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Effects of plant density on the yield and yield components of true potato seed (TPS) hybrids in early and main crop potato production systems

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ABSTRACT

This study was conducted to evaluate true potato seed (TPS) technology for use in ware or seed potato production in two contrasting environments in Turkey during 2002 and 2003. The field experiments were carried out in the Hatay and Nevsehir provinces in Turkey, which represent a Mediterranean early crop potato production area and a temperate main crop potato production area, respectively. The plug seedlings of six TPS hybrids were transplanted to the fields at four densities (15, 20, 25 or 30 plants m^{-2}). The seed tubers of the medium early cultivar Marfona were also planted in the experimental plots to compare the performance of the TPS hybrids with traditional seed tubers. Transplanting of the seedlings was significantly delayed in Hatay due to unsuitable weather conditions in both years. The seedlings needed an adaptation period of 2–4 weeks after transplanting depending on the location and the growing conditions. The adaptation period was longer in Hatay due to high air temperatures after transplanting. Although the yield performance of the TPS hybrids differed depending on the location and year, the TPS hybrids produced noticeably higher total tuber yields in Nevsehir location (ranging from 43.1 to 62.5 t ha^{-1} in 2002 and from 39.5 to 50.6 t ha^{-1} in 2003) than in Hatay (ranging from 15.3 to 19.6 t ha^{-1} in 2002 and from 15.1 to 19.1 t ha^{-1} in 2003). The percentage of marketable tubers (>28 mm) was also considerably higher in Nevsehir. The optimal plant density varied between 25 and 30 plants m^{-2} with regard to the total yield, while the optimal density with regard to the marketable yield was 20 or 25 plants m^{-2} depending on hybrids in Nevsehir. However, none of the tested plant densities caused competition between plants in Hatay, where the environmental conditions during the growing period considerably restricted the growth of individual TPS seedlings.

It was concluded that transplanting of TPS seedlings can be considered a feasible alternative for ware or seed potato production in temperate environments like Nevsehir that have growing periods of at least 4 months. However, there are several obstacles, such as difficulties with the timing of transplanting, long adaptation period that threaten the practicability of TPS technology in Mediterranean-type environments. Further agronomical studies focused on reducing inter- and intra-plant competition are needed for both environments in order to improve the acceptability of TPS technology to farmers.

1. Introduction

In Turkey, as in vast majority of the world, the potato has traditionally been propagated vegetatively using seed tubers. Potato production systems based on seed tubers have several disadvantages, such as low multiplication rates, high storage and transportation costs, and high pest and disease transmission risk due to vegetative propagation. Furthermore, environmental conditions limit seed (tuber) potato production in warmer climates. Potato farmers in these regions are largely dependent on healthy seed tubers imported from other regions or countries. The cost of healthy planting material in these regions can account for 50–70% of the total production cost (Almekinders et al., 1996, Carputo et al., 1996). True potato seed (TPS) technology was proposed as a captivating alternative that would be able to overcome the above mentioned problems with seed tubers, especially for small scale farmers, by several authors (Malagamba, 1988; Almekinders et al., 1996; Carputo et al., 1996; Chujoy and Cabello, 2007). TPS technology refers to a potato production system using sexual seed, also known as botanical seed or true seed, instead of the seed tubers, which are used in the conventional potato production system. The main advantages of TPS technology over the use of seed tubers are a lower seed cost and a reduced risk of disease dissemination. The seed material can be easily transported and stored in simple storage facilities since only 20–200 g of TPS, depending on production type, are required to

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plant 1 ha of potatoes. The hybrid TPS of 100–150 kg ha^{-1} can be produced using male sterility and mother plant management (Chujoy and Cabello, 2007). Most of the pathogens affecting potato crops cannot be transmitted via TPS, only one exception is Potato spindle tuber viroid (PSTV). TPS technology has also been particularly useful for maintaining food security in developing countries since 2–5 t of tubers per hectare are used as seed in the conventional potato production system. After an extensive review of the on-farm profitability of TPS usage in different countries, Chilver et al. (2005) concluded that both the environmental and socio-economic conditions of a particular region determine the feasibility of TPS technology, and this technology can only be profitable in regions where poor yield is the result of a lack of healthy seed material and where there is high disease pressure. The availability of high quality seed material is a significant problem in Turkey; certified seed accounts for only 10% of the total seed usage in the country (Arioglu et al., 2006). Moreover, the high price of healthy seed material forces poor farmers in rural areas to use poor quality tubers as seed. Therefore, TPS technology can be a valuable alternative for poor Turkish farmers to produce ware or seed potatoes.

Several alternative systems using TPS technology have been developed for different agro-economic conditions. The most commonly employed methods are (1) potato production via direct seeding of TPS into fields, (2) transplanting of seedlings derived from TPS to fields used for seed or ware potato production, and (3) production of seedling tubers in nursery beds as seed material for the subsequent season. Detailed descriptions of the different systems and their applicability under various conditions have been written by several authors (Malagamba, 1988; Martin, 1988; Pallais, 1991; Almekinders et al., 1996). Transplanting can be a feasible method to produce ware potatoes, especially for small scale farmers in areas under high disease pressure or for farmers lacking storage facilities and water for irrigation. Variable tuber yields have been reported from seedling transplanting trials in different countries such as the United States (Rowell et al., 1986), the Philippines (Vander Zaag et al., 1989), Peru (Benz et al., 1995), Uganda (Sikka et al., 1994), the Netherlands (Pangaribuan, 1994) and Nepal (Adhikari, 2005). These studies indicated that the yields of tubers grown from seedlings are generally lower than the yields achieved with seed tubers, although there were some exceptions. However, the transplanting method could be feasible in some environments when one takes into account the extra inputs in terms of transport, storage and seed cost that are associated with the use of heavy tubers. Yield differences between seedlings and seed tubers have been shown to vary widely depending on the genotype of the potato plants, the climate, the length of the growing season and the health status of the seed tubers (Rowell et al., 1986). Vander Zaag et al. (1989) reported that plant growth from transplants was extremely sensitive to daylength and temperature. They also reported that in environments with high temperatures after transplanting, a shorter daylength (>12 h) and a short growing period were not suitable for potato production via transplanting. Similarly, Engels et al. (1994, 1995) reported that seedling transplanting is not a suitable method for ware potato production in the Nile Delta in Egypt because of the short, hot growing season. Potato production with seedling transplanting requires good management practices, high labor cost and horticultural skills. However, transplanting has a long tradition all over the world in the production of many vegetables, including *Solanaceaous* crops such as tomatoes, peppers and eggplants. Therefore, the TPS method can be easily adopted by farmers if they can get satisfactory tuber yields.

Although TPS technology offers an excellent seed alternative for potato production, TPS has also several well-known disadvantages including lack of uniformity, slow initial growth rate, lateness, small tubers and low yield (Almekinders et al., 1996). When tubers are used as seed, they (the mother tubers) feed the growing sprouts and contribute to plant development up to at least the 20-cm height growth stage (Bohl et al., 2001). This feeding results in vigorous and rapid crop growth during early growth stages, which is probably what leads to higher tuber yields. Therefore, breeding and adapting of early TPS cultivars that have high yield potentials and uniform tubers are very important for increasing the likelihood that potato growers will adopt TPS technology (Clulow et al., 1995). Open pollinated (OP) TPS was the most common type used in earlier studies on adapting TPS technology. Most of these OP true seeds were derived from late maturing parents due to longer the flowering period and higher seed set ratio in late cultivars. Macaso-Khwaja and Peloquin (1983) reported that it is possible to get a tuber yield two times greater using hybrid TPS than with OP TPS clones. Although the number of TPS breeding programs in the world is still limited, there have been admirable breeding efforts undertaken in recent years by the International Potato Centre (CIP), especially in some Asian countries. The aim of these efforts was to develop hybrid TPS cultivars that have more desirable traits. Now, achievements have been obtained in the development and adaptation of hybrid TPS in some Asian countries (Fuglie, 2001). Some promising yield results on adaptability of TPS technology using hybrid lines were also reported in the USA (Love et al., 1997), Romania (Prodan et al., 2005) and Japan (Roy et al., 2005). Some preliminary studies have been conducted on the adaptability of TPS technology in Turkey using OP cultivars (Yıldırım et al., 1987), but there is no information about the adaptability and yield potential of hybrid TPS cultivars in Turkish environments. Hence, agronomic studies using new hybrid cultivars are important in establishing the potential of TPS technology for potato production in different types of environments.

The optimization of plant density is one of the most important subjects of potato production management because it affects the seed cost, plant development, yield and quality of the crop (Allen and Wurr, 1992). In conventional potato production using seed tubers, the plant density is manipulated by varying the number and size of the seed tubers planted. Several sprouts can develop as main stems from a single seed tuber, the number of which depends on the tuber size. Each main stem acts as a separate plant with its own root and shoot system, and these plants compete each other for water, nutrients and other inputs (Struik, 2007). Therefore, the number of main stems per unit area is considered a more appropriate definition of plant density than number of seed tubers planted per unit area (Allen and Wurr, 1992). Many studies have been conducted to establish the optimal combination of seed tuber size and planting density for a certain environment (Iritani et al., 1972; Entz and La Croix, 1984; Schotzko et al., 1984; Vander Zaag and Demagante, 1987; Strange and Blackmore, 1990; Creamer et al., 1999).

In contrast to tuber planting, plant density should be optimized via managing the planting distance between and within rows when planting TPS since only one main stem develops from each seed. Therefore, planting distance of TPS should be closer than seed tubers to get a similar final plant density. Although it is largely depends on cultivars, in general, a plant derived from TPS produces more tubers per main stem than plants derived from seed tubers do (Wiersema, 1984; Benz et al., 1995). This characteristic of TPS plants indicates the importance of determining a suitable planting distance in ware potato production using TPS since there is a well-known negative correlation between the number of tubers per unit area and the average tuber weight due to increasing competition. Despite the great importance of determining the optimum planting distance in promoting the adoption of TPS technology, studies on the effects of the planting distance on growth, yield and quality in ware potato production with transplanted TPS seedlings