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Agro-techniques for Production of Seed Size Tubers in Conventional Seed Potato Production System–A Review

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Abstract

The seed potato cost is very important component in total potato production and account for 30 to 70% which varies depending on the country or region. Tuber size is an important factor to decide the seed requirement per unit area. Seed size affects total yield, graded or marketable tuber yields. Standard seed tuber of 25–125 g weight (30–55 mm) is known as seed size tubers in India. Obtaining seed size tuber is important for achieving higher potential of the cultivars. The tuber size profile can be reduced or expanded by altering inter and intra row seed spacing, controlling days of growth by planting late or killing vines/haulm early, regulating inputs like fertilizer and water etc. An ideal combination of plant population, row width, and in-row seed spacing for a particular variety were the major factors for optimizing tuber size. Variation in tuber bulking ability in different genotypes results in variation in proportion of seed size tubers among different varieties. 70–80 days haulm killing found most suitable for getting higher proportion of seed size tubers in high bulking varieties. Proper management of N, P and K fertilizers is considered very important to maximize tuber yield and attain desirable quality. Variability in nitrogen dose/ha was observed which ranged from 100–150 between different regions of the world. Hence proper combination of above Agro-techniques should be adopted in seed production programme as per the region for getting higher proportion of seed size/plantable seed tubers.

Keywords: Agro-techniques, conventional system, planting geometry, seed potato

1. Introduction

Good quality seed is almost universally considered a requirement for high productivity in all potato production systems. Much of the yield gap currently constraining productivity is attributed to the poor quality of seed. Potato seed sector development is thus a major concern of governments, researchers, development agencies, and civil society organizations (Forbes et al., 2020). Seed is the most important part of the production cycle of many crops, including potatoes. Seed determines important factors such as yield, quality and overall crop health. Starting with good- quality seed is the first step to a successful crop year (Merk, 2019). Selecting and planting clean, disease-free potato seed tuber is the first step to assure a successful potato crop. Seed quality has a direct bearing on the potato productivity. Seed multiplication rate in

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potato is only 1:6 and production cost is very high due to stringent quality control. Seed production is very technical aspect and needs careful attention during all stages like date of planting, spacing, fertilization, top-dressing, irrigation, roguing, weeding, earthing up, spraying of pesticides, date of dehaulming, harvesting, etc (Mahmud et al., 2009). Quality of seed potato is important for good yield therefore seed production; harvesting (haulming and harvesting) and storage should be carefully carried out (Correa et al., 2007).

Sustenance, ensuring harvest and higher income are important quality attributes that farmers look for in both variety and seed source in potato (Urrea-Hernandez et al., 2016). The seed accounts for 30 to 70% of the total production cost depending on the country or region (Struik and Wiersema, 1999; Kabir et al., 2004; Karim et al., 2010). In India, it ranges from 40 to 50% (Beata et al., 2020, Singh et al., 2019, Chakraborty et al., 2013, Venkataselam et al., 2011). The situation is further aggravated in high bulking cultivars Kufri Sutlej which has tendency to produce more numbers of over size tubers (Sharma et al., 2001) and Kufri Khyati which produces up to 50% under and over size tubers (Sadawarti et al., 2017 and 2021a). Seed cost actually depends on seed size and intra-row spacing (Islam et al., 2012). Seed tuber is the single most important factor in potato cultivation and if the seed does not possess good qualities, then optimum production could not be achieved (Chakraborty et al., 2013). Potato yields are affected by several factors. Quality seed is a very important factor. The average yield increase from the use of good quality seed is 30 to 50 percent compared to farmers' seeds (Wang, 2008; Sadawarti et al., 2020).

2. Significance of Seed Size Tubers in Potato

Size of seed tuber is an important factor to decide the seed per unit area because it affects total yield and graded or marketable tuber yields (Singh and Kushwah, 2010 and Dagne et al., 2019). Seed rate depends on the size of tubers used in planting for ware as well as seed crop. Standard seed tuber of 25–125 g weight (30–55 mm) is rated as seed size tubers in India (IMSCS, 2013). The highest values of tuber yield was established with planting of seed tuber sizes of 35–45 mm under Angola conditions (de Almeida et al., 2016). Appropriate seed tuber size has very important implication on potato production. Seed size influences the seed rate per hectare (Singh and Kushwah, 2010; Kumar et al., 2009b). The number of sprouts that develop from a seed tuber is influenced by the size of seed tuber. In larger tubers, growth is faster because of greater food reserve availability for each sprout and generally produce more sprouts which may result in the production of too many stems and eventually produce too many tubers (Dagne, 2015). If larger seed is used, a greater quantity of seed is required for planting per unit area. it is avoided because it increases seed costs and reduce planter's accuracy (Singh and Kushwah, 2010). Conversely, smaller seed size tubers have less sprouts per unit due to the lesser amount of reserves available for sprout growth leading to small number of stems that produce only a few tubers, thereby reducing yield (Dagne, 2015). Big size seed will increase cost and seed that are too small may rot before emergence (Wang, 2008). Cut tubers may be deteriorate by bacteria and have less food reserve for the emerged plants which results to poor growth performance and lower yield (Chala, 2016).

The plantable tuber size for potato production is 30–50 g for gaining maximum production potential from field. Small and medium size seed tubers are preferred by farmers engaged in small scale cultivation to reduce seed cost under Bangladesh conditions (Islam et al., 2012). For normal production, a reasonable size of seed tuber or tuber pieces should be about 40 to 50 g. Many factors determine tuber size distribution such as number of stems per plant and the rate of crop growth which are difficult to manipulate. One of the most controllable factors is seed size (Struik et al., 1990). Low variation of tuber size is desirable in seed production (Dimante, 2019).

3. Agro-techniques for Enhancing Seed Size Tuber

Obtaining seed size tuber is important for achieving higher potential of the cultivars. The tuber size profile can be reduced or expanded by altering inter and intra row seed spacing, controlling days of growth by planting late or killing vines/haulm early, regulating inputs like fertilizer and water, applying growth regulators, and manipulating seed tuber physiological age (Kumar et al., 2009). When potatoes are grown for seed, cultural practices need to be used in order to maximize the proportion of seed size tubers and decrease the yield of large tubers (Sanli, 2015). In practice, the space between the potato plants is manipulated by the number and size of the tubers planted which increased total yield, but decreased the percentage of large potato tubers that will be produced. The possibility of ensuring a high yield largely depends on the maintenance of an optimal number of plants per unit area and their spatial arrangement in the field (Dawinder et al., 2020). In the present review different aspects/ Agro-techniques of production of seed size/ plantable tubers is discussed.

3.1. Effect of genotype on proportion of seed size tubers

The genotype determines tuber number, tuber size and yield potential for any given cultivar (Wang, 2008). Varietal difference may occur for seed size tuber production as the cultivars vary in maturity and their bulking capacity. In terms of seed tuber percentage, Multa was the best (72.60%) followed by Ailsa (71.82%) and Dheera (71.74%) under Bangladesh conditions (Mahmud et al., 2009). Kufri Jyoti (217 thousand ha^{-1} and 48.30%) and Kufri Gaurav (288 thousand ha^{-1} and 44.60%) recorded significantly higher seed size tuber number over Kufri Lauvkar (185 thousand ha^{-1} and 49.39%) under Gwalior conditions of Madhya Pradesh, India (Sadawarti et al., 2021b unpublished). Cultivar can influence whether size or weight of minitubers will affect yield of progeny tubers. For example, for cultivar 'Nicola' the size of minitubers did not affect total tuber number and yield, whereas a significant effect of the size of minitubers on these variables were observed for 'Russet Burbank' (Radouani and Lauer, 2015). Seed size tuber (25–125 g) varied inearly planting study for seed production where Kufri Lauvkar (206000 ha^{-1} and 55.53%), Kufri Chandramukhi (207000 ha^{-1} and 54.62%), Kufri Chipsona-1 (270000 ha^{-1} and 49.72%) and Kufri Sindhuri (316000 ha^{-1} and 47.09%) recorded seed size tuber number and percent (Sadawarti et al., 2013). This indicates the variation in tuber bulking ability in different genotypes resulting in variation in proportion of seed size tubers among different varieties.

3.2. Influence of fertilizer combinations for production of seed size tubers

Apart from the choice of cultivar, plant protection and continuous water supply, a further important agronomic measure for potato production is adequate nutrient management (Gondwe et al., 2020). Nitrogen (N), phosphorous (P) and potassium (K) are the nutrients which are most commonly applied in potato production (Davenport et al., 2005). Proper management of N, P, and K fertilizers is considered very important to maximize tuber yield and attain desirable quality. (Gondwe et al., 2020). Increasing N supply can increase the proportion of large-sized tubers which is unfavorable for seed production (Zebarth and Rosen, 2007). According to De la Morena et al. (1994), potato yield can be divided into the three components: 'number of stems per square meter', 'number of tubers per stem' and 'average tuber weight', whereby N has the greatest impact on the average tuber weight.

P has a significant impact on the setting of potato tubers, especially in the early growth states (Jenkins and Ali, 2000; Hopkins et al,. 2014), but also at later growth stages where P enhances tuber maturity (Hopkins et al., 2014; Rosen et al., 2014). Higher P fertilization rates decreases the yield of large-sized tubers (Jenkins and Ali, 2000). Most P is taken up between 40 and 60 days after emergence (Horneck and Rosen, 2008; Rosen et al., 2014). A sufficient supply of K is also needed for high biomass production and leaf area development. Under K deficiency, there can be a decrease in the number of leaves as well as a decrease in the leaf size. This can be attributed to K's role in osmoregulation and cell extension (Gerardeaux et al., 2010; Jakli et al., 2016). The potato plant shows maximum uptake of K in early plant development, approximately 30 to 40 days after emergence (Stark et al., 2004; Horneck and Rosen, 2008).

Application of 75 kg N ha^{-1} resulted in 15.2 t ha^{-1} of seed sized tuber yield and 150 kg N ha^{-1} had no significant effect over 75 kg N ha^{-1} at a close spacing of 50×10 cm^2 to get maximum yield of seed sized tubers (Roy and Sharma, 2000). Generally, maximum yield of medium size tubers was recorded for intra row spacing (20 cm) and 150 kg N ha^{-1} (Wakjira, 2017). Among the various treatment combinations, the number of total and seed size tubers was found to be maximum (579000 and 364000 tubers ha^{-1}, respectively) at maximum plant density (166666 plants ha^{-1}) with 160 kg nitrogen ha^{-1} (Sharma and Kumar, 2014). Narrow in-row spacing (15 cm) and moderate N fertility levels (200 kg ha^{-1}) shifted the tuber size distribution towards the smaller size ranges (30–45 mm) Waterer, 1997. Medium dose of 100 N: 120 P_2O_5: 60 K_2O kg ha^{-1} recorded 58% of 20–80 g tuber size with highest net return (Singh, 1999). 15 cm intra-row spacing×70 days haulm killing×120 kg N recorded highest seed size tuber number (432 thousand ha^{-1}) and found to be most suitable combinations in seed production system of Kufri Khyati under Gwalior condition of Madhya Pradesh (Sadawarti et al., 2017). Reduction in intra row spacing from 20 to 15 cm, dehaulming at 65 DAP and decrease in nutrient levels from 100% RD of NPK (200;100:150 kg ha^{-1}) to 50% RD of NPK, seed grade size (25–50 and 50–75 g) tuber yield and numbers and total tuber numbers were increased significantly in Kufri Himalini under West Bengal conditions of India (Das et al., 2020). Plant spacing of 10 cm, 150 kg N+120 kg P_2O_5+80 kg K_2O ha^{-1} and 80 days duration recorded highest seed size tubers than other combinations and standard control (Rawal et al., 2005).

3.3. Effect of planting geometry on proportion of seed size tubers

Planting geometry influenced yield, tuber size distribution, number, stem density and net returns of potato cultivars (Love and Thompson-Johns, 1999; Bussan et al., 2007; Zamil et al., 2010; Nasir and Akassa et al., 2018 and Dawinder, 2020). Optimizing of plant density is one of the most important agronomic practices of potato production, because it directs seed cost, plant development, yield and quality of the crop (Bushan et al., 2007). One way to adjust the size of tubers is to manipulate plant density (Gregoriou, 2000). Increasing the planting density may lead to a decrease in the average weight of the tuber and the percentage of the large size tubers (Love and Thompson-Johns 2006; Gasimova et al., 2010; Mahmoodabad et al., 2010; Somarin et al., 2010). An ideal combination of plant population, row width, and in-row seed spacing for a particular variety were the major factors for optimizing tuber size and increasing grower's revenue (Rex and Mazza, 1989). Planting of seed tubers on ridges is widely followed method with some modifications from place to place. As against single-row geometry of planting on each ridge, paired-row planting on ridges at different spacing has also been tested keeping constant or variable seed rates (Mishra, 2013).

Seed size tubers (25–125 g) are very important for use as seed tubers in the successive crop season (Sadawarti et al., 2019). Significant highest percent of number of seed size tubers (25–125 g) was recorded in 60×20 cm^2 (50.75) followed by 66×15 cm^2 (48.15) and paired row system (46.82) in Kufri Khyati under Gwalior conditions of Madhya Pradesh, India (Sadawarti et al., 2021a unpublished). Percent production of seed size tubers to total tubers (both on weight as well as number basis) was higher at narrow intra row spacing (Singh and Singh, 2016). Sadawarti et al., 2017 reported that significantly higher seed (25–125 g) size (405000 ha^{-1}) tuber number with closer intra row spacing of 15 cm over 20 cm intra–row spacing (337000 ha^{-1} seed size). Medium-sized seed tubers (40–75 g) increased as spacing reduced, closer spacing of 50 cm×25 cm^2 and 60×25 cm^2 produced higher tuber number m^{-2} over wider spacings of 80×30 cm^2 and 75×30 cm^2

(Binalfew et al., 2015).

Mean individual tuber weight decreased in early planting at closer spacing and may have been due to the greater production of tubers per plant where they faced inter-plant competition for space, light and nutrient. (Al Mamun et al., 2016; Mahmud et al., 2012 and Sarker et al., 2011). When the vertical distance was greater than 10 cm and the lateral distance greater than 20 cm, tubers over 80 g were significantly reduced under Southwest China conditions (Zheng et al., 2016). For getting higher proportion of seed size tubers (25–125 g), 15 cm intra-row spacing×70 days haulm killing×120 kg N was found to be most suitable combination in seed production system of early bulking cultivar Kufri Khyati (Sadawarti et al., 2017). Highest percent of 31% medium size tubers (40–55mm) were recorded in 60×20 cm^2 spacing under Srilankan conditions (Rajadurai, 1994). 60×20 cm^2 spacing gave highest yield of B (50–75 g) and C (25–50 g) grade tubers than 60×15 and 60 × 25 cm^2 spacing in Kufri Joyti (Negi et al., 1995).

The highest number of medium sized potatoes (2.5–3.5 cm) was found in 30×20 cm^2 spacing which was at par with 45×20 cm^2 and followed by 30×30, 30×40, 60×30, 60×20, 45×40, 45×30 and lowest in 60×40 cm^2 spacing under Nepal conditions (Dhakal et al., 2019). plant spacing 60×20 cm^2 recorded maximum seed size tuber yield of 163.3 q ha^{-1} and minimum yield (132.4 q ha^{-1}) was recorded in plant spacing of 60×8 cm^2 under Punjab conditions of India (Dawinder et al., 2020).The highest number of medium sizeseed tuber (35–45 mm) was obtained at 50×20 cm^2 and is appropriate for seed tuber production by considering better seed saving and intercultural operations (Dagne et al., 2019). Generally, maximum yields of medium-sized tubers (40–75 g) were recorded for closer inter-row spacing (50 cm and 60 cm) and intra row spacing (25 cm) under Ethopian conditions (Binalfew et al., 2015). Highest yield of tubers 35–55 mm in diameter was obtained from triple-row beds (McKeown, 1987). Doubling the plant density from 83 333 plants ha^{-1} to 166 666 plants ha^{-1} resulted in a significant increase in the number of seed size (20–80 g) tubers (176 to 333 thousand ha^{-1}) Sharma and Kumar, 2014. With the reduction of plant to plant spacing from 20 to 15 cm, seed size (25–50 and 50–75) tuber numbers and total tuber numbers were significantly increased but marketable grade (> 75 g) tuber number was significantly reduced (Das et al., 2020) Table 1 and Figure 1.

Figure 1a: Field view of different spacing combinations

Figure 1b: Field view of paired row spacing combinations

Figure 1c: Field view of normal spacing combinations

Figure 1d: Field view of normal close spacing combinations

Table 1: Effect of spacing on production potential of seed size tubers

Sl. No.	Agro-climatic zone/region/ state	Variety	Spacing (cm^2)	Plant population	Yield	Reference
1.	Gwalior Madhya Pradesh, India	Kufri Khyati	60×20 cm^2	83,333	50.75% seed size tuber yield	Sadawarti et al., 2021a
2.	Patna, Bihar	Kufri Pukhraj	60x15 cm^2	1,11,111	304400 and 17.67 t ha^{-1} seed size tuber number and weight	Singh and Singh, 2016
3.	Gwalior Madhya Pradesh, India	Kufri Khyati	60×15 cm^2	1,11,111	405000 and 22.44 t ha^{-1} seed size tuber number and weight	Sadawarti et al., 2017
4.	Eastern Ethiopia	Badhassa, Chala, Batte and Zemen	50 x 25 cm^2	80,000	8.63 t ha^{-1}	Binalfew et al., 2015
5.	Gwalior Madhya Pradesh, India	Kufri Khyati	15 cm intra-row spacing×70 days haulm killingx120 kg N	1,11,111	427000 and 23.69 t ha^{-1} seed size tuber number and weight	Sadawarti et al., 2017
6.	Kilinochchi, Srilanka	-	60×20 cm^2	83333	31% medium size tubers (40–55 mm)	Rajadurai, 1994
7.	Kukumseri Himachal Pradesh, India	Kufri Joyti	60×20 cm^2	83,333	11.95 t ha^{-1} 25–50 g seed size tuber yiels	Negi et al., 1995
8.	Bhatkada, Dadeldhura, Nepal	Desiree	30×20 cm^2	1,66,667	97.25 M^{-2} 2.5–3.5 mm medium size tuber	Dhakal et al., 2019
9.	Amritsar, Punjab, India	-	60×20 cm^2	83,333	163.3 q ha^{-1}	Dawinder et al., 2020
10.	Holetta, Ethiopia	-	50 x 20 cm^2	1,00,000	242667 and 11.82 t ha^{-1} number and yield of medium seed tuber sizes	Dagne et al., 2019
11.	Kufri (Fagu Unit), Shimla, HP, India	Kufri Giriraj	60×10 cm^2	166 666	333000 and 156.4 q ha^{-1} seed size tuber number and weight	Sharma and Kumar, 2014
12.	Nadia, West Bengal India	Kufri Himalini	60 x 15 cm^2	1,11,111	200463 (25–50 g) 141204 (50–75 g) tuber number ha^{-1}	Das et al, 2020

3.4. Effect of haulm killing on proportion of seed size tubers

Haulm/vine killing is one of the criteria used in seed potato production primarily to regulate tuber size profile (Singh and Kushwah, 2010; Kumar et al., 2009 and Virtanen and Seppanen, 2014). Haulm killing is done to stop tuber growth in order to optimize seed size and to obtain a uniform size distribution with a maximum proportion of the tubers in the most profitable size class. Vine killing is also done to reduce the risk of spread of viral infection by inhibiting plant-to-plant spread through vectors such as aphids (Kempenaar and Struik, 2007). Where the growing season is short, haulm killing can be used to advance harvesting, obtain a suitable tuber size, strengthen tuber skins before harvesting, and prevent plant pathogens from spreading among the foliage and crop(Struik and Wiersema, 1999). Haulm killing method is used for controlling tuber size, is easy to implement, and >70% of the tubers were distributed in the preferred size and is often carried out on unsenesced plants (Virtanen Elina, 2014). Haulm pulling to cut off the tubers from the roots was found to be most effective (Misener and Everett, 1981).

Haulm killing for 70 days recorded significantly higher seed size tuber (409 thousand ha^{-1}) over 80 and 90 days of haulm killing which were at par with each other in Kufri Khyati. Delay in haulm killing decreased the seed size tuber % both by number and weight and highest was reported in early 70 days haulm killing (48.16% by number and 65.12% by weight) than 80 (46.31 and 58.58%) and 90 days (45.83 and 54.95%) Sadawarti et al., 2021a unpublished. The percentage of seed yield was 72% for 65 days after planting and least 63% at 80 days after harvesting (Mahmud et al., 2009). Among haulm killings duration, 80 and 90 days haulm killing which are at par (238 000 ha^{-1}) recorded significantly higher tuber number over 70 days haulm killing (214000 ha^{-1}) in three cultivars viz Kufri Lauvkar (early maturing) and Kufri Jyoti and Kufri Gaurav (both medium maturing) when evaluated for production of seed size tubers (25–125 g) with three haulm killing dates viz 70, 80 and 90 days after planting. Hence from study 80 days haulm killing resulted in 48.18 and 61.52% seed size tubers by number and weight respectively (Sadawarti et al., 2021b unpublished).

The haulm cutting at 80 days after planting gave the highest tuber number (635 thousands ha^{-1}) of seed size tubers, "up to 40 g size, whereas haulm cutting at 70 and 60 days gave 621 and 579 thousands tubers ha^{-1}, respectively. The proportion of 25–75 g tubers in the produce was more in seed tubers of 70/80 days than in the produce of 60–days old haulm cut crop (Roy and Sharma, 2000). Number of >20 g tubers increased up to 80 DAP, which was significantly higher than all other haulm cutting treatments. Highest total number of tubers were recorded at 80 days after haulm cutting which was significantly higher over all other haulm cutting dates under Gwalior conditions of India (Singh and Kushwah, 2010). Higher percent (54.5) of seed size tubers (20–50 g) were recorded at 60 days of haulm killing and decreased with delay in days to haulm killing (Kumar et al., 2009). Haulm killing at 70 DAP maximized the seed-size tuber yield and number by 19.08 and 16.5%, respectively, over the recommended date of haulms killing (90 DAP) in high bulking variety Kuri Sutluj (Singh et al., 2007). Haulm killing at 80 days recorded higher (>40 g) tubers than 70 days halum killing (Kumar and Lal., 2006). Thus, there is the variability in days to haulm killing for production of seed size tubers, but 80 days haulm killing found suitable for production of seed size tubers. Dehaulming at 65 DAP enhanced the seed size (25–50 and 50–75 g) tuber numbers and total tuber numbers of potato and significantly decreased the marketable grade (>75 g) tuber numbers. Maximum seed yield was observed when haulm cutting was done at 70 DAP i.e. 19.75 t ha^{-1} and similar to the non-seed yield but seed yield was statistically similar between haulm cutting at 75 and 80 DAP i.e. 19.56 t ha^{-1} and 18.69 t ha^{-1} simultaneously (Upadhyay and Bashyal., 2020). Advancing the date of haulm killing linearly increased the yield and number of seed-size tubers in the produce where haulm killing at 70 DAP maximized the seed-size tuber yield and number by 19.08% and 16.5%, respectively, over 90 days of haulms killing in Kufri Sutlaj under Jalandhar condition of India (Singh et al., 2007).

4. Conclusion

Size of the seed potato tuber plays important role in augmenting the production potential of potato cultivar. Narrow planting geometry (60×15 cm^2) with higher plant population (1, 11, 111), haulm killing after 70–80 days and nitrogen dose (100–150 kg ha^{-1}) and factor combinations increased the seed size tuber number and weight in seed potato production system in high bulking cultivars with variability in different regions and countries.

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