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# Yield levels of potato crops: Recent achievements and future prospects

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ABSTRACT

The potential yield of potato is defined as the theoretical yield that can be assessed for a well-adapted cultivar, grown from the best possible seed under optimal conditions. More than in crops that are grown from generative seeds, the growth, development, yield and quality of the potato crop are strongly influenced by the quality of the seed tubers, including their genetic, physical and physiological quality and their seed health status. Potato is very variable in maturity type: late cultivars can intercept large quantities of light whereas early cultivars show more efficient resource use. We describe potential and actual yields as well as impact of climate change on these yields, based on simple, robust models. Potential yields may be as high as 160 Mg ha$^{-1}$, in production systems with abundant irrigation, high radiation levels and long seasons. In such systems, actual yields of above 120 Mg ha$^{-1}$ are feasible. However, potato is also grown as a short-cycle crop and in those conditions potential and actual yields are much lower. Potential yields might not change much in potato over time, but there is still a large gap between actual and potential yields to fill. The ratio between actual and potential yield ranges from 10 to 75%, but typical values are between 30 and 40%, although they obviously depend on the level of input. These ratios allow great yield improvements provided inputs are economically feasible in practice and if climate change does not interfere. In most countries, yields of potato might increase by climate change, provided water supply remains adequate. Main changes through climate change will probably occur by changes in the number of growing days per crop cycle. In some areas with abundant potato production, such as the Indo-Gangetic plains, however, climate change might reduce yield because of a reduction in number of growing days, but it has been projected that the effects of climate change on potato will be regionally diverse.



## 1. Introduction

Potato (*Solanum tuberosum* L.) originates from the Andean region where it has been grown for over 7000 years as a staple food crop. Spooner et al. (2010) showed that its specific origin is in present-day southern Peru. Since the introduction of the crop into Europe in the 16th century and its worldwide distribution, potato has become the third largest food crop following rice and wheat (Spooner et al., 2010). In this paper, we focus on *S. tuberosum* ssp. *tuberosum*, to which more than 99% of the currently widely grown varieties belong.

Potato used to be a 'local for local' crop and to a certain extent it still is, also because of its bulkiness of the seed tubers and the ware, and the limited storability of the ware. It is grown as an early crop or main crop in many cropping systems. It also serves as a hunger-breaking crop as it has a relatively short cycle in some cropping systems (e.g., in southern Ethiopia; Gildemacher et al., 2009a), but also, and for the same reason, as an intermediate short cycle crop between two main crops (e.g., in rice-based systems of Vietnam; Tung, 2000) or as a temporary companion crop in intercropping systems with perennial crops that have a long period of crop establishment (e.g., in the sugar cane production of Mauritius; Govinden, 1990).

However, in modern times, there is also a strong tendency to trade potatoes (both seed and ware) globally. Seed potato companies in the Netherlands for example export seed potatoes in total volumes of 600,000–800,000 t per year (Anonymous, 2015) and

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transport seed tubers to as faraway places as Cuba and Bangladesh. Frozen potato products from North America go trans-Pacific and from North-West Europe to, e.g., Australia and Chile in large, albeit very variable quantities (FAO, 2015a). Potato as raw material for crisps production is imported by, e.g., the Philippines from countries like Germany, USA, Australia, and Canada in quantities up to about 47,000 MT per year (Wustman et al., 2010). As a crop for food security and cash, potato is obviously on a steep rise.

Where potatoes are grown they have some important advantages over cereals (Guenthner, 2001). Their harvest index is 0.75 (Kooman and Haverkort, 1994) although even ranges of 0.85–0.95 have also been reported (Vos, 1997) compared with 0.4–0.6 for cereals (Hay, 1995) indicating that of all dry matter produced a larger proportion is distributed to edible parts of the potato plant than for cereal crops. The propagation material carries its own water so emergence is not threatened by transient droughts, such as is the case with wheat (Farooq et al., 2012). When grown in the winter in a cool monsoon climate potato uses far less water per kg dry matter than rice grown in the hot pre-monsoon (FAO, 2008a), which is an advantage where water shortage is a problem. Disadvantages of potato are its perishability and bulkiness (Guenthner, 2001), its very low rate of multiplication (number of seed tubers harvested per seed tuber planted) (Struik and Wiersema, 1999), the great diversity of serious air-borne, water-borne, vector-borne or soil-borne pests and diseases known for this crop (Wale et al., 2008), its seed-borne pests and diseases (Wale et al., 2008), the wide diversity of physiological disorders of the tubers (Wale et al., 2008) and the considerable amount of soil movement to prepare the seed bed, and to carry out the hilling and harvesting (FAO, 2008b). Some of these disadvantages challenge the creation of a functional seed system in emerging economies where the institutions for strict management and quality control of seed are weak (e.g., Gildemacher et al., 2009b; Hirpa et al., 2010).

With an annual production of 365 million tonnes potato ranks 4th in crop tonnage and 5th in crop value (Table 1; FAO, 2015b). When taken into account that a large proportion of the maize crop is used for biofuel and a large proportion (most) of the soybean crop is used as animal feed, the potato is the third food crop after rice and wheat, despite the large proportion of produce used for seed, industrial uses of potato (alcohol, starch) and potato used as animal feed. Its yield globally is 19 Mg ha$^{-1}$ against 3.11 Mg ha$^{-1}$ of that of wheat (FAO, 2015b). When it is considered, however, that wheat and maize contain 15% water and potato 80% water, the global dry matter yield of wheat is 2.64 Mg ha$^{-1}$ against 3.80 Mg ha$^{-1}$ of dry matter produced by potato, close to 4.18 Mg ha$^{-1}$ of dry matter produced by maize. Potato and maize are often grown in more resource-endowed environments than wheat which is typically a crop of the marginal or dry areas. The total value of the crops wheat and potato is of the same order of magnitude but that of rice is around three times more (Table 1; FAO, 2015b).

Until 50 years ago the vast majority of the potato crop was grown in the developed world (FAO, 2015a; Devaux et al., 2014) and not much yet in what were then considered developing countries. Currently the acreage in developing countries exceeds that of developed countries and the acreage is still increasing rapidly in the former and declining in the latter (FAO, 2015a). The reason for the decline in areas like Russia, Central and Northern Europe is a decline in potato consumption per capita, but especially in Eastern Europe feeding animals with potato has ceased to be practised (Commission of the European Communities, 2007). The total productions for developed and for developing countries show similar trends (FAO, 2015a, 2015c; Devaux et al., 2014): developing countries nowadays produce more potatoes than developed countries (Fig. 1).

Production in (formerly) developing countries increased rapidly because of increased demand such as in China and India and was made possible by the introduction of modern seed technology, fertilizers and fungicides (Guenthner, 2001; Sing and Kaur, 2009). Area expansion took mainly place in subtropical rice growing regions where in winter an irrigated potato crop is grown such as in India where 90% of the crop in the Indo-Gangetic plains is grown in winter (Wustman et al., 2011). Fig. 2 shows the enormous production increase in China and Eastern Africa after 1990. In China this was achieved both by increase of area harvested and yield per ha. In Eastern Africa the area harvested expanded even more on a relative scale. Haverkort et al. (2009) reported that in some parts of Africa yields declined in the 20-year period between 1987 and 2006, as growers might not have applied fertilizers and/or have moved to more marginal soils.

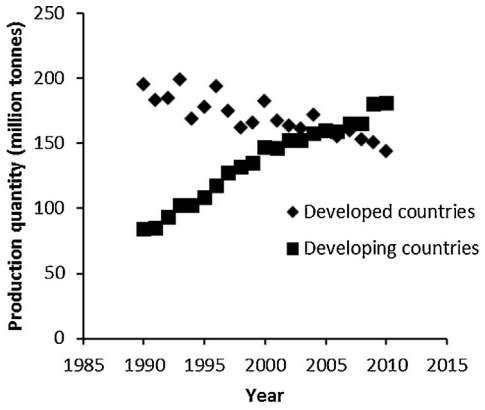


**Fig. 1.** Trends in production quantity of potato in developed and developing countries during recent years (*Data source:* FAO, 2015a; see also Devaux et al., 2014).

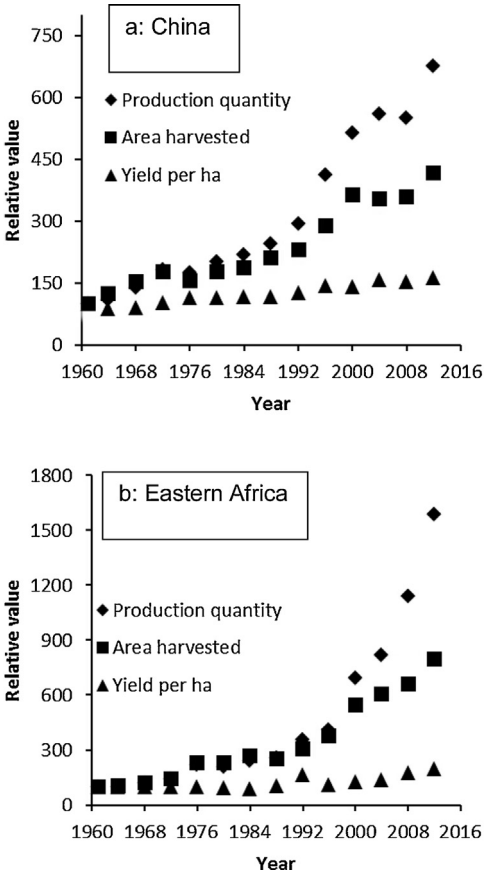


**Fig. 2.** Relative development of production quantity, area harvested and yield per ha of potato (1961 = 100) in China (a) and Eastern Africa (b). *Data source:* FAO, 2015c. Accessed 26 March 2015.