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Performance of different potato varieties in grow bags: An urban farming approach

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Abstract

Growing potatoes in grow bags is a technique for solving space constraints, especially in urban and small-scale agricultural environments. By improving root development, increasing aeration, and making harvesting easier, the grow bags provide the conditions for the best possible potato growth. In urban and peri-urban regions, where access to large land parcels is often limited, this approach is very helpful. The study evaluated the growth and yield parameters of different potato varieties in grow bags that grow well in North Indian Plains. These varieties were grown in the poly grow bags with the growing mixture of soil, vermicompost and cocopeat (4:3:1). All the bags had the same soil mixture. The findings revealed that the Kufri Chandramukhi gave the highest yield (1037.50 g/bag) in the grow bags, followed by Diamond (908.26 g/bag) in the same soil mixture under Punjab conditions. Kufri Chandramukhi also had the highest plant height (29.41 cm), haulm girth (6.50 mm) and number of haulms (4.90). It adapted successfully in the constrained environment without any incidence of insect pests or any disease. The soil mixture used for the production of potato was helpful by increasing the tuber yield and decreasing the irrigation intervals.

Keywords: Potato, tubers, potato varieties, *Solanum tuberosum*, grow bags, urban farming, growth, yield

Introduction

Potato (*Solanum tuberosum*), one of the most popular crops in the world, that valued for their nutritional value, adaptability, and affordability of production. Large land plots with fertile and productive and well-drained soil are usually needed for the traditional cultivation of potato, but for sustainable farming, urban and suburban areas become more constrained, and alternative growing methods *i.e.,* production in grow bags, are gaining popularity. Growing potatoes in grow bags is a technique that has drawn the interest of urban dwellers because of its effectiveness, accessibility, and appropriateness for small-scale agriculture or homes with limited space. Grow bags, which are usually composed of permeable cloth, plastic or other materials, provide a unique way to grow potatoes in cities. Through this technique, plants get a number of benefits, like enhanced root aeration and better drainage, which enable the plants to adapt to the environment of the bags. It may also help to reduce the incidence of diseases and pests, and growers can easily control the soil from contamination as in grow bags it is easy to detect as compared to fields. The planting of potatoes in grow bags technique was borrowed from the United States and Israel. This method utilizes discarded bags, reduces the usage of pesticides for disease control, conserves moisture, allows controlled fertilizer application, and efficiently uses limited urban space (Gusha, 2014). Economically, this method fosters a stronger local economy by enabling communities to produce their food, thereby reducing the need to import agricultural products (Mubvami, 2011).

As a sustainable way to raise food in urban areas, urban farming has become more and more popular in recent years. Urban dwellers may produce food in a small area by using non-traditional agricultural techniques like grow bags. Potato is a crop that can be planted not just in pots but also in sacks and old compost bags, and is a solution for many space-constrained gardeners. Among the many benefits mentioned were higher achievable yields, the reduction of fertilizer and chemical loss to the ground during the growing season, the retention of moisture for longer, improved management of weeds, insect pests, and diseases, and the reduced spread of disease to other plants (Tanyaradzwa *et al.*, 2015). Cultivation in grow bags has now been trending these days among people living in urban areas, but the problem they are facing is low yield as they are unaware of different varieties which perform well in grow bags.

Potato is rich in starch carbohydrates. A small amount of minerals are also present like iron, potassium, phosphorus and some amount of vitamins B and C, which are essential for the human body (Dhaliwal *et al.*, 2025). It is an essential crop for food security in the context of rising hunger and increasing populations. Due to the growing population and unstable markets, the global food system will need to be improved in the next decades. The world's population does not get enough nutritious food from the food system, which is not sustainably balanced (Kusnierek *et al.,*2023). According to the United Nations Food and Agriculture Organization, the world's population of 9.7 billion people is predicted to need 70% more food at the end of 2050. It will require 100% extra for the developed and developing countries. That's why they set up a committee regarding eliminating the hunger problems by 2030 (FAOSTAT, 2025). Food security is an emerging concern because of reducing fertile land, increasing

population, climate change and natural disasters. Grow bags are the solution for this concern in which the soil can be modified according to the crop and can be placed in a limited space.

The method of growing potatoes in grow bags is similar to the expanding urban gardening, which has gained popularity due to being easy to use, easily available, portable, and can adapt into the place easily. The possibility of growing bags as a substitute technique for potato cultivation is investigated in this study, which including yield, growth parameters, and sustainability.

Materials and methods

Material used: The study on various growth and yield parameters of potato tubers grown in grow bags was conducted at the agricultural farm of Lovely Professional University, Punjab, India, in September 2023-2024 and the harvesting was done in December. Fifteen distinct varieties of potato, namely Kufri Uday, Kufri Chipsona-1, Kufri Jyoti, Kufri Surya, Kufri Lalima, Kufri Chandramukhi, Kufri Mohan, Kufri Lima, Kufri Khyati, Kufri Pukhraj, Kufri Himsona, Diamond, 302, 3797, and 5758 typically cultivated in the North Indian plains, were sourced from a commercial cold store and subsequently planted in white plastic grow bags of dimensions 24 × 40 cm.

Preparation of growing media: A growing medium consisting of soil, vermicompost, and cocopeat was prepared in a 4:3:1 (v/v) ratio to enhance the growth of the plant and tuber. To mitigate the risk of fungal diseases, the mixture was initially treated with carbendazim fungicide at a concentration of 0.3%. Each grow bag was filled halfway with the prepared mixture, equating to 15 kg of soil per bag. Irrigation was given at an interval of 20 days with the help of the rose cane. The purpose of using this soil mixture is to increase the yield as vermicompost contains essential nutrients. Using the cocopeat in the soil mixture reduces the irrigation intervals because it has water retention properties.

The pH of the soil mixture was found to be neutral (7.0), with an electrical conductivity of 0.18 mmhos/cm. The available mineral content in the soil included nitrogen (45 mg/kg), phosphorus (34 mg/kg), potassium (120 mg/kg), zinc (1.68 mg/kg), manganese (0.79 mg/kg), iron (150 mg/kg), boron (0.64 mg/kg), sulphur (14 mg/kg), copper (5.42 mg/kg), and calcium (254 mg/kg).

Planting of tubers: Heathy sprouted tubers were selected for planting, each tuber weighed between 20 and 30 grams for each variety. Every grow bag was planted with five to six tubers, spaced 10 cm apart from one another. Irrigation was given on according to the moisture present on the upper layer of soil as the mixture contained cocopeat which has higher water holding capacity, moreover, water doesn't drain out easily from grow bags. Inorganic fertilizer (N:P:K 19:19:19) 3 g/L spray was given after two weeks of emergence to escalate the growth of the plants.

Data collection: The plant height, haulm girth, number of haulms, and number of leaves were recorded at 30 DAP, 60 DAP and at de-hauling. The number of flowers per variety was counted. The average tuber yield per bag was recorded at harvesting. The grade of tubers was classified into two categories 15-30 g and 30-50 g. The number of tubers was counted and the total yield per bag and grade wise and was measured on the weighing balance after the harvesting of the tubers.

Experimental design: Three separate replications of each of the 15 varieties were carried out simultaneously using Completely Randomized Design (CRD).

Statistical analysis: The data analysis for the study was performed using IBM SPSS version 25. One-way Analysis of Variance (ANOVA), one-way Analysis of Variance (ANOVA), Least Significant Difference (LSD) and Post- Hoc test (Duncan's Multiple Range Test) were applied, with a significance level set at $P = 0.05$ was used to compare the varieties. Proper management and practices were carried out to investigate the effect of various growth and yield parameters on potato germplasms when they grow in bags.

Results and discussion

Emergence percentage: The emergence percentage was found to be highest in Kufri Uday (88.34), which was significantly higher over the other, followed by Kufri Chandramukhi (84.93) and the lowest was recorded in Kufri Himsona (60.80) (Table 1). Kufri Uday is an very early variety amongst the other varieties; that's why it emerged early and showed the highest emergence percentage. The varieties that showed high emergence were mostly early or mid-maturing varieties, whereas those showed less were later maturing and grew according to their favourable environmental conditions. Kwambai *et al.* (2023) also discussed sprouting and environmental factors like rainfall, humidity and seasons of early and late genotypes of potato that affect the emergence of the tubers. Emergence is dependent on the microclimate and genetic composition. It may be because the seed tubers already contain nutrients that help in developing plants (Ayyub *et al.,* 2006). According to the research of Tanyaradzwa *et al.* (2015) emergence also depends on the depth of the planting of the tubers in grow bags. Tubers which were planted at a short distance emerged early as compared to the deep planting tubers.

Plant height: The variety that attained the maximum plant height after the month of planting was Kufri Chandramukhi (29.41), which was at par with the variety Kufri Uday (28.03) however on 60th day Kufri Uday had the highest plant height (36.95) and attained the highest until dehaulming (38.81) (Table 1). Both the varieties Kufri Uday and Kufri Chandramukhi have the characteristic of getting maximum plant height even when growing in the main field. In addition to, the environmental factors, plant nutrition, which are available in the soil and the type of variety are the factors on which the growth of the potato plant depends. Plant growth in grow bags comes out to be less as compared to traditional farming. Furthermore, compact soil and less soil depth may also affect the plant height; the more the soil depth more the root initiation, which simultaneously increases the plant height in grow bags (Tanyaradzwa *et al.*, 2015). According to Zhu *et al.* (2006), limiting the amount of soil in tiny pots for root development decreased plant growth while increasing root growth. Shi *et al.* (2007) claimed that deficiency of oxygen mostly occurs in small pots or containers and also affects the plant height.

Number of haulms: The number of haulms was found to be maximum in Kufri Chandramukhi (4.90) after the month of planting till de-haulming (5.20), which was significantly higher over the other varieties, minimum haulms were formed in Kufri Himsona till dehaulming ranged from 2.30 to 2.83 (Table 1). It was also found that the Kufri Chipsona-1 stem was hollowed

Table 1. Performance of different potato varieties on emergence percentage, plant height, number of haulms, haulm girth planted in grow bags

Germplasm	Emergence percentage	Plant height (cm)			Number of haulms			Hualm girth (mm)		
		30 Days	60 Days	At Dehaulming	30 Days	60 Days	At Dehaulming	30 Days	60 Days	At Dehaulming
Kufri Uday	88.34^{a}	28.03^{a,b}	36.95^{a}	38.81^{a}	4.40^{b}	4.73^{b}	4.90^{b,c}	2.70^{n}	3.30^{k}	3.63^{l}
Kufri Chipsona-1	83.50^{c}	21.50^{c}	29.39^{c}	30.33^{c}	4.26^{b}	4.53^{c}	4.70^{d,e}	5.10^{e}	5.66^{e}	5.83^{f}
Kufri Jyoti	81.07^{d}	18.74^{d,e}	25.88^{f}	26.63^{e}	4.40^{b}	4.56^{c}	4.83^{c,d}	6.30^{b}	6.90^{b}	7.30^{b}
Kufri Lalima	74.40^{h}	16.39^{f,g}	23.29^{g}	24.26^{f}	4.10^{c}	4.30^{d}	4.63^{e,f}	3.20^{l}	3.76^{j}	4.20^{k}
Kufri Pukhraj	79.51^{e,f}	12.90^{i}	22.34^{g}	24.80^{f}	3.53^{e}	3.70^{g}	4.00^{i}	3.50^{k}	4.36^{i}	4.80^{j}
Kufri Surya	80.37^{d,e}	20.03^{c,d}	26.93^{e,f}	29.01^{d}	3.83^{d}	4.30^{d}	4.46^{f}	4.36^{h}	4.80^{g,h}	5.16^{h,i}
Kufri Lima	75.29^{h}	12.12^{i,j}	19.00^{i}	20.13^{h}	3.23^{f}	3.53^{h}	3.73^{j}	4.16^{i}	5.00^{g}	5.50^{g}
Kufri Chandramukhi	84.93^{b}	29.41^{a}	33.27^{b}	35.93^{b}	4.70^{a}	4.93^{a}	5.20^{a}	6.50^{a}	7.30^{a}	7.80^{a}
Kufri Mohan	76.67^{g}	17.65^{e,f}	26.243^{f}	27.23^{e}	2.60^{g}	2.80^{h}	3.13^{k}	3.70^{j}	4.60^{h}	5.00^{i}
Kufri Khyati	79.15^{f}	14.48^{h}	22.77^{g}	23.96^{f}	3.66^{e}	3.90^{f}	4.06^{h,i}	3.33^{k,l}	4.63^{h}	5.33^{g,h}
Kufri Himsona	60.80^{i}	10.65^{j}	22.58^{g}	25.08^{f}	2.30^{h}	2.63^{i}	2.80^{k}	4.70^{g}	5.36^{f}	5.80^{f}
Diamond	81.08^{d}	27.21^{b}	32.80^{b}	35.16^{b}	4.60^{a}	4.83^{a,b}	5.06^{a,b}	5.60^{c}	6.40^{c}	6.90^{c}
302	79.03^{f}	16.31^{f,g}	27.75^{d,e}	28.97^{d}	3.90^{d}	4.13^{e}	4.26^{g}	2.90^{m}	3.60^{j}	4.10^{k}
5758	76.59^{g}	14.81^{g,h}	20.64^{h}	22.10^{g}	4.10^{c}	4.20^{d,e}	4.50^{f}	5.40^{d}	6.00^{d}	6.40^{d}
3797	77.29^{g}	19.54^{d}	28.54^{c,d}	30.90^{c}	3.63^{e}	3.90^{f}	4.23^{g,h}	4.90^{f}	5.76^{e}	6.20^{e}

from the inside, and stem membranes were weak, as a result, haulms of Kufri Chipsona-1 dried early in comparison to the other fourteen varieties. Haulm formation also depends on the genetic traits of the potato variety. The aim of choosing the soil mixture used in the research was to get better air circulation to the roots so that haulms could develop freely. If the tuber gets enough aeration, then it emerges out easily and forms the haulm. The number of stems per plant depends on the type, size of the tuber, and physiological state of the plant. According to research by Gulluoglu and Arioglu (2009), seed tubers of the same size yield the same number of haulms per plant and, therefore, the same number of sprouts.

Haulm girth: The haulm girth recorded as greater in Kufri Chandramukhi 6.50 mm at 30 DAP, 7.30 mm at 60 DAP and 7.80 mm at de-haulming, and this variety was significantly higher among the varieties, whereas lesser girth was found in Kufri Uday 2.70 mm-3.63 mm (Table 1). The haulms of Kufri Uday started to fall after maintaining the height but didn't dry early. It is also noted that haulm girth is dependent on the distance between the tubers; if they are planted close together, the plant's diameter will be affected; if there is a significant distance, the tubers will grow thick and healthy. The haulm girth dropped because of the shallow-rooted tubers in grow bags were unable to withstand the temperature. The same results regarding the space and depth of planting tubers in bags were recorded by Tanyaradzwa *et al.* (2015). The haulm size increased and maintained its green colour after the spray of N:P:K. This spray was only given once to enhance both vegetative and reproductive growth but this spray helped in increasing haulm girth and made the stem tender. According to the research of Vidushi *et al.* (2022) potash helped in thickening the stem and increased the other metabolic activities.

Number of flowers: The flowers on potato plants have a negative effect on the growth and yield of the tubers. The varieties on which the flowers showed were Kufri Chipsona-1, Kufri Jyoti, Kufri Mohan, Kufri Lima, Kufri Khyati. The maximum number of flowers was on Kufri Chipsona-1 (11.66), followed by Kufri Jyoti (8.00) (Table 2). However, the flowers as well as their buds, were removed from the plants to decrease the effect on growth and yield. Flowering usually depends on the variety and their genetic character. The flowering in grow bags occurred due to the rich nutrients present in the soil mixture and the N:P:K fertilizer that was sprayed only once. In grow bags accumulation of nutrients takes at one place and does not leach out because of less space and drainage. These nutrients are sufficient for the plant to enter the reproductive phase, during which it uses more resources and less necessary nutrients, hence decreasing its development and productivity. Jansky and Thompson (1990) explained the flowering effect on potato tubers in their research.

Number of leaves: The leaves were highest at 30 DAP in Diamond (34.66), at 60 DAP in Kufri Uday (54.00), and at de-haulming in Diamond (73.33), whereas the lowest leaf count was found in Kufri Himsona till de-haulming ranged from 11.66 to 28.33 (Table 2). While Kufri Uday had longer stems with a narrow leaf pattern and a less thick canopy, Diamond had a dense canopy and the quantity of leaves was also considerable. However, Kufri Himsona produced fewer leaves because of its modest plant height and fewer stems. In comparison to other varieties, Diamond had more photosynthetic surface and more conducting tissue because it had more leaves. Leaves produce carbohydrates through photosynthesis, which are transported downward via the phloem to the developing tubers thereby contributing to higher tuber yield. Ndwamato *et al.* (2022) also discussed about the number of leaves and their role in photosynthesis in sweet potato grown in grow bags.

Grade-wise number of tubers: The tubers of 15-30 g were highest in 3797 (36.00) and was significantly higher, followed by Kufri Chandramukhi (35.00) and lowest in Kufri Jyoti (8.33). The tubers that were between 30-50 g were highest in Kufri Chipsona-1 (15.00) followed by Kufri Jyoti (14.00) and no tubers of 30-50 g were recorded in Kufri Lima, Kufri Himsona, 5758 (Table 2). It shows that each variety had its unique capacity for yield production. Although all of the germplasm had the same soil conditions, some produced little tubers, some produced large ones, and others produced both. The tuber adjusts to its environment appropriately.

Furthermore, due to the limited space in grow bag as compared to field ones, but the bags were deeper, so they got efficient depth to

Table 2. Performance of different potato varieties on number of leaves, number of tubers, grade-wise yield of tubers and total yield of tubers planted in grow bags

Germplasm	Number of Flowers	Number of leaves			Number of tubers/ grow bag		Grade-wise yield of tuber/ grow bag (g)		Total yield of tuber/grow bag (g)
		30 Days	60 Days	At Dehaulming	15-30g	30-50g	15-30g	30-50g	
Kufri Uday	0.00^{a}	32.00^{b}	54.00^{a}	62.33^{b}	23.00^{d}	5.66^{b}	526.66^{g}	225.70^{e}	748.03^{e}
Kufri Chipsona-1	11.66^{d}	18.33^{g}	35.00^{e}	$43.00^{e,f}$	12.00^{f}	15.00^{a}	268.20^{l}	601.63^{b}	859.96^{c}
Kufri Jyoti	8.00^{c}	13.00^{i}	35.00^{e}	48.66^{d}	8.33^{g}	14.00^{a}	190.26^{m}	559.70^{c}	740.60^{f}
Kufri Lalima	0.33^{a}	$25.00^{d,e}$	39.00^{d}	59.33^{b}	19.00^{e}	1.33^{c}	435.46^{h}	52.33^{i}	488.10^{j}
Kufri Pukhraj	1.00^{a}	$14.00^{h,i}$	27.00^{g}	52.00^{c}	$25.66^{c,d}$	2.00^{c}	578.50^{e}	79.53^{g}	658.03^{h}
Kufri Surya	0.33^{a}	$16.00^{g,h}$	$23.00^{i,j}$	37.00^{g}	$24.66^{c,d}$	5.00^{b}	570.36^{e}	199.86^{f}	769.5^{d}
Kufri Lima	5.00^{b}	28.00^{c}	34.00^{e}	47.33^{d}	19.00^{e}	0.00^{c}	437.53^{h}	0.00^{k}	437.66^{k}
Kufri Chandramukhi	0.00^{a}	$16.66^{g,h}$	$36.66^{d,e}$	54.66^{c}	35.00^{a}	6.00^{b}	799.50^{b}	238.96^{d}	1037.50^{a}
Kufri Mohan	0.66^{a}	17.66^{g}	$25.00^{h,i}$	35.66^{g}	31.00^{b}	1.00^{c}	709.50^{c}	39.40^{j}	735.60^{f}
Kufri Khyati	4.33^{b}	21.00^{f}	30.00^{f}	40.33^{f}	14.00^{f}	1.66^{c}	323.90^{i}	65.20^{h}	363.20^{l}
Kufri Himsona	0.00^{a}	$11.66^{i,j}$	22.00^{j}	28.33^{h}	10.33^{f}	0.00^{c}	253.30^{j}	0.00^{k}	250.63^{m}
Diamond	0.00^{a}	34.66^{a}	47.66^{b}	73.33^{a}	13.00^{f}	15.33^{a}	295.56^{k}	613.13^{a}	908.26^{b}
302	0.00^{a}	10.00^{j}	21.33^{j}	36.66^{g}	$28.33^{b,c}$	1.33^{c}	648.80^{d}	52.80^{i}	702.63^{g}
5758	0.66^{a}	$23.00^{e,f}$	34.66^{e}	$43.00^{e,f}$	24.33^{d}	0.00^{c}	558.80^{f}	0.00^{k}	554.50^{i}
3797	0.00^{a}	$27.33^{c,d}$	41.66^{c}	$45.66^{d,e}$	36.00^{a}	1.00^{c}	827.53^{a}	40.06^{j}	863.46^{c}

grow. In addition, harvesting in grow bags is easy, hands harvested tubers without damaging the other tubers. Karunananda and Ranathunga (2017) also noticed the same and discussed this in their research on sweet potato grown in grow bags.

Grade-wise yield of tubers per bag: The yield of 15-30 g tubers was highest in 3797 (827.53g) and also highest among the varieties and lowest in Kufri Jyoti (190.26g), whereas the yield of tubers ranged between 30-50 g found maximum in Diamond (613.13g) while no yield was found in Kufri Lima, Kufri Himsona, and 5758 because tubers of these varieties were small in size (Table 2). Due to the compact space, large size tubers were fewer in number, and few had large-size tubers. Small-size tubers usually be consumed for table purposes and more preferrable. The yield of small sizes was high in some varieties. Additionally, the size of the tuber varies from variation to variety; in traditional farming, some produce big tubers, while others produce medium or small-sized tubers. Kratky *et al.* (2006) also examined the sizes of the tubers of different varieties in grow bags and pots using different mulch materials.

Total yield of tubers per bag: The total yield of tubers was found to be significantly higher in Kufri Chandramukhi (1037.50) followed by Diamond (908.26) and the lowest was recorded in Kufri Himsona (250.63) (Table 2). It showed that there is no correlation between the emergence and the yield of tubers. Additionally, the yield of the tubers depends on the number of tubers and their weight. The yield of the variety Kufri Chandramukhi was surprisingly higher compared to others; it could adapts to the grow bag environment as well as suitable for the weather conditions of Punjab and also the number of leaves was also highest, which helped in the formation of photosynthates and due to all these factors, the yield got increased.

Furthermore, the yield was higher in grow bags because there was no damage of tubers while harvesting. Additionally, no insect pests or disease was observed in the grow bags. Gebregwergis *et al.* (2021) also observed the marketable and non-marketable yield of potato in bags. Karunananda and Ranathunga (2017) didn't observe insect pests in sweet potato grow bags except for rats. Rats made holes in the grow bags, but didn't affect the yield.

The study revealed that Kufri Chandramukhi yielded the most in grow bags as well as showed the highest plant height, haulm girth and number of haulms under Punjab conditions, followed by Diamond. This research emphasizes the significance of choosing suitable potato variety for such a system. Furthermore, no insect pest was found in any of the varieties in grow bags. The soil combination in grow bags reduced the amount of water consumed by the crop. Cultivation in grow bags is quite affordable and easy for an individual in comparison to the traditional farming system.

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