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Stakeholder perception of wheat production constraints, capacity building needs, and research partnerships in developing countries

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Abstract In order to update the available information on the main current and future constraints on wheat production and human capacity development, a survey covering nineteen developing countries, including major wheat producers, was conducted prior to the 2006 International Symposium on Increasing Wheat Yield Potential in Ciudad Obregon, Mexico. The results emphasize the substantial yield losses associated with a number of critical abiotic, biotic and socioeconomic constraints, and indicate their global prevalence. The most important constraints on wheat production are heat (affecting up to 57% of the entire wheat area in surveyed countries), competition with weeds, and diseases (both affecting up to 55% of wheat area). Of the socioeconomic constraints listed and evaluated by respondents, access to mechanization and availability of credit were the most often highlighted. The most-reported infrastructural constraints were insufficient resources for field station operations. When evaluating the importance of research partnerships to achieve national wheat program goals, respondents from all 19 countries assigned the highest importance to partnerships with international agricultural research centers. The most desired outputs from these include development and exchange of germplasm and assistance in capacity building and knowledge sharing. These findings confirm the anticipated constraints and needs over the next 10–20 years and affirm the importance of international agricultural research centers in providing support to address them.

Keywords Wheat · Production · Constraint · Research · Capacity · Building

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Introduction

For the past 40 years, international agricultural research centers (collectively the Consultative Group on International Agricultural Research [CGIAR]) have provided support to national agricultural research systems (NARS) of developing countries for agriculture and natural resources research. The CGIAR system, of which CIMMYT is one of the oldest and largest centers, is a nonprofit organization that is guided in its research by the diverse goals of its stakeholders (Reynolds and Borlaug 2006). Plant breeding is a lengthy process in which the lag time between the initiation of crossing and the release of an improved variety can easily last more than a decade, and an additional decade often elapses before the released variety is adopted by the most suitable farmers (Brennan and Byerlee 1991). Great care

should be therefore taken in ensuring that medium- and long-term research objectives are aligned with stakeholder needs.

Prior to participation in the International Symposium on Increasing Wheat Yield Potential (Reynolds et al. 2007), participants from 19 developing countries, representing the main sources of wheat production in the developing world—including Central Asian countries of the former Soviet Union—completed a questionnaire covering, *inter alia*, the main current and future constraints to wheat production in their countries, the most important partnerships, and the areas of need in capacity building. The data from the completed questionnaires included Latin America (LAM) (Argentina, Brazil, and Mexico); Sub-Saharan Africa (SSA) (Ethiopia, Sudan, and Zimbabwe); Central and West Asia and Northern Africa (CWANA) (Morocco, Egypt, Turkey, Azerbaijan, Kazakhstan, Uzbekistan, Tajikistan, and Iran); and South and Southeast Asia (SSE Asia) (Pakistan, Nepal, India, Bangladesh, and China). Collectively these countries represent 102 million hectares of wheat (47% of the global wheat area or 89% of the wheat area in developing countries) and 285 million tons of wheat production (45% of the global wheat production or 92% of wheat production in developing countries (FAO 2006).

In relation to the interpretation of the summary results that follow, it is worth noting several points. First, the responses to the questionnaires are often only best estimates and perceptions of senior national wheat breeders. In many cases their estimates are not supported by detailed studies at the country level as these have often never been conducted. Second, the summary results presented in the following sections are, for the most part, area weighted sums and averages. Therefore, the responses from India and China have a strong influence on the area weighted results. Third, while the data may be viewed only as subjective estimates of national wheat breeders, they represent the best available information on the subject. Moreover, this data underpins major national policy-making and resource allocation decisions, and therefore is worth sharing with other scientists and policy-makers associated with research on wheat.

Current and emerging constraints to wheat production

Abiotic stress

A major constraint that is estimated to affect up to 58.7 million hectares of wheat area in sample countries (57.3% of entire wheat area in surveyed countries) is heat (see Figs. 1 and 2). Average estimated yield loss caused by extreme temperatures varies between 14.7 and 31.3%, depending on the region. The total estimated loss (aggregated over the 19 sample countries) amounts to 21 million tons. The largest areas affected by heat stress were identified in Central, South and Southeast Asia. The major threat identified by respondents was terminal heat stress during anthesis and grain filling period, which accelerates maturity and significantly reduces grain size, weight, and yield.

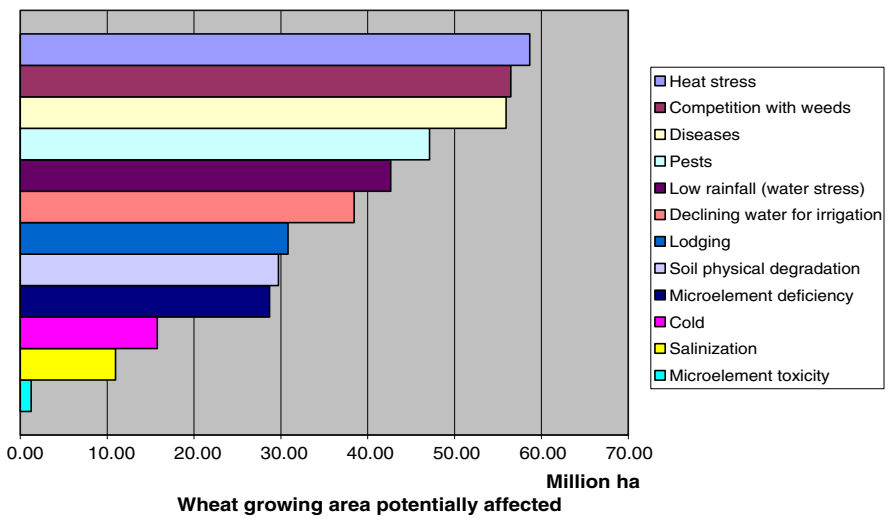

Fig. 1 Wheat area (in million ha) potentially affected by various abiotic and biotic production constraints

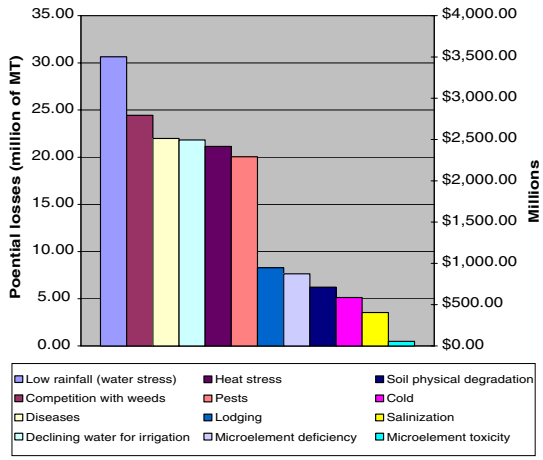

Fig. 2 Potential wheat production losses (in terms of MT and US$) caused by biotic and abiotic constraints (presumption 1 MT of wheat = US$115)

Low rainfall (moisture stress) is the second most significant abiotic constraint to wheat production in terms of area potentially affected, 42.6 million hectares (41.6% of wheat area in surveyed countries). Average estimated yield loss caused by low rainfall varies between 19.3 and 50.4%, and overall is estimated to cause 31 million tons in losses, the highest among all constraints identified in this survey. The areas potentially affected by low rainfall are present in all four regions: SSE Asia, CWANA, SSA, and LAM. The most common threat according to the respondents is yearly fluctuation (periodically occurring 'dry years') and uneven seasonal distribution of rainfall.

A third constraint to wheat production, potentially affecting up to 38.4 million hectares of wheat in 19 surveyed countries, is the declining availability of irrigation water. Average estimated yield losses caused by declining availability of irrigation water varies between 20 and 37.2% and can cause losses of up to 21.8 million tons of wheat annually. The largest proportion of potentially affected areas appears to be in SSE Asia. Reasons for declining availability of irrigation water include overexploitation of ground water resources, competition with other crops (cash crops), restrictive governmental policies, and deterioration of irrigation infrastructure.

Factors such as lodging, physical soil degradation, and microelement deficiencies each affect approximately 28–30 million hectares. Potential losses in terms of wheat production oscillate between 7.7 and 20%, which represents an aggregate loss of 6–8 million tons of wheat for each of the three constraints. The main causes of lodging include tall varieties (weak straw), poor crop management, high yield (over 6 t/ha) in wet years (excessive irrigation), heavy rains, and windy conditions. Soil degradation is reported to occur mainly due to heavy tillage and mismanagement causing soil compaction, organic matter depletion, soil erosion, and water logging. Micronutrient deficiencies, such as an unavailability of zinc and boron, often stem from pH imbalances.

Relatively smaller areas of wheat production are affected by other factors such as cold (15.8 million hectares) principally in Central and West Asia, China and South America; salinization (11 million hectares) in Central and South Asia; and microelement toxicity (1.2 million hectares) mainly in Turkey and Brazil. These three constraints may cause annual losses of 5, 3.5, and 0.5 million tons of wheat, respectively.

Cold refers to sporadic frost damage to susceptible varieties, particularly in the case of winter wheat and in mountain areas. Saline soils are a growing problem, especially in arid and semiarid areas and in fields exposed to excessive irrigation. Problems with microelement toxicity (Al, Mn, and Bo) occur mainly in areas with low pH conditions. It is important to mention here, that micronutrient imbalances, and in particular micronutrient toxicities, are not well researched and may have a greater importance to cereals production than the survey data suggest, especially in rainfed environments.

Other mentioned production constraints of minor importance include macronutrient deficiencies (especially in humid years) and preharvest sprouting.

Biotic stress

Biotic stresses are reported to affect roughly the same area as heat stress (Figs. 1 and 2). Reported across all 19 countries, weeds affect approximately 56.5 million hectares. Estimated yield loss caused by weeds varies between 8.5 and 23.9%, depending on the region, and overall could cause up to 24 million tons in losses annually. Among the most often mentioned weeds are *Avena* spp., *Phalaris* spp., *Chenopodium* spp., *Rumex* spp., *Medicago* spp., *Amaranthus* spp., *Lolium* spp., *Polypogon* spp., *Convonvulus* spp., and *Echinochloa* spp. Likewise, diseases are rated nearly equally in importance, affecting roughly 56 million hectares.

Also reported across all 19 countries, yield losses caused by diseases varies between 14 and 27.1%, depending on the region, and, overall, can cause annual losses of up to 22 million tons. The most serious diseases cited were the leaf and stripe rusts (*Puccinia triticina* and *P. striiformis*), *Fusarium* head blight (*Fusarium* spp.), Septoria blotch (*Septoria tritici)*, powdery mildew (*Erysiphe graminis*), tan spot (*Pyrenophora tritici repentis*), spot blotch (*Bipolaris sorokiniana*), bunts (*Tilletia* spp.), and eyespot (*Cercosporella herpotrichoides*).

Although pests (especially insect pests) are usually reported as a less binding constraint in wheat, potentially affected areas within the group of 19 surveyed countries cover approximately 47 million hectares. Estimated yield loss caused by pests varies between 12.2 and 22% and can overall cause up to 20 million tons of loss annually. The most often mentioned insect pests include aphids, sunn pest (*Eurygaster* spp.), Hessian fly (*Mayetiola destructor*), weevils, termites and some other species of minor importance. Losses are also reportedly caused by rodents and birds.

Although Soil Borne Pathogens (SBPs), including microscopic nematodes (cyst—*Heterodera* spp. and lesion—*Pratylenchus* spp.) and dryland root rotting fungi (including *Fusarium* spp. and *Bipolaris* spp.), have not been mentioned as a constraint by survey respondents, in several studies they are reported to be a major constraint to wheat monoculture based systems, particularly in dryland areas (rainfed or semi-supplementary irrigation). Unfortunately, due to their non-specific symptoms they are easily confused with other ailments such as nitrogen deficiency or poor soil types. Yield loss caused by these SBPs has been reviewed and documented in many regions of the world including Europe, America, and particularly in the more marginal cereal production areas of West Asia, North Africa, Australia and Canada. These areas reported losses between 3 and 50% (Diehl et al. 1983; Burgess et al. 2001; Singh et al. 2005; Nicol et al. 2001, 2004). Recent yield loss studies in Turkey have also reported significant yield losses up to 45% with both cereal nematodes and dryland root rots as the cause (Nicol et al. 2005 and Hekimham et al. 2004). Similar reports have indicated the widespread distribution and economic importance of these pathogens in China, India, West Asia and North Africa (Nicol and Rivoal In Press; Mergoum et al. 1994; Gargouri et al. 2003).

Socioeconomic constraints

Many socioeconomic constraints are related to agricultural policies and institutions that potentially affect the entire wheat crop. Therefore, the data on socioeconomic constraints was reported on the basis of number of countries and, in contrast to the preceding results, was not related to wheat area and production. Fifteen of the nineteen surveyed countries (78.9%) reported lack of access to mechanization (suitable machinery) as a constraint, mainly related to high purchasing and operational costs, and unavailability of small-scale and zero tillage machinery (see Fig. 3).

The second most cited socioeconomic constraint (73.7% of sample countries) is availability (and level) of credit. High interest rates, insufficient credit resources, lack of timely access in rural areas, and unwillingness of financial institutions to provide credit to the agricultural sector (particularly to subsistence/staple crops) were the most frequently reported constraints.

Twelve responding countries (63.2%) listed seed availability/quality and fertilizer availability as a constraint. In relation to seed, the class of improved seed (shortage of certified seeds) and lack of timely avail-

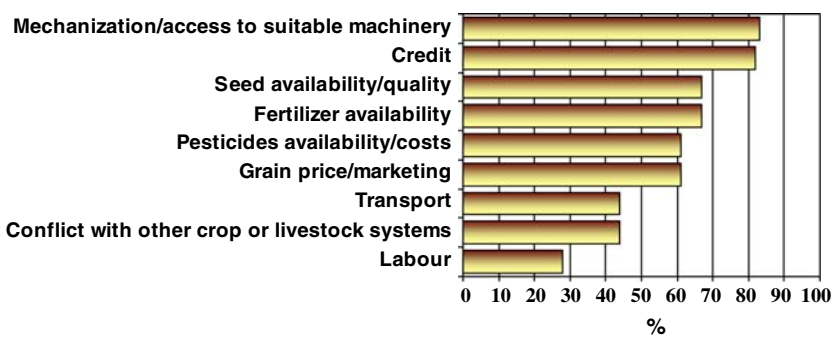

Fig. 3 Socioeconomic constraints to wheat production—percentage of surveyed countries facing the constraint

ability of improved varieties were emphasized. In the case of fertilizer availability, problems such as high price, timely availability, and quality were the main issues raised. Grain price and marketing and pesticide availability were reported as important constraints by 11 countries (57.9%). The most frequently recurring issues included seasonal fluctuation of wheat price, low selling price (not matched with production costs), inflation, purchasing that is not based on quality (protein content), and high competition with lower-priced imported wheat. In the case of pesticides, high cost and limited access to mechanization for application were the most frequently cited constraints.

In relation to transport, eight countries (42.1%) reported poor infrastructure and high costs of transport as a major issue. The same number of respondents (42.1%), but not necessarily the same countries, believed that wheat is competing (for area or time) with other crops (cash crops i.e., cotton, other field and horticultural crops) or livestock systems. Labor constraints were reported in only five of the 19 countries (26.3%). Labor constraints cited high labor cost, lack of skills, non-availability of workers at peak times, and urban migration.

Infrastructure constraints

Infrastructure constraints data were not related to wheat area and production. However, in terms of infrastructural constraints, scientists from 18 surveyed countries (94.7%) reported insufficient resources for field station operations as a high priority area (Figs. 4 and 5). In a few cases, limited land area and insufficient human resources (skilled technical staff) were listed as priority areas. Scientists from 17 surveyed countries identified insufficiently equipped laboratories and unavailability of field machinery, on average, as a high to moderate constraint (2.8 and 2.5, respectively, on a scale of 0–4, with 4 being the highest level of constraint). The most frequently reported issues were the lack of suitable laboratory facilities, modern equipment, technical expertise, proper field machinery and implements, and high purchasing costs. Insufficient resources to support collaboration and information sharing (namely access to bibliographic resources, insufficient language skills, internet connectivity, and limited financial resources) and lack of controlled growth environment facilities (greenhouses and growth chambers) were reported by 16 countries as a moderate priority. In 14 countries (73.7%), transport within the country/region was an issue due to old or insufficient vehicles and high costs (moderate importance). Lack of socioeconomic expertise for market and impact analysis (13 countries) and overall technical expertise in the areas of genetics, pathology, and agronomy (12 countries) was reported at a moderate level of importance. Eight to nine countries from the surveyed group also identified

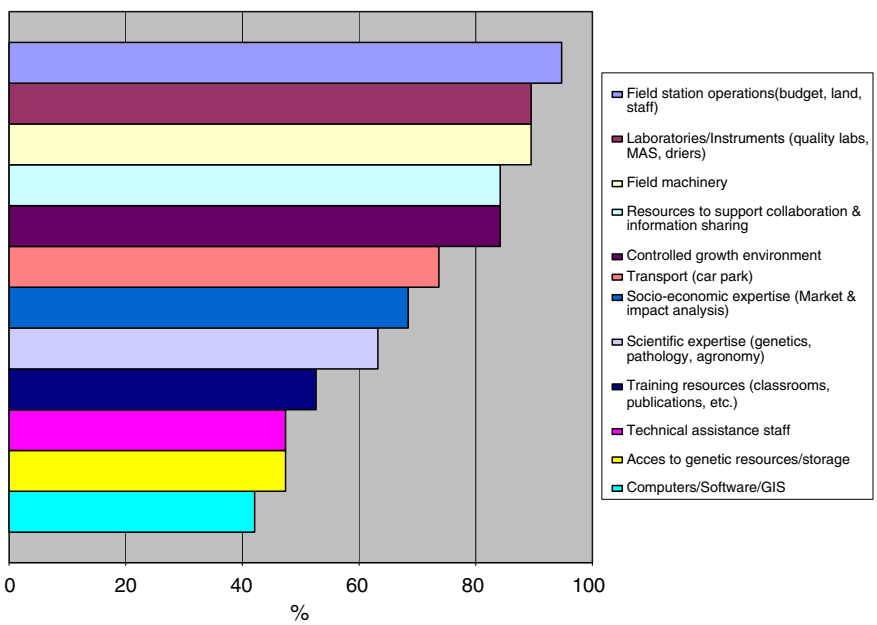

Fig. 4 Infrastructural constraints to research—percentage of surveyed countries facing the constraint

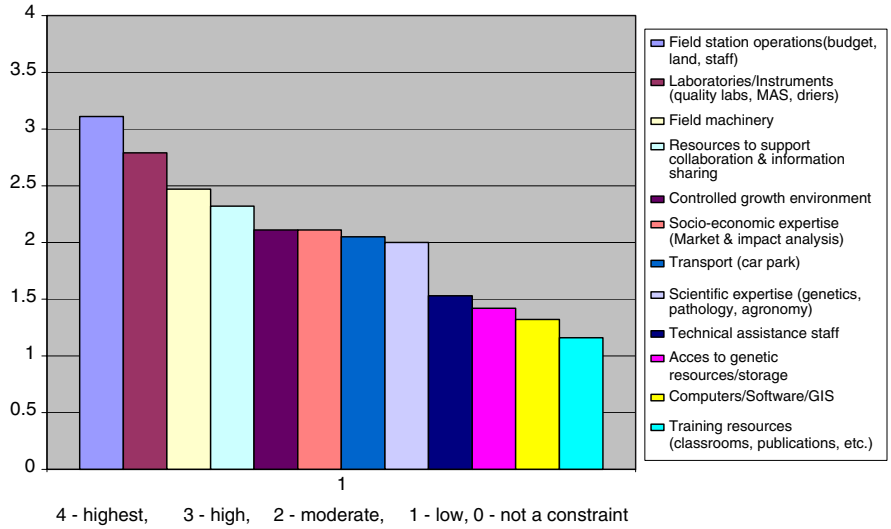

Fig. 5 Infrastructural constraints to research in surveyed countries in order of its importance

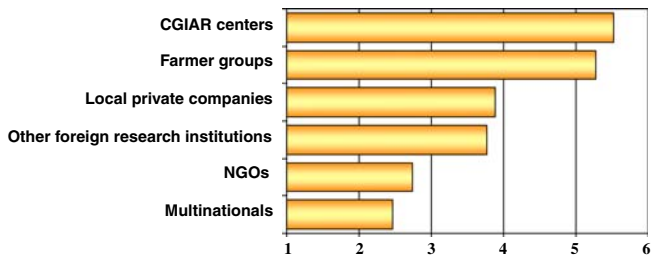

Fig. 6 Relative importance of research partnerships for achieving national wheat program goals in surveyed countries on a scale of 1–6 (6 represents highest importance)

technical assistance staff availability (lack of skilled technicians), training resources availability (classrooms, equipment, and access to literature), access to genetic resources and its storage (limited storage facilities, unwillingness to share genetic resources), and availability of computers and software (GIS, statistics) as a moderate- to low-level priority, depending on the country/region.

Importance of research partnerships to achieve national wheat program goals

On a scale of 1–6 (6 represents highest importance), scientists from 19 surveyed countries assigned the highest importance (average score of 5.5) to partnerships with international agricultural research centers, specifically in the areas of germplasm exchange, capacity building and professional development, information and knowledge sharing, expertise and technical assistance, and collaborative research (Fig. 6). The second most important set of partnerships were considered to be farmers' groups (average score 5.3) in the areas of participatory on-farm research, seed multiplication, distribution, germplasm maintenance, extension, and technology transfer. Partnerships with local private companies (germplasm exchange, participatory research, testing of new technologies, and seed multiplication) and with foreign research institutions (germplasm exchange, technical assistance/research support, and capacity building) were rated at scores of 3.9 and 3.8, respectively.

A relatively lower level of importance (average 2.7) was given to partnerships with Non-governmental Organizations (NGOs) (development projects, technology transfer collaborative research, and capacity building) and to partnership with multinational companies (credit and input supply, networking, information sharing), with an average score of 2.5.

Most useful/desirable outputs from CGIAR centers

The respondents to the survey identified the three "most useful and desirable outputs" from international agricultural research centers; these included: (i)

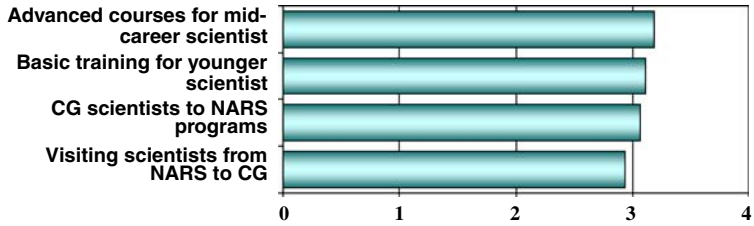

Fig. 7 Desirable outputs from CGIAR centers in the area of capacity building and training on a scale of 0–4 (4 represents the most desirable output in the surveyed countries)

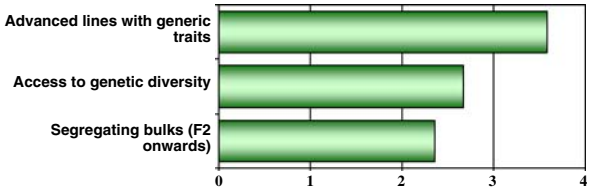

Fig. 8 Desirable outputs from CGIAR centers in terms of germplasm on a scale of 0–4 (4 represents the most desirable output in surveyed countries)

capacity building and training, (ii) germplasm, and (iii) knowledge sharing in the respective order.

Based on responses from 19 surveyed countries, the most desirable outputs of CGIAR centers (CIMMYT and ICARDA in particular) in the area of training and knowledge sharing were (i) advanced courses for mid-career scientists, (ii) basic training courses for young scientists, (iii) visits of CGIAR scientists to NARS programs, and (iv) visiting scientists from NARS coming to CGIAR centers. However the difference in their rating was negligible (Fig. 7).

In terms of germplasm, the most desirable output from the CGIAR centers were advanced lines with generic traits (3.6 on a scale of 4), followed by access to genetic resources in general (2.7 out of 4), and segregating bulk populations (2.4 out of 4) (Fig. 8).

Not surprisingly (given the disciplinary background of the respondents) the highest priority amongst the areas for knowledge sharing was given to breeding, followed by pathology and pest control, crop management, and statistics and experimental design—all areas representing the core business of both CIMMYT and ICARDA (Fig. 9).

Conclusions

The survey of senior collaborating wheat scientists from 19 wheat producing countries covers 89% of the wheat area in developing countries. Although based on subjective assessments in many cases, this data represent the information on which many national policy and resource allocation decisions are made. This presented survey is seen as a part of continuous monitoring of stakeholders perceptions of major constraints and challenges.

As expected, the survey indicates the prevalence and great yield losses associated with abiotic, biotic, and socioeconomic constraints to wheat production. Heat stress is the factor impacting the largest area, but water constraints are associated with largest economic losses. The list of infrastructural constraints, the importance of research partnerships, and desirable outputs from CGIAR centers (germplasm, capacity building and knowledge) correspond well, in most instances, to the global survey of national plant breeding and biotechnology capacity recently conducted by the Food and Agriculture Organization (FAO 2005; Guimaraes et al. 2006a, b). The survey indicated the high level of importance given to collaboration with international agricultural research centers and the clear correspondence between constraints identified by the survey and wheat research areas identified in the recently formulated CIMMYT Business Plan (CIMMYT 2006)—a good indicator of the strength of this alliance.

In relation to capacity building, the results align well with and reinforce the conclusions of the study ordered by the CGIAR Science Council on "Evaluation and Impact of Training in the CGIAR" (CGIAR 2006), and also the report on "CIMMYT's Formal Training Activities: Perceptions of Impact from Former Trainees, NARS Research Leaders, and CIMMYT Scientists" (Cooksy and Arellano 2006) concluding the importance and strong demand for various means of capacity building—advanced

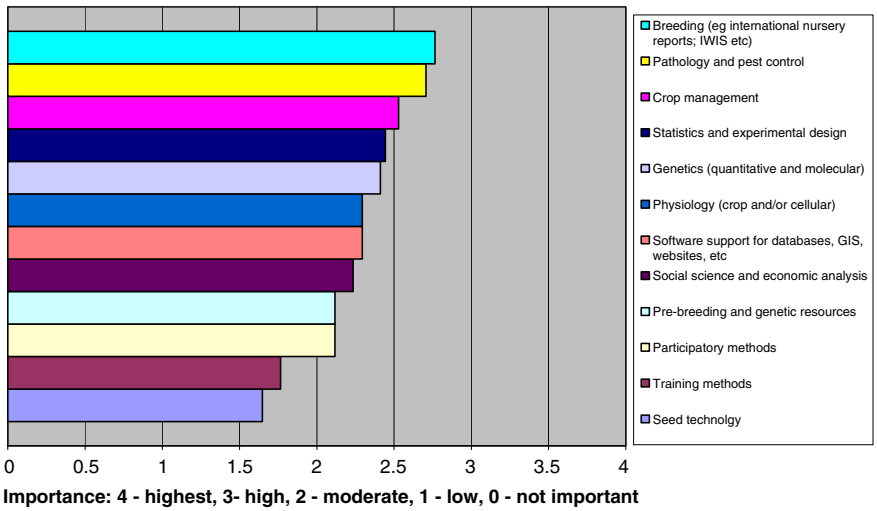

Fig. 9 Desirable areas for knowledge sharing (information, methodologies, publications) on a scale of 0–4 (4 represents the most desirable output in surveyed countries)

degree training for new scientists, support of continuous development of professionals through advanced specialized courses and visiting scientist stays, and access to information and knowledge (methodologies, best practices, scientific publications, etc.).

The findings confirm the anticipated constraints over the next 10–20 years and also the ongoing demand for capacity building and knowledge sharing. Projecting into the future, these needs will be met through multiple training and professional development modalities, which are necessary for sustainable continuous capacity development across all surveyed countries.

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