentially toxic levels of NO_3^- and NO_2^- in the leaves. Nitrate content in vegetables is enhanced to excessive N applied, but also with cultivars and light intensity. Nitrate content in 13 studies in Europe vary substantially from 907 to 4674 mg NO_3^- kg^{-1} of fresh product (FP) for open leaf lettuce, 390 to 3383 mg NO_3^- kg^{-1} FP for spinach, 37 to 715 mg NO_3^- of kg^{-1} FP for cauliflower, and 80 to 210 mg NO_3^- of kg^{-1} FP for onions. Europen Union established then NO_3^- maximum levels in lettuce and spinach leaves (2500 - 4500 mg NO_3^- kg^{-1} FP), depending on harvest time and production method (EU, 1999; Carranca, 2002). The World Health Organization stated a maximum daily NO_3^- consumption of 3.65 mg NO_3^- kg^{-1} of body weight.

An adequate Ca supply is important for tomato to avoid the occurence of "blossom end rot" in the plants (Mengel & Kikby, 1982).

Micronutrients are also particularly important in vegetables. For example, B deficiency causes carrots to split open, and broccoli and cauliflower to develop brown, hollow stems; Mo deficiency causes a reduced leaf development in cabbage, cauliflower, and spinach (Figure 2) (Branco & Fragoso, 1989; Carranca, 2002).

5.3. Fruits

The quality of fruits not only depends on their content of organic constituents but also to considerable extent on fruit size, colour, shape, flavour, and taste. These characteristics are especially affected by variety, climate, management practices, and mineral nutrition. Fruit size, juiciness, colour and yield depend mainly on N. Excessive N also delays ripening.

Potassium is another important nutrient for yield, plant resistance to lodging of the fruit-bearing stem, and firmness, acidity, colour, and resistance to damage during transport. Fruit quality is thus managed by careful attention to the N:K ratio and the timing of their application. Satisfactory Ca supply is another important factor to ensure high quality of many fruits. Its deficiency causes "bitter pit" in apples (the appearance of small brown spots on and in the fruits) (Mengel & Kirkby 1982).

Table 3

Nutritive values of spinach leaves at maturity stage (Source: Carranca, 2002)

Water	85-93 g/100g FP
Lipids	0.4-1 g/100g FP
Mono unsaturated fat acids	0.1 g/100g FP
Poly unsaturated fat acids	0.5 g/100g FP
Cholesterol	nd
Energy value	25 kcal/100g FP
Carbohydrates	0.8-3.6 g/100g FP
Starch	0.1 g/100g FP
Cellulose	0.8 g/100g FP
Ash	2.3 g/100g FP
Vitamin A	9 420 UI/100g FP
Vitamin B_1	110 μg/100g FP
Vitamin B_2	200 μg/100g FP
Vitamin B_6	0.17 mg/100g FP
Vitamin B_{12}	nd
Ascorbic acid	26-59 mg/100g FP
Vitamin D	nd
Vitamin E	1.71 mg/100g FP
Carotene	3 535 μg/100g FP
Thiamin	0.07 mg/100g FP
Riboflavin	0.09 mg/100g FP
Niacin	1.2 mg/100g FP
Biotin	0.1 μg/100g FP
Total N	29-65 g kg^{-1} DM
$NO_3^- - N$ (total leaf)	995-5 337 mg kg^{-1} DM
NO_2^- (total leaf)	0-3.8 mg kg^{-1} DM
P (total leaf)	2.5-7.2 g kg^{-1} DM
K (total leaf)	40-82 g kg^{-1} DM
Na (total leaf)	1.4-4 g kg^{-1} DM
Ca (total leaf)	6-15 g kg^{-1} DM
Mg (total leaf)	6-19 g kg^{-1} DM
B (total leaf)	25-70 g kg^{-1} DM
Mo (total leaf)	0.1-3.0 mg kg^{-1} DM
S (total leaf)	306-600 mg/100g DM
Cu (total leaf)	5-25 mg kg^{-1} DM
Fe (total leaf)	60-2 300 mg kg^{-1} DM
Mn (total leaf)	30-250 mg kg^{-1} DM
Zn (total leaf)	25-100 mg kg^{-1} DM
Cl (total leaf)	98 mg/100g FP
Ni (total leaf)	2.4-10 mg kg^{-1} DM
Cd (total leaf)	0.7-1.5 mg kg^{-1} DM
Ag (total leaf)	2.5 mg/100g DM
Edible proportion	0.81-0.95

nd = not determined; FP = fresh product; DM = dry matter.

Figure 2

Symptoms of molybdenum deficiency in spinach leaves (Carranca, 2002).

Total fruit production in Portugal, in 1999, accounted for 16% of total Portuguese agricultural production, where apples and pears, mainly in Ribatejo and Oeste zone, were around 250,000 Mg and 110,000 Mg, respectively, in 21.2 Mha and 12.4 Mha total areas. Citrus are also important agricultural products in the Mediterranean countries, protected by CMO. In South of Portugal (Algarve), climatic conditions favour them giving a particular quality that is differentiated by Protected Geographical Indication ("Citrus from Algarve"). A total citrus production area of 27 Mha produced 330,000 Mg (GPAA, 2000/2001). Portugal cannot any longer compete for citrus production with other countries. The actual issue is enhanced for fruit quality.

Grapes to produce red wines are grown in the marginal regions between the temperate Central European climate and Mediterranean climate. In Portugal, they accounted for 30% of final agricultural production in 1999.

5.4. Pulses

Also included in the CMO regime, eligible for an area premium and included in the set-aside scheme in EU, are peas, field beans and sweet lupines. At present, the area of protein crops in EU is 1.1 million ha. In Portugal, the area devoted to proteaginous crops slightly decreased to about 5.3 Mha, with a production of 4.300 Mg (GPAA, 2000/01).

Similarly to vegetables and fruits, pulses are much richer sources of micronutrients, compared to cereals.

6. Conclusions

Declaration of Hamburg (2000) expressed the concern of crop scientists about the role of science and society in meeting the demands of future human needs with maintenance of natural reserves.

Achieving food quality is the major objective in the 21st century in developed countries because people prefer high quality food.

Good agricultural management practices are the key to achieving food production with quality and minimal environmental impact. A better understanding of interactions between nutrients, crops and their residues, and soils and their organisms under relevant climatic conditions, is required for fertiliser improvements. Optimal fertiliser application with a correct balance between nutrients is required to ensure both yield and quality, with reduction of environmental risks. Soil conservation tillage with residues mulching and crop rotation would restore the degraded soils.

REFERENCES

AFRC (Agricultural and Food Research Control) (1992) — *Research on the nitrogen cycle.*

APOSOLO (Associação Portuguesa de Mobilização de Conservação do Solo) (2001) — Agricultura de conservação: Situação actual a nível mundial. *Boletim Informativo* (4): 4-5.

BRANCO, M.A.C.; FRAGOSO, M.A.C. (1989) — *Carências de boro e molibdénio em brássicas,* in “Resumo das Comunicações do 1° Colóquio Nacional de Brássicas Associação Portuguesa de Horticultura e Fruticultura”, Lourinhã.

CAKMAK, I. (2001) — *Plant nutrition research: Priorities to meet human needs for food in sustainable ways,* in "Plant Nutrition – Food Security and Sustainability of Agro-ecosystems” (W.J. Horst *et al.*, Eds), Kluwer Academic Publishers, Netherlands.

CARRANCA, C. (2000) — *Principais processos do ciclo do azoto numa agricultura sustentável. Avaliação através do marcador* ^{15}N, EAN, Oeiras.

CARRANCA, C. (2002) — *Crop management and postharvest quality of spinach for fresh consumption and processing,* in “Plant Nutrition and Postharvest Quality of Horticultural Crops” (R. Dris,Ed.), Finland, (in press).

CARRANCA, C.; DE VARENNES, A.; ROLSTON, D.E. (1999a) — Biological nitrogen fixation by fababean, pea, and chickpea under field conditions estimated by the ^{15}N isotope dilution technique. *Eur. J. Agron.*, 10: 49-56.

CARRANCA, C.; DE VARENNES, A.; ROLSTON, D.E. (1999b) — Variation in N-recovery to winter wheat under Mediterranean conditions, studied with ^{15}N-labelled fertilizers. *Eur. J. Agron.*, 11: 145-155.

CARVALHO, M.; BASCH, G. (1996) — Optimisation of nitrogen fertilisation. Relationship between precipitation and expected yield. *Fert. Res.* 43: 127-130.

DE CLERQ, P.; GERTSIS, A.C.; HOFMAN, G.; JARVIS, S.C.; NEETESON, J.J.; SINABELL, F. (2001) — *Nutrient management legislation in European countries*, Wageninden Pers, Netherlands.

DE VRIES, F.W.T.P. (2001) — *Food security? We are losing ground fast,* in "Crop Science Progress and Prospects" (J. Nöberger; H.H. Geiger; P.C. Struik,Eds), CABI Publishing, Bristol.

EU (1999) — Commission Regulation (EC) nº 864/1999 of 26 April amending Regulation (EC) nº 194/1997 setting maximum levels for certain contaminants in foodstuffs. *Official Journa*l 108, 16-18.

FAO (1998) — *Guide to efficient plant nutrition management.* Food and Agriculture Organization of the UN, Rome.

FAO (2000) — *Fertiliser requirements in 2025 and 2030,* Rome.

GPAA (2000/2001) — *Anuário 2000/01 Hortofrutícola e Culturas Arvenses, Azeite e Tabaco.* Ministério da Agricultura, Desenvolvimento Rural e das Pescas, Lisboa.

HORST, W.J. (2001) — *Preface,* in "Plant Nutrition - Food Security and Sustainability of Agro-ecosystems" (W.J. Horst *et al.*, Eds), Kluwer Academic Publ., Netherlands: *xxxviii.*

HOWIESON, J.G.; FILLERY, I.R.P.; LEGOKI, A.B.; SIRORSKI, M.M.; STEPKOWSKI, T.; MINCHIN, F.R.; DILWORTH, M.J. (1998) — *Nodulation, nitrogen fixation and nitrogen balance,* in "Lupins as Crop Plants - Biology, Production, and Utilization" (J.S. Gladstones; C. Atkins; J. Hamblin, Eds), CAB Internet, New York: 149-180.

HURREL, R.F. (2001) — *Modifying the composition of plant foods for better human health,* in "Crop Science Progress and Prospects" (J. Nöberger; H.H. Geiger; P.C. Struik, Eds), CABI Publishing, Bristol: 53-64.

KLEIN, I.; LEVIN, I.; BAR-YOSEF, B.; ASSAF, R.; BARKOVITA, A. (1989) — Drip nitrogen fertigation of 'Starking Delicious' apple trees. *Plant and Soil*, 19: 305-314.

LAL, R. (2001) — Managing world soils for food security and environmental quality. *Advances in Agronomy,* 74: 155-192.

LÆGREID, M.; BØCKMAN, O.C.; KAARSTAD, O. (1999) — *Agriculture, fertilizers and the environment.* CABI Publishers, Norsk Hydro ASA, Norway.

MAURIZIO, Q.; MILLARD, P.; TAGLIAVINI, M. (2002) — Storage and remobilisation of nitrogen by pears (*Pyrus communis* L.) trees as affected by timing N supply. *Eur. J. Agron.*, 17: 105-110.

MENGEL, K.; KIRKBY, E.K. (1982) — *Principles of plant nutrition*, 3rd ed. International Potash Institute, Bern.

NICOLARDOT, B.; DUTHION, C.; CHÉNEBY, D. (1996) — The composition of crop residues: a rather slow mineralization. *Grain Legumes*, 14: 18-19.

OLESEN, J.E.; BINDI, M. (2002) — Review. Consequences of climate change for European agricultural productivity, land use and policy. *Eur. J. Agron.*, 16: 239-262.

PEOPLES, M.B.; HERRIDGE, D.F.; LADHA, J.K. (1995) — Biological nitrogen fixation: investments, expectations and actual contribution to agriculture. *Plant and Soil*, 141: 13-39.

PIRES, C.B. (2000) — *Agricultura e ambiente. Contradições*, INIA, Lisboa.

SEQUEIRA, E.M. (1998) — *Contribuição para o programa de acção nacional de combate à desertificação.*

SEQUEIRA, E.M.; CARRANCA, C. (1994) — *Surface and ground water pollution with nitrate from fertilizer use. Assessment and reduction of risks. Policy measures to control environmental impacts from agriculture in the European Union. Mineral Emissions (Air 3. CT93-1164)*, 2: 1-7.

SOARES, M.C. (2001) — *Agricultura intensiva e riscos alimentares. Realidade e percepção*, Lisboa.

TORRES, L.G. (2002) — *Agricultura de conservación en olivar: sus beneficios medioambientales*, in "Actas do 1° Congresso Nacional de Mobilização de Conservação do Solo Évora" (G. Basch; F. Teixeira, Eds): 63-73.

VOS, G.J.M. (1994) — *The fate of ^{15}N-ammonium nitrate in an agricultural soil-plant system*. These n° 1208 (1994) pour l'obtention du grade de Docteur des Sciences Techniques, Lausanne.