Estimate for Crop Productivity and Water-Limited Yield Enhancement in Major Agricultural Crops

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ABSTRACT: It is anticipated that demand for food, feed and biofuel feedstock would level off over the next four decades. There is a need for 1.16–1.31 percent annual growth in crop yields under potential (Yp) and water scarce conditions (Yw) for the three major cereal crops (maize, wheat, and rice) to satisfy anticipated global demand in 2050. Assume that the present absolute rates of yield improvement remain constant and/or that the recent signs of yield standstill for certain crops in some areas of the globe spread globally. There are many ways to increase genetic improvement rates for Yp and Yw, including genetic engineering of photosynthesis, above-ground ideotype design, and improving root capacity for water uptake, as well as improving root capacity for water uptake via root capacity improvement. To ensure timely development from possible beneficial characteristics to field-ready cultivars and broad acceptance by farmers, the time frames needed for each stage are carefully considered. The significance of molecular breeding tools for genetic improvement of basic and complex characteristics is discussed, as well as the needs of breeders for inclusion of potentially significant features in traditional breeding processes. Useful traits can be adopted into the breeding process faster if they are not protected by intellectual property or regulatory requirements. Increasing funding for focused research and identifying and eliminating or reducing drags at various stages of the idea to farmer-ready cultivar chain could speed up the exploitation of unexploited Yp or Yw opportunities in some crops and/or cropping systems. However, genetic enhancements such as hybrid vigor in rice or potential breakthroughs in photosynthetic gene editing are unlikely to affect Yp or Yw in a significant way. It is important to note that the unmet demand for cereals in 2050 would be much higher if we do not continue to invest in finding new genetic improvement sources and improving breeding tools.

KEYWORDS: Agriculture, Crop, Genetic Improvement, Productivity, Yield.

1. INTRODUCTION

The global population estimates for 2050 are about nine billion, leading to higher need for food and feed. Over the next four decades, other major drivers of demand for food and feed grain include improving living standards in many developing countries governmental measures targeted at decreasing present malnutrition levels and regulating laws that support the use of biofuels from grain. An estimate of the consequences of these factors on grain and food consumption by 2050 is a difficult job hidden by uncertainties, but thorough analyses indicate that cereal researchers would have to grow by 49% in order to satisfy anticipated demand. The estimate of first-generation biofuels' use of cereals as a feedstock is even more difficult to formulate, but the researchers estimated that additional quantities (more than what is needed for food and feed) from between 163 and 363 Mt y^{-1} will be required for 2050, equivalent to an increase of cereal grains demand globally by between 9 and 19% at the time. Meeting these grain needs requires world harvests to grow by 1.16% y^{-1} or 1.31% y^{-1} from now until 2050 at year-on-year compound rates[1].

In science and policy-making groups, there is a growing, though wide, agreement that only a tiny percentage of the increase in food production needed can be derived from the extension of the existing area. Limited availability of agriculturally suitable soils which have not been exploited, increasing appreciation of the magnitude of CO_2 emission from organic soil matter that inevitably ensures the conversion of grassland and forest into crops. The strong will to preserve untouched portions of important ecosystems such as tropical rainforests and to realize the hazards associated with the expansion in addition, high quality agricultural soil is anticipated to be lost for urban and other non-agricultural use. Finally, the realization is increasing that possibilities for extending irrigation are limited and that water presently utilized for irrigation in certain production systems at least has to be decreased in favor, for example, of industrial and urban usage. The reduction of inputs used by farmers in developed countries, whether because of the increased related prices of fertilizer or because of regulatory restrictions aimed at reducing reactive nitrogen losses from farms into the broader environment are difficult to quantify, which could have an impact on food production in the near future. Researchers proposed that modifications of this type may help to identify a widening yield gap between farmers and prospective yields for oilseed breeding in the UK, and researchers have included this as a possible reason for wheat yield stagnation in France.

The foregoing calculations conclude that much of the higher food production in the next four decades must be accomplished via higher crop yields in presently exploited agricultural soils. There are considerable opportunities for improving yields in some developing countries, particularly in Africa, through the use of well-understood fertilizing technologies but effective implementation of this strategy will also require significant off-farm changes, for example, infrastructure improvement, increased availability of agricultural input and effective markets for agricultural product The successful realization of the "Africa Option" alone would not be enough to meet the necessary growth to 2050 would must take decades[2].

Literature has been widely debated whether present yield improvement rates would be enough to satisfy increasing demand by 2050. This debate involves several dimensions and conclusions reached depend greatly on scales, plant species, approach used in the process. Another important aspect of the debate is whether progress in yields shows signs of the plateau and whether the relative increases observed by crops and areas in which yields increase are sufficient to meet the 1.16–1.31 percent y^{-1} compound rates needed to satisfy the demand for food, food and biofuels cereals, 2050 and rice or both plants. The picture is considerably less clear for maize, and especially in the US. Some country-wide analyses indicate steady growth in farmers' yields. It is also necessary to mention that researchers assessed the relative growth rate in Iowa's prospective maize y^{-1} yield of 1 percent and researchers suggested that an irrigated maize yield plateau might emerge. The harsh truth of these different approaches, scales and crops is that the vast majority of data indicate that relative rates of potential yield progress fall below the required exponential rate required to meet the demand forecasted for 2050 and that there is strong evidence of yield plateaux in a worrying number of countries and regions. Some writers have assumed that present relative rates of yield advancement, calculated from linear functions that are consistent with historical data yield, are expected to be maintained in the future. Even in the absence of insuperable physiological constraints, this seems improbable. Continued linear yield trends are almost likely the greatest feasible result, and this indicates a continued decline rather than a steady relative rate of yield development[3].

The paths towards achieving enhanced and sustained global food security by 2050 are numerous and involve genetic improvements in unstressed (Yp) and dryland (rainfed) settings to grain crop yield potential and in water restricted yield potential (Yw). In this article we try to evaluate the present state, prospects and advancement needs and verify them in Yp and Yw in particular, with special emphasis on probable time frames. Because of the main contribution they make to the present and probable future global food, feed and biofuel demand, we focus on the most significant cereals (maize, rice, wheat).

1.1 Genetic Yield Improvement:

Breeding is the core of any Yp or Yw improvement process and is presently expanded quickly with the technological choices accessible to advance any set of objectives, including Yp and Yw. We therefore take full account of the nature and practical needs of breeding procedures to achieve farmer-ready cultivars with enhanced Yp or Yw. The improvement of genetic engineering or the mining of existing genetic variability may be further increased by the introduction of new or better characteristics. The identification of these features and their significance should be evaluated by seeing whether they fit into frameworks suitable for the improvement of either Yp or Yw, therefore we try to tackle that problem. In view of the 2050 deadline, the germplasm development and breeding periods, we utilized some pub estimates of the probable time needed to enhance the photosynthetic capability of crops through genetic engineering to highlight this element of the road ahead. In a similar spirit, we have recorded the time needed in the past to advance certain concepts and findings of characteristics relating to enhanced Yw to evidence of concept or stage of cultivar release. It also takes time for farmers to adopt better cultivars broadly and we speak briefly on this problem[4].

The variety of features proposed as potential contributions to improving either or both Yp and Yw is extremely wide, and we do not try to address these ideas in full. Instead, we have chosen two specific processes, as examples of the difficulties we encounter, that we think are potentially extremely significant and, at the same time, provide very big obstacles to move towards better output. Firstly, improved photo-synthetics capabilities for non-stressed and water-limited situations and secondly, the ability to collect water in dry settings root systems.

1.2 Water-Limited Potential Output Frameworks and Tools:

The issue of raising Yw is much more complicated than the problem of increasing Yp in unstressed water-restricted settings. Seasonal crop-disposable water patterns differ across settings and particularly between years. Environmental interaction understanding of the genotype findings is vital to both designing successful selection methods for genetic yield enhancement and to properly interpret results acquired in multi-environmental trials. Another layer to this problem is that not everything that may help to water scarcity yield reduction is equally beneficial in all settings with water shortage. In addition, the genetic architecture of the crop may affect the selection method, leading to the optimal combination of genes or characteristics for a particular environment. And last but not least, the dividing line between many attempts at isolating genes or genomic regions which could serve as sources of reduced yields under water scarcity and the realities of crops growing in water scarce fields, in too many cases, has led to an emphasis on the survival of plants rather than on crop yield loss mitigation as a tolerance to water scarcity.

The Passioura framework has been widely accepted by breeders and crop Eco physiologists who operate in water scarcity settings and was recently recommended in the context of molecular breeding. Crop simulation models, together with soil specifications and extended climate records, may provide a robust quantitative biophysical diagnosis which, in combination with Passioura, will help to understand crop response to water scarcity and to develop breed-in strategies (including the use of management water supply systems, suited to the specific target environment). It is very likely that Yw can make success via these frameworks and tools, but it should not underestimate the required investments in time, experimentation and research facilities to fully execute this approach[5].

1.3 Successful Breeding Requirements:

It is necessary to examine the nature of plant breeding in the future and if the breeding rate for Yp and Yw will likely be improved as new technologies become accessible and more prevalent. This is significant because the period required in most breeding operations from first releases to varieties is typically about 10 years when improvements in the combinations of existing variations are desired. Conventional breeding in the next decades will remain the cornerstone of genetic advancements in crops. The basic prints and methods employed in breeding today will thus very likely continue. Nevertheless, real breeding methods will continue to develop and improve, as in the last two decades, and new technology will be applied to strengthen breeding operations. Recent developments focus on methods that enhance selection and market speed and include, amongst other things, application of simple hereditary characteristics molecular markers, more efficient experimental design and statistical data cessation and better data collection. In addition, new thinking on a gene for phenotypic models is developing, integrating different omics with information management and crop growth models, for complex features related to the target population of settings and yield-trait performance landscapes in agricultural contexts. Genetic engineering will continue to evolve when new genes are added utilizing transformation techniques as new genes and valuable gene combinations are identified. However, these genes/traits will be incorporated into a traditional breeding programme and will rely on it. In other words, they will become part of the traditional breeders' toolbox. Likewise, hybrid technology is anticipated to become increasingly common in other crops as rice has made significant progress over the last decade. The breeding of the hybrid parent lines will also rely on a traditional breeding programme[6].

2. DISCUSSION

Over the last 100 years, plant breeders have effectively recombined genetic diversity in each of our main food crops in order to achieve continuous profit increases. In the 1960s, genetic advances combined with improved crop management lead to significant increases in yields, in particular irrigation in poor nations and, in turn, food surpluses and cheaper food in the developed world. In recent years, however, there has been a worrying fall in global grain stockpiles, leading to rising food costs and societal discontent, coupled with severe weather conditions in certain areas. This, along with a strong rise in fertilizer prices and a focus on the decline in water resources available for agriculture, gave the wake-up call needed for society to realize that by the middle of this century we cannot satisfy the worldwide demand for food and feed. The world's crops must grow at an annual compound rate of between 1.16 and 1.31 percent y-1 to satisfy the demand for our main grains, maize, wheat and rice[7].

In the examination of long-term studies that assessed elite genetic material and the better released varieties of maize, wheat and rice in well-managed trials of both unlimited and hybrid historical sets of best varieties or hybrids, we could not find examples that show current rates of Yp and Yw increase close to 1.16–1.31 percent y–1 required In fact, a disturbing number of zero increases of Yp or Yw in different crop/environment combinations were identified or proposed. These findings are generally consistent with what others have discovered in sub-national or national statistics, but the management element adds to the actual significance of such discoveries some ambiguity[8].

Thus, the timing of the Yp and Yw development to satisfy the forecast grain demand by 2050 isn't a solid foundation for confidence. On the other side, the biotechnological revolutions, in particular the cheap cost of DNA sequence information and progress in recombinant DNA technology, combined with rapid and non-destructive phenotyping and computational wizardry, have been somewhat optimistic. However, although these new instruments provide us a valuable insight, their effect on future yield increases and acceleration of breeding is still unclear. Untapped possibilities exist for boosting Yp or Yw by targeting the genetic improvement of the most essential characteristics designed to restrict output. In addition, new methods for analyzing seasonal variability and the effect of characteristics have enhanced the procedures to identify key characteristics for different areas and will offer a better focus[9].

There are many pathways for Yp or Yw improvement, and there are a lot of potential features and genes. Here we highlight the photosynthetic capacity and root system as two that we think are most promising. One significant issue is that genetically complicated characteristics provide an additional difficulty. In addition, the time required to integrate new characteristics into varieties for farmers dominates. In this instance, we have examined examples of effective integration into breeding the time-scale from initial research to the distribution of novel crops to farmers or evidence-of-concept on elite germplasm for 20 years. Even if the entry-tradition of fairly basic characteristics, controlled by one or two genes, was supported by the full power of the present molecular reproductive tools, this period was about 10 years. The variety is subsequently adopted by the farm, and it may be quick for blockbusters with GM characteristics, such as resistance to glyphosate and resistance to pests (Bt) or rice and wheat dwarfing genes in the 1970s, but longer for hybrid rice in China nowadays. Times for other characteristics are anticipated to be considerably more progressive. Regulatory constraints and IP considerations will likely add an additional degree of unpredictability to the delivery time[10].

3. CONCLUSION

It is very difficult to be hopeful that the present compound rate of advances in Yp and Yw will grow much even in the finest methods and breeding programmes in the near future. While it is clearly speculative, the (naive) alternative is also hopeful. Furthermore, ambiguity and doubts about the effectiveness of transgenic methods (aside from the bioengineering photosynthesis), and the extremely lengthy time of gestation since a new or existing delivery characteristics in new cultivars developed, leave us with a gloomy perspective.

Although it is essential to emphasize that increasing funding in research is crucial to sustain the existing pace of progress, there is also an urgent need to concentrate on structural problems in the research, development and delivery chain and educating a new generation of farm scientists. There is a big divide between researchers close to the molecular organizational level and the reality faced by breeders, agronomists and farmers. Researchers debate passionately about the need to alter the way research is organized generally and of the essential necessity to promote a culture of conversation among scientists of various fields. This in turn will concentrate attention on the most essential and viable methods to the development of plant genetics and will divert certain research activities into more productive ways. It should also allow a quicker transmission of characteristics to breeders. Cultural development and delivery is more essential by commercial enterprises and thus private and public partnerships are becoming increasingly crucial for coordinating and agreeing mutually acceptable terms and conditions of participation. The need for greater investment in research and structural/social transformation is obviously urgently needed if we are to satisfy food demand.

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