WHEAT PRODUCTION IN STRESSED ENVIRONMENTS

Developments in Plant Breeding

VOLUME 12

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Wheat Production in Stressed Environments

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Bread wheat field in the Argentine pampas

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PREFACE

Wheat researchers have made unique contributions and excellent progress to the production increase over the past several decades, mainly in the less developed countries; however, there are many challenges that still lie ahead to make food more accessible than ever before in a sustainable manner and to meet the needs of a global growing population. Numerous biotic and abiotic stresses affect wheat in major production areas and its future growth will most likely come from marginal environments where such stresses play even more important role. Developing countries are becoming increasingly urbanized. As urban populations grow, productive land disappears and this implies the need for more intensive cropping to keep pace. Water utilization for agriculture is also facing more competition from uses in urban areas. Focused efforts to improve wheat water-use efficiency are crucial to ensure sustainability of food production in water-constrained regions.

Current crop management systems such as reduced or zero tillage, stubble retention and precision agriculture are vital to satisfy the increasing needs of food and maintain at the same time the sustainability of natural resources. The widespread adoption of conservation farming techniques requires the introduction of changes to wheat varieties in disease resistance, particularly stubble-born diseases.

Global climate change will impact on agriculture due to temperature, precipitation and length of growing season alterations, and might also modify the impact of pests, diseases and weeds, increasing the risk of crop failure in certain wheat producing areas. Stresses represent a challenge for wheat researchers and impact the world food production; stabilization of production in all environments remains an important aim in the future. We believe that the future challenge to wheat production will find solutions much faster today than in the past: today the wheat community is more united to understand and handle problems in a collaborative way.

The program of the Seventh International Wheat Conference (7 IWC) held at Mar del Plata, Argentina, between November 27 and December 2, 2005, included, besides two opening lectures, oral and poster presentations grouped in seven sessions according to main topics. Each session was opened by two keynote talks delivered by invited speakers. A guided half day tour to Balcarce Experimental Station of the National Institute of Technology for Agriculture and Animal Husbandry located 60 Km W from Mar del Plata showed participants the Station wheat breeding program as well as wheat fields on different crop rotations and under several agricultural systems. The 7 IWC Conference was preceded by a workshop on International Wheat Improvement at the CGIAR Centers and Global Initiatives on Rust sponsored by the US AID, the USDA-ARS and the National Wheat Improvement Committee. In addition, the Conference was an excellent opportunity for an open workshop organized by the International Wheat Genome Sequencing Consortium.

Feeding the world does not only mean addressing the need for total energy requirements but also the need of micronutrients. Wheat biofortification may be one way to reach this goal. In the post-Conference mini-symposium HarvestPlus: Breeding for Public Health, current researches and achievements of CGIAR HarvestPlus Challenge Program on this topic were presented. The Conference was distinguished by the presence of Dr. Norman Borlaug, 1970 Nobel Peace Prize Laureate, who was in charge of the Dinner Conference, and Dr. Evangelina Villegas, 2000 World Food Prize Laureate.

These Proceedings compile the 7 IWC oral presentations and hopefully will be useful to wheat researchers, breeders, agronomists and students.

We are indebted to Dr. S. Rajaram, Integrated Gene Management Director at ICARDA, and Chair of the International Scientific Committee of the Conference, for his guide in the outline of the scientific program and his overall support. We extend our appreciation to each of the International and Local Organizing Committees members and to the Session Chairs. Special thanks are due to the scientists who collaborated with valuable suggestions to improve this publication: P. Abbate, Z. Bedö, D. Calderini, F. García, S. Germán, M. M. Kohli, D. Lafiandra, S. Nagarajan, J. Rogers, P. Ruckenbauer, N. Saulescu, M.L. Seghezzo, E. Souza and R. Trethowan. We thank M. Pérez for the technical edition of the manuscripts and would like to express our special gratitude to Nelly Salomón for her permanent dedication, and our tribute, on behalf of the Local Organizing Committee, to Enrique Suárez, who joined us in this endeavour up to May 2005.

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THE GLOBAL NEED FOR A SUSTAINABLE AGRICULTURAL MODEL

Its adoption and some of the benefits derived from the process with special reference to the Argentinean case

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THE CULTIVATION OF PLANTS AND THE FEEDING OF MANKIND. THE RELATIONSHIP BETWEEN THE RURAL AND URBAN SECTOR

Since the beginning of agriculture, ten thousand years ago, the cultivation of plants were basically managed by doing some kind of soil tillage. Even the strategy was useful to accompany an ever increasing human demand for agricultural products, the cost in terms of natural resources degradation — as soil erosion, fresh water depletion and other undesirable impacts — were too high and at the present time they should be consider as no longer affordable by humanity. A new conciliatory formula and agricultural approach is absolutely needed to be able to simultaneously keep and even enlarge the actual agricultural output and at the same time keep the capacity to do it in the future. In other words the achievement of a higher level of productivity and profit obtained with a higher level of sustainability must be seen as the new goal and as an urgent need.

In the present world and in direct relationship with the degree of socioeconomic development achieved by a society, an ever-growing disconnection between the urban and rural populations can be noticed worldwide. Frequently, this disconnection generates a state of ignorance (and even confusion) about the fundamental value and key role that the rural sector fulfils within societies and within our present civilization. This state of things delays — and even hinders — the possibilities for

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the global agricultural sector to speed up the process oriented to the achievement of the needed levels of productivity with sustainability and profit. However, reaching these levels proves indispensable to satisfy the ever-increasing demand of quality and quantity of food and other products and services derived form agriculture. At this point we should also take into account the fact that nowadays directly or indirectly it's from the cultivation of plants that mankind obtains around ninety percent of the food and that up to the present, with only a few exceptions of limited relative magnitude such as hydroponics (the cultivation of plants in an aquatic medium and under controlled conditions), the agro-productive processes are carried out on soils and environments reasonably apt for agriculture. Therefore, we should strive for society to reach an adequate level of information so it can appreciate the substantial role that the rural sector plays — by means of its agro-productive system — when it comes to using the soils and other natural resources as the basis to satisfy the feeding demands of mankind as a whole.

THE PROBLEM OF HUNGER AND THE ENLARGEMENT OF TOTAL PRODUCTION AND THE NEED TO ACHIEVE HIGH PRODUCTIVITY WITH SUSTAINABILITY

As part of the world agricultural production system we should have clear in mind that the problem of hunger is not only linked to total world food production if not also related to issues like the deficiencies in distribution and access to the productions as well as to technological, cultural, social, political, ideological, religious, economic, structural and even war-related constraints. Also, and even we are aware that most of these restrictions and problems extend beyond our reach and possibilities as producers, we clearly understand that without an increase in productivity and in the total world food production output, mankind will probably have very little chances to enlarge its cut so we have to keep our efforts oriented to permanently increase the capacity to enlarge the total world food output or the size of the world food cake.

Up to the present, there are only two basic mechanisms known to enlarge the total agricultural production; namely: the expansion of the agricultural area by converting ecosystems into agro-ecosystems and/or the achievement of a higher level of productivity on those already converted. During the past a combination of both mechanisms were utilized to accompany the increase of the food demand. While looking at the future and been aware of the progressive scarcity of the resources needed to carry out the agricultural process (particularly the natural resources), the permanent maximization of productivity within a more sustainable frame should be considered as a must and should be prioritized over the alternative of expanding the agricultural areas to increase total production as the basic mechanisms. If we do so we may be able to reduce the rate of conversion of less disturbed ecosystems into agro-ecosystems. Also, to be able to maximize productivity in a sustainable manner, the wise use of all the capacities and knowledge humanity has developed up to the present and will continue to develop in the future appears us a must. The capacities and knowledge needed to achieve this goal, span from those of pragmatic origin —

and even ancestral ones very much related to the observation and experience as producers in close contact with our environment and everyday agricultural process reality-, to those related to the most revolutionary and state of the art advancements of science and derived technology. None of them should be dismissed, but science — and not ideologies — should be the reference base in every case. History shows us that it's no other but this the pattern that mankind has adopted in the past to progress in other fields such as human health and the development and offering of all kinds of goods and services included the agricultural ones.

THE CAAPAS EXPERIENCE AND THE EMERGING OF A NEW AGRICULTURAL PARADIGM

Conventional agriculture, based on tillage (mainly plough) of soils, was the agricultural paradigm that humanity applied for nearly ten thousand years since the advent of agriculture. However, and even admitting that it help to feed humanity in the past, the utilization of this system in many cases generated an staggering level of degradation of the natural agro-ecosystem components as soil, water and others. Just as an example of such undesirable phenomenon we can consider that in many situations we were losing over ten tons of soil per each ton of grain produced. Clearly it represents a cost that mankind can not any longer afford in the present and will not be able to afford in the future. Therefore, we feel that this model (based on plough and tillage), upon which still nowadays most of the world's agricultural system is based, must be abandoned for good. The no till system, among others based on main principles as the absence of tillage and the covering of the topsoil by stubble, allows us to access a reasonable, sustainable — and even restoring — use of the basic agro-ecosystems components such as soils, water, biodiversity, etc.

Other technological tools such as the use of biotechnology, fertilizers and agrochemicals, the application of the most modern concepts regarding the handling of agro-ecosystems such as soil nutrition rather than crop fertilization, nutrient recycling, integrated pest management (weed, insects, diseases), the utilization of thresholds for economic damage of pests, the concept of rotation as general premise (and not just as variation of crops); constitutes only some examples of the pillar principles of the realistic building ground of the modern agriculture that we heavily promote and utilize within CAAPAS.

Considering the experience accumulated during the last twenty five years across many different agro-ecosystem conditions, we can state that wheat can be perfectly and successfully grown under No Till. Furthermore, along with other winter and summer grasses and legumes (and other broadleaf crops), play an important role in widening the rotational pattern needed to further improve the system functioning.

The fully utilization of them comprises a paradigmatic change absolutely needed to be able to enlarge the chances to satisfy the needs of a human population that doesn't cease to expand both in size and in economic capacity that allows to improve the diets both in quality and quantity further enhancing the need to enlarge total production.

The objective measurements carried out in the over 50 millions hectares under the No Till belonging to the countries members of CAAPAS (and over the around 90 millions hectares worldwide) show a significant increase in productivity and in a highly efficient control — and even reparation — of the erosion and degradation of our soils and water.

The above mentioned, together with the possibility of retaining atmospheric carbon (as organic substance of the soil) it's what makes our eco-systems become more healthy, what increases the biodiversity contained in them and what makes them become more resilient and at the same time more reactive, i.e., they deliver more output for each unit of applied input. (di Castri 2002) These achievements constitute only some of the indisputable proves of the value that this new paradigm can provide to make further advancements in the provision of food and in the relationship with our soils, our fellow men and the environment in general. The new agro-productive proposal of CAAPAS, is not based in a new hypothesis or in something that can theoretically happen, but in our daily reality as farmers under No Till, which, with the introduction of adaptations to the particular conditions of each agro-ecosystem, results applicable across the great variety of agro-ecosystem conditions that we can find across the world.

THE CASE OF ARGENTINA. NO TILL AND THE MOSHPA (MODERN SUSTAINABLE HIGH PRODUCTIVITY AGRICULTURAL) MODEL DEVELOPMENT AND ADOPTION

The Argentinean farmers were aiming, and found in No Till and the MOSHPA model principles, a valid (realistic and applicable) way to improve productivity and profit but at the same time to counteract the evident soil erosion (water and wind born) and general agro-ecosystem degradation process, that was becoming more and more evident and worrisome during the last third of the past century. (Casas, Roberto R. 1997). The first No Till extensive Argentinean trials started on the seventies; however, it was not until after the end of the eighties, and beginning of the nineties, that the adoption process boomed. The evolution of the adoption process can be seen on next Fig. 1. From a couple of hundred thousand hectares in 1990; the adoption jumped to more than sixteen millions hectares that account for around 65 % of the Argentinean grain cropped area.

The full utilization of new technical developments and approaches were strongly supporting and pillaring the Argentinean No Till adoption process. An evolved and more specific use of agro-chemicals to control weeds, diseases and insects as well as a further development and utilization of integrated weed, disease and insect management principles. Also, new rotational strategies; the development, selection and utilization of superior genotypes created by conventional breeding as well as by biotechnology; and the development of a new generation of specially adapted No Till drillers and planters able to properly operate under a soil covered condition and no tilled condition; can be considered as some of the most relevant factors that allowed the practical implementation and evolution of No Till.

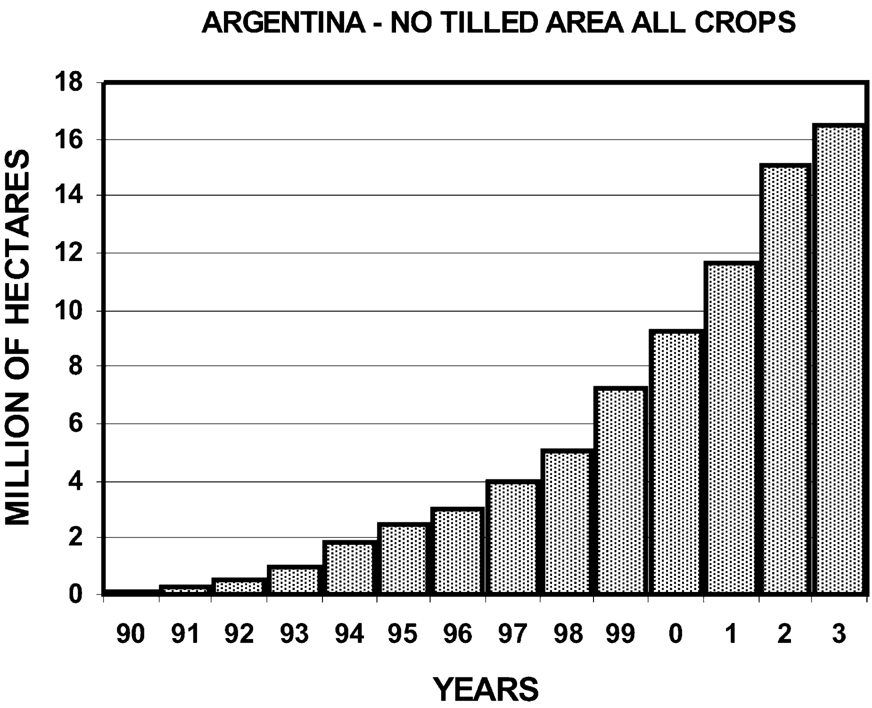

Figure 1. Evolution of the No Till adoption in Argentina

Also, a systemic approach and a clear proactive farmer attitude lead to the improvement of several agronomic and organizational strategies that allowed to quickly scaling up the process. Besides this, the strong domestic and international interactions among farmers promoted by CAAPAS (American Confederation of Organizations for a Sustainable Agriculture) and by AAPRESID (Argentinean No Till Farmers Association), represented a valid mechanism to keep improving, adjusting, evolving, and scaling up, the No Till and MOSHPA model principles adoption in America all and in other parts of the world. (Peiretti, Roberto A, 2003).

EVOLUTION OF THE ARGENTINEAN GRAIN PRODUCTIVITY AND TOTAL PRODUCTION

After 25 years of No Till experience in certain cases, it appears that the longer the period under no till the healthier and more productive the agro- ecosystem becomes. Erosion and soil deterioration symptoms almost disappeared and instead of them, clear evidences of a soil that increases its fertility or ability to produce can be detected.

During the nineties, all these phenomena together with an economic environment that strongly stimulates investment along all the Argentinean farming chain, yielded a significant increase of the total production in a sustainable manner. Focusing on

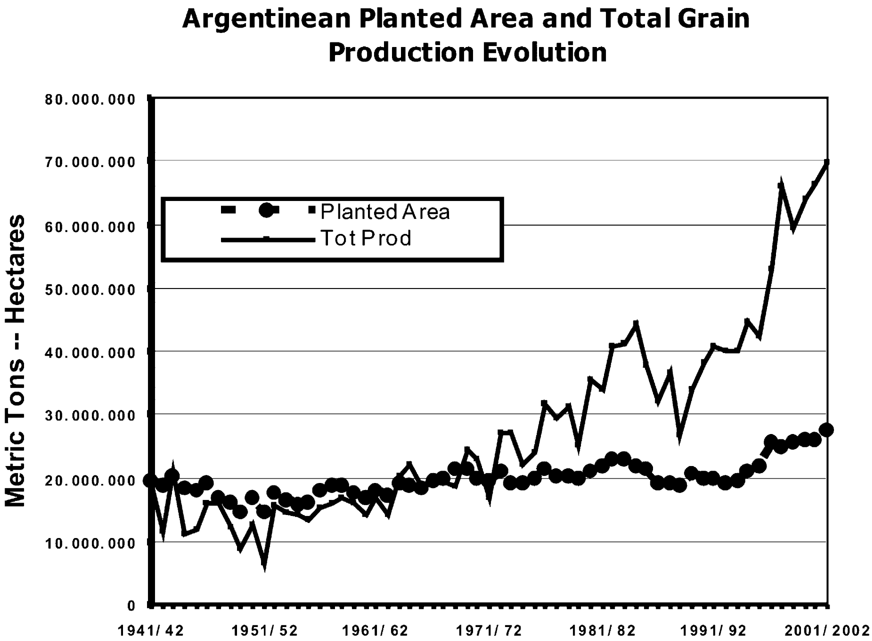

Figure 2. Evolution of Argentinean Grain Production

next graphic that includes the area cropped and the evolution of total Argentinean grain production between 1941/42 and 2001/02. In Fig. 2., we can see how much the total production grew especially during the last fifteen years in coincidence with cropping/farming system transformation.

Even part of the total production growth may be explained by an enlargement of the total area cropped on the country as well as from a variation of the area share among different crops, the biggest part of the explanation can be found in a relevant productivity increase. The productivity increase (paired with a significant reduction in production costs of all type), allowed a profitability and competitiveness improvement, but now obtained within a sustainable frame. (Peiretti, Roberto A, 2001).

The more evolved Argentinean cropping and farming system, yielded significant benefits that even with different intensity, reached all the farm size; from those large scale market oriented ones to the small scale mostly subsistence ones.

CONCLUSIONS

A few years ago, Dr. Norman Borlaug, the agronomist's father of the Green Revolution and Novel Peace Price Laureate 1970, stated: One of the most serious challenges that humanity will be faced with during XXI century, will be to develop the capacity to produce enough food for humanity but conserving the environment at the same time.

The new agro-productive model that we promote at CAAPAS is based on science — but not in ideologies — and also on humanitarian and realistic feeling. This model promotes the abandoning of tillage and the criteria of exploitation and plundering of resources to enter a new phase in which agriculture — based now on No Till — will develop efficiently, with high productivity and stability but also with sustainability and improvement of all the resources involved in the process. Without a doubt, the thorough understanding of these issues by the international community will help the world farming system to speed up the transformation of the farming system and agricultural paradigm toward a more evolved stage. If so, we will be increasing in a magnitude similar to our success, the generation of many benefits that, apart from benefiting the producers will spread simultaneously to the whole society and mankind as well.

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THE ECONOMICS OF WHEAT

Research challenges from field to fork

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Abstract: During the two generations leading up to the turn of the century the global population grew by 90% whilst food production expanded by 115%. As with other food crops, wheat productivity rose steadily during the past 40 years through the availability of better varieties, inputs, markets and management. As a result of the growth in supply – wheat is the most widely internally-traded cereal- producer prices have fallen by approximately 40% during the past two generations. Notwithstanding the increase in per capita food production, around 800 million people are hungry and around 1.2 billion people live below the international consumption poverty line of US $ 1 per capita per day. Wheat is grown on a significant scale in 70 countries and for many poor households wheat is a significant production or consumption item. Nevertheless, global food security is quite fragile, particularly when looking towards the middle of the century: because of projected needs for human, animal and industrial uses, global wheat production is expected to increase from nearly 600 million tons to around 760 million tons in 2020, with limited expansion of sown area

The estimates of rates of returns on past breeding and agronomic research are very high, partly because of the wide adaptability of many new wheat cultivars. The paper distinguishes returns to productivity and maintenance research, as well as socio-economic and policy research. In the search for means to accelerate the achievement of the MDGs, the effectiveness of targeting research to marginal areas and marginal farmers becomes an important question

Wheat, therefore, is crucial to current and future global food security – the question is: can the achievements of the past be continued in the coming decades? The global demand for wheat is projected to grow modestly at 1.2% p.a. for food and 0.8% p.a. for feed. Greater growth may be experienced in certain end-uses including flour, pasta and bakery products; consequently, quality attributes are assuming greater importance. Many developing countries have implemented trade reforms but annual producer subsidies in OECD countries amount to about $17 billion. There has also been significant tariff

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escalation in flour, pasta, bakery products, so trade tends to occur within trading blocks such as EU and NAFTA. There is strong evidence of fast growth in value added along wheat value chains including retailing

Keywords: wheat economic , markets, trade, research impacts

INTRODUCTION

During the two generations leading up to the turn of the century the global population grew by 90%. Although food production expanded by 115% during this period, chronic hunger still afflicts more than 800 million people and some 1200 million people subsist on US $ 1 or less per day. The global community recently re-affirmed the importance of the reduction of hunger and poverty during the UN Millennium Summit. Adequate nutrition and rural livelihoods, which depend upon efficiency and value added along the chain from “field to fork”, i.e. from production to consumption, underpin poverty reduction and rural economic development. Moreover, discussion of the link between food security and political stability is growing in the popular press and academic literature (see, for example, Falcon and Naylor 2005). Although the argument that poverty reduction is an international public good is contested, there is little doubt that most of the knowledge generated through international research system is an International Public Good (IPG) (Ryan 2005). The road to household and global food security faces major challenges, not least because of the substantial projected increases in food and feed requirements and the pressure on available land and water resources (Runge et al. 2003).

Wheat, along with maize and rice, underpin the world food supply, providing 44% of total edible dry matter and 40% of food crop energy consumed in developing countries. Bread wheat, which accounts for 90% of total wheat production, is grown on a substantial scale in more than 70 countries on 5 continents (Lantican et al. 2005). Durum wheat accounts for the remaining 10% of wheat production, of which more than half is found in North Africa and West Asia. Wheat is produced in a wide range of climatic environments, production environments and farming systems (Dixon et al. 2001). Of the total harvested bread and durum wheat area in 2005 of approximately 226 million ha (FAO 2006), about half is located in developing countries; and about one-third is found in countries where average farm household income is less than US $ 1 per capita per day.

As with other food crops, wheat science (including breeding, pathology, agronomy and economics) has contributed to a steady increase in wheat productivity and improved livelihoods of producers during the past 40 years through, inter alia, the availability of better varieties, more effective pest and disease control, better production practices and improved household management. In developing countries modern varieties were sown on 83% of irrigated and high rainfall wheat land by the late 1970s and on practically all high potential crop land by 1990 and with substantial increases in productivity (Byerlee and Moya 1993).

Looking into the future, global wheat requirements are expected to increase from around the current 600 million tons to approximately 760 million tons by 2020 (CIMMYT 2004). Thus, wheat not only has a key role to play in current food security, but also in future global food security and poverty reduction. It is argued that the Green Revolution approach that created the enormous success in past decades is not the only, and indeed not necessarily the best, way forward in the coming decades: wheat scientists are now confronted with many new research challenges in relation to the sustainable intensification of production and value addition at all stages from field to fork as well as a new set of opportunities including the Gene Revolution (Pingali and Raney 2005).

The second section of the paper considers changes in wheat markets and trade. The third section summarizes evidence related to research impacts. These two analyses provide the basis for a discussion of drivers of change and plausible futures of wheat in the fourth section. The conclusions on ways forward appear in the fifth section.

WHEAT MARKETS AND TRADE

Notwithstanding the general decline in agricultural exports from developing countries, from more than 50% of international merchandise trade in 1960 to less than 20% now (FAO 2003), wheat is the most traded food grain in international markets. During the past few decades developing countries have gradually become major net importers (to the degree that wheat now accounts for 43% of food imports to developing countries). On the other hand, 81% of wheat is produced and utilized within the same country, and a large proportion within the same community or household. The increase in per capita supply and productivity has led to the well-known steady decline in international wheat prices – by some 40% since 1960 – while input prices are steady or rising. Such a situation can lead to increased domestic cost of production, favours the importation of wheat and may have discouraged the adoption of new cultivars.

Even though international market prices have declined, wheat production is protected in many countries. Consequently, producer prices differ markedly between countries, ranging from more than US $ 1000 per ton in Japan and more than US $ 500 per ton in Iran, Korea and Nigeria to less than US $ 200 per ton in a majority of countries during 2001 (Aksoy and Beghin 2003). The full implications of such high prices for sustainable production and for wheat science are not clear. Such high and stable producer prices provide incentives for the intensification of production, including the adoption of new cultivars, albeit at the cost to Government of the producer subsidies or the cost to consumers, notably the poor, of high food prices.

While urbanization increases demand, the marked shift from cereal-based diets to energy-dense diets with more vegetable oil, meat and sugar diminishes the relative importance of wheat in the diets of many middle and upper income countries