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EVOLUTION OF AN INDIGENOUSLY DEVELOPED CLIMATE-RESILIENT POTATO VARIETY "KASHMIR" IN PUNJAB, PAKISTAN

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ABSTRACT

Climate change significantly challenges agriculture, impacting crop yields, water availability, pest attacks and soil health. Adaptation strategies like crop diversification, efficient mode of irrigation, and resilient crop varieties are the solution. In Pakistan, potato, a major food as well as cash crops, face climate change-related threats. "Kashmir" a high-yielding, early bulking, frost, and disease tolerant potato (Solanum tuberosum L.). variety was developed at the Potato Research Institute, Sahiwal, Pakistan. This is the result of a cross "FD 35-36 x SH-5" attempted at Potato Breeding Sub-Station, Murree in 2004. The nursery was raised during 2005-08, and evaluation trials were conducted from 2008-10 at Vegetable Research Institute, Faisalabad. The experimental design used in all trials was randomised Complete Block Design (RCBD). Varietal, Advanced Varietal, frost tolerance, National, and Zonal trials were conducted from 2012 to 2019 under different agro-climatic conditions using the same design. A split plot arrangement was implemented for early bulking studies conducted during 2016-17 at PRI, Sahiwal. Plant pathological studies were conducted under field conditions using CRD design at Kaghan during 2016-17, while agronomic studies were conducted at PRI, Sahiwal during 2016-17. Value addition studies were conducted at Post Harvest Research Institute, AARI, Faisalabad during 2020-21. In these studies, this variety exhibited a 53.6% higher yield than the commercial checks and took 100 days to maturity. Federal Seed Certification and Registration Department assessed its morphological features under the distinctness, Uniformity and Stability (DUS) trial in their field. This variety has been approved by Punjab Seed Council headed by the Minister of Agriculture.

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INTRODUCTION

Potato is one of the most adaptable crops and has the potential to exhibit its potential in a wide range of agroecological conditions (CIP 2017; Burke 2017). Potato grown from southern Chile to Green land demonstrates the variability (CIP, 2017). Breeding programs in agriculture mainly aim to breed new crops that can withstand biotic stresses, leading to higher yields. Since the 1950s application of low-cost agronomic practices, i.e. fertilization, pest management,

and irrigation, has contributed significantly to the goal of sustainable agriculture, taking into consideration the impressive growth in population size (Brummer et al., 2011). Nevertheless, the behaviour of these breeds in standard environmental conditions remains only partially investigated, in the diverse habitats selected according to the needs of different geographical areas (Amdie et al., 2017).

In Pakistan, potato is largely grown to meet the demands of domestic consumers. Potato productivity in Pakistan is still lower as compared to neighbouring countries like India and Bangladesh. Production of potato in Pakistan has seen a notable increase i.e. from 24,000 tons in 1947 to a current figure of 4.536.9 million tons in 2022-23. During 2021-22 and 2022-23 potato production experienced an upward growth of 4.8% to 7.9 million tons in 2021-22. In Punjab potato is among the leading crops. During the year 2019-20172,400 hectares were cultivated with production of 4,381,400 tons and 25.4 tons per hectare yield. It is worth mentioning that the average yield of potatoes in Pakistan is lower than that in developed countries like the USA, New Zealand, Netherlands, France and Germany, where the yield is even higher than 40 tons per hectare (Majeed and Muhammad, 2018).

The higher average potato yields in the countries mentioned above can be attributed to some factors that include the longer growing period which ranges from 150-180 days. The extended daylight hours (18-19 hours) and favorable environment support potato growth. Potato varieties are classified as early, mid, and late maturing. The early-maturing varieties mature in 70 to 80 days in subtropical climates and in 90 to 145 days in temperate climate. However, the mid and late-maturing varieties mature in 95 to 110 days and 120 to 135 days, respectively. In Pakistan, 90% of potatoes are grown in Punjab, specifically in autumn with 10-11 hours of daylight and a growing season span of 100-120 days. Several abiotic and abiotic stresses affect potato production and result in loss of yield. In Pakistan, the main crop (autumn) is cultivated in October, and harvested during February extendable up to 120 days (Raza et al., 2019).

The real cause of variability in potato production is the effect of biotic and abiotic stresses. One of the major biotic stresses is diseases like early blight, late blight, Scab, bacterial wilt, viral infections and nematodes, which cause significant reductions in potato production. The abiotic stresses like frost and drought etc. cause reduced potato production and quality (Majeed and Muhammad 2018). Late blight can reduce yield up to 50% to 70% (Lal et al., 2016). Frost in January destroys issues and food (Hussain et al 2018).

Locally developed potato varieties have a great advantage along with high yield in that they can withstand biotic and abiotic stresses (Almekinders et al., 2014). Emerging challenges affecting the potato crop include climate change factors such as early planting season with the late onset of winter and fluctuating potato market prices during the peak season so there is a need to cultivate short-season (early bulking) potatoes. Hence, it is paramount to adopt high-yielding potato varieties that can stand natural factors that prevail in the region and get a reasonable marketable yield if harvested early to enable local farmers to make reasonable profits from the potatoes "Kashmir" has the optimum yield of 29.6 t/ha in 130 days and demonstrates early bulking. This is crucial as the main crop is harvested in February and there is a shortage of potatoes in January (Raza et al., 2022)

The recorded yield of 20.8 t/ha in 90 days demonstrates a promising performance, even surpassing the national average production of Pakistan (25.1 t/ha) and that of Punjab province (25.4 t/ha) (Agriculture Statistics of Pakistan).

MATERIALS AND METHODS

The potato variety "Kashmir" was developed through a breeding process which started with hybridization between two different potato genotypes or clones: **SH-5** and FD 35-36. FD 35-36 was selected for its early bulking nature and high yield while SH-5 for frost resistance (Brown and Dale, 1998).

The cross was attempted in 2004 at Potato Breeding Sub-Station, Murree. Subsequently, berries were collected and TPS (True potato seed) was extracted. Next year, a nursery was raised from 2000 potato seeds of the said cross. Mini-tubers were produced during 2005 at Vegetable Research Institute, Faisalabad and their multiplication was done during 2007-08. The tubers were collected directly from each plant (Howard, 1978). Standard production technology was adopted. Randomized complete block design (RCBD) was used to conduct the evaluation trials except for early bulking studies in which the split-plot layout opted to keep days to harvest in main plots and the varieties in subplots.

The variety was primarily evaluated at the Vegetable Research Institute, Faisalabad during 2008-2009 and Potato Research Institute, Sahiwal during 2009-2010. The primary and secondary evaluations were undertaken at Potato Research Institute, Sahiwal during 2010-2011 and 2011-2012, respectively. The new clone was selected for its high yield, disease resistance and tuber shape. The cosmetic value of potato tubers is the most critical factor in the potato market. The attributes including disease (Rhizoctonia, cracking & common scab), tuber yield and tuber grade (<35mm,35-55mm, and >55m) were assessed on a basic visual basis and pathological lab testing. The variety was tested in varietal yield trials, advanced varietal yield trials, and frost resistance trials using RCB design at PRI, Sahiwal during 2012-2013 and 2013-2014, Plant pathological screening was conducted at Potato Research Station, Kaghan during 2016-2017. Natural disease incidence is at its peak at Kaghan due to the favourable climatic conditions i.e. high humidity, low temperature, and abundant rainfall. So, the breeding material was subjected to natural screening at this site. Frost tolerance trials were conducted in the naturally frost-occurring areas. Zonal yield trials and agronomic studies were carried out at PRI, Sahiwal, during 2016-17, 2017-18, and 2018-19. value addition studies were conducted at Post Harvest Research Institute Ayub Agricultural Research Institute, Faisalabad, during 2020-21. Early bulking studies were conducted at PRI Sahiwal during 2016-17 with three early bulking check cultivars and two experimental genotypes using split Plot design, with four treatments (T1= 60 crop days T2=80 crop days, T3=100 crop days and T4=120 crop days) allocated to main plot and varieties to subplots.

The Experts Sub Committee recommended the variety for cultivation in potato core and sub-core areas of Punjab after a comprehensive examination. Punjab Seed Council approved the variety entitled “Kashmir” in 2021.

To differentiate between various genotypes of potato, morphological attributes are elucidated by Federal Seed Certification and Registration Department FSC&RD(Islamabad). The variety was evaluated for its Distinctness, Uniformity and Stability (DUS). The data recorded by FSC&RD are presented below:

Table 1. Morphological Features of Variety (Kashmir) FD 73-44.

Morphological Character	Description
Seedling color	Green
Seedling height	Medium
Shoot length (cm)	40-60
Plant type	Intermediate
Growth habit	Spreading
Stem thickness	Thick
No. of tillers per plant	3-7
Stem anthocyanin	Medium
No. of branches per tiller	Single
Leaf type	Broad
Leaf color	Dark green
Leaf anthocyanin	Medium
Leaf silhouette	Medium
Leaf pubescence	Present
No. of leaves per tiller	7-10
Leaflets per leaf	15-21
Days to maturity	110-120
Pre dominant tuber skin color	Sharp Red
Tuber flesh color	Yellow
Skin texture	Smooth
Tuber shape	Oval
Tuber length (cm)	4-10cm
Tuber width (cm)	4-7 cm
Tuber eye depth	Medium
No. eyes per tuber	7-13
Tubers / plant	5-13

Distribution of tuber eyes	Evenly distributed
Tolerance to Rhizoctonia	Tolerant
Tolerance to common scab	Medium
Tolerance to frost	Medium

RESULTS AND DISCUSSION

Varietal Yield Trials

The results presented in Table No. 2 prove the impressive tuber yield performance of the potato variety "Kashmir" (FD 73-44) in varietal yield trials conducted during 2012-13 and 2013-14. This variety exhibited a range of yield, between 33.5 t/ha to 34.8 t/ha with 109.37% to 118.86%. increase over the check variety Sante. On average, this variety showed a 114.10% improvement over the check variety.

Table 2. Comparison of yield (t/ha) of Candidate variety "Kashmir" FD-73-44 in varietal yield trial with check variety.

Year	Season	Emergence %		Tuber yield (t/ha)		Increase over check emergence (%)	Increase over check yield (%)
		Kashmir	Sante (C)	Kashmir	Sante (C)		
2012-13	Autumn	90.8	86.0	33.5	16.0	5.58	109.37
2013-14	Autumn	95.33	89.4	34.8	15.9	6.63	118.86
Average		93.06	87.7	34.15	15.95	6.11	114.10

Zonal and National Uniform yield trials (NUYTs)

National Uniform Yield Trials were conducted across the major potato-growing areas to find new promising potato cultivars. "Kashmir" displayed a significant performance concerning tuber yield i.e. 33.8 and 27.6% more than commercial check, Sante with 21.5 t/ha and 18.2 t/ha respectively. On average, "Kashmir" showed 25.8 t/ha tuber yield, which is 30.7% higher than the check variety Sante (19.85 t/ha). Zonal Yield Trials were conducted for three consecutive years i.e., 2016-17, 2017-18 & 2018-19 at Potato Research Institute, Sahiwal, Pakistan. The data depicted in Table No. 3 shows that this "Kashmir" variety exhibited promising results also. It yielded 35.6 t/ha, which is 13.01% higher than the check variety Sadaf (31.5 t/ha). These findings report tuber yield ranging from 30.0 t/ha to 38.7 t/ha.

Table 3. Yield performance of Kashmir in National Uniformity Yield Trials at different Locations (2014-2015) and (2015-2016).

Year	Season	No. of locations	Tuber yield (t/ha)		Increase over check (%)
			Kashmir	Sante (C)	
2014-15	Autumn	3	33.8	21.5	57.20
2015-16	Autumn	4	27.6	18.2	51.64
Average			30.7	19.85	54.65

Table 4. Yield performance of Kashmir in Zonal Yield Trials at different Locations (2016-2017), (2017-2018) and (2018-2019).

Year	Season	Emergence %		Tuber yield (t/ha)		Increase over check emergence (%)	Increase over check yield (%)
		Kashmir	Sadaf	Kashmir	Sadaf		
2016-17	Autumn	85.9	88.8	33.1	33.9	-3.2	-2.35
2017-18	Autumn	91.1	87.8	39.7	38.0	3.75	4.47
2018-19	Autumn	91.7	93.9	35.6	31.5	-2.34	13.01
Average		89.56	90.16	35.46	34.46	-0.66	2.90

Early Bulking Studies

At harvest, after 60 days, FD 73-49 showed maximum bulking, followed by "Kashmir" (FD 73-44). While the remaining two entries i.e., FD 76-67 & FD 77-4 remained below the checks in this regard. At harvesting after 80 days, almost the same varietal trend was observed. Kashmir (FD 73-44) surpassed the checks regarding tuber yield (bulking), securing the first two positions

respectively, while FD 77-4 remained at the last. At harvesting, after 100 days (FD 73-49) exhibited the highest tuber yield, followed by "Kashmir" FD 73-44 and FD 76-67, while FD 73-38 surpassed the checks and FD 77-4 remained last.

The performance marked a significant increase over the check variety "SH-5" after 60 to 100 days of harvesting with an increase in percentage ranging from 25.98% to 42.56%. As a result of these studies, "Kashmir" (FD 73-44) &FD 73-49 emerged as early bulking potato lines which can be harvested after 60 days of planting with reasonable tuber yield to get a good market price. However, its harvesting can be delayed up to 80 & 100 days to get a good market yield. Mihovilovich et al. (2014) evaluated that some potato varieties matured earlier than 100 days or up to 100 days are grouped in early bulking or early maturity varieties. The variation between early and late varieties was due to their differing responses to temperature conditions. Early varieties, benefiting from minimal temperatures, swiftly shift from vegetative growth to the reproductive phase. In contrast, with their growth cycle initiated under cooler temperatures, late varieties remain in the vegetative stage longer.

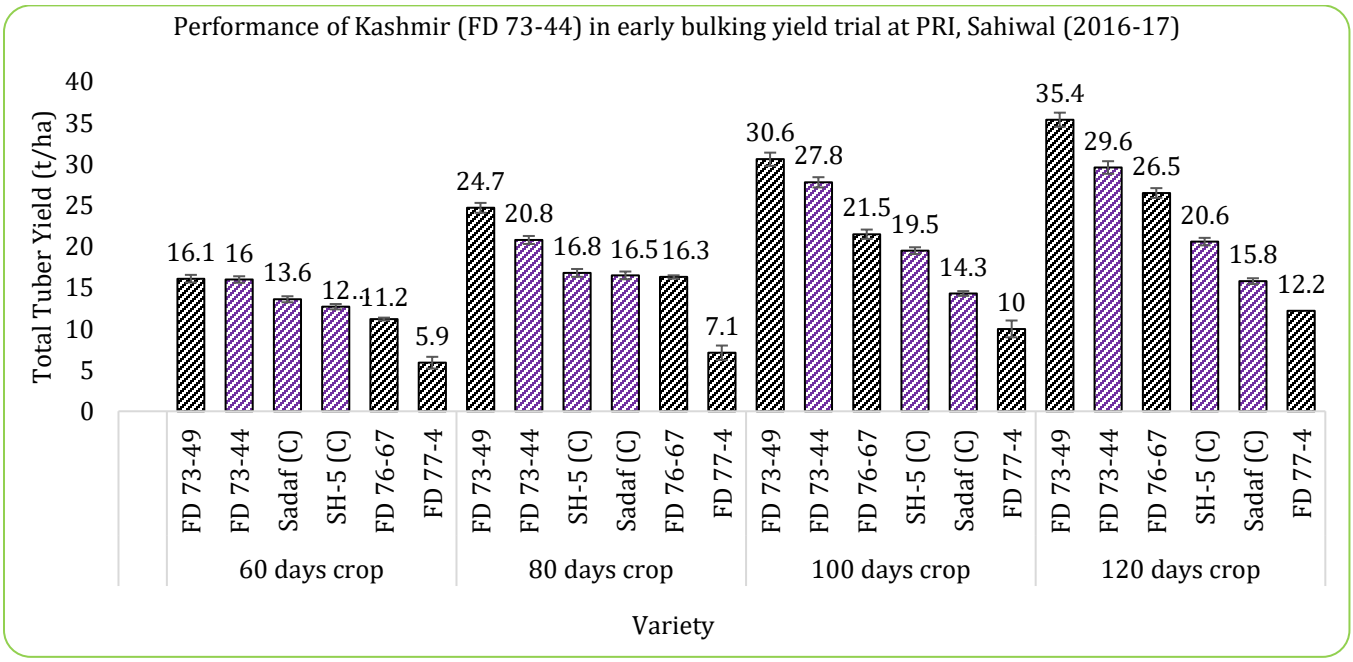

Figure 1. Early Bulking studies of Kashmir (FD 73-44) at PRI, Sahiwal (2016-17).

Frost tolerance studies

Potato varieties "Kashmir" and "Sadaf" were subjected to extensive frost tolerance studies conducted across multiple years and locations, meticulously analyzing their yield and frost tolerance during 2013-14, Kashmir shows frost tolerance with a score, depicting moderate tolerance. In the trials conducted 2016-2017 at PRI, Sahiwal, "Kashmir" yielded 28.0 t/ha with a frost tolerance of 7.3 scores (good tolerance), demonstrating a significant (29.62%) increase over "Sadaf" which yielded 21.6 t/ha with a frost tolerance of 6.7 scores (fairly tolerant). In the trials conducted during 2017-2018 at PRI Sahiwal, "Kashmir" yielded 44.4 t/ha with a score of 7.3 (good tolerance), and also showed a 13.84% increase over "Sadaf," which yielded 39.0 t/ha with a frost tolerance of score 9 (Maximum tolerance). During the same year at NARC, Islamabad, "Kashmir" yielded 9.1 t/ha with a frost tolerance of score 3.5 (less tolerant), indicating a decrease of 16.51% as compared to "Sadaf," which yielded 10.9 t/ha with the same level of frost tolerance.

In the trials conducted during 2018-2019 at PRI, Sahiwal, "Kashmir" yielded 40.7 t/ha with a frost tolerance of score 7 (good tolerance), showing a marginal (1.92%) increase over check "Sadaf," which yielded 41.5 t/ha with a frost tolerance of score 9 (maximum tolerance). Finally, in 2018-2019 at BARI, Chakwal, "Kashmir" yielded 24.3 t/ha with a frost

tolerance of score 4.0 fairly tolerant, indicating a notable increase (38.06%) over "Sadaf," which yielded 17.6 t/ha with a frost tolerance score of 3.7 (low tolerant). Overall maximum frost tolerance was observed during 2013-14, 2016-17, 2017-18 and 2018-19 at PRI, Sahiwal. While low tolerance was observed during 2017-18 at NARC Islamabad. However, the same results were obtained during 2018-19 at BARI Chakwal as shown below:

Table. 5. Frost tolerance studies of Kashmir (FD 73-44) during different years and locations.

Year/ Location	Candidate and Check Varieties	Yield (t/ha)	Frost Incidence	Increase % over check yield
2013-2014/PRI, Sahiwal	Kashmir	-	7	-
2016-2017/ PRI, Sahiwal	Kashmir	28.0	7.3	29.62
	Sadaf (C)	21.6	6.7	
2017-2018/ PRI Sahiwal	Kashmir	44.4	7.3	13.84
	Sadaf (C)	39.0	9	
2017-2018/ NARC, Islamabad	Kashmir	9.1	3.5	-16.51
	Sadaf (C)	10.9	3.5	
2018-2019/ PRI, Sahiwal	Kashmir	40.7	7	1.92
	Sadaf (C)	41.5	9	
18-2019/ BARI, Chakwal	Kashmir	24.3	4.0	38.06
	Sadaf (C)	17.6	3.7	

9=Maximum tolerance, 1=Maximum susceptibility

Plant Pathological Studies

Plant Pathological studies were conducted in 2016-17 at the Summer Agricultural Research Station (SARS) Kaghan, Pakistan (Figure 2). This demonstrated that the variety (Kashmir) is moderately resistant to late blight as compared to the check varieties “Sante” and “Simply Red”. It is assessed that multiple fungal infections are bounding potato productivity and yields in Pakistan. These include late blight (*Phytophthorainfestans* Mont. de Bary), early blight (Alternariasolani), black Scurf and stem canker (*Rhizoctoniasolani Kuhn*) and powdery scab (*Spongospora subterranean*). Across the various potato-growing regions of the country, Fusarium dry rot and wilt (Fusarium sp.) are suspected with reported changes in their consequence on yield and productivity (Rauf et al., 2007; Majeed et al., 2014).

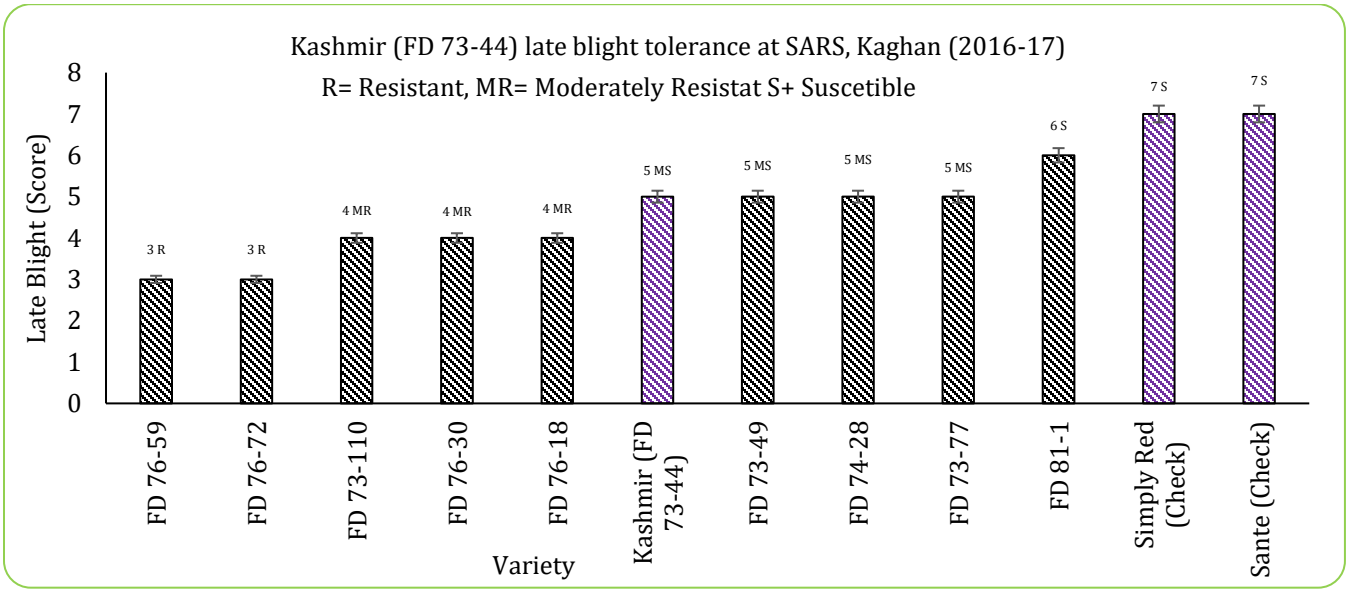

Figure 2. Assessment of late blight tolerance in Kashmir (FD 73-44) and other varieties at (SARS), Kaghan.

Agronomic studies

Comparative yield studies were conducted to investigate how several potato varieties react when sulfur-coated and ordinary urea are used. The results show that with sulfur-coated urea treatment, the "Kashmir" (FD73-44) variety showed a tuber yield of 32.68 t/ha, as compared to 30.59 t/ha with the ordinary urea treatment which is 6.86% higher. The results show that this special formulation of the fertilizer increase the productivity of this potato varieties.

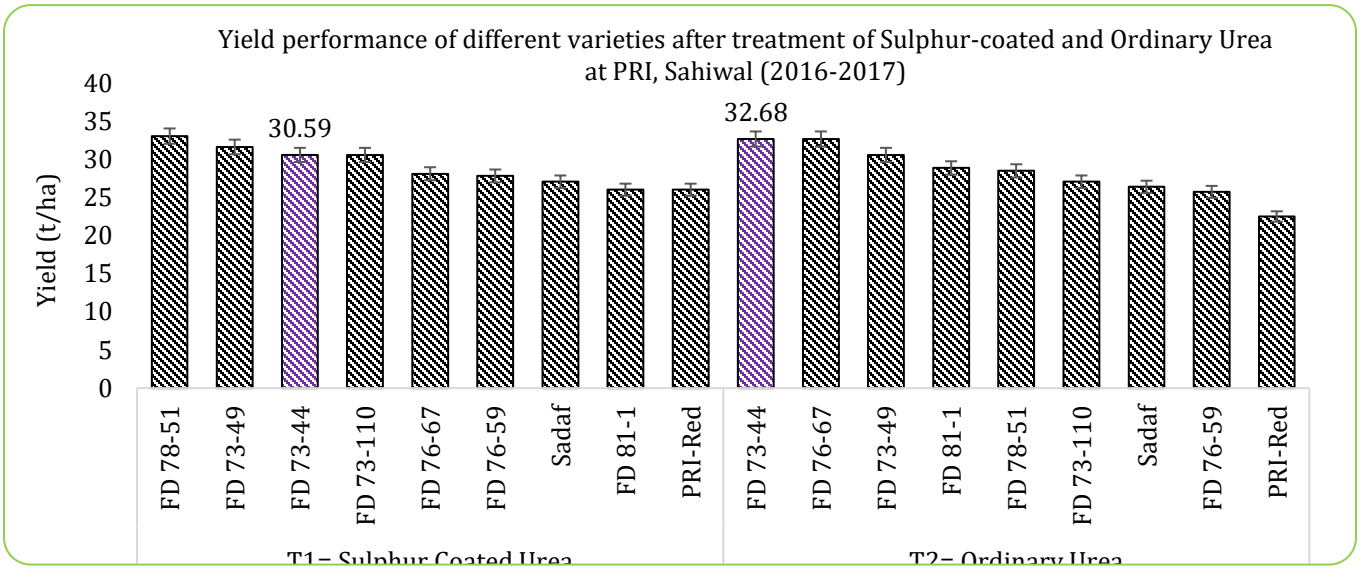

Figure 3. Yield performance of different varieties after treatment of Sulphur-coated and Ordinary Urea at PRI, Sahiwal (2016-2017).

Value Addition Studies

Value addition studies were conducted for the variety “Kashmir” (FD 73-44) and check variety “Simply Red” in 2021 at AARI, revealing some distinct variation among different attributes. The "Kashmir" variety demonstrates a slightly lower dry matter percentage (19.2%) as compared to "Simply Red" (19.4%), along with a marginally reduced specific gravity. However, the dry matter content of a potato tuber is an important characteristic that influences the processing quality of a variety (Leonel et al., 2017). It is also considered a good parameter for potato storage quality (Lisinska and Leszczynski, 1989). The tuber dry matter content must be greater than 20% for processing. However, it is important to note that tuber dry matter content can vary between cultivars, as it is a highly genetically determined trait (Ezekiel et al., 1999). Moreover, "Kashmir" presents lower levels of total sugar, crude protein, and total minerals, contrasting with "Simply Red," which shows higher starch content. In past studies, Kaur and Aggarwal (2014) reported that specific gravity is crucial for estimating potatoes' dry matter and starch content, with values above 1.080 indicating good quality (higher starch content, crude protein and total protein) suitable for processing. Both the varieties have the same vitamin C content while "Simply Red" is a little bit stronger. In addition, the "Kashmir" Variety exhibits superiority in antioxidant level, as proven by its DPPH absorbent value that is, higher than "Simply Red" variety.

Interestingly, though differing in composition, both varieties are equally long-lasting with 60 days shelf life at ambient temperature after harvesting. The above study reveals varied nutritional profiles between "Kashmir" and "Simply Red". However, each is suitable for market consumers on a large scale. Interestingly, specific gravity is the foremost criterion in high-quality tubers, where values are near 1.080 (Kaur and Aggarwal, 2014). Moreover, Berhanu and Tewodros (2016) highlighted the significant influence of cultivar-location interaction, notably seen in the specific gravity of the Belete variety, highest at both locations Adea and Berga. The rise in particular gravity may come from genetic or environmental factors (Tesfaye et al. 2013; Chemeda et al., 2014). Bio Chemistry Section, Post Harvest Research Institute, Ayub Agricultural Research Institute, Faisalabad on 07.04.2021 performed the analysis as presented in Table 6.

Table. 6. Comparison of candidate variety with commercial varieties w.r.t different value addition aspects.

Parameters	Kashmir (FD 73-44)	Simply Red (Commercial checks)
Dry matter (%)	19.2	19.4
Specific gravity	1.081	1.082
Total Sugar (%)	0.98	1.01
Crude protein (%)	7.79	8.58
Total minerals (%)	4.66	4.43
Starch content (%)	16.5	18.0
Vitamin C (mg/100g)	20.0	21.0
Antioxidant % DPPH	65.0	62.8
Shelf life	60 days at ambient temperature (after harvesting)	60 days at ambient temperature (after harvesting) (Sante)

CONCLUSION

"Kashmir," a short season/early bulking potato variety, with disease resistance and higher yield, is a big saviour. It possesses high dry matter, crude protein minerals, and starch. It takes 120-130 days to achieve its full bulk. However, it can be harvested after 100 days having a reasonable marketable yield. The average yield is 44.4 t/ha with a potential of 53.6 t/ha. For its dissemination among farmers, close coordination between the agricultural extension services providers, local government, research organization and farmers is required. Measures like the use of demonstration plots, and seed multiplication, at farmers' fields will help expand the area of adoption of this variety and improve potato production in Pakistan.

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