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Contents

Research Papers

1. Growth, instability and profitability of potato production in eastern India – Sant Kumar, Kingsly Immanuelraj T, Nalini Ranjan Kumar and N.K. Pandey 93

2. Variations in the mineral concentration among different potato (*Solanum tuberosum* L.) accessions – Baljeet Singh, Jagdev Sharma, Vinay Bhardwaj, Salej Sood, Sundaresha Siddappa, Umesh Goutam, Dalamu, Hemant B. Kardile, Bhawna Dipta and NK Pandey 99

3. Optimizing potato productivity in food grain-based organic farming system under sprinkler irrigation – Sanjay Rawal, Pooja Mankar, SK Luthra, Mehi Lal, VK Dua, Manoj Kumar and NK Pandey 108

4. Varietal adoption pattern and economic analysis of potato production in south Bihar, India – Dhiraj K Singh, NK Pandey, Kharumnuid P, Ujjwal Kumar and Rohan Kumar Raman 117

5. Utilization of potato waste for production of bioethanol: a novel technology – Dharmendra Kumar, Som Dutt, SS Changan, MK Lal, AK Jaiswal, RK Tiwari, Vikas Mangal, Pinky Raigond and Brajesh Singh 124

6. Impact of concurrent elevation in CO_2 and temperature on tuber yield and associated traits of potato genotypes – Prince Kumar, Devendra Kumar, Jagdev Sharma, Sunayan Saha, Brajesh Nare, Anil Sharma, Raj Kumar, YK Gupta, VK Gupta, VK Dua and NK Pandey 134

7. A study on sources, management and replacement of potato (*Solanum tuberosum* L.) seed in western Uttar Pradesh – Pynbianglang Kharumnuid, NK Pandey and Dhiraj K Singh 141

8. Influence of integrated crop management technology on potato productivity, profitability, energy dynamics and carbon footprints in north-western Himalayas – Anil K Choudhary, DS Yadav, Pankaj Sood, VK Dua, Amar Singh and Shakuntla Rahi 148

9. Evaluation of newer insecticides for the management of *Myzus Persicae* (Sulzer) – Kailash C Naga, Ajay Kumar, Rahul K Tiwari, Ravinder Kumar, S Subhash, Gaurav Verma and Sanjeev Sharma 161

10. Efficacy and economic of sulfoxflor 12% SL against sucking insect pests of potato – Anuj Bhatnagar 166

Review Paper

11. Updates on molecular markers linked to potato virus y (PVY) resistance genes in potato – Vikas Mangal, Salej Sood, Baswaraj Raigond, Dalamu, Ajay Kumar Thakur, Vinod Kumar, Baljeet Singh, Ashwani Kumar, Rajinder Singh and Vinay Bhardwaj 173

12. Strengthening the intellectual property management and commercialization portfolio of institute potato technologies – Rajender Singh, Vinay Bhardwaj, Baljeet Singh, Sukhwinder Singh and NK Pandey 181

Corrigendum i

Acknowledgement to reviewers (2021) ii

Potato J (2021) 48 (2): 93-98

GROWTH, INSTABILITY AND PROFITABILITY OF POTATO PRODUCTION IN EASTERN INDIA

Sant Kumar[1*], Kingsly Immanuelraj T[1], Nalini Ranjan Kumar[1] and N.K. Pandey[2]

ABSTRACT: This study has examined the historical performance of potato production in eastern India, a key producing region. It has utilized the state-level time-series data collated from secondary sources for the period 2000-01 to 2018-19. Growth in potato is analyzed employing ACGR, while instability is measured applying index method. Positive and significant growth in area, production and productivity of potato has been noticed during study periods (I, II and overall) in states, regional and all-India levels. Further, growth during 2010s has weakened over the previous decade at all level. Analysis of instability revealed decline in variability in period II over period I, and this infers spread and adoption of improved technologies in potato growing states. Economics of potato has shown that net returns per ha increased with varying degrees across states during 2008-18. However, a strict vigil is needed on prices and required steps need to be taken to save interest of the farmers. Also, attention is drawn to develop and promote site-s pecific improved technologies to improve growth and reduce instability.

KEYWORDS: Potato, growth rate, instability, profitability, Eastern India

INTRODUCTION

Potato (*Solonum tuberosum*) is one of the main food crops worldwide. Its production at global level reached at 366.2 million tonne (Mt), covering 17.6 million ha (Mha) with a yield of 20.8 t/ha during triennium ending (TE) 2018. India is the second largest contributor after China, both in area and production of potato. It contributed over 12 % share in both area and production of potato with a yield of 21.8 t/ha during TE 2018. About a third of global production of potato comes from China and India (FAO, 2017).

The value of potato output in India was ₹ 29,062 crore (at 2011-12 prices) during TE 2018-19 (GoI, 2021). Potato production in India reached at 53.03 Mt from harvested area of 2.2 Mha in 2019-20. The eastern region of India is the key potato producing tract and accounts for about 72 % of total output in 2019. In this region, Uttar Pradesh (eastern part), West Bengal, Bihar, Assam, and Jharkhand are the key producers and share over 95 % of total output of the region. Since, eastern India is the key producing region and substantial area falls in this region, the updated knowledge of growth and instability is a necessary condition for moving the potato sector forward.

Measurement of growth and instability in agricultural production has been a topical subject in agricultural economics literature in India. While the increase in agricultural output or growth is taken as obvious, the rise in instability is viewed adverse due to several reasons. It raises the risk involved in farm production, affects farmers' income and decisions to adopt capital-intensive technologies and make investments in farming (Chand and Raju, 2009). Instability in output affects price stability, consumers' demand, and increases vulnerability of low income households. A large number of studies have been made in assessing the performance using physical output and value of production for major foodgrains, oilseeds, pulses, sugarcane, and commercial crops (Hazell, 1982; Mahendra

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Dev, 1987; Saha and Swaminathan, 1994; Larson *et al.*, 2004; Sharma *et al.*, 2006; Chand and Raju, 2009; Kumar and Jain, 2013; Tewari *et al.*, 2017). However, studies dealing with potato in major states of eastern India are limited. The present study analyzes the growth performance, instability and profitability of potato production in eastern India. The paper is organized in four sections. Background of the paper is provided in section I, and the methodology is dealt in section II. The results and discussion is described in section III and the last section summarized conclusions and suggestions emerged from the study.

MATERIALS AND METHODS

The present study is based on the state-level time-series data collated from secondary sources (DES, 2020; GoI, 2021; and ICAR-CPRI Annual Reports, various years). The historical growth performance of potato has been analyzed for key states of eastern India. This key producing region cover states of Assam, Bihar, Chhattisgarh, Jharkhand, Odisha, West Bengal and Uttar Pradesh (eastern parts). It contributed to about 72 % of total potato output during TE 2019. The study covered last two decades from the period 2000-01 to 2018-19. This long time period was divided into two sub-periods, period I (2000-2010) and period II (2011-2019). The basis for dividing into sub-periods was to understand the decadal performance. The analysis for Chhattisgarh and Odisha states could not be done due to paucity of required data, while whole Uttar Pradesh was taken due to absence of district level data to arrive at figures for eastern parts.

The annual compound growth rates (CAGR) of area, production and productivity of potato were computed to examine growth performance. The exponential model is used to estimate growth rate.

$$Y_t = ab^i$$

where, Y is Area/ production/ yield; a refers intercept, b denotes Regression co-efficient, i is Time trend and e_t is residual of regression. The above equation can also be expressed as follows after taking natural log transformation of both side and estimating the regression equation:

$$Ln\ Y_t = Ln\ a + i\ Ln\ b + e_t$$

The compound growth rate was worked out by:

$$CAGR\ (r) = [e(ln\ b) - 1] * 100$$

where, r is compound growth rate, e is exponential function.

Measurement of instability in potato performance is another dimension and has been analyzed using index method suggested by Ray (1983) and widely used to estimate instability in agricultural production (Mahendra Dev, 1987; Rao *et al.*, 1988; Chand and Raju, 2009). This method of instability is measured by:

$$Instability\ index = std.dev\ (ln\ (^{Y_{t+1}} / Y_t))$$

where, Y_t is the Area/production/yield in the current year and, Y_{t+1} refers for the next year. This index is unit free and very robust, and it measures deviations from the underlying trend (log linear in this case). When there are no deviations from trend, the ratio of Y_{t+1}/Y_t is constant and thus standard deviation is zero. As the series fluctuates more, the ratio of Y_{t+1} and Y_t also fluctuates more, and standard deviation increases.

Another data set used in this study was costs and returns associated with potato production and derived from Cost of Cultivation series presented by Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, Government of India.

RESULTS AND DISCUSSION

Production Profile and Growth

Total production of potato increased substantially at all-India level during past

forty years, from 9.7 Mt in 1981 to 53.0 Mt in 2019 (Figure 1). During the above period, area increased by 3-times, productivity by 2-times, and output by 5-times. The increase in productivity was due to release of stress tolerant (drought and disease) and input responsive potato varieties, particularly of improved genetic potential, use of certified quality seeds and its frequent replacement (CPRI, 2019), and micro irrigation replacing furrow method (Kumar *et al*., 2009; Singh, 2013). Evidence revealed that on an average, seed replacement rate (SRR) for improved varieties was 100 % and 91.2 % in West Bengal and Uttar Pradesh, respectively, and the SRR for certified seeds was 40.3 % and 30 % in West Bengal and Uttar Pradesh, correspondingly (CPRI, 2019), while it was very poor (14.2 %) in Bihar (CPRI, 2018).

Historical Performance

This section briefly presents the historical performance and growth of potato production in key states of eastern region of India.

(i) Changes in Production

The eastern India is a major producing region of potato in the country. In the region, potato output increased nearly 88 %, from 19,424 thousand tonne to 36,484 thousand tonne during 2001-19 (Table 1). The region



Figure 1. Trend in area, production and yield of potato in India, 1981-2019

contributed 69 % of total output at all-India and 96 % at region level in TE 2019. Further, 62 % of additional potato production in past two decades (2001-2019) came from eastern region (Uttar Pradesh, West Bengal and Bihar). In view of poor progress, special attention is needed for states of Assam and Jharkhand to stabilize production in the region.

(ii) Growth Performance

Growth performance of potato was analyzed for sub-periods viz. 2000s, 2010s and overall period (2001-2019) and presented (Table 2). Analysis shows that during the overall period, growth in area, production and yield was positive and significant at all-levels. Also, growth in production was contributed by both area and yield. It is noted that growth in output was highest in Bihar (15.8 %), followed by Jharkhand (4.3 %), Uttar Pradesh

Table 1. Change in production of potato in eastern India

State/ region	Production during TE (thousand tonne)			Change in production (thousand tonne)			Share in changed production (%)
	2001	2011	2019	2001-11	2011-19	2001-19	2001-2019
Assam	658.4	647.1	742.6	-11.3	95.5	84.2	0.30
Bihar	1,605.4	5,632.6	7,289.7	4,027.2	1,657.1	5,684.3	20.76
Jharkhand	3,76.2	529.2	683.4	153.0	154.2	307.2	1.12
West Bengal	7,282.7	8,787.1	12,210.1	1,504.4	3,423.0	4,927.4	18.00
Uttar Pradesh	9,502.3	12,611.2	15,558.1	3,108.9	2,946.9	6,055.8	22.12
Eastern India	19,423.9	28,207.2	36,483.8	8,783.3	8,276.6	17,059.9	62.33
All-India	23,604.0	37,769.2	50,980.3	14,165.2	13,211.1	27,376.3	100.00

Source: Authors' estimate

Table 2. Annual compound growth rates in area, production and yield of potato in eastern states during

State/ region	Period I (2001-10)			Period II (2011-2019)			Overall period (2001-2019)		
	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
Assam	0.33	-1.14	-1.46	2.09 [b]	-0.10	-2.15	2.20 [a]	2.53 [a]	0.32
Bihar	7.85[a]	13.34 [a]	5.09 [a]	-0.26	3.00	3.27	6.06 [a]	15.82 [a]	9.20 [a]
Jharkhand	0.40	1.20 [c]	1.16	1.23	0.61	-0.61	1.79 [a]	4.26 [a]	2.43 [a]
West Bengal	3.24 [a]	-1.56	-4.65	1.35	0.81	-0.53	2.07 [a]	3.33 [a]	1.23
Uttar Pradesh	3.04 [a]	3.24 [a]	0.20	1.26 [a]	1.66 [b]	0.40 [b]	2.47	3.41 [a]	0.92 [a]
Eastern India	3.73 [a]	2.99 [a]	-0.71	1.01 [b]	1.53	0.52	2.92 [a]	5.50 [a]	2.51[b]
All-India	4.90 [a]	4.55 [a]	-0.34	2.01 [a]	2.91 [a]	0.89	3.78 [a]	5.68 [a]	1.84 [a]

Note: a, b and c indicate significance at 1, 5 and 10 per cent, respectively.
Source: Authors' estimate

(3.4 %), West Bengal (3.3 %), and lowest in Assam (2.5 %). Further, during 2000s and 2010s, area and output growth was positive and significant, except in Assam and West Bengal. This suggests for a yield enhancing technologies and suitable policies for Assam and West Bengal. Also, during 2010s, growth in output and yield weakened and area growth was mainly responsive for increase in output.

Instability in Production

Instability in potato output is caused by variability in area and yield. If the instability in both components decline, the instability in output declines. The instability index (derived from standard deviation of natural logarithms of area, production and yield) of potato production is presented here. It is interesting to note that instability in area and yield of potato has declined in states of eastern region and at all-India during the Period II over the period I (Table 3). The effect of decline is reflected as declining instability in output at all levels. This infers large scale spread and adoption of improved technologies and use of quality inputs across potato growing regions. However, rise in instability in area and almost stagnating in output and yield has been reported for periods between 1950-51 and 2006-07 (Chand and Raju, 2009). The instability in output could be further reduced by adopting area-specific recommended cultivars resistance to key diseases, insect-pests and climate resilient.

Table 3. Instability in area, area production and yield of potato in eastern states during

State/ region	Period I (2001-10)			Period II (2011-2019)			Overall period (2001-2019)		
	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
Assam	0.064	0.233	0.240	0.042	0.232	0.207	0.054	0.227	0.210
Bihar	0.248	0.488	0.255	0.022	0.075	0.086	0.179	0.352	0.255
Jharkhand	0.033	0.162	0.154	0.085	0.053	0.064	0.063	0.120	0.154
West Bengal	0.092	0.473	0.502	0.074	0.250	0.219	0.082	0.374	0.502
Uttar Pradesh	0.062	0.110	0.094	0.041	0.046	0.058	0.052	0.084	0.094
Eastern India	0.066	0.156	0.180	0.023	0.352	0.255	0.050	0.127	0.180
All-India	0.074	0.113	0.091	0.021	0.076	0.071	0.055	0.094	0.091

Source: Authors' estimate

Economics of Production

(i) Profitability

The profitability in potato production is studied using the cost of cultivation data. Quinquennial average for operating cost, gross returns and net returns were worked out to understand changes occurred between 2004-08 and 2014-18. In the cost concept terminology, the operational cost also called as Cost A1 included those items of cost for which farmers pay from their pocket plus land revenue. Analysis shows that operational cost increased proportionately higher than that of gross returns during above period (Table 4).

In West Bengal, farmers incurred higher cost in potato cultivation (₹ 115,169/ ha), followed by Uttar Pradesh (₹ 74,439/ha) and Bihar (₹ 59,906/ha). Regarding net returns, Uttar Pradesh was at top (₹ 60,354/ ha), followed by Bihar (₹ 41,186/ha), and it was lowest in West Bengal (₹ 27,722/ha) during 2014-18. Almost similar trend is seen during previous period (2004-08) as well. The higher operational cost was associated with higher input cost, especially on family labour, fertilizers, insecticides, and manures. In depth scrutiny has revealed that family labour cost was 2-times higher than that in other states of eastern region. Data show that benefit-cost (B-C) ratio was positive and declined marginally in recent over previous period.

(ii) Yield and Price

To further probe the reasons for lower returns in West Bengal, the yield, production cost and price received per quintal was correlated. Data show that potato yield was higher in West Bengal, followed by Uttar Pradesh and Bihar during 2014-18 (Table 5). About price, potato farmers in Bihar and Uttar Pradesh received ₹ 600/q, and ₹ 664.7/q, respectively, while farmers in West Bengal received ₹ 551/q during 2014-18. In addition, wide fluctuations in prices of potato per quintal noted as ₹ 835, ₹ 351, ₹ 717 and ₹ 419 during the year 2015, 2016, 2017, and 2018, respectively, in West Bengal (https://eands.dacnet.nic.in). These evidences suggest that low average prices are mainly causing lower returns. Findings suggest to keep a strict vigil on prices to save interest of producers. However, a study of 100 sample farms in West Bengal (50 each in Bardhaman and Hooghly districts) reported average price of potato received ₹ 696/q during

Table 4. Economics of potato production i n major states of eastern India

(₹/ha)

State	Operational cost		Gross returns		Net returns		B:C ratio	
	2004-08	2014-18	2004-08	2014-18	2004-08	2014-18	2004-08	2014-18
Bihar	31,972.4	59,906.0	65,014.0	1,01,092.6	33,041.6	41,186.6	2.03	1.69
Uttar Pradesh	38,591.6	74,439.1	80,029.9	1,34,793.2	41,438.1	60,354.1	2.07	1.81
West Bengal	53,533.6	1,15,169.4	67,963.9	1,42,892.3	14,430.3	27,722.9	1.27	1.24

Source: Authors' estimate

Table 5. Average yield and farm gate price received by potato farmers in major states of eastern India

State	Yield (q/ha)		Production cost (₹/q)		Farm gate price (₹/q)	
	2004-08	2014-18	2004-08	2014-18	2004-08	2014-18
Bihar	165.8	168.3	192.8	355.9	392.1	600.7
Uttar Pradesh	204.3	202.8	188.9	367.1	391.7	664.7
West Bengal	196.4	259.3	272.6	444.2	346.0	551.0

Source: Authors' estimate

2018 (CPRI, 2019). Thus, potato cultivation in West Bengal is remunerative like other states of eastern region of India.

CONCLUSION

The findings of study indicate that states of eastern India are important producer of potato and shared about 72 % of total output in the country during TE 2018-19. The growth in output was contributed by growth in area and yield during 2001-2019, while growth weakened during 2010s over the previous decade (2000s), and negative growth in yield noticed for West Bengal in both periods. The negative yield growth in West Bengal and weakening growth in other states needs special attention of potato researchers and policy makers to improve the situation. Because, the eastern region of the country will remain the key producing region in years to come owing to crop suitability and quick income generating crop. Decline in instability in potato is noticed and this shows wide-scale spread and adoption of improved technology. This also infers that potato production has become less-riskier than was two-decades ago. Economics of potato shows that this crop is profitable. Wide fluctuations in prices in alternate years, particularly in West Bengal, needs a strict vigil and steps required to save the interest of farmers.

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LITERATURE CITED

Chand, R and Raju SS (2009) Instability in Indian Agriculture During Different Phases of Technology and Policy, *Indian Journal of Agricultural Economics*, **64** (2): 187-207.

CPRI (2018) Annual Report 2017-18. ICAR-Central Potato Research Institute, Shimla, India.

CPRI (2019) Annual Report 2018-19. ICAR-Central Potato Research Institute, Shimla, India.

DES (2020) Cost of Cultivation of Principal Crops in India. Directorate of Economics and Statistics, Ministry of Agriculture & Farmers Welfare, Government of India.

FAO (Food and Agriculture Organization of the United Nations) (2017) FAOSTAT. FAO Statistics Division. http://faostat3.fao.org

GoI (2021) State-wise and Item-wise Value of Output from Agriculture, Forestry and Fishing 2011-12 to 2018-19. National Statistical Office, Ministry of Statistics and Programme Implementation, Government of India.

Hazell, Peter B. R. (1982) Instability in Indian Foodgrain Production, *Research Report No. 30*, International Food Policy Research Institute, Washington, D.C., U.S.A.

Kumar, Y, and Jain R (2013) Growth and Instability in Agricultural Productivity: A District Level Analysis, *Agricultural Economics Research Review*. **26** (Conference):31-42.

Kumar S, Asrey R., Mandal G, and Singh R (2009). Micro-sprinkler, drip and furrow irrigation for potato (*Solanum tuberosum*) cultivation in a semi-arid environment. *Indian Journal of Agricultural Sciences*. **79** (3): 165–169.

Larson, DW, Jones E, Pannu R S and Sheokand RS (2004) Instability in Indian Agriculture – A Challenge to the Green Revolution Technology, *Food Policy*.**29** (3): 257-273.

Mahendra Dev S (1987) Growth and Instability in Foodgrains Production: An Interstate Analysis, *Economic and Political Weekly*. **22** (39), September 26, pp. A82-A92.

NHB (2020) National Horticulture Board. Ministry of Agriculture & Farmers Welfare, Government of India. Online data on area, production and yield from website downloaded from http://wwww.nhb.gov.in/Default.aspx.

Rao, CH Hanumantha, Ray SK, and Subbarao K (1988) Unstable Agriculture and Droughts: Implications for Policy, Vikas Publishing House Pvt. Ltd, New Delhi.

Ray S K (1983) An Empirical Investigation of the Nature and Causes for Growth and Instability in Indian Agriculture: 1950-80, *Indian Journal of Agricultural Economics*. **38**(4): 459- 474.

Saha Y, and Swaminathan M (1994) Agricultural Growth in West Bengal in 1980s: A Dis-Aggregation by Districts and Crops, *Economic and Political Weekly*. **29** (13), March 26, pp. A2-A11.

Sharma, HR, Singh K and Kumari S (2006) Extent and Source of Instability in Foodgrains Production in India, *Indian Journal of Agricultural Economics*. **61** (4): 648-666.

Singh O P (2013) Hydrological and Farming System Impacts of Agricultural Water Management Interventions in North Gujarat, *Indian Journal of Agricultural Economics*. **68** (3): 292-312.

Tewari H, Singh H P, and Tripathi U (2017) Growth and Instability in Wheat Production: A Region Wise Analysis of Uttar Pradesh, India, *International Journal of Current Microbiology and Applied Sciences*. **6**(9):2537- 2544.

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VARIATIONS IN THE MINERAL CONCENTRATION AMONG DIFFERENT POTATO (*SOLANUM TUBEROSUM* L.) ACCESSIONS

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ABSTRACT: A collection of one hundred tetraploid potato accessions was evaluated in relation to the concentrations of nine minerals (Fe, Zn, Cu, Mn, Ca, Mg, S, P and K) required for human nutrition. Large amount of variability for selected minerals was observed in the germplasm. Significant positive correlations (P < 0.001) were found between Fe-Cu (r^2=0.41), Zn-Cu (r^2=0.46), Mn-K (r^2=0.51) and Ca-Mg (r^2=0.40), whereas significant negative correlation (P < 0.001) was observed between P-K (r^2= -0.36). The first two principle components accounted 42.72% of the total observed variations. Unweighted pair group method with arithmetic mean (UPGMA) based clustering distinguished the potato accessions into different groups based on Gower distances. These results will be useful for developing biofortified potato varieties using traditional and modern breeding methods. Moreover, variations in the mineral contents within the potato germplasm could also be used for the identification of molecular markers associated with mineral concentrations through genome wide association studies (GWAS).

KEYWORDS: Potato, germplasm diversity, minerals, biofortification, iron, zinc

INTRODUCTION

To maintain optimal health, human body requires a diverse as well as balanced diet containing both micronutrients and macronutrients. The micronutrients are vitamins and minerals, which are required in minute quantities but are essential for human health. Minerals are categorised into two sub-groups; 1) macro-minerals and 2) micro-minerals (trace minerals). The macro-minerals involves calcium (Ca), magnesium (Mg), sulphur (S), phosphorous (P), potassium, (K) sodium (Na) and (Cl), while the micro-minerals involves iron (Fe), zinc (Zn), copper (Cu), manganease (Mn), cobalt (Co), boron (B), molybdenum (Mo), chromium (Cr) and fluoride (F) (Mohammad *et al.,* 2017). These minerals play important roles in human body to maintain a good health and there deficiencies may lead to serious health issues (reviewed by Mohammad *et al.,* 2017; Sun *et al.,* 2021). The micronutrient malnutrition is a global issue, which is highly common in developing countries. Globally about 2 billion people are suffering from it and around one third out of these 2 billion people live in India (Kotecha 2008). Among all the minerals, the deficiency of iron and zinc is widespread. Iron deficiency cause anemia. Worldwide, anemia affects 1.62 billion individuals and highly prevalent in children and adolescent girls (McLean *et al.,* 2009). The largest portion of global malnourished population live in India. The Indians take a daily diet that is far from satisfactory and less than 50% of recommended dietary allowance (RDA) is taken by over 70% of Indian population (Kotecha 2008). In India, about 69% children below age 5 years and are affected by anemia (Kotecha 2008).

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During the last decade, several scientific and technological attempts were made to reduce the micronutrient malnutrition. The governments has developed several new policies with an aim to reduce hidden huger throughout the world (Tulchinsky 2015). Most of these policies are based upon the use of diversified diet, food supplements, food fortification and crop biofortification. All these have their own merits and demerits. However, among all crop biofortification has emerged as a sustainable solution for this serious issue. In the recent years, a large number of studies were conducted to develop biofortified crops by using different approaches (Garg *et al.,* 2018; Singh *et al.,* 2021a). Potato is world's most consumed non-grain staple food crop. It can produce more food per unit time, water and area compared to other major food crops (Azimuddin *et al.,* 2009). It is a modest source of nutrients and previous studies showed that the high bioavailability of Fe and Zn from potato tubers compared to cereals (Andre *et al.,* 2015; Jongstra *et al.,* 2020). The presence of genetic variations for mineral content in the potato germplasm suggest that nutrient rich potato cultivars have potential supply a much higher portion of RDA for various minerals than the present potato cultivars (Sharma *et al.,* 2017; Subramanian *et al.,* 2017; Singh *et al.,* 2021b). Potato appears as an ideal crop for biofortification as it is a versatile crop with an enormous industrial demand and high consumer's acceptability. The biofortified potatoes can be developed by using agronomic approaches, conventional and modern breeding. The generation of biofortified crops by breeding is considered as the most suitable way as crops developed by this method produce self-biofortified seeds. Therefore, once a biofortified variety developed it can be used for years. However, the knowledge of nutrient rich accessions in the crop germplasm is the most basic need to develop biofortified crops. In this study, one hundred highly diverse potato accessions were studied for nine mineral concentrations.

MATERIALS AND METHODS

One hundred highly diverse tetraploid potato accessions used in the current study were obtained from Indian Council of Agricultural Research - Central Potato Research Institute (ICAR-CPRI), Shimla, India. Seed tubers were sown in November 2019 at ICAR-Central Potato Regional Station (CPRS), Modipurum, India. The plot size was 3.6m^2 and the row to row and plant to plant spacing was 60 X 20 cm. The crop was raised under uniform agronomic practices. The tubers were harvested after 90 days from the date of planting. The soil of the experimental field has pH 6.69 in reaction and the available mineral nutrients were in sufficient amounts. The standard protocols were followed for field sampling of potato tubers and for preparation of oven-dried and milled potato tuber samples (Porras *et al.,* 2014). Seven even sized unblemished tubers of each accession were selected for this study. As the tubers of some accessions were small and irregular in shape. Therefore, whole tubers were used for the mineral analysis. The tubers were thoroughly washed with tap water to remove the surface soil, then by 0.1% nitric acid and then with double distilled water. Later the air-dried tubers were chopped with high quality stainless steel knives and were kept in hot air oven at 70°C and then powdered samples were used for the estimation of mineral concentrations after acid digestion. Acid digestion was performed with nitric acid in analytical grade nitric acid in microwave digester (CEM, MARS6™) and mineral analysis was performed using inductively coupled-plasma mass spectrometry (iCAP 7000 Series ICP-OES, Thermo Scientific™). The

concentration of phosphorus was estimated by using vanadate-molybdate (yellow) method using spectrophotometer (UV-1700 PharmaSpec Shimadzu™).

Data of the mineral concentrations was used to calculate Pearson's coefficient of correlation among the minerals. The correlation analysis was performed in R software using the package 'psych'. Box plots were used to illustrate the extent of diversity of tuber mineral content among the 100 potato accessions. The principal component of analysis was computed after data transformation and a biplot was obtained using correlation matrix to illustrate the relationships among the traits. A cluster analysis of the mineral concentrations was performed using Gower distances and a dendrogram was constructed.

RESULTS AND DISCUSSION

Variation in the mineral concentrations

There were larger variations in the mineral concentrations in the potato germplasm studied. The descriptive statistics (range, mean, standard deviation (SD) and the coefficient of variance) for the mineral content are presented in the table-1. The concentrations Fe varied from (23.60-76.90 mg kg^{-1}), Zn from (6.80-36.00 mg kg^{-1}), Cu from (3.80-23.10 mg kg^{-1}), Mn from (7.20-28.40 mg kg^{-1}), Ca from (0.02-0.10%), Mg from (0.04-0.29%), S from (0.11-0.49%), P from (0.13-0.39%) and K from (0.48-2.61%) on dry weight basis. The substantial differences among the accessions for different mineral concentrations were observed and are presented as boxplots in figure 1. Each boxplot represents five statistical bars from bottom to top; 1) the lowest observed value, 2) lower quartile, 3) median, 4) upper quartile, 5) highest observed value. The distributions of concentration of these minerals in the germplasm are depicted in figure 2. There were significant differences in the mineral content within the whole set of 100 potato accessions tested in this study, suggesting that for these minerals there is some genetic potential, which can be used to enhance mineral content in the potato tubers.

The accessions with highest Fe content (76.90 mg kg^{-1} in JEX/A-274, 76.40 mg kg^{-1} in JEX/A-413, and 74.90 mg kg^{-1} in JEX/A-199 and JEX/A-920) were belongs to *Solanum tuberosum* ssp. *andigena*. The mean Fe content (54.19 mg kg^{-1}) in potato germplasm was higher than the mean Fe content (43.87 mg kg^{-1}) observed in the cultivated Indian potato varieties. Sharma *et al*. (2017) reported a mean Fe concentration of 43.94 mg kg^{-1} in the whole tubers of popular Indian potato varieties, while Andre *et al*. (2007) reported an average Fe concentration of 54.95 mg kg^{-1} in Andean potato cultivars. In this study, the mean Zn concentration (22.56 mg kg^{-1}) observed was slightly higher than previously reported (20.40 mg kg^{-1}) by Haynes *et al*. (2012) and there were 40 accessions with Zn concentration more than mean. Dalamu

Table 1. Summary of variations in terms of mean, standard deviations (SD), and ranges in the whole tuber mineral content in 100 potato accessions

	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mn (ppm)	Ca (%)	Mg (%)	S **(%)**	P (%)	K (%)
Min	23.60	6.80	3.80	7.20	0.02	0.04	0.11	0.13	0.48
Max	76.90	36.00	23.10	28.40	0.10	0.29	0.49	0.39	2.61
Mean	51.71	22.56	10.27	14.93	0.04	0.12	0.24	0.23	1.37
SD	14.22	6.02	4.03	6.16	0.02	0.05	0.08	0.06	0.69
CV	27.50	26.67	39.26	41.25	44.91	45.15	34.52	25.23	49.98

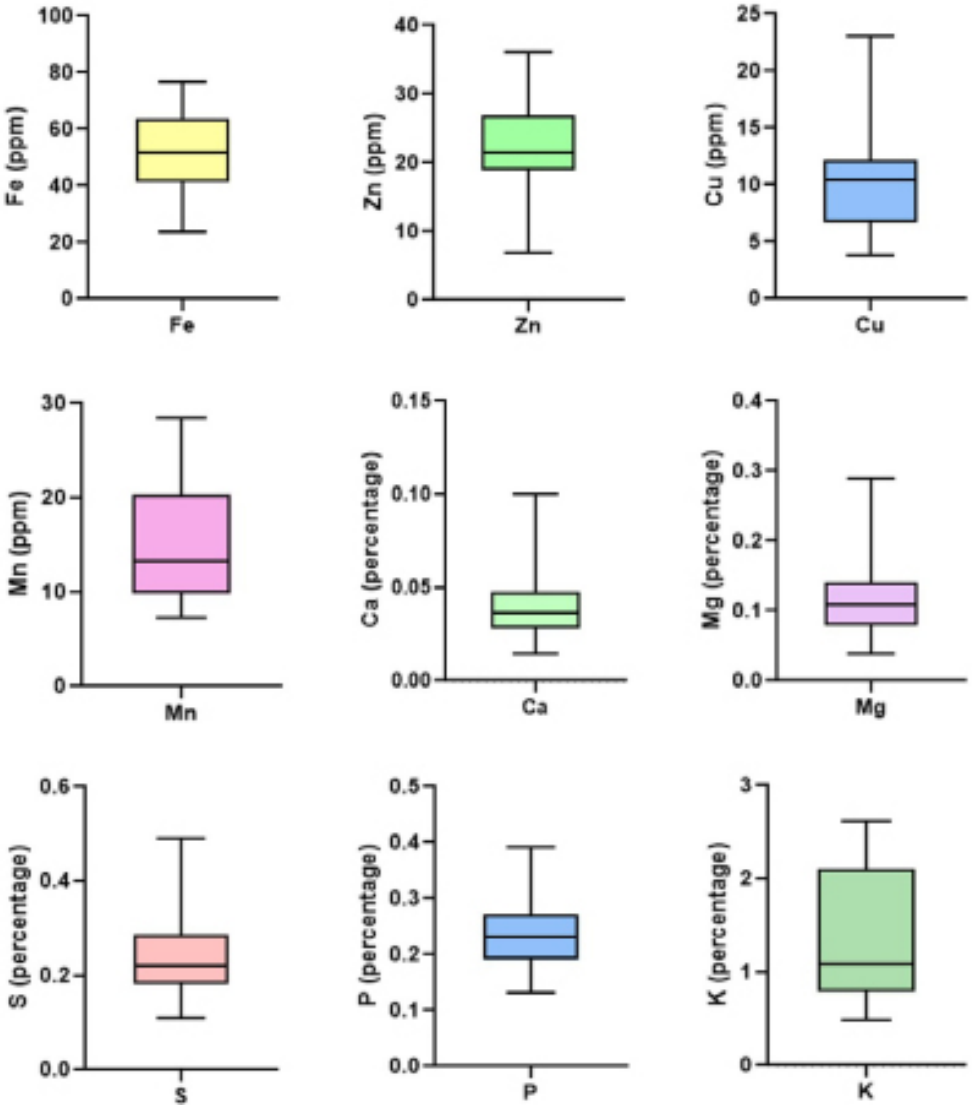


Figure 1. Box plots representing variations in potato tuber mineral (Fe, Zn, Cu, Mn, Ca, Mg, S, P and K) content

et al. (2017, 2019) reported similar ranges for Zn content in potato tubers. Highest Zn concentration was observed in CP 3191. There were significant differences in the Cu content within the germplasm studied. The Cu content observed in the current study ranged from (3.80-23.10 mg kg^{-1}), while in the previous studies values reported for Cu content in potato ranged from 2.6 - 10.8 mg kg^{-1} (Subramanian *et al*., 2017), 4.43 - 22.47 mg kg^{-1} (Singh *et al*., 2020) and 5.13 - 21.06 mg kg^{-1} (Sharma *et al*., 2017). The concentration of Mn varied from 7.20 mg kg^{-1} in CP 3144 to 28.40 mg kg^{-1} in CP 3245 and CP 1679. The Mn concentration above 20 mg kg^{-1} were observed in 25% accessions. We observed a mean Mn concentration of 14.93 mg kg^{-1} was higher than previously reported by Subramanian *et al*. (2017), but less than the mean Mn concentration reported by Sharma *et al*. (2017) in whole tubers. There were significant variations among the accessions for secondary as well as macro elements (Ca, Mg, S, P and K) (Table 1).

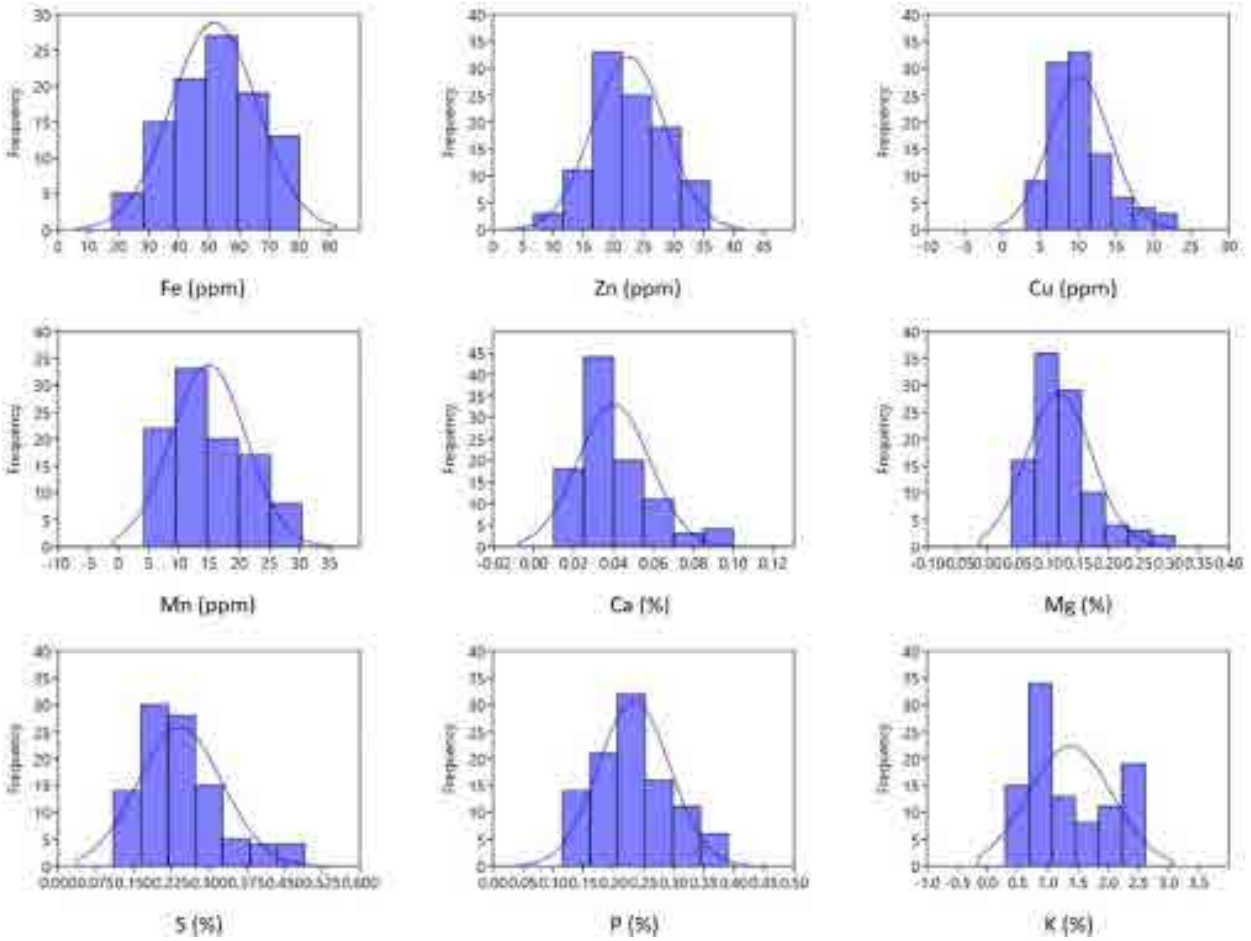


Figure 2. Distribution of mineral concentrations in the tubers of 100 tetraploid potato accessions

Relationships among the traits

In this study, correlations between different minerals were studied and it was observed that Fe, Zn and Cu were positively correlated (Figure 3). Positive and significant correlations were found between Fe-Zn (r^2 = 0.27, p = 0.01), Fe-Cu (r^2 = 0.41, p = 0.001), Zn-Cu (r^2 = 0.46, p = 0.001), Mn-K (r^2 = 0.51, p = 0.001) and Ca-Mg (r^2 = 0.40, p = 0.001). Some other weak to moderately positive correlations were observed between the traits studied. Previous studies also reported positive correlations between these micronutrients in potato (Dalamu *et al.*, 2019; Singh *et al.*, 2020). Significant positive correlations were also observed between P-Fe (r^2 = 0.31, p = 0.01) and P-Zn (r^2 = 0.27, p = 0.01). Earlier, Abebe et al. (2012) also reported positive correlations between P-Fe and P-Zn concentrations in the potato tubers. A negative and significant correlation was observed between K and P (r^2 = –0.36, p = 0.001). The UPGMA based clustering by utilizing the Gower dissimilarity matrix confirms the existence of wide diversity among the potato germplasm studied (Figure 4). The potato germplasm was grouped into three larger clusters, which would be helpful to select and breed the accessions from different groups to unite the desirable genes.

Principal component analysis

The vector view of genotype trait biplot provided a brief summary of the

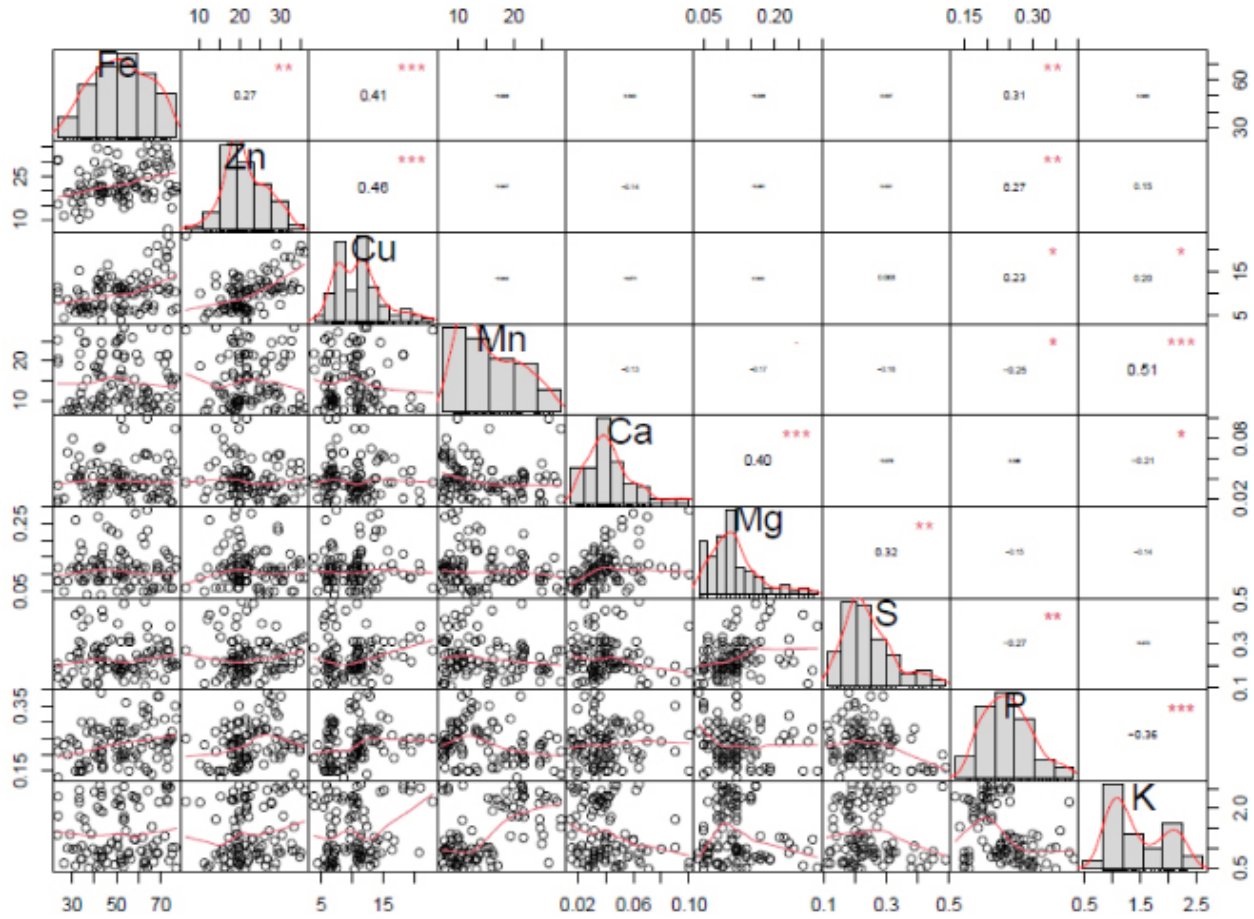


Figure 3. Pearson's correlation matrix for tuber mineral (Fe, Zn, Cu, Mn, Ca, Mg, S, P and K) content of potato accessions.
Note: ***, significant at P < 0.001; **, significant at P < 0.05; *, significant at P < 0.05

inter relationships among the mineral concentrations (Figure 5). The cosine of the angle between different vectors of any traits approximates the correlation coefficient between them (Akçura 2011; Akcura and Kokten 2017). The angles between the different mineral vectors suggest that Fe, Zn, Cu and P concentrations were positive and significantly correlated. Likewise, significant positive correlations were found between Mg–Ca and Mn–K, respectively. Other associations among the traits were not highly significant. The PC1 and PC2 explained 22.23% and 20.49% of the total variations. PC1 was positively loaded with Fe, Zn, Cu and P and negatively loaded by Mn, Mg and K. In PC2, K and Mn were dominating variables on the positive side, whereas Ca and Mg were the negatively dominating variables. The first three principal components showed 59.32% of the total variation. The details of the eigenvectors, eigenvalues and percent variation explained by first five principal components are provided in table 2.

CONCLUSION

Potato is a staple crop of many countries. India is the second largest potato producing country, after China. The information about the diversity present in potato germplasm will help in the screening of germplasm with desirable traits. The present study provides

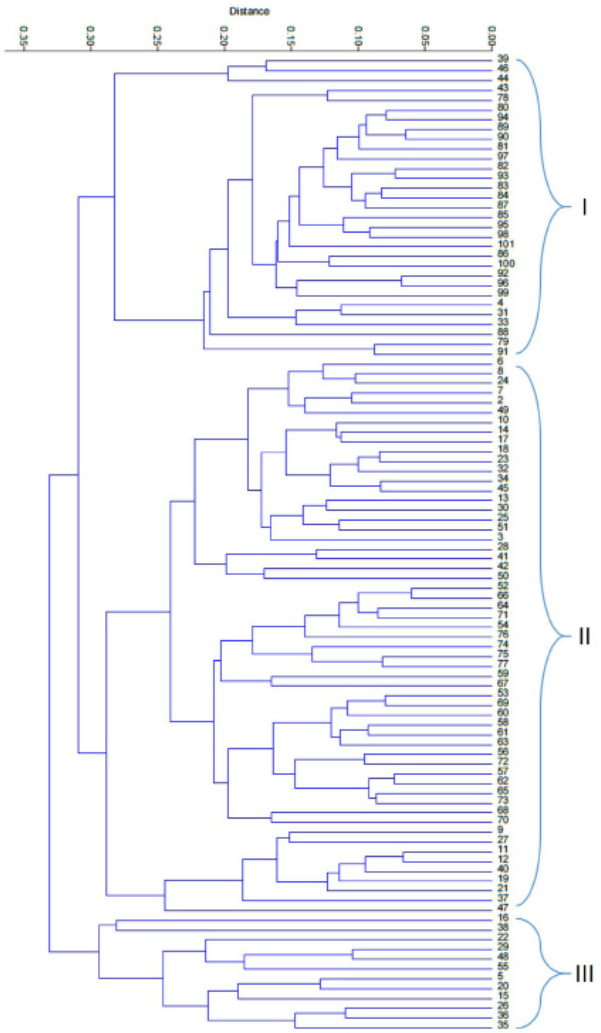


Figure 4. UPGMA based clustering for mineral content in 100 tetraploid potato accessions

Table 2. The details of loadings, eigenvalues, individual and cumulative percentages of variation explained by the first five principal components after accessing the nine mineral traits in 100 tetraploid potato accessions.

Variables	PC 1	PC 2	PC 3	PC 4	PC 5
Fe (ppm)	0.63852	0.14812	0.18301	0.14271	0.64711
Zn (ppm)	0.61292	0.33011	0.22477	-0.06395	-0.46048
Cu (ppm)	0.66902	0.27593	0.34559	0.08096	-0.11766
Mn (ppm)	-0.38949	0.64073	0.11123	0.32583	0.23925
Ca (ppm)	0.06453	-0.63886	0.13361	0.65362	0.00395
Mg (ppm)	-0.05661	-0.52914	0.66887	0.25450	-0.13103
S (ppm)	0.02371	-0.19570	0.67522	-0.59601	0.20086
P (ppm)	0.74270	-0.06140	-0.45054	0.10717	-0.00434
K (ppm)	-0.24185	0.70475	0.39139	0.29945	-0.13117
Eigenvalue	2.00069	1.84446	1.49316	1.08555	0.77664
Variance (%)	22.23	20.49	16.59	12.06	8.63
Cumulative variance	22.23	42.72	59.32	71.38	80.01

the information about the diversity for mineral concentrations in the potato tubers. Our results suggest that a broad range of variations exist in the concentration of different minerals critical for human health in the potato germplasm. These findings would be a useful resource for developing nutrient-rich potato varieties. Development of biofortified potato cultivars can play a crucial role to overcome the mineral deficiencies.

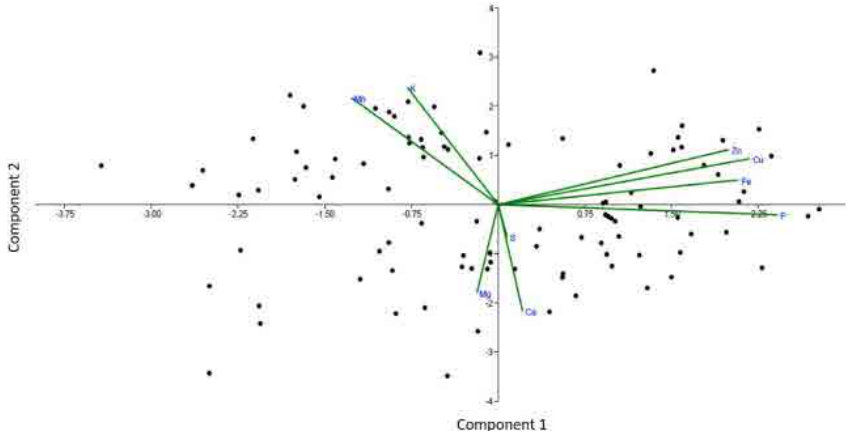


Figure 5. Biplot of Principal component analysis (PCA) of mineral (Fe, Zn, Cu, Mn, Ca, Mg, S, P and K) concentrations present in the potato tubers of 100 potato accessions.

The variations observed in this study can be used to identify the molecular markers associated with mineral concentrations. This study provides the basic insights in relation to the presence of variations in the mineral content. However, there is a need to perform more such experiments under different geographical locations. The findings of this study would be very advantageous for potato breeders, who are breeding to develop nutrient rich potato cultivars.

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CONFLICTS OF INTEREST

The authors confirm that this manuscript has no conflicts of interest

LITERATURE CITED

Abebe T, Wongchaochant S, Taychasinpitak T, et al (2012) Variation of mineral concentrations among different potato varieties grown at two distinct locations in Ethiopia. Agriculture and Natural Resources 46:837-50

Akçura M (2011) The relationships of some traits in Turkish winter bread wheat landraces. Turkish J Agric For 35:115–125. doi: 10.3906/TAR-0908-301

Akcura M, Kokten K (2017) Variations in grain mineral concentrations of Turkish wheat landraces germplasm. Qual Assur Saf Crop Foods 9:153–159. doi: 10.3920/QAS2016.0886

Andre CM, Evers D, Ziebel J, et al (2015) In Vitro Bioaccessibility and Bioavailability of Iron from Potatoes with Varying Vitamin C, Carotenoid, and Phenolic Concentrations. J Agric Food Chem 63:9012-9021. doi: 10.1021/acs.jafc.5b02904

Andre CM, Ghislain M, Bertin P, et al (2007) Andean potato cultivars (*Solarium tuberosum* L.) as a source of antioxidant and mineral micronutrients. J Agric Food Chem 55:366-378. doi: 10.1021/jf062740i

Azimuddin M, Alam Q, Production MB-SC, 2009 undefined (2009) Potato for food security in Bangladesh. ggfjournals.com 4:94–99

Dalamu, Sharma J, Kumar S, et al (2019) Mineral content of red skinned potatoes of Eastern India. J Hortic Sci 4:83-86.

Dalamu, Sharma J, Sharma V, et al (2017) Evaluation of Indian Potato Germplasm for Iron and Zinc Content. Indian J Plant Genet Resour 30:232-236. doi: 10.5958/0976-1926.2017.00029.8

Garg M, Sharma N, Sharma S, et al (2018) Biofortified Crops Generated by Breeding, Agronomy, and Transgenic Approaches Are Improving Lives of Millions of People around the World. Front Nutr 5:12. doi: 10.3389/fnut.2018.00012

Haynes KG, Yencho GC, Clough ME, et al (2012) Genetic Variation for Potato Tuber Micronutrient Content and Implications for Biofortification of Potatoes to Reduce Micronutrient Malnutrition. Am J Potato Res 89:192-198. doi: 10.1007/s12230-012-9242-7

Jongstra R, Mwangi MN, Burgos G, et al (2020) Iron Absorption from Iron-Biofortified Sweetpotato Is Higher Than Regular Sweetpotato in Malawian Women while Iron Absorption from Regular and Iron-Biofortified Potatoes Is High in Peruvian Women. J Nutr 150:3094-3102. doi: 10.1093/jn/nxaa267

Kotecha P (2008) Micronutrient malnutrition in India: Let us say "no" to it now. Indian J Community Med 33:9. doi: 10.4103/0970-0218.39235

McLean E, Cogswell M, Egli I, et al (2009) Worldwide prevalence of anaemia, WHO Vitamin and Mineral Nutrition Information System, 1993-2005. Public Health Nutr 12:444–454. doi: 10.1017/S1368980008002401

Mohammad S, Gharibzahedi T, Jafari SM (2017) The importance of minerals in human nutrition: Bioavailability, food fortification, processing effects and nanoencapsulation. Trends Food Sci Technol 62:119–132. doi: 10.1016/j.tifs.2017.02.017

Porras E, Burgos G, Sosa P, Felde TZ (2014) Procedures for sampling and samplepreparation of sweetpotato roots and potato tubers for mineral analysis. Lima (Peru). International Potato Center (CIP). Global Program Genetics and Crop Improvement 13.

Sharma J, Dalamu, Sharma V, et al (2017) Variations in micronutrient content in tubers of Indian potato varieties. Potato J 44:101-109.

Singh B, Goutam U, Kukreja S, et al (2021a) Potato biofortification: an effective way to fight global hidden hunger. Physiol Mol Biol Plants 27:2297–2313. doi: 10.1007/S12298-021-01081-4

Singh B, Goutam U, Kukreja S, et al (2021b) Biofortification Strategies to Improve Iron Concentrations in Potato Tubers: Lessons and Future Opportunities. Potato Res 1–14. doi: 10.1007/s11540-021-09508-x

Singh B, Sharma J, Sood S, et al (2020) Genetic Variability for Micronutrient Content in Andigena Potato Genotypes. Plant Cell Biotechnol Mol Biol 21: 1–10

Subramanian NK, White PJ, Broadley MR, Ramsay G (2017) Variation in tuber mineral concentrations among accessions of Solanum species held in the Commonwealth Potato Collection. Genet Resour Crop Evol 64:1927-1935. doi: 10.1007/s10722-016-0483-z

Sun A, Li H, Sun A, Li H (2021) Minerals. Essentials Food Chem 291–325. doi: 10.1007/978-981-16-0610-6_7

Tulchinsky TH (2015) The Key Role of Government in Addressing the Pandemic of Micronutrient Deficiency Conditions in Southeast Asia. Nutrients 7:2518. doi: 10.3390/NU7042518

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OPTIMIZING POTATO PRODUCTIVITY IN FOOD GRAIN-BASED ORGANIC FARMING SYSTEM UNDER SPRINKLER IRRIGATION

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ABSTRACT: Field trials were carried during 2013-16 in randomized block design for groundnut-potato-maize+greengram system consisting seven organic input treatment combinations. For crop raising, regional recommendations were adopted, and their nutritional requirement in various organic treatments was calculated as per their recommended inorganic doses. Cultural weed control was followed, and disease-pest management was done through permitted organic means. Observations of growth, yield attributes and yield were recorded for all component crops of the system. Process grade tuber yield improved from 10.5 t/ha to 18.5 t/ha, while total tuber yield increased from 59.9% to 88.3% from first to third year. Tuber weight loss (18.8%) reduced drastically in organic system (IA) over inorganic nutrition (24.5%) at 90 days under ambient storage conditions. System productivity of organic system (IA) improved to 91.3% of inorganic nutrition in third year. Organic system (IA) observed lower net returns in first year, while improvement was observed in third year as this gap reduced to 16.7%. This study suggests that sustainable potato yields can be harnessed in food grain-based cropping systems by including leguminous crops and integrating different organic nutrient sources.

KEYWORDS: Potato, Organic farming, Maize, Green gram, Groundnut, System productivity

INTRODUCTION

Organic farming has gained considerable attention and has emerged as a dynamic 'Alternate Farming System'. Its principal objective is quality food production for humans and animals while maintaining ecological and economic viability. Safety, protection, and conservation of environment are the need of hour and organic cultivation practices ensure this. It is also becoming popular in domestic and international markets as consumers are becoming more serious about food quality, especially chemical residues. This awareness and demand for quality food have created new market opportunities for farmers with premium selling prices and potato is no exception to all these trends and market avenues.

Potato is a significant diet component at the national level as it is consumed fresh and processed in numerous ways. Globally, India is the second-largest potato producer and the second advance estimate of 2020-21 has estimated total production of 53.7 mt from a 2.25 mha area with approximately 2.4 t/ha of average yield (Anon, 2021). North Indian plains contribution is around 87% in total national potato production. Current crop scenario in India suggests its diversified production and utilization in the domestic and export market, and organic potatoes can be one alternative. In addition, higher profits can be earned in domestic and international markets through organic potato production.

Adopting intercropping or sequential cropping and efficient irrigation system helps in efficient utilization of precious resources, *viz.*, land, water, and nutrition. Further, integration of nutrient management options for a cropping systems may economise the

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crop's nutrition requirement effectively. To meet the future challenges of increasing food demand while simultaneously decreasing its negative impact on the environment, efforts should be on for increasing the efficiency of both conventional and organic production systems (Pawelzik *et al*., 2014). Nelson *et al*. (2009) have suggested that extended rotations used in organic potato production systems retain soil organic matter and allow recovery of crucial attributes of soil following the potato phase. With this background, field experiments have been conducted for optimizing the potato productivity under food grain-based organic farming systems.

MATERIALS AND METHODS

A field experiment was conducted on fixed plots at ICAR- Central Potato Research Institute Regional Station, Modipuram (29° 05'19'' N, 77° 41'50'' E, 237 m asl) under semi-arid and sub-tropical agro-ecology during 2013-16. The soil of experimental site was sandy loam in texture with neutral pH, and was low in organic carbon content and available nitrogen, while available phosphorus and potassium was in medium range. Crop rotation of groundnut- potato- maize+ Green gram in replicated randomized block design was followed. Treatments (7) consisted of T_1- control; T_2 - Conventional system; T_3- Organic system of crop residue recycling (CRR); T_4- Organic system of bio-fertilizers and microbial application (BM); T_5- Organic system of organic manures incorporation (OM); T_6- Organic system with homeopathic approach (HO) and T_7- Organic system with all combinations of source of nutrition excepting homeopathic products (IA). Potato planting was done in the last week of October and haulms cutting was done at 110 days for Kufri Himsona. Water application was made at 125% CPE level through the sprinkler system. Harvesting was done 10 days later, where grading was done manually and a tuber of >45 mm was considered marketable for cv. K. Himsona (processing size). Succeeding crops, i.e., Maize (Pahuja hybrid Kanchan) & Green gram (Pahuja cv. Nirali/ Sudha) in 1:1 inter-cropping were raised during March- June by following the recommended package of practices. Likewise, Groundnut (BARC cv. TG37A) was grown during July- October by adopting standard practices. Nutrient management under various treatments is given in Table 1. Observations of emergence, growth, yield attributes and yield were recorded as per the schedule of the technical program for all component crops of this system. The data was compiled and analysed using statistical software IRRISTAT (IRRISTAT, 1999).

RESULTS AND DISCUSSION

Potato

Growth and physiological parameters: Pooled analysis of three years revealed that plant height (cm) and Leaf area Index (LAI) varied significantly, while shoot number/ plant, compound leaf number/ plant, and chlorophyll content (SPAD values) did not have any significant differences **(Table 2)**. Maximum plant height (55.9), leaf no. (52.3), chlorophyll content (48.4) and LAI (3.06) were recorded in inorganic treatment, whereas organic system (IA) tended to have better plant height (43.8), leaf no. (45.5), chlorophyll content (40.8) and LAI (2.35). Fresh and dry leaf and stem weight (gram) at 60 days differed significantly, and inorganic nutrition observed the highest of these traits. But tuber fresh and dry weight remained at par. Inorganic nutriton had fresh leaf (200.9), stem (115.6) and tuber (273.2) weight and organic system (IA) achieved fresh leaf (110.5), stem (56.1) and tuber (200.0) weight. Dry matter weight followed a similar trend. Crop performance in initial establishment of

Table 1: Treatment details for nutrient management (doses and method of application)

Nutrient management	Groundnut	Potato (Processing purpose)	Maize+ *moong* bean
T_1- Control (No nutrient application)	-	-	-
T_2- Conventional system (Inorganic)	25 N-50 P_2O_5-50 K_2O kg/ha; Band placement	270 N-80 P_2O_5-150 K_2O kg/ha; Band placement and broadcasting	150 N-80 P_2O_5-80 K_2O kg/ha; Band placement and broadcasting
T_3- Organic system (Crop residue recycling of preceding crop within the plot)	Maize+ *moong* bean Stover: Approx. 15-19 t/ha; *in situ* incorporation	Groundnut Stover: Approx. 5-10 t/ha; *in situ* incorporation	Potato haulms: Approx. 4-7 t/ha; *in situ* incorporation
T_4- Organic system* (Biofertiliser/ microbial formulation)	*Rhizobium, Bacillus subtilis, Trichoderma*; seed treatment & mixed with FYM	*Azotobacter, Bacillus subtilis, Trichoderma*; seed treatment & mixed with FYM	*Azotobacter, Rhizobium, Bacillus subtilis, Trichoderma*; seed treatment & mixed with FYM
T_5- Organic system (Organic manure: One-third of each: FYM, compost, vermicompost on nitrogen content basis)	FYM (2 t/ha)+ compost (2 t/ha)+ vermi-compost (1 t/ha); FYM & compost before sowing, vermi-compost at sowing	FYM (15 t/ha)+ compost (33 t/ha)+ vermi-compost (6 t/ha); FYM & compost before planting, vermi-compost at earthing	FYM (6 t/ha)+ compost (21 t/ha)+ vermi-compost (3 t/ha); FYM & compost before sowing, vermi-compost at 30-35 days
T_6- Organic system* (Homeopathic approach)	FYM (5 t/ha)+ Homeo products	FYM (5 t/ha)+ Homeo products	FYM (5 t/ha)+ Homeo products
T_7- Organic system (Integrated Approach except homeopathic products)	Maize+ *moong* bean Stover: Approx. 15-19 t/ha; *in situ* incorporation + *Rhizobium, Bacillus subtilis, Trichoderma*; seed treatment & mixed with FYM + FYM (2 t/ha)+ vermi-compost (1 t/ha); FYM before sowing, vermi-compost at sowing	Groundnut Stover: Approx. 5-10 t/ha; *in situ* incorporation + *Azotobacter, Bacillus subtilis, Trichoderma*; seed treatment & mixed with FYM+ FYM (15 t/ha)+ vermi-compost (6 t/ha); FYM before planting, vermi-compost at earthing	Potato haulms: Approx. 4-7 t/ha; *in situ* incorporation + *Azotobacter, Rhizobium, Bacillus subtilis, Trichoderma*; seed treatment & mixed with FYM+ FYM (6 t/ha)+ vermi-compost (3 t/ha); FYM before sowing, vermi-compost at 30-35 days

*Organic system (Biofertiliser/ microbial formulation): *Rhizobium* (250g/ha seed treatment), *Bacillus subtilis* (250g/ha seed treatment), *Azotobacter* (250g/ha seed treatment), *Trichoderma* (4 kg/ha with 100 kg FYM for mixing in soil)

*Organic system (Homeopathic approach): Organic home products used as per the literature given on the website:
Sanjeevani: Soil treatment @ 1.3 L+ 5 kg jaggary+ 4q FYM/ ha and three spray @ 2.5 L+ 10 kg jaggery in 500 L water per ha for nitrogen (groundnut, potato, maize+ *moong* bean)
Amrit: Seed treatment @ 2 L+ 4kg jaggary+ water/ ha for phosphorous and potassium (groundnut, potato, maize+ *moong* bean)
Rakshak: Three sprays @ 2.5 L+ 10 kg jaggery in 500 L water per ha for diseases (potato)
Jeevan: Three sprays @ 2.5 L+ 10 kg jaggery in 500 L water per ha for diseases (groundnut, potato, maize+ *moong* bean)
Vardaan: Three sprays @ 2.5 L+ 10 kg jaggery in 500 L water per ha for diseases (groundnut)
Moksha: Two/ three spray @ 2.5 L in 500 L water per ha for pests (groundnut, potato, maize+ *moong* bean)

organic farming is a challenge and growth suffers due to lower nutritional supply particularly nitrogen (Finckh *et al*., 2006).

Graded tuber number and yield: Process grade and total tuber yield (t/ha) varied statistically with variations in source of nutrition **(Fig. 1)**. Lower tuber bulking adversely affected graded and total tuber yield in organic treatments. In first crop season, conventional system attained highest process grade (26.8) and total (44.2) tuber yield, which was distinctly higher over all other treatments. Organic system (IA) had process grade (10.8) and total (26.5) tuber yield, which was respectively, 59.7 and 40.0% lower over conventional system. During second year again, maximum and statistically better process (22.1) and total tuber yield (25.6) was recorded in conventional system. Organic system (IA) had process (18.5) and total tuber yield (22.6), and this treatment could maintain 83.7 and 88.3% of tuber yields, respectively, in comparison to inorganic system. In third season also, highest and significantly better process (22.6) and total tuber yield (28.0) was attained by inorganic treatment. Organic

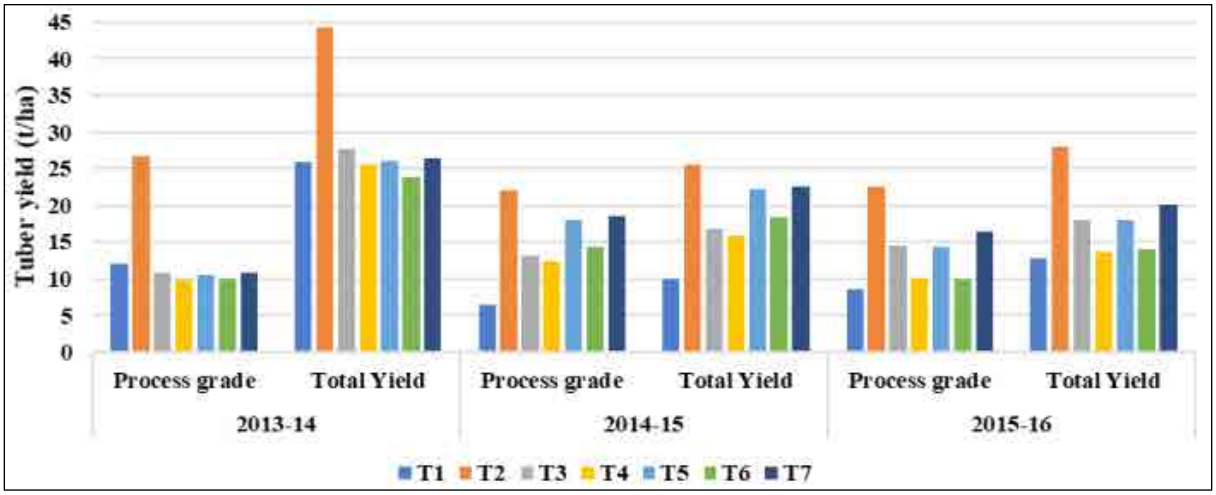


Fig 1: Yield performance of Kufri Himsona under conventional and organic systems

Table 2: Influence of nutrient management options on plant growth and physiological traits of potato

Treatments	Plant height (cm)	Shoot no./ plant	Leaf no./ plant	Chlorophyll content	Leaf area index	Leaf weight (g)*		Stem weight (g)*		Tuber weight (g)*	
						Fresh	Dry	Fresh	Dry	Fresh	Dry
T_1	32.8	4.69	35.6	39.1	1.70	84.6	10.6	35.6	3.18	179.0	43.4
T_2	55.9	4.69	52.3	48.4	3.06	200.9	21.5	115.6	8.61	273.2	55.8
T_3	40.3	5.56	42.6	40.5	2.12	108.3	11.9	53.4	4.57	209.6	52.5
T_4	39.4	5.15	37.9	40.4	1.81	97.4	11.6	41.2	3.37	228.5	55.6
T_5	42.2	5.05	39.3	41.6	2.17	100.2	10.8	52.9	4.37	227.1	52.3
T_6	39.2	5.40	40.4	38.8	1.94	89.9	9.8	47.1	3.77	204.3	48.2
T_7	43.8	4.50	45.5	40.8	2.35	110.5	12.5	56.1	5.23	200.0	46.0
CD 0.05	10.48	NS	NS	NS	0.54	30.60	3.99	16.4	1.61	NS	NS

*At 60 days of growth

system (IA) recorded process (16.5) and total tuber yield (20.2). It was highest among organic systems and statistically better over organic system (BM) and organic system (HO). This treatment maintained 73.0 and 72.1% of process and total tuber yields, respectively as compared to inorganic nutrition. Singh *et al.* (2006) observed maximum tuber yield and net return from 30 t/ha with FYM application and recommended application of N, P and K. Hagman *et al.* (2009), in their experimental results, implied the timing of N application is essential for yield and concluded that the importance of P and K fertilization is underestimated in organic production and that the most crucial cultivar trait in achieving acceptable yield is long-lasting foliage, a characteristic of resistannce to *Phytophthora infestans*. Economic and biomass yield revealed that harvest index (HI) was similar in all organic treatments (**Table 3**). Inorganic nutrition recorded HI of 0.84, while organic system (IA) had a harvest index of 0.91. Green manure at higher rates (400 and 200 Kg/ha) increased the accumulation of dry matter in potato aboveground parts and tubers observed by Mohamed *et al.* (2017).

Tuber quality and storability: Tuber dry matter content (TDMC in %), specific gravity (SG), reducing sugars (mg/ 100g fresh tuber

Table 3: Influence of nutrient management options on quality traits, biomass yield and storability

Treatment	Tuber dry matter content	Specific gravity	*Reducing sugars (mg)	**Chip colour score	Haulms		Tuber		Biomass yield (t/ha)#	Harvest index#	Total weight loss (%) at 30 days interval		
					Fresh	Dry	Fresh	Dry			30	60	90
T_1	22.2	1.094	34.4	2.7	2.47	0.28	16.2	3.60	3.88	0.93	4.6	8.1	17.5
T_2	21.3	1.089	43.3	2.9	13.23	1.37	32.6	6.95	8.32	0.84	6.1	17.5	24.5
T_3	22.1	1.091	28.3	2.6	4.92	0.51	20.8	4.60	5.11	0.90	6.0	11.9	19.8
T_4	22.3	1.093	28.1	2.7	3.45	0.36	18.4	4.11	4.47	0.92	5.6	10.5	18.0
T_5	22.0	1.093	27.6	2.5	4.65	0.50	22.1	4.87	5.37	0.91	8.1	11.5	20.0
T_6	22.6	1.093	33.2	2.6	3.13	0.34	18.7	4.23	4.57	0.93	4.7	10.2	18.1
T_7	22.3	1.092	32.0	2.7	4.69	0.51	23.1	5.14	5.65	0.91	4.7	10.2	18.8
CD 0.05	0.5	NS	3.12	NS	0.81	0.08	5.24	0.67	1.04	-	1.42	2.85	4.88

*mg/100g Fresh tuber weight; **Chip colour score: 1-9 where up to 3 the product is in an acceptable range; #dry weight basis

weight) and chip colour score (on 1- 10, acceptable up to 3) improved significantly in organic nutrition **(Table 3)**. Lombardo *et al.* (2012) reported organic farming to produce potatoes with a higher nutritional value due to higher total phenolic and lower nitrate content and better sensory performance after frying (strong taste and crisp flesh). The highest TDMC (22.26) & SG (1.092) and lowest reducing sugars (32.0) & chip colour (2.7) were found in the organic system (IA), whereas inorganic treatment had TDMC (21.32), SG (1.089), reducing sugars (43.3) and chip colour (2.9). Similar observations were reported by Bandana *et al.* (2018) while studying the source of nutrition on potato tuber quality under elevated storage conditions. Organic treatments had better storability than inorganic treatments (Bandana *et al.*, 2018). Minimum total weight loss was observed in the organic system (BM) at ninety days (18.0%), whereas inorganic nutrition had the highest losses (24.5%). Organic system (IA) recorded 18.8% weight loss at 90 days. The same observations were reported by El-Sayed *et al.* (2015).

Maize

Growth and physiological parameters: Germination of Maize and plant population (>90%) were not influenced due to different treatments **(Table 4)**. Plant height (cm)

Table 4: Influence of nutrient management options on growth and yield performance of Maize

Treatment	Plant height (cm)		Chlorophyll content		Leaf area index		Cob number (000/ha)		Grain yield (t/ha)		Straw yield (t/ha)		Biomass (t/ha)	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_1	1.69	1.22	45.9	33.9	3.47	1.41	52.2	51.8	3.7	1.9	13.7	13.9	21.4	15.8
T_2	1.74	1.32	55.2	45.4	4	2.27	58.2	70.1	5	3.9	18.1	18.2	26.9	22.1
T_3	1.73	1.32	46.2	38.1	3.65	2.29	53.3	58.1	4.33	2.7	13.2	14.9	21.6	17.6
T_4	1.69	1.21	46.7	37.1	3.75	2.04	52.5	55.6	4.25	2.6	13.2	13.8	21.3	16.4
T_5	1.73	1.25	51.2	42.7	3.92	1.95	53.8	66.9	4.33	3.1	14.2	15.5	22.1	18.6
T_6	1.69	1.27	43.5	38.5	4	2.07	52.7	63.1	4.31	3.5	13.1	15.4	21.2	18.9
T_7	1.72	1.37	49.1	41.3	3.95	2.25	53.8	67.6	4.35	3.6	15.7	17.7	24	21.3
$CD_{0.05}$	NS	NS	2.59	3.26	0.27	0.39	3.1	3.1	0.51	0.63	2.09	1.72	2.67	2.52

also remained statistically similar with different nutritional sources. However, in both years, LAI and chlorophyll content exhibited significant differences. In the first season, the organic system (IA) recorded comparable plant height (172.5) to inorganic nutrition (174.1). This treatment attained a similar LAI (3.95) to the conventional system (4.00). Whereas maximum chlorophyll content (SPAD values) was observed with inorganic source (55.2), which was distinctly higher than overall organic treatments, and organic system (IA) attained SPAD value of 49.1. Alike, organic system (IA) recorded comparable LAI (2.25) to organic system CRR (2.29) and inorganic nutrition (2.27) in the second crop season. On the other hand, maximum chlorophyll content was recorded with an inorganic source (45.4), which was significantly higher than overall organic treatments and the organic system (IA) attained a SPAD value of 41.3. Bilalis and Karamanos (2010) also reported comparable growth of maize crop in conventional and organic treatments in organic experiments.

Yield attributes and yield: The clear-cut difference was visible in yield attributes, i.e., cob number (000/ha), grain, straw, and biomass yield (t/ha) with inorganic and organic nutrition **(Table 4)**. During 2013-14, Inorganic sources attained maximum and statistically superior cob no. (58.2), grain (5.00), straw (18.1) and biomass yield (26.9) over other treatments. Organic system (IA) remained the second-best option and it had cob no. (53.8), grain (4.35), straw (15.7) and biomass yield (24.0). This treatment could achieve 87% grain productivity compared to the inorganic system. Similarly, inorganic sources attained maximum cob no. (70.1), grain (3.9), straw (18.2) and biomass yield (22.1) during 2014-15, which was statistically better over several other treatments. Organic system (IA) remained second best and had cob no. (67.6), grain (3.6), straw (17.7) and biomass yield (21.3). This treatment achieved 92.3% grain yield over an inorganic system. Bilalis and Karamanos (2010) also concluded that sustainable yield of maize is possible in organic agriculture systems.

Green gram

Growth and physiological parameters: Green gram attained normal germination and plant stand (>90%) in both years **(Table 5)**. Plant height showed statistically significant differences in the first season. The highest plant height (64.9 cm) was attained by the organic system (IA), which was significantly better over inorganic, organic (CRR), and organic (BM) treatments. Chlorophyll content did not exhibit any significant differences and organic system (IA) recorded a SPAD value of 58.2, similar to inorganic nutrition (60.5). While in second year, plant height and chlorophyll content remained at par in all treatments. The highest plant height (36.2 cm) and SPAD value (66.3) was recorded in the organic system (BM), while organic (IA) had plant height (34.6) and SPAD value (63.7). Acharya and Mondal (2010) also reported that Green gram performed alike in inorganic and organic treatments.

Yield attributes and yield: In the first year, yield attributes and yield were not influenced by variation in plant nutrition in component crop Green gram **(Table 5)**. Organic system (IA) recorded comparable pod (0.36), grain (0.23), straw (1.8) and biomass yield (2.2). Yield attributes and yield were affected significantly by nutrition sources during 2014-15. The organic system (BM) observed the highest grain (0.44) and biomass yield (3.4), remaining statistically better over several treatments. The organic system (IA) had a comparable pod (0.35) and lower biomass yield (2.6). Inorganic nutrition, higher Maize Equivalent Yield (MEY) 5.14 was observed

Table 5: Influence of nutrient management options on growth and yield performance of Green gram

Treatment	Plant height (cm)		Chlorophyll content		Pod yield (t/ ha)		Grain yield (t/ ha)		Straw yield (t/ha)		Biomass (t/ha)		Maize equivalent yield (t/ha)	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_1	49.6	33.7	55.5	63.8	0.34	0.42	0.22	0.24	1.7	1.7	2	2.12	4.45	2.81
T_2	60	34.9	60.5	64.5	0.42	0.52	0.23	0.33	1.7	2.1	2.1	2.62	5.79	5.16
T_3	60.1	35.9	58.4	65.2	0.37	0.65	0.23	0.39	1.7	2.3	2.1	2.95	5.12	4.19
T_4	60.8	36.2	58.2	66.3	0.39	0.7	0.25	0.44	1.7	2.7	2.1	3.4	5.11	4.28
T_5	63.4	34	60.7	63.4	0.34	0.59	0.21	0.34	1.7	2.1	2	2.69	5.05	4.4
T_6	65.4	34.2	58.1	64	0.36	0.53	0.22	0.31	1.8	1.9	2.2	2.43	5.06	4.68
T_7	64.9	34.6	58.2	63.7	0.36	0.6	0.23	0.35	1.8	2	2.2	2.6	5.14	4.94
$CD_{0.05}$	4.77	NS	NS	NS	NS	0.11	NS	0.08	NS	0.4	NS	0.51	-	-

in the organic system (IA), which was 88.8% of the productivity of inorganic nutrition (5.79) in the first year. Similarly, the highest MEY (4.94) was in this system and 95.7% of inorganic treatment (5.16). Productivity of Green gram was similar in inorganic and organic plots and was not affected by lower N supply due to symbiotic N- fixation (Acharya and Mondal, 2010).

Groundnut

Growth and physiological parameters: Groundnut had normal germination and plant stand (>90%) in all treatments in both years **(Table 6)**. Growth and physiological parameters *viz.*, plant height (cm) and LAI depicted significant differences during 2013-14. Organic system (IA) recorded comparable plant height (22.8) to inorganic nutrition (22.4) and most of the organic sources. Maximum LAI (1.90) was observed in the organic system (CRR), which was statistically at par with the organic system (IA) and inorganic source having values of 1.52 and 1.87, respectively. Chlorophyll content (SPAD values) did not vary statistically among all treatments, and organic system (IA) recorded a value of 37.6 like inorganic treatment (36.6). Growth and physiological parameters viz., plant height (cm), LAI and chlorophyll content did not differ significantly due to source of nutrition during 2014-15. Organic

Table 6: Influence of nutrient management options on growth and yield performance of Groundnut

Treatment	Plant height (cm)		Leaf area index		Chlorophyll content		Pod yield (t/ ha)		Grain yield (t/ha)		Straw yield (t/ha10		Biomass yield (t/ha)	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_1	19.3	22.9	1.71	2.13	37.4	37.1	0.78	0.53	0.57	5.33	5	5.86	5.6	5.86
T_2	22.4	21.8	1.87	2.22	36.6	37.7	0.81	0.54	0.59	5.8	5.4	6.34	6.1	6.34
T_3	22.8	20.4	1.9	2.23	36.1	36.2	0.76	0.53	0.55	5.4	5.1	5.93	5.8	5.93
T_4	20.5	22.1	1.39	2.24	38.4	35.9	0.8	0.57	0.58	5.12	4.9	5.69	5.6	5.69
T_5	22.8	20.8	1.57	1.96	38.1	35.8	0.73	0.52	0.53	5.17	5	5.69	5.6	5.69
T_6	23	20.8	1.39	2.09	37.5	37.5	0.76	0.51	0.55	5.53	5	6.04	5.7	6.04
T_7	22.8	21.8	1.52	2.29	37.6	36.7	0.81	0.53	0.59	5.79	5	6.32	5.8	6.32
$CD_{0.05}$	2.2	NS	0.39	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

system (IA) recorded plant height (21.8), LAI (2.29) and chlorophyll content (36.7). In trial of Basu *et al*. (2008), Groundnut attained similar growth traits in organic nutrition as with inorganic fertilizers.

Yield attributes and yield: In both crop seasons, pod, grain, straw and biomass yield (t/ha) were not affected significantly by a different source of nutrition in Groundnut **(Table 6)**. Organic system (IA) recorded comparable pod (0.81), grain (0.59), straw (5.0) and biomass yield (5.8) to inorganic nutrition. A similar trend was observed in second year. Organic system (IA) observed grain (0.53), straw (5.79) and biomass yield (6.32), which were comparable to inorganic treatment. Yield attributes and yield of Groundnut crop were found to be comparable in organic and inorganic treatments (Basu *et al*., 2008).

System productivity and economics: System productivity of Potato- Maize+ Green gram-Groundnut rotation was computed based upon support price fixed by the government for cereals and the prevailing market price of potatoes during harvest time **(Table 7)**. In the first year, organic system (IA), organic system (OM) and organic system (HO) recorded 56.6, 55.5 and 47.8 t/ha system productivity, respectively, which was 89.0, 87.3 and 75.2% of the inorganic treatment productivity (63.6 t/ha). Alike, inorganic nutrition had 16.7 and 11.6-16.0 % higher net return and B: C ratio over best organic system (OM) and organic system (IA). As a result, the organic system (IA) had 35.7 t/ha system productivity in the second year, 91.3% of the inorganic treatment (39.1 t/ha). On the other hand, inorganic nutrition had a 21.3 and 21.5 % higher net return and B: C ratio over the best organic system (IA). Wachter *et al*. (2019) studied productivity, economics and soil quality parameters in conventional, mixed and organic dryland farming systems in eastern Washington State. They concluded that productivity of the system stabilizes slowly over the years in organic farming system and becomes sustainable.

CONCLUSION

A sustainable organic farming-based cropping system must be developed to achieve optimum potato yields as this crop requires higher quantity of nutrients for growth and productivity. Yield maintenance under organic farming (IA) was stable in potato crop in third year in sprinkler irrigation as it attained 73.0% of process grade and 72.1% of total tuber yield in comparison to inorganic treatment. Similarly, organic system (IA) had 35.7 t/ha system productivity, which was

Table 7: Influence of nutrient management options on system productivity and economics of production.

Treatment	*System productivity (t/ha)		Cost of cultivation (Rs/ha)		Gross returns (Rs/ha)		Net returns (Rs/ha)		B: C ratio	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_1	30.1	19.4	160710	168745	240800	155200	80090	-13545	0.5	-0.08
T_2	63.6	39.1	180807	189847	508800	312800	327993	122953	1.81	0.65
T_3	44.7	28.6	165850	174142	357600	228800	191750	54658	1.16	0.31
T_4	43.0	28.2	165800	174090	344000	225600	178200	51510	1.07	0.3
T_5	55.5	34.4	170800	179340	444000	275200	273200	95860	1.6	0.53
T_6	47.8	30.8	168000	176400	382400	246400	214400	70000	1.28	0.4
T_7	56.6	35.7	179900	188895	452800	285600	272900	96705	1.52	0.51

*Potato equivalent yield (based upon the price of produce and yield)

91.3% of the inorganic treatment (39.1 t/ha). However, inorganic nutrition had 16.7 and 16.0 % higher net return and B: C ratio over organic system (IA).

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LITERATURE CITED

Acharya D and Mondal SS (2010) Effect of integrated nutrient management on the growth, productivity and quality of crops in rice (*Oryza sativa*)- cabbage (*Brassica oleracea*)- green gram (*Vigna radiata*) cropping system. *Indian J Agron*. **55**(1): 1-5

Anonymous (2021) Department of agriculture and farmers welfare, HTTP:// https://agricoop.nic.in/en/statistics/horticulture-crops-2019-20-second-advance-estimates, 20 December 2021

Basu M, Bhadoria PB and Mahapatra SC (2008) Growth, nitrogen fixation, yield and kernel quality of peanut in response to lime, organic and inorganic fertilizer levels. *Bioresource technology* **99**(11): 4675-83

Bilalis DJ and Karamanos AJ (2010) Organic maize growth and mycorrhizal root colonization response to tillage and organic fertilization. *J Sustainable Agriculture* **34**(8): 836-49

El-Sayed SF, Hassan HA and El-Mogy MM (2015) Impact of bio-and organic fertilizers on potato yield, quality and tuber weight loss after harvest. *Potato Research* **58**(1): 67-81

Finckh MR, Schulte-Geldermann E, Bruns C (2006) Challenges to organic potato farming: disease and nutrient management. *Potato Research* 49(1): 27-42

IRRISTAT (1999) Windows version 4.0., Biometrics unit, IRRI, Los Banos, Philippines

Kaundal B, Kumar D, Kumar P, Rawal S, Saini N and Sharma V (2018) Influence of source of nutrition on potato (*Solanum tuberosum*) tuber quality in elevated temperature storage. *Indian J of Agril Sci* 88: 1371-1378

Lombardo S, Pandino G and Mauromicale G (2012) Nutritional and sensory characteristics of "early" potato cultivars under organic and conventional cultivation systems. *Food Chemistry* 133(4): 1249-1254

Mohamed EM, Watthier M, Zanuncio JC and Santos RH (2017) Dry matter accumulation and potato productivity with green manure. *Idesia* **35**(1): 79-86

Nelson KL, Lynch D and Boiteau G (2009) Assessment of changes in soil health throughout organic potato rotation sequences. *Agriculture, ecosystems & environment* **131**(3-4): 220-228

Pawelzik E and Möller K (2014) Sustainable potato production worldwide: the challenge to assess conventional and organic production systems. *Potato Research* **57**(3-4): 273-290

Singh SP and Kushwah VS (2006) Effect of integrated use of organic and inorganic sources of nutrients on potato (*Solanum tuberosum*) production. *Indian J Agron* **51**(3): 236-238

Wachter JM, Painter KM, Carpenter-Boggs LA, Huggins DR and Reganold JP (2019) Productivity, economic performance, and soil quality of conventional, mixed, and organic dryland farming systems in eastern Washington State. *Agriculture, Ecosystems & Environment* **286**: (https://doi.org/10.1016/J.AGEE.2019.106665).

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VARIETAL ADOPTION PATTERN AND ECONOMIC ANALYSIS OF POTATO PRODUCTION IN SOUTH BIHAR, INDIA

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ABSTRACT: Potato is the most important vegetable crop of India and largely grown in Eastern plains of the country. Bihar is the third largest potato producing state of India after Uttar Pradesh and West Bengal. However, productivity of Bihar is lower than many states due to prevalence of older varieties and limited adoption of improved package of practices among farmers. Current study was planned to find out the economic benefits of potato cultivation and adoption pattern of different potato varieties in south Bihar. Primary data were collected from farmers of highest potato growing districts of South Bihar i.e Nalanda and Patna using survey and personal observation method. Analysis of data revealed that Patna and Nalanda together contributed more than 15 per cent of potato production in the state. Moreover, red skinned varieties viz. Kufri Sindhuri, C-1, C-40 and Lal Gulab were mostly adopted by farmers in Patna while in case of Nalanda, white skinned variety Kufri Pukhraj was adopted by majority (80.6%) of them. Variable cost of potato cultivation was estimated to be ₹ 1.32 lakhs per ha in Nalanda and ₹ 1.06 lakhs per ha for Patna district. Cost of seed potato had contributed more than one third of total cost of cultivation. On an average, farmers earned a gross income of ₹ 1.8 lakhs/ha and net return of ₹ 61,579/- per ha from potato. The BC ratio ranged from 1.4 to 1.6 in selected districts. It can be concluded that enough scope is available for increasing productivity of potato in Bihar by large scale demonstration and adoption of high yielding new potato varieties. Moreover, farmers should be motivated to grow their own seed through organization of trainings, exposure visits and supply of breeder seed so that seed cost can be minimized to increase economic returns from potato.

KEYWORDS: Adoption, Bihar, cost of cultivation, economic analysis, potato

INTRODUCTION

The agriculture sector in India continues to play a very important role in growth and development of the country. It is the largest employment providing sector of Indian economy as 54.6% of the total workforce is engaged in agricultural and allied activities and contributed 17.1% of the country's Gross Value Added (GVA) for the year 2017-18 at current prices (DAC & FW, 2019). Still, majority live in rural areas of the country and draw their livelihood from cultivation of various crops as well as animal husbandry enterprises. As per data from census of India, 68.84% of Indian population (around 833.1 Million) live in 6,40,867 different villages distributed across the country (Ministry of Home Affairs, 2011). Total geographical area of the country is around 328.7 million hectares, of which 140.1 million hectares is the reported net sown area and 198.4 million hectares is the gross cropped area. Food grains has the highest share (63.77%) in grossed cropped area followed by total oilseeds (14.28%), total fibres viz. cotton, jute, mesta (5.7%) and total vegetables (3.35%).

Potato is considered as a highly nutritious food and it gives high productivity per unit area and time as compared to many food grains. The crop matures faster within 90 to 100 days, with short duration varieties provide good tuber yield even in just 60 days. Overall, potato production is one of the most efficient means of converting plant,

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land, water and labour into a palatable and nutritious food (Sahadevan, 2007). Due to its unique features, potato has been declared as "Future food crop" by Food and Agricultural Organization, Rome in the year 2008 (Hussain, 2016). India is the second largest potato producer in the world after China and both these countries together contribute nearly one third of total world potato production (Scott and Suarez, 2012). Among all vegetables, potato is the most important vegetable covering nearly 1% of gross cropped area of the country during 2016-17 (Anonymous, 2021). India produced a total of 50.2 million t of potatoes from an area of 2.17 million ha with an average productivity of 23 t/ha. Uttar Pradesh is the highest potato producing state of India followed by West Bengal, Bihar, Gujarat and Madhya Pradesh. These five states together contributed more than 80% of total potato production in the country. In order to solve farmers' problem, Indian Govt. has set a target of doubling farmers' income by the year 2022-23 through many welfare schemes including increase in minimum support prices (MSP) of major crops (Chand, 2017). Potato is an important cash crop for Indian famers but because of its perishable nature, Government is not providing any MSP for it. It was estimated that this country will require nearly 125 million t of potato from an enhanced area of 3.62 million ha with an average productivity of 34.5 t/ha during the year 2050 (CPRI, 2015). This is very challenging task for both farmers and policy makers.

In order to increase potato production and productivity in future, farmers must get better profit by cultivating it using high yielding varieties and scientific package of practices. But, due to highly volatile nature of its price round the year, many times farmers do not get expected return. Several studies have been conducted on economic analysis of potato production covering different parts of the country (Peer *et al.* 2013; Lal and Sharma, 2006; Durgawati *et al.*, 2005). It has been observed by various researchers that cost of seed, labour and fertilizer are major components of total cost of cultivation. (Noonari *et al.*, 2016; Peer *et al.* 2013; Lal and Sharma, 2006).

Bihar state is third highest potato producing state of India contributing almost 16% of total production. During the year 2017-18, Bihar recorded 81.54 lakh tonnes of potato production from an area of 3.22 lakh ha (Anonymous, 2021). Potato is a major cash crop for farmers of Bihar. It is grown in almost all 38 districts but districts lying in southern part of Bihar dominate in its production. It is mainly cultivated during rabi season in Nalanda, Patna, Saran, East Champaran, West Champaran, Vaishali and Samastipur districts. Keeping the importance of potato in mind, current study was undertaken to analyze the cost cultivation of potato in Bihar and its impact of farmers' income.

MATERIALS AND METHODS

Selection of study area and sampling: It was revealed from published literature that southern Bihar is hub of potato production. Therefore, this study was carried out in Nalanda and Patna districts of Bihar. Both these districts were selected purposively on the basis of maximum area and production of potato crop in whole state.

A multi-stage random sampling design was adopted for the ultimate selection of potato growers. Three blocks were selected from each districts and 15 farmers were selected randomly from each block. Thus, a total sample of 90 farmers (45 from each Patna and Nalanda) were selected for this study (Fig.1).



Fig. 1: Map of Bihar showing study area

Data collection and analysis:

Ex post facto research design was used in which investigation starts only after the event has already occurred. Personal observation and survey method of data collection was employed for collection of primary data on variables like cost components (labour, seed, fertilizers, irrigation, pesticides), yield of potato, gross income, price etc. For this purpose, a pre tested structured interview schedule was used as survey instrument during data collection from potato growers. Survey was carried out during the year 2016-17. Secondary data were also collected from Government websites and published literature on district wise area, production and yield of potato in Bihar. Collected data were tabulated and analysed using descriptive statistics *viz.* frequency, percentage etc. Inferences were drawn based on results and personal observations. The standard cost concepts approach was used to find out the costs and returns from potato production.

RESULTS AND DISCUSSION

Status of area, production and yield of potato in Bihar

Secondary data on area and production of major potato growing districts of Bihar was analyzed to find out the contribution in total potato production (Table 1). Out of

Table 1: Area, production and yield in major potato producing districts of Bihar during the year 2017-18

Name of the districts	Area (ha)	Contribution to total area* (%)	Production (t)	Contribution to total production* (%)	Yield t/ha)
Nalanda	24000	7.87	691975	8.94	28.83
Patna	17800	5.84	512394	6.62	28.79
Muzaffarpur	15408	5.06	231120	2.99	15.00
Saran	13602	4.46	353244	4.56	25.97
Gopalganj	12800	4.20	307200	3.97	24.00
West Champaran	12000	3.94	323624	4.18	26.97
Samastipur	12000	3.94	326086	4.21	27.17
Vaishali	12000	3.94	351036	4.53	29.25
Rohtas	11445	3.76	295996	3.82	25.86
East champaran	10700	3.51	299600	3.87	28.00
Madhubani	10800	3.54	289000	3.73	26.76
Darbhanga	10020	3.29	285817	3.69	28.52
Siwan	9800	3.22	291444	3.77	29.74
Others	172375	56.56	3182254	41.11	18.46
Bihar Total	304780	100.00	7740790	100.00	25.40

Source: Directorate of Horticulture, Govt. of Bihar, *Authors' calculation

38 districts, six major districts namely Patna, Nalanda, Saran, Vaishali, Samastipur and West Champaran together contributed nearly one third of total potato production of the state. Nalanda was top ranked district in terms of both area and production followed by Patna during 2017-18. The district has continuously topped in productivity also as many new reports suggested world record productivity (> 70 tonnes/ha) of potato (Anonymous, 2013).

Bihar state as a whole produced 77.4 lakh tones of potato from 3.05 lakh ha area clocking an average yield of 25.4 t/ha. This yield level is better than national average yield of around 23 t/ha but less than some states viz. Gujarat and Punjab. Still, there is a lot of scope for increasing productivity as this region has good quality soil and ample water for irrigation. Selected study area i.e Patna and Nalanda together contributed more than 15 per cent of potato production in the state. Nalanda alone had 24000 ha area under potato with production of 6.9 lakh tones while Patna is distant second placed with an area of 17,800 ha and production of 5.1 lakh tones. It was observed that districts falling in south Bihar contributed significantly in total overall potato production.

Varietal Adoption Pattern in Study Area

Survey of farmers was carried out to find out extent of adoption of different potato varieties and results of the same is presented through a pie chart (Fig. 2). It can be seen that red skinned varieties viz. Kufri Sindhuri, C-1, C-40 and Lal Gulab are very popular among farmers in Patna district. In case of Nalanda, white skinned variety Kufri Pukhraj was adopted by majority (80.6%) of farmers while varieties from Punjab S-1/S-2 also had significant area under cultivation. Although, Kufri Pukhraj was widely adopted variety in Patna too with 23.2 per cent adoption, red skinned varieties were mostly adopted with nearly 70 per cent area under its cultivation. Dominance of Kufri Pukhraj was also observed in a study where it was reported to cover maximum area in Bihar (39%) followed by red skinned Kufri Sindhuri & Bhura Aloo (Pradel *et al*, 2019).

It's a proven fact that variety alone can enhance the yield of crop by 10 to 20 per cent and same is true in potato also. Yield level in Nalanda was significantly higher than Patna since red skinned varieties (Kufri Sindhuri) are generally lower in yield as compared to white skinned variety (e.g Kufri Pukhraj).

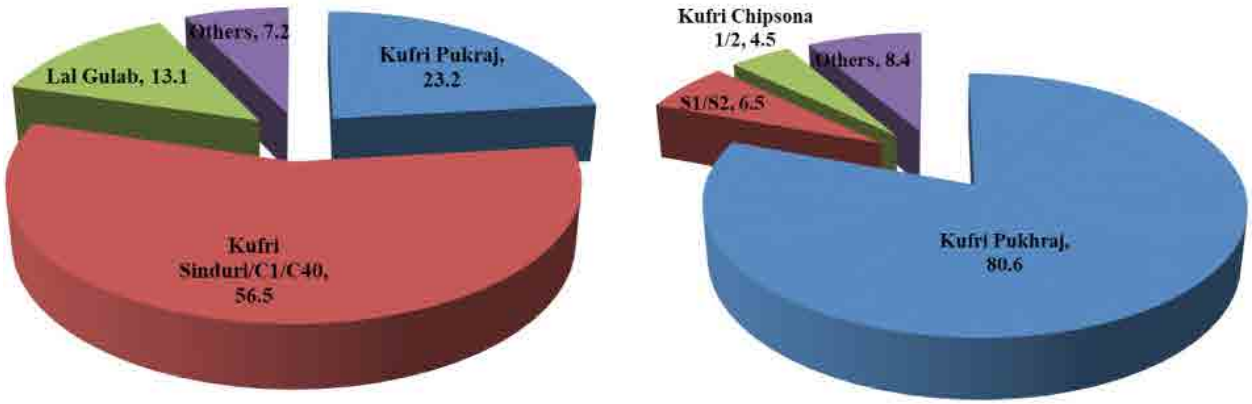


Fig. 2: Percentage area under different potato varieties in Patna (A) and Nalanda (B)

The potential yield of Kufri Sindhuri (30-35 t/ha) is lower than Kufri Pukhraj which can yield upto 40 t/ha (Kumar *et al*, 2014). There was very less presence of processing varieties like Kufri Chipsona-1 & 3 in Nalanda while in Patna, it was completely absent.

Variable cost of potato cultivation

In order to assess the economic impact of potato cultivation on farmers' profitability, it was necessary to estimate cost of cultivation. Therefore, variable cost of cultivation for potato was estimated for both the selected districts (Table 2). Results revealed that average cost of potato cultivation was found to be ₹ 131985/- per ha in Nalanda and ₹ 106083/- per ha for Patna. Pooled data for both the districts showed that cost of seed potato had the highest contribution of 35.2 per cent in total cost of cultivation (Figs. 3). It was followed by cost of human labour which contributed around one third of total cost. The average size of land holding in Bihar is around 0.39 ha which is among lowest in the country (Agriculture Census Division, 2019). This is major reason for low mechanization and thereby increase in cost of human labour in the reason.

There was not much difference in different cost components in Nalanda and

Table 2: Variable cost of potato cultivation in Patna and Nalanda districts of Bihar

N=90

Cost Components (₹/ha)	Patna ($n_{1=}$45)	Nalanda ($n_{2=}$45)	Average cost of cultivation (₹/ha)	% contribution to total variable cost
Cost of human labour	37706	39162	38434	32.29
Cost of machine labour	14004	13844	13924	11.70
Cost of seed potato	27262	56564	41913	**35.21**
Fertilizers and manure	14764	11982	13373	11.23
Plant Protection charges	6837	4407	5622	4.72
Irrigation charges	5510	6026	5768	4.85
Total cost	106083	131985	119034	100.00

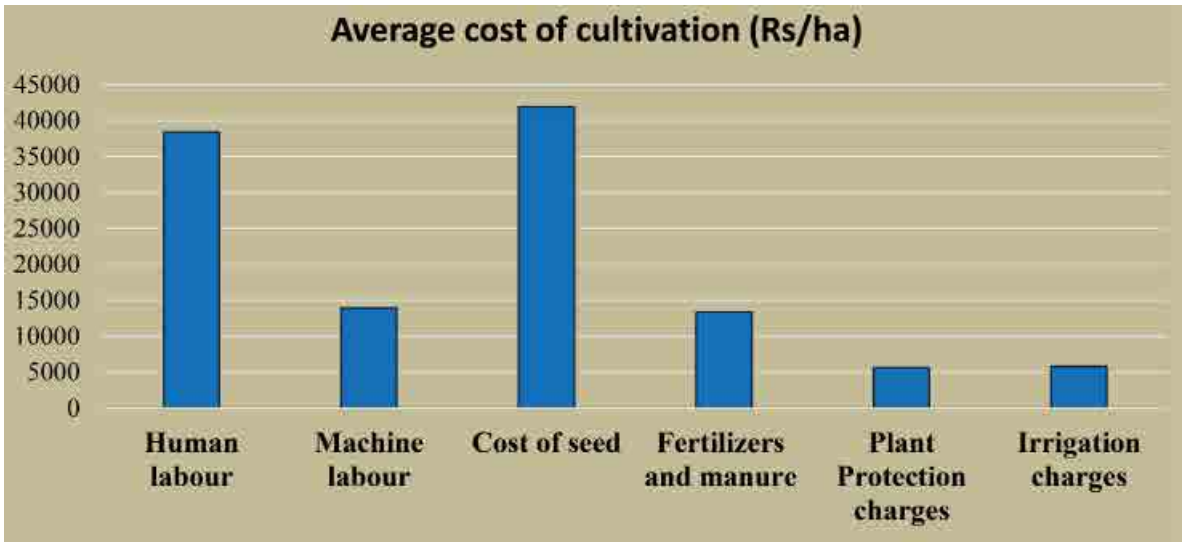


Fig.3: Graphical representation of different cost components in potato cultivation in Bihar

Patna district except cost of seed potato. It was found that seed cost was almost double in Nalanda as compared to Patna. During the survey and discussion, it was clear that majority of farmers in Nalanda purchased seed potato from Punjab at a higher cost including cost of transport. However, in Patna, most of the farmers used seed potato available in local market at low price. Cost of machine labour and fertilizer/manure cost were next important cost components which contributed 11.7 and 11.23 per cent respectively in total variable cost of cultivation.

Economics of potato cultivation

There are various parameters to analyze the economic benefits to farmers which include estimating gross return, net return and Benefit Cost (BC) ratio. Pooled average for both the districts showed that farmers earned a gross income of ₹ 180,613/- and net return of ₹ 61,579/- per ha from potato. Being a labour intensive crop, potato has higher cost of cultivation but higher yield ensures better economic return to farmers. The BC ratio revealed that farmers get ₹ 1.5 with an investment of ₹ 1.0 in potato crop.

Table 5: Economic profitability analysis of potato cultivation in Bihar

N=90

Economic Parameters	Patna (n_1 = 45)	Nalanda (n_2 = 45)	Pooled Average value
Average cost of cultivation (₹/ha)	106083	131985	119034
Average yield (t/ha)	22.34	32.16	27.25
Average selling price (₹/t)	6685	6570	6628
Gross return (₹/ha)	149400	211302	180613
Net return (₹/ha)	43317	79317	61579
Benefit Cost ratio at variable cost of cultivation	1.4	1.6	1.5
Variable cost of production (₹/t)	4748	4105	4368

When we compare the returns from Nalanda and Patna districts, this study highlighted that despite higher cost of cultivation; Nalanda recorded 41.4 per cent more gross return as compared to Patna. This was mainly possible due to more productivity in Nalanda. Comparative study of net return also showed similar trend, as it was nearly double in Nalanda as compared to Patna. Variable cost of production in terms of cost per ton of potato was found to be ₹ 4748 for Patna and ₹ 4105 for Nalanda. It was interesting to see that using early maturing improved variety i.e Kufri Pukhraj in Nalanda, farmers got higher return per unit area and time.

CONCLUSION

This study highlighted the potato economics at farmers' field in two top potato producing districts of Bihar i.e Nalanda and Patna. Being a cash crop, potato earned handsome returns to farmers per unit area and time. Study of varietal adoption pattern showed the popularity of high yielding potato variety Kufri Pukhraj in Nalanda and red skinned low yielding variety Kufri Sindhuri in Patna district. Based on the results, Government should take initiative to popularize high yielding varieties among farmers in Patna district in order to increase its productivity. The variable cost of cultivation was estimated to be ₹ 119,034/- per ha with seed component contributing more than one third of total. This seed cost can be reduced with availability of quality seed at affordable price. This is possible if farmers are motivated to grow their own seed through organization of trainings, exposure visits and supply of breeder seed. Moreover, awareness should be generated among farmers to use high yielding varieties instead of local cultivars

like C-1/C-40 etc. Because of fragmented land holding, organizing small and marginal farmers into farmers group, cooperatives or farmer producer organization will be most effective strategy for enhancing net return from potato. Group formation will not only facilitate input purchase at reasonable price but also help in marketing of final produce at decent price.

LITERATURE CITED

Anonymous (2021). Agricultural statistics at a glance 2020, Directorate of Economics & Statistics, Department of Agriculture Cooperation and Farmers Welfare, Ministry of Agriculture, Govt. of India. https://eands.dacnet.nic.in/PDF/Agricultural%20Statistics%20at%20a%20Glance%20-%202020%20(English%20version).pdf.

Anonymous (2013) https://www.ndtv.com/india-news/bihar-potato-farmer-sets-new-world-record-513698

CPRI (2015) Central Potato Research Institute Vision 2050. Central Potato Research Institute, Shimla, Himachal Pradesh, India.

Chand, R (2017) Doubling Farmer's Income: Rationale, Strategies, Prospects and Action plan, NITI Policy paper No. 1/2017, NITI Aayog, Govt. of India.

Agriculture Census Division (2019). Agriculture Census 2015-16, All India Report on Number and Area of Operational Holdings. Agriculture Census Division, Department of Agriculture, Co-operation & Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India.

Department of Agriculture Cooperation and Farmers Welfare (DAC&FW). 2019. Annual Report 2018-19, Ministry of Agriculture and Farmers Welfare, Govt. of India. https://agricoop.nic.in/sites/default/files/AR_2018-19_Final_for_Print.pdf

Directorate of Horticulture (2021), Government of Bihar http://horticulture.bihar.gov.in/MainSite/Statistics.aspx

Durgawati, W, Rajput, AM and Saraf, GP (2005) Economic analysis of potato and onion in Malwa region of Madhya Pradesh. *Indian Journal of Economics and Development*, **38**(3): 7779.

Hussain T (2016) Potatoes: ensuring food for the future *Adv Plants Agric Res*. 3(6): 178-182. DOI: 10.15406/apar.2016.03.00117.

Lal, H and Sharma, KD (2006) Economics of potato production in Lahaul Valley, Himachal Pradesh. *Journal of the Indian Potato Association*, **33**(3-4): 139-143.

Ministry of Home Affairs (2011) Census of India 2011: Rural-urban distribution of population. Ministry of Home Affairs, Government of India, New Delhi, India.

Noonari, S, Hakimzadi, W, Noor, I and Ahmed, F (2016) Economic analysis of potato production in sindh Pakistan. *Journal of Biology, Agriculture and Healthcare*, **6**(5): 100-107.

Peer, QA, Ahmad, N, Kaur, J, Chesti, MH, Ahman, HS, Bhat, A and Bhat, BA (2013) Study on economics of potato growing towards livelihood security in Jammu division, India. *African Journal of Agricultural Research*, **8**(45): 5639-5644.

Pradel, W, Gatto M, Hareau G, Pandey SK and Bhardwaj V (2019) Adoption of potato varieties and their role for climate change adaptation in India. *Climate Risk Management* **23**: 114–123.

Scott, GJ and Suarez, V (2012) The rise of Asia as the centre of global potato production and some implications for industry. *Potato Journal*, **39**(3- 4):1-22.

Sahadevan, KG (2007) Advantages of Commodity Futures Trading Through Electronic Trading Platform for Farmers of Uttar Pradesh: A Study of Potato and Mentha, Multi Commodity Exchange of India Limited, Mumbai.

Vinod Kumar, SK Luthra, Vinay Bhardwaj and BP Singh (2014) Indian Potato Varieties and their Salient Features. CPRI Technical Bulletin No. 78 (revised) ICAR-Central Potato Research Institute, Shimla, Himachal Pradesh, India.

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UTILIZATION OF POTATO WASTE FOR PRODUCTION OF BIOETHANOL: A NOVEL TECHNOLOGY

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ABSTRACT: This study was conducted on the exploration of the potential use of potato as feedstock for bioethanol production, through saccharification and fermentation. The saccharification was performed via thermal and enzymatic hydrolysis through the use of commercial enzymes such as cellulase, α-amylase, β-amylase and glucoamylosidase. The potato mash was mixed with 100 mL distilled water. The mixture was treated with different enzyme concentrations 10 U, 15 U and 20 U. The mixture was incubated at the temperature of 75 °C and pH 5.0. The saccharification process was completed with 10 U of amyloglucosidase at 60 °C, pH 4.5 for 72 h. Samples were withdrawn at different time intervals and the ethanol and consumed sugar assays were carried out by YSI Analyser. The use of commercial α-amylase led to higher reducing sugars release (69.21 ± 0.34 ± 0.32 g/100 g) and in the combination of enzymes found the maximum efficiency of saccharification i.e. 81.40 ± 0.56 g/100 g. The results showed that the enzymatic treatment led to higher saccharification efficiency (81.40%) equivalent to 96% of the maximum theoretical. The fermentation process by using various strains of Yeast at different time intervals. The maximum ethanol yield was obtained by *Saccharomyces cerevisiae* MTCC 178 after 72 h was 84.19 g/L.

KEYWORDS: Potato, bioethanol, fermentation, saccharification, microorganisms

INTRODUCTION

Biofuel is a liquid green energy source that is both renewable and sustainable, and it is a viable alternative to petroleum-derived fossil fuels. Its market is promising in near future because of the energy security of fossil fuels and environmental problems (Joshi *et al;* 2017; Niphadkar *et al;* 2018; Usmani 2020). In 2009, the Union Ministry of New and Renewable Energy drafted the National Policy on Biofuels to promote biofuels in India. The Ethanol Blended Petrol (EBP) initiative was started by the Indian government in January 2013, making it necessary for oil firms to sell petrol that contains at least 5% ethanol. The government of India reintroduced the Biofuel policy in 2018 and this policy has set the target bioethanol blending 10% and 30% in petrol up to 2022 and 2030 respectively (Saravanan *et al;* 2018). Currently, in India, the total production of bioethanol is 1.9 billion litres which are 57.6% of the total demand of 3.3 billion litres. Presently the major portion comes through the sugarcane industry. The sugarcane for the production of biofuel is not the sustainable solution because it is an exhaustive and long duration crop (18 months) also sugar mills has a balance sheet problem. Therefore in Biofuel policy, 2018 recommended much feedstock for bioethanol production one of them is potato (Singh *et al;* 2017; Saravanan *et al;* 2020; Usmani 2020). Potato (*Solanum tuberosum* L.) is the world's third most significant food crop in terms of human consumption, after wheat and rice. After China, India is the world's second-largest producer of overall potato production. The potato has

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the highest energy per time per space for any other existing crops (photosynthetic assimilation potential) and less duration crop (3 Months). Approximately 68 % of potato production is consumed fresh, 8.5 % as seed, 7.6% for processing, and approximately 16 % go to waste (At harvesting level 3-4%, at post-harvest handling 3-8% and storage level 6-8%) (Kumar *et al*; 2020; Singh *et al;* 2020). Presently potato processing industries are blooming and they create waste of potatoes in the range of 20-40% in various potato processing based products such as chips, french fries, potato flakes, crisps and potato hash etc. (Srichuwong *et al;* 2009; Khawla *et al;* 2014; Thatoi *et al;* 2016). Potato shows an attractive feedstock for bioethanol production in some regions in Europe, because ethanol yields from potato tubers are approximately 1400–1800 L/ha or more than 74 L/t (Arapoglou *et al;* 2010). Potatoes are carbohydrate-rich sources. In a nutshell, potatoes have a huge potential for industrial bioethanol production because they are ecologically sound, green fuel, highly productive, cost-effective, and manageable. There is a dire need for technology to the alternative use of waste potatoes (by-product in processing and surplus production of potatoes). Using these waste /surplus potatoes for bioethanol production can be an as useful approach by creating wealth from the waste of potatoes.

In this work, we examine how the process conditions such as the type of potato tuber, the type and concentration of enzymes, type of microorganisms, optimum conditions for saccharification and fermentation such as temperature, pH, inoculum size etc. All affect the rate of fresh potato tuber mash hydrolysis, saccharification and fermentation. The main goal was to define the kinetics of the fresh potato tuber starch enzymatic and thermal hydrolysis and the optimal process conditions concerning the total reducing sugars and ethanol formation. In addition, an enzymatic potato tuber hydrolyzate was tested as a substrate for bioethanol production using commercial various bakery yeast strains.

MATERIALS AND METHODS

Microorganism, starchy feedstock and chemicals

The commercially various bakery yeast strains (*Saccharomyces cerevisiae*) were purchased from CSIR-Institute of Microbial Technology, Chandigarh, India. These yeast strains were screened for ethanol production prom potato i.e. *Saccharomyces cerevisiae* MTCC 170, *S. cerevisiae* MTCC 171, *S. cerevisiae* MTCC 173, *S. cerevisiae* MTCC 174, *S. cerevisiae* MTCC 177 and *S. cerevisiae* MTCC 178. The processing varieties of potatoes which have more than 20% dry matter such as Kufri Chipsona 1, Kufri Chipsona 2, and Kufri Frysona are mainly grown in India, were used for bioethanol production. Potato tubers were washed, peeled, sliced and milled into a mash before use. Enzymes were obtained from Merck (Darmstadt, Germany). All products were analytical. The *Saccharomyces cerevisiae* strains were was maintained on a malt agar slant. The agar slant consisted of beef extract (3 g L^{-1}), yeast extract (3 g L^{-1}), peptone (5 g L^{-1}), agar (18 g L^{-1}) and distilled water (up to 1 L). For the inoculum, the culture was grown aerobically in 250 mL flasks in a shaking water bath at 32 °C for 48 h. The liquid media consisted of yeast extract (3 g L^{-1}), peptone (3.5 g L^{-1}), KH_2PO_4 (2 g L^{-1}), $MgSO_4 7H_2O$ (1 g L^{-1}), $(NH_2)_2SO_4$ (1 g L^{-1}), glucose (10 g L^{-1}) and distilled water. Three to six per cent of inoculum was used for the fermentation of potato (Tasić *et al*; 2009; Delgado *et al*; 2009; Khawla *et al*; 2014; Thatoi *et al*; 2016; Wang *et al*; 2016).

Thermal and enzymatic hydrolysis of fresh potato tubers

Saccharification denotes the breakdown of complex carbohydrates into a simpler form of carbohydrate. The saccharification needs liquefaction and hydrolysis of the substrate. Hydrolysis was performed in a 0.5 L glass three-necked round-bottom flask, equipped with a stirrer and a reflux condenser, immersed in a boiling water bath. Then, the potato tuber mash was added, so that the total volume of the reaction mixture was 200 mL. The different units of enzymes were poured into the flask and heated until boiling. During the hydrolysis process, samples of 3–5 mL were periodically taken from the reaction mixture, centrifuged at 3000 min^{-1} for 15 min. After appropriate dilution of the supernatant, the concentrations of reducing were estimated by YSI analyser (Delgado *et al*; 2009; Thatoi *et al*; 2016; Wang *et al*; 2016; Sheikh *et al*; 2016).

Fermentation for bioethanol production

Fermentation is the conversion of glucose to ethanol by using yeast. The selection of suitable, efficient, effective and tolerant yeast strains for fermentation is the most critical point. The standardized and optimized fermentation conditions for ethanol production such as pH, inoculum size, the concentration of sugar, ethanol concentration, and temperature etc. Moreover, the conversion of potato starch into glucose by enzymes is more cost-effective, and fermentation with baker's yeast *Saccharomyces cerevisiae* yields the maximum amount of ethanol, optimized conditions and evaluated different strains of yeast such as *Saccharomyces cerevisiae* MTCC 170, *S.cerevisiae* MTCC 171, *S.cerevisiae* MTCC 173, *S.cerevisiae* MTCC 174, *S.cerevisiae* MTCC 177 and *S.cerevisiae* MTCC 178.

The substrate was obtained from a fresh saccharification process. The hydrolyzate was rapidly cooled and adjusted to pH 5.0 by adding 3 M KOH. The main part of the hydrolyzate (2 L) was poured into an Erlenmeyer flask (5 L), and the yeast inoculum (prepared by homogenizing 5 g of yeast in 100 mL of the hydrolyzate) was added. The flask was then fixed on a rotary shaker (120 rpm) placed in a thermostated cabinet at 30°C. Samples of the fermentation medium (about 50 mL) were periodically withdrawn and centrifuged (5000 rpm for 10 min). The supernatants were used for the analysis of reducing sugars and ethanol by YSI analyser after proper preparation and dilution (Montesinos and Navarro 2000; Zhang *et al*; 2011; Izmirlioglu and Demirci 2012).

RESULTS AND DISCUSSION

Chemical composition of potato mash

The chemical composition of potato mash was analyzed to evaluate the feasibility of using it for ethanol production. As shown in Table 1, starch and dry were the major components of potato pulp, contributing to 70 gm/100gm and 20.2%, w/w of the biomass, respectively.

The dietary fiber consisted mainly of cellulose (1.9% of biomass), pectin (about

Table 1. Biochemical composition of potato variety Kufri Chipsona 1

Moisture (%)	80
Dry matter (%)	20.2
Cellulose (%)	1.9
Protein (mg/100gm FW)	2.5
Lipid (%)	0.7
Pectin (%)	2
Hemicellulose (%)	0.47
Amylose (%)	28
Starch %(gm/100gm)	70
Glucose (mg/100gm FW)	60
Sucrose (mg/100gm FW)	104

2% of biomass), and very little hemicellulose (<0.5% of biomass). The starch remaining in the potato pulp would adhere to the cell wall, probably due to embedding in fibers. Therefore, amylase should be co-used with the other cell wall degrading enzymes, such as cellulase and pectinase, to achieve a high hydrolysis rate of starch. Moreover, the use of cellulase would result in the conversion of cellulose in the potato pulp to glucose, making the resulting hydrolyzate more suitable for ethanol fermentation. The protein and lipid contents were 2.5% and 0.7% of the biomass, respectively. Glucose, galactose, and galacturonic acid were the main monosaccharides in the potato pulp. The glucose content of the biomass was 60 mg/100 gm FW, and it was primarily derived from cellulose and starch, as this figure was similar to the total quantity of cellulose and starch in the potato pulp. Because the potato pulp contains negligible hemicellulose, the majority of the sugars are most likely generated from pectin. The sugars would be released simultaneously during pectin hydrolysis. The sugars' enzymatic breakdown was not studied in the study due to their limited levels or unavailability to yeasts. Bandana et al. (2016) also analyzed the variations in biochemical parameters among eight different portions of potato cultivars. Kufri Chipsona-1 showed the highest dry matter content (SEC 30.34%) in the stem end cortex, followed by Kufri Frysona (SEC 27.71%). The bud end cortex (BEC 111.3 mg/100 g FW) had the highest mean reducing sugar values (BEC 111.3 mg/100 g FW) while the stem end medulla (SEM 44.05 mg/100 g FW) had the lowest.

In comparison to other lignocellulosic biomass, potato pulp was poor in hemicellulose and lignin, suggesting that it could be saccharified by common yeast, without the need for an engineered yeast capable of fermenting xylose, and it could be treated without delignification process. On the other hand, the use of a complicated enzyme system has to be taken into account to hydrolyze starch, cellulose, and pectin simultaneously. In addition, the presence of protein in potato residue offers a potential economic benefit, indicating the possibility of enhancing the value of the waste (Arapoglou *et al*; 2010).

Impact of Glucoamylase, α-amylase, β- amylase and cellulose on saccharification of the potato pulp

Since potato pulp contains large amounts of starch, cellulose, and pectin, the effects of α-amylase, cellulase, and pectinase on saccharification of the potato pulp were investigated. The experiments were carried out with 8.5% potato slurry in 5 mL citric acid buffer (0.1 M). The enzyme loadings of α-amylase and glucoamylase were set to 0.1% (v/v) and 0.05% (v/v) respectively, which could be represented by 5 U/g of biomass and 0.1 U/g of biomass in this study. As expected, when the α-amylase with the supplementation of was β- amylase used, glucose was produced, which was derived from starch (Table 2). The potato slurry was treated with different enzyme concentrations 10 U, 15 U and 20 U. The reaction was incubated at 75 °C and pH 5.0. The saccharification step was performed using 10 U of amyloglucosidase at 60 °C, pH 4.5 for 72 h. Samples were withdrawn at different time intervals and the ethanol and consumed sugar assays were carried out by YSI Analyser.

The use of commercial alpha-amylase led to higher reducing sugars released after 72 h (69.21 ± 0.34± 0.32 g/100g) and in the combination of enzymes found the maximum efficiency of saccharification i.e. 81.40 ± 0.56 g/100 g. The results indicated that the enzymatic treatment by commercial

Table 2. The enzymatic hydrolysis for saccharification

Enzymatic hydrolysis yield (%) for saccharification				
Enzymes	At the end of the experiment (72 h)	48 h	36 h	24 h
Control (Only heat pretreatment)	20.4 ± 0.45	20.34 ± 0.12	20.04 ± 0.01	19.84 ± 0.17
Cellulase	41.64 ± 0.22	36.44 ± 0.29	31.14 ± 0.32	29.84 ± 0.12
Alpha-amylase	69.21 ± 0.34	65.57 ± 0.14	61.35 ± 0.85	55.30 ± 0.74
Beta- amylase	21.12 ± 0.15	20.18 ± 0.05	18.62 ± 0.05	17.42 ± 0.27
Glucoamylase	18.12 ± 0.65	16.62 ± 0.27	15.72 ± 0.05	14.02 ± 0.36
Mixture of above	81.40 ± 0.56	77.21 ± 0.28	70.61 ± 0.41	69.32 ± 0.45

enzymes led to higher saccharification efficiency (81.40%) and ethanol yield (0.49 g/g consumed sugars) corresponding to 96% of the maximum theoretical yield of glucose. The combination of cellulose, α-amylase,β-amylase and glucoamylase resulted in significant increases in the concentrations of monosaccharide sugars such as glucose, galactose and galacturonic acid, and provided a half times higher glucose production rate in the first 24 h and a 3.1 times higher concentration after 72 h. This suggests a "multiplier effect" involving the enzymes on starch and cellulose hydrolysis.

Meyer *et al*; (2009) reported the significant decrease in viscosity of the potato slurry was observed when cellulase was combined with amylases and glucoamylase.

Together with galacturonic acid, a large amount of galactose was detected, suggesting that the pectic substrates in the potato residue were probably made up of highly galactose-branched pectin. The formation of galactose that can be converted to ethanol by yeast would lead to a higher conversion rate of the waste to ethanol. Moreover, even though it did not lead to an increase in glucose production, the addition of the pectinase increased glucose production rate; the saccharification of glucan came to its end within 24 h while there was no glucose detected within 24 h in the case of using amylase alone. The improvement in glucose production rate would be due to that the destruction of cell-wall by the pectinase, cellulase led to the leakage of starch, which made enzymes easily attack starch. Besides starch, cellulose is also a main component of the potato pulp and can be converted to glucose (Collado and Corke 1999; Meyer *et al*; 2009; Ben Atitallah *et al*; 2019).

The combination of cellulase and pectinase resulted in significant increases in the concentrations of galactose and galacturonic acid and provided a 1.6 times higher glucose production rate in the first 24 h and a 1.4 times higher concentration of glucose compared with the use of cellulase alone. This suggests a "multiplier effect" involving the 2 enzymes, on cellulose hydrolysis. The multiplier effect can be explained by that due to the hydrolysis of pectin by the pectinase, the viscosity decreased significantly so that cellulose was easily hydrolyzed by cellulase.

Pretreatment of the potato pulp with steam

Since potato pulp contains cellulose, lignin, little hemicellulose and a large amount of starch, pretreatment under mild conditions would be reasonable. The potato pulp was treated to a 90-minute hydrothermal treatment at 100°C to see if the treatment

was effective. After saccharifying the treated potato pulp with enzymes, the glucose and galactose concentrations were examined. Without adding enzymes, 19.84 g/L glucose was obtained, as shown in Table 1. In that situation, the combination of enzymes yielded the highest saccharification efficiency of 81.40 %. The findings suggested that pretreatment is sufficient for certain enzymatic hydrolysis of potato slurry.

According to Saha and Bothast (1999), a hot water pretreatment at 121°C for 1 hour resulted in inefficient enzymatic hydrolysis of the starch and cellulose part of maize fibre. Starch would be influenced by this preparation in comparison to cellulose. During this pretreatment, starch gelatinization occurred, resulting in the loss of crystalline areas in starch granules, drastically boosting the accessibility of α-amylase to starch.

Zavareze *et al*; (2010) also reported a heat-moisture treatment boosted starch's enzymatic vulnerability and decreased relative crystallinity. The pretreatment in this study consumed less energy since the temperature (121 ^{0}C) was lower than that of usual hot-compressed water pretreatments of lignocellulosic biomass (160–200 ^{o}C). The hydrolyzate produced had a 3.7-fold greater glucose concentration than the untreated one.

Even though the pretreatment liquefied starch and pectin, it was anticipated that the accompanying enzymes would easily hydrolyze them, and cellulose would be easily attacked by cellulase due to the disintegration of the cell wall. They acquired the predicted result with glucan hydrolysis. In the case of galactan hydrolysis, however, the pretreatment had minimal effect on the galactose yield. The results showed that enzymes could liquefy galactan without the use of pretreatment, and subsequently hydrolyze it. (Cheng *et al*; 2019).

Therefore, for the production of well-balanced enzymes, the study on enzyme production would be focused on how to improve the activity of pectinase in future. It will be highly helpful for enhancing the efficiency in galactan hydrolysis.

Bioethanol fermentation with the saccharification potato slurry

The YEPD or yeast extract peptone dextrose media, also often abbreviated as YPD, is a complete medium for yeast growth. It contains yeast extract, peptone, double-distilled water, and glucose. YPD medium is rich in protein, free amino acids, and vitamins, and is, therefore, suitable for yeast growth (Zhao and Bai 2009; Lee *et al*; 2012). However, its outrageous cost limits it from being used in industry. Low-cost nutrients and agricultural wastes high in protein have been evaluated as yeast extract and polypeptide alternatives. Hashem and Darwish (2010), for example, found that due to the presence of nitrogen in the substrate, efficient ethanol fermentation by *S. cerevisiae* was possible using a potato residual stream. The potato pulp, in addition to carbohydrates, provides protein (Table 1), which was revealed to be a nutritional source for yeast growth in this research.

As a result, hydrolyzate was examined as a carbon and nutrient source for ethanol fermentation in this study. For the control tests, the nutrient-poor medium and the YPDG medium containing 10 g L^{-1} yeast extract, 20 g L^{-1} peptone, and 20 g L^{-1} dextrose, as well as the hydrolyzate, were utilised. When glucose was ingested from 15% to 5% within 96 hours, as illustrated in Figure. 1, it was consumed from 15% to 5% within 96 h when the hydrolyzate was used without supplementation of nutrients, indicating the feasibility of the hydrolyzate as the nutrient source for ethanol

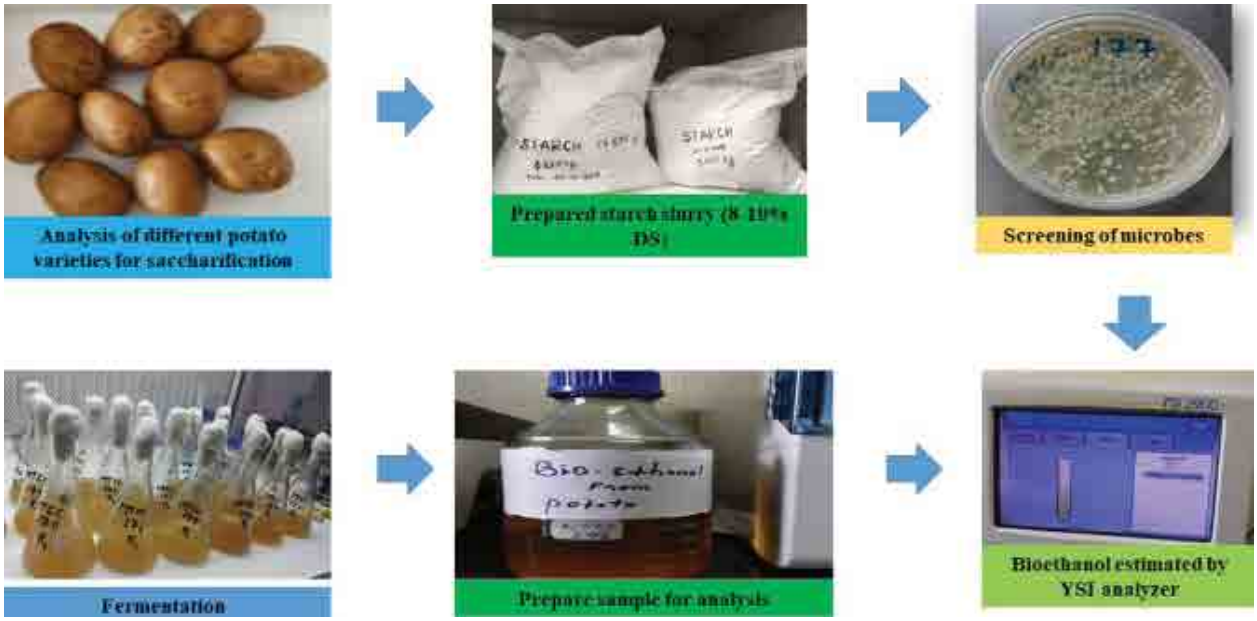


Figure 1. The bioethanol production process from potato

fermentation. The concentration of ethanol was very similar to that achieved in the YPDG medium fermentation. Although the ethanol conversion efficiency in the hydrolyzate fermentation seemed to be a little slower.

In the nutrient-poor medium, however, glucose could not be entirely digested during fermentation. The high initial sugar content would have a significant impact on fermentation efficiency. The osmotic effect may be important in glucose ingestion and ethanol generation at high glucose concentrations (Hashem and Darwish 2010).

The cost of potato would be substantially cheaper than that of YE because potato is also a type of agricultural by product. The use of potato pulp as a nutrient would help to reduce the nutrient cost of ethanol fermentation. However, the galactose is not entirely utilised in both the hydrolyzate and the YPDG medium fermentation, most likely due to the inhibiting impact of ethanol. Because galactose is a yeast fermentable sugar, improving galactose to ethanol conversion would increase the total production of ethanol from potato pulp.

In the future, the fermentation variables and strategy should be researched to improve galactose to ethanol conversion rates and, as a result, ethanol yields.

At the end of fermentation, the reducing sugars were 5.53 g L^{-1}. Therefore, the sugars consumed were 10 g L^{-1} (Figure 2). In all treatments, the non-fermented sugar at the end of fermentation was very low. The consumed sugar during fermentation was very high (up to 67%), indicating the high ability of *S. cerevisiae* to bioconvert reducing sugars.

Table 3 shows the ethanol production (g L^{-1}) and ethanol productivity (g $L^{-1}h^{-1}$) with the use of various strains of *S. cerevisiae*. In all treatments, *S. cerevisiae* MTCC 178 produced high quantities of ethanol (84.194 g L^{-1}), with the ethanol productivity (0.877 g $L^{-1}h^{-1}$) and the incubation period was 96 h. In all cases, the product yield corresponded up to 91% of the max theoretical yield. The results indicate

Table 3. Bioethanol yield and productivity in a different time interval

Microorganisms	Ethanol yield and productivity in a different time interval							
	36h		48h		72h		96h	
	Ethanol Yield (g/l)	Ethanol productivity (g/l/h)	Ethanol Yield (g/l)	Ethanol productivity (g/l/h)	Ethanol Yield (g/l)	Ethanol productivity (g/l/h)	Ethanol Yield (g/l)	Ethanol productivity (g/l/h)
Saccharomyces cerevisiae MTCC 170	37.300	1.036	49.633	1.034	77.200	1.072	81.710	0.851
Saccharomyces cerevisiae MTCC 171	45.000	1.250	59.067	1.230	82.400	1.144	87.164	0.908
Saccharomyces cerevisiae MTCC 173	28.633	0.795	43.567	0.907	67.500	0.937	76.572	0.798
Saccharomyces cerevisiae MTCC 174	36.971	1.027	50.514	1.052	75.700	1.051	80.500	0.838
Saccharomyces cerevisiae MTCC 177	31.300	0.869	43.770	0.911	76.291	1.059	79.113	0.824
Saccharomyces cerevisiae MTCC 178	39.315	1.092	48.603	1.012	79.200	1.100	84.194	0.877

LSD (P=0.05) Time = 2.225, Microorganism = 2.225, Time Microorganism =NF

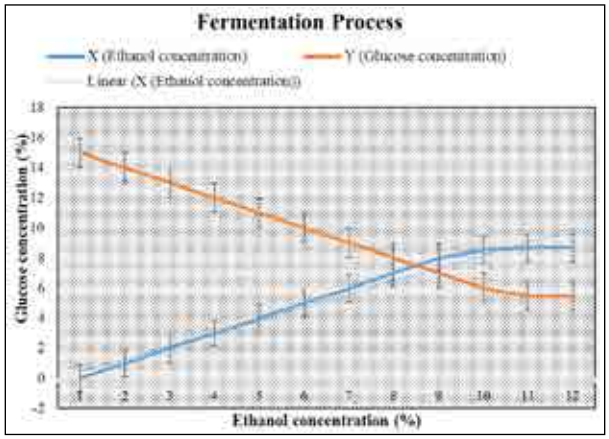


Figure 2. Bioethanol production of fermentable sugar from enzymatic hydrolysis of potato slurry

that the critical parameters for ethanol production from PPW were the enzyme combination, the dose and the residence time of hydrolysis. After liquification and saccharification, fermentation by *S. cerevisiae* converted sugars to high yields of ethanol.

CONCLUSION

In this study, the feasibility of potatoes for ethanol production was investigated. Analytic results of the components showed that the potato was abundant in starch, cellulose, and other carbohydrates. The enzymes are suitable for saccharification of potato pulp due to its high starch, pectin, cellulose and α-amylase activities. A hydrothermal treatment increased the glucose yield by 2 times. The resulting hydrolyzate was efficiently converted to ethanol without nutrient supplementation by various strains of yeast.

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LITERATURE CITED

Arapoglou D, Varzakas T, Vlyssides A, Israilides C (2010) Ethanol production from potato peel waste (PPW). Waste Manag 30:1898–1902. https://doi.org/10.1016/J.WASMAN.2010.04.017

Bandana, Sharma V, Kaushik SK, Singh B, Raigond P (2016) Variation in biochemical parameters in different parts of potato tubers for processing purposes. J Food Sci Technol 53:2040. https://doi.org/10.1007/S13197-016-2173-4

Ben Atitallah I, Antonopoulou G, Ntaikou I, Alexandropoulou M, Nasri M, Mechichi T, Lyberatos G (2019) On the evaluation of different saccharification schemes for enhanced bioethanol production from potato peels waste via a newly isolated yeast strain of Wickerhamomyces anomalus. Bioresour Technol 289:121614. https://doi.org/10.1016/j.biortech.2019.121614

Cheng L, Hu X, Gu Z, Hong Y, Li Z, Li C (2019) Characterization of physicochemical properties

of cellulose from potato pulp and their effects on enzymatic hydrolysis by cellulase. Int J Biol Macromol 131:564–571. https://doi.org/10.1016/J.IJBIOMAC.2019.02.164

Collado LS, Corke H (1999) Heat-moisture treatment effects on sweet potato starches differing in amylose content. Food Chem 65:339–346. https://doi.org/10.1016/S0308-8146(98)00228-3

Delgado R, Castro AJ, Vázquez M (2009) A kinetic assessment of the enzymatic hydrolysis of potato (Solanum tuberosum). LWT - Food Sci Technol 42:797–804 https://doi.org/10.1016/j.lwt.2008.11.001

Hashem M, Darwish SMI (2010) Production of bioethanol and associated by-products from potato starch residue stream by Saccharomyces cerevisiae. Biomass and Bioenergy 34:953–959 . https://doi.org/10.1016/J.BIOMBIOE.2010.02.003

Izmirlioglu G, Demirci A (2012) Ethanol production from waste potato mash by using Saccharomyces cerevisiae. Appl Sci 2:738–753. https://doi.org/10.3390/app2040738

Joshi G, Pandey JK, Rana S, Rawat DS (2017) Challenges and opportunities for the application of biofuel. Renew Sustain Energy Rev 79:850–866 https://doi.org/10.1016/J.RSER.2017.05.185

Khawla BJ, Sameh M, Imen G, Donyes F, Dhouha G, Raoudha EG, Oumèma NE (2014) Potato peel as feedstock for bioethanol production: A comparison of acidic and enzymatic hydrolysis. Ind Crops Prod 52:144–149. https://doi.org/10.1016/j.indcrop.2013.10.025

Kumar D, Dutt S, Raigond P, Changan SS, Lal MK, Sharma D, Singh B (2020) Potato Probiotics for Human Health. In: Potato. Springer Singapore, pp 271–287

Lee WS, Chen IC, Chang CH, Yang SS (2012) Bioethanol production from sweet potato by co-immobilization of saccharolytic moulds and Saccharomyces cerevisiae. Renew Energy 39:216–222. https://doi.org/10.1016/j.renene.2011.08.024

Meyer AS, Dam BP, Lærke HN (2009) Enzymatic solubilization of a pectinaceous dietary fibre fraction from potato pulp: Optimization of the fibre extraction process. Biochem Eng J 43:106–112 . https://doi.org/10.1016/j.bej.2008.09.006

Montesinos T, Navarro JM (2000) Production of alcohol from raw wheat flour by Amyloglucosidase and Saccharomyces cerevisiae. Enzyme Microb Technol 27:362–370 https://doi.org/10.1016/S0141-0229(00)00211-8

Niphadkar S, Bagade P, Ahmed S (2018) Bioethanol production: insight into past, present and future perspectives. Biofuels 9:229–238

Saha BC, Bothast RJ (1999) Pretreatment and enzymatic saccharification of corn fibre. Appl Biochem Biotechnol 1999 762 76:65–77. https://doi.org/10.1385/ABAB:76:2:65

Saravanan AP, Mathimani T, Deviram G, Rajendran K, Pugazhendhi A (2018) Biofuel policy in India: A review of policy barriers in sustainable marketing of biofuel. J Clean Prod 193:734–747. https://doi.org/10.1016/J.JCLEPRO.2018.05.033

Saravanan AP, Pugazhendhi A, Mathimani T (2020) A comprehensive assessment of biofuel policies in the BRICS nations: Implementation, blending target and gaps. Fuel 272:117635 https://doi.org/10.1016/J.FUEL.2020.117635

Sheikh RA, Al-Bar OA, Soliman YMA (2016) Biochemical studies on the production of biofuel (bioethanol) from potato peels wastes by Saccharomyces cerevisiae: effects of fermentation periods and nitrogen source concentration. Biotechnol Biotechnol Equip 30:497–505. https://doi.org/10.1080/13102818.2016.1159527

Singh A, Raigond P, Lal MK, Singh B, Thakur N, Changan SS, Kumar D, Dutt S (2020) Effect of cooking methods on the glycemic index and in vitro bioaccessibility of potato (Solanum tuberosum L.) carbohydrates. LWT 127: https://doi.org/10.1016/j.lwt.2020.109363

Singh S, Adak A, Saritha M, Sharma S, Tiwari R, Rana S, Arora A, Nain L (2017) Bioethanol Production Scenario in India: Potential and Policy Perspective. Sustain Biofuels Dev India 21–37. https://doi.org/10.1007/978-3-319-50219-9_2

Srichuwong S, Fujiwara M, Wang X, Seyama T, Shiroma R, Arakane M, Mukojima N, Tokuyasu K (2009) Simultaneous saccharification and fermentation (SSF) of very high gravity (VHG) potato mash for the production of ethanol. Biomass and Bioenergy 33:890–898 . https://doi.org/10.1016/j.biombioe.2009.01.012

Tasić MB, Konstantinović B V., Lazić ML, Veljković VB (2009) The acid hydrolysis of potato tuber mash in

bioethanol production. Biochem Eng J 43:208–211 . https://doi.org/10.1016/j.bej.2008.09.019

Thatoi H, Dash PK, Mohapatra S, Swain MR (2016) Bioethanol production from tuber crops using fermentation technology: a review. Int J Sustain Energy 35:443–468 https://doi.org/10.1080/14786451.2014.918616

Usmani RA (2020) Potential for energy and biofuel from biomass in India. Renew Energy 155:921–930. https://doi.org/10.1016/J.RENENE.2020.03.146

Wang F, Jiang Y, Guo W, Niu K, Zhang R, Hou S, Wang M, Yi Y, Zhu C, Jia C, Fang X (2016) An environmentally friendly and productive process for bioethanol production from potato waste. Biotechnol Biofuels 9:1–10 https://doi.org/10.1186/s13068-016-0464-7

Zavareze E da R, Storck CR, de Castro LAS, Schirmer MA, Dias ARG (2010) Effect of heat-moisture treatment on rice starch of varying amylose content. Food Chem 121:358–365. https://doi.org/10.1016/J.FOODCHEM.2009.12.036

Zhang L, Zhao H, Gan M, Jin Y, Gao X, Chen Q, Guan J, Wang Z (2011) Application of simultaneous saccharification and fermentation (SSF) from viscosity reducing of raw sweet potato for bioethanol production at laboratory, pilot and industrial scales. Bioresour Technol 102:4573–4579 https://doi.org/10.1016/j.biortech.2010.12.115

Zhao XQ, Bai FW (2009) Yeast flocculation: New story in fuel ethanol production. Biotechnol. Adv. 27:849–856

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IMPACT OF CONCURRENT ELEVATION IN CO_2 AND TEMPERATURE ON TUBER YIELD AND ASSOCIATED TRAITS OF POTATO GENOTYPES

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ABSTRACT: Carbon dioxide (CO_2) concentration in the atmosphere is rising continuously and consequently global average surface temperature is anticipated to rise in near future which tends to affect tuber yield, associated physiological traits of potato. This necessitate to explore some resilient cultivars to counter the adverse impact of anticipated changing climate scenario. So, in order to explore such cultivars, an investigation was carried out in open top chambers having controlled facility (CO_2 and Temperature) at ICAR-CPRS, Jalandhar, Punjab. Two advance stage heat tolerant potato genotypes *viz.*, HT/7-1105 and HT/7-1329 and two commercial varieties, *viz.*, Kufri Surya (heat tolerant) and Kufri Badshah were evaluated under three treatments, *viz.*, (i) elevated CO_2 (600 ppm) along with elevated temperature (3°C rise over ambient); (ii) elevated CO_2 (600 ppm) and (iii) ambient. Impact of higher temperature with elevated CO_2 on tuber yield was negative only in Kufri Badshah (-10.17 t/ha). Response to CO_2 enrichment, in terms of tuber yield, was positive in case of all the genotypes i.e. Kufri Badshah, Kufri Surya, HT/7-1105 and HT/7-1329. These results suggest the overall superiority of Kufri Surya and heat tolerant cultivars in terms of productivity under high CO_2 and high temperature. Net photosynthesis (PS) rate was 34.4 µmol CO_2 $m^{-2}s^{-1}$ under elevated CO_2 in Kufri Badshah that reduced to 27.10 µmol CO_2 $m^{-2}s^{-1}$ on exposure to high temperature (around 3°C) and CO_2. These values were statistically significant over PS rate under ambient conditions.

KEYWORDS: Potato, tuber yield, net photosynthesis, high temperature and elevated CO_2

INTRODUCTION

Potato (*Solanum tuberosum* L.) is an annual, herbaceous, dicotyledonous and vegetatively propagated tuberous crop belonging to the family solanaceae. It is the world's third largest food crop following rice and wheat (Pinhero *et al.*, 2016). Potato was originated in the area of southern Peru and extreme north-western Bolivia is believed to have domesticated independently in multiple locations approximately 7,000–10,000 years ago. It is believed that the crop has been introduced into India in the late sixteenth century, most probably by the Portuguese or the Spaniards (Anonymous, 1989). Earlier days of its introduction, potato cultivation was confined to cool summers and long days in hilly regions. Organized crop improvement through breeding and selection by ICAR - Central Potato Research Institute, Shimla adapted the crop to short winter days and now is a major *Rabi* crop in Indo-Gangetic plains from Punjab to West Bengal. Indo-Gangetic plains account for more than 85 per cent of potato acreage with hills and plateaus accounting for about 15 per cent of the total acreage under the crop (Minhas and Kumar, 2015). The potato is grown for edible tubers rich in carbohydrate content especially starch with vitamins and minerals as well as an assortment of phytochemicals, such as carotenoids and natural phenols (Zarzecka *et al.*, 2015). In India, potato is cultivated in an area of 2.17 million hectares (ha) with a total production of 50.19 million tonnes (t)

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having an average productivity of 23.12 t ha^{-1} (Anonymous, 2019). Being consumed by more than a billion people and much higher future demand for potato worldwide especially from developing nations, Food and Agriculture Organization of UN has declared potato as 'Food for future'.

Climate change is a global phenomenon due to emission of greenhouse gases (CO_2, NO_2, CH_4 *etc*.) by various natural and anthropogenic activities. Over the past 4,20,000 years, the upper limit of CO_2 concentration was about 280 ppm (Hogy and Fangmeier, 2009) and currently the average global CO_2 concentration is about 400 ppm (Abebe *et al*., 2016) have been predicted to at least 550 ppm by the middle of this century (IPCC, 2007). Exaggerated concentration of greenhouse gases (GHGs) in the atmosphere causing greenhouse effect, consequently global average surface temperature is predicted to rise 0.3–1.7°C by 2081–2100 and 2.6–4.8°C under high CO_2 emission scenarios (IPCC, 2013). The growth, development and yield of crops are greatly influenced by above as well as below ground environmental conditions (Madhu and Hatfield, 2016). It is presumed that elevation in CO_2 and rising temperature may affect the growth pattern, tuber yield, quality and other physiological processes of crops (Thinh *et al*., 2017).

Several studies have been conducted inside OTCs earlier to quantify the possible effect of CO_2. It is well known fact that increased concentration of atmospheric carbon dioxide stimulates crop growth by the carbon fertilization effect and positive effect of CO_2 enrichment on potato tuber yield was noticed in our previous studies by Minhas *et al*., 2018 and Kumar *et al.,* 2018. It is also evident that positive effect of elevated CO_2 might be offset by the adverse effect of associated global warming particularly excessive heat (Kumari *et al*., 2017).

The rise in temperature affects the phenology, growth, yield, and quality of the crop (Kaur *et al*., 2019). High temperatures delay, impede or even inhibit tuber initiation and affect the distribution of dry matter between tubers and haulms, night temperatures being especially crucial. Bushnell (1925) defined 17°C as an optimum temperature for good yield in potatoes. Minimum temperature plays an important role in tuberisation of potato and night temperature above 18°C reduce tuberisation and formation of tuber will be hold up beyond 25°C. This situation alarm potato cultivation both in view of productivity as well as regions where potato is already being grown under extreme temperatures (night temperature >=20°C) (Minhas *et al*., 2006).

Under anticipated climate change scenarios, adoption of high temperature tolerant cultivars by exploiting genetic diversity is one of the most viable option to sustain productivity of potato. Further information on responses of potato to both high CO_2 coupled with rising temperature is also very scanty. Keeping this in view, experiment was conducted inside OTCs to analyse the tuber yield and associated traits of potato genotypes and to identify the high temperature tolerant cultivars which may be further adopted to sustain potato productivity in India.

MATERIALS AND METHODS

Experimental site and soil details

The present investigation was carried out at the ICAR-Central Potato Research Station, Jalandhar, Punjab (Latitude: 31°16'26.21" N; Longitude: 75°32'46.32" E; Elevation: 233m AMSL) during the winter season of 2017-18. The experiment was conducted under controlled environment facility i.e. within open top chambers (OTCs), each of which

had a dimension of 3m X 3m X 2.5m and 6.25 m^2 of open top area. The walls of OTCs were made up of 3-4 mm thick clear multi-layered, polygal grade PVC/polycarbonate sheets having 80-85 per cent transparency to solar radiation. The soil under the OTCs were sandy loam in texture having pH of 8.0, EC 0.27 ds/m, organic carbon 0.40 per cent (Walkley and Black 1934), available N 324.0 kg/ha (Subbiah and Asija, 1956), available P 19.7 kg/ha (Olsen *et al*., 1954) and available K 292.3 kg/ha (Jackson, 1973).

Planting materials and treatments

Two potato genotypes *viz.,* HT/7-1105 and HT/7-1329 which are at advance stage of selection for heat tolerance trait and two commercial varieties, *viz.,* Kufri Surya (heat tolerant) and Kufri Badshah were evaluated. Each of the four genotypes were tested under three different treatments, *viz.,* T_1-elevated CO_2 (600 ppm) along with elevated temperature (3^0C rise over ambient); T_2-elevated CO_2 (600 ppm) and T_3-ambient (control). Temperature and carbon dioxide concentrations within and around the OTC micro-environment were recorded diurnally at one-minute interval through automated system and monitored periodically for achieving the desired levels of elevated CO_2 and temperature levels. Air temperature was measured using PT100 sensors (kept within radiation shields) and CO_2 level through non-dispersive infrared absorption (NDIR) method.

Planting and crop management practices

The seed size tubers (40-50 g) of each genotype were planted at 60 cm x 20 cm spacing on 11th October 2017. The crop was fertilized with urea, di-ammonium phosphate and muriate of potash wherein N, P_2O_5 and K_2O were applied at the rate of 240 kg, 100 kg and 150 kg per hectare, respectively. Half dose of N and full dose of P and K were applied at the time of planting, while the remaining N was applied at the time of earthing-up *i.e.* 25 days after planting. Irrigation scheduling was based on pan evaporation rate recorded using a USWB class A open pan evaporimeter at 08:30 IST daily and drip method was followed to deliver water at every 3-4 days interval depending on soil conditions. Other standard package of practices was followed for healthy crop stand (Kumar *et al*., 2020). In each year, dehaulming was done at 110 days after planting, 20 days later tubers were harvested.

Leaf net photosynthesis measurement

Photosynthesis and stomatal conductance was measured at 40 days after planting using LI-6400 portable photosynthesis system.

Statistical analysis

Statistical analysis was done using Microsoft Excel programme and SPSS 16.0 software.

RESULTS AND DISCUSSION

Tuber yield of various potato genotypes as influenced by elevated CO_2 and temperature, elevated CO_2 only and ambient conditions

Tuber yield of various potato genotypes as influenced by elevated CO_2 and temperature conditions is presented in Figure 1. A noticeable variation in tuber yield in all the varieties was observed. Relatively higher tuber yield in all the varieties under elevated CO_2 conditions was observed with values being 40.00 t/ha in Kufri Badshah, 48.83 t/ha in Kufri Surya, 49.33 t/ha in HT/07-1105 and 42.00 t/ha in HT/7-1329 genotypes. Under elevated CO_2 and temperature conditions the tuber yield of Kufri Badshah, Kufri Surya, HT/7-1105 and HT/7-1329 was 24.50, 35.17, 41.17 and 39.33 t/ha, respectively. Under

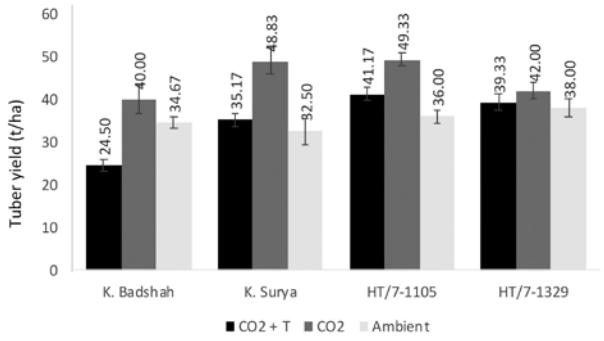


Fig. 1: Tuber yield of various potato genotypes as influenced by elevated CO_2 and temperature, elevated CO_2 only and ambient conditions.

ambient conditions the tuber yield was 34.67, 32.50, 36.00 and 38.00 t/ha for Kufri Badshah, Kufri Surya, HT/7-1105 and HT/7-1329, respectively.

It was further observed that the variation in tuber yield due to elevated CO_2 and temperature conditions as well as under elevated CO_2 conditions was different for different varieties when compared to ambient conditions (Figure 2). Under elevated CO_2 + temperature conditions the tuber yield of Kufri Badshah decreased by 10.17 t/ha, whereas in all the other three varieties this variation was positive with increase being 2.67, 5.17 and 1.33 t/ha in Kufri Surya, HT/7-1105 and HT/7-1329, respectively. Similarly, under elevated CO_2 conditions the

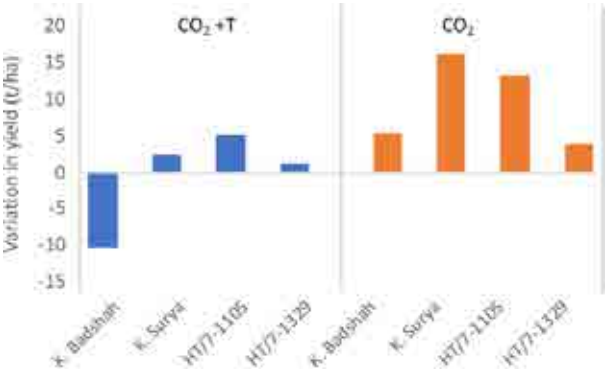


Fig. 2: Variation in tuber yield of different potato genotypes under elevated CO_2 with temperature and elevated CO_2 only as against ambient conditions.

tuber yield increased in all the four varieties, when compared to ambient conditions. This increase was highest in Kufri Surya (16.33 t/ha) followed by HT/7-1105 (14.33 t/ha), Kufri Badshah (5.33 t/ha) and HT/7-1329 (2.78 t/ha). A positive effect of concurrent and appropriate elevation of CO_2 and temperature was also observed by Lee *et al*. 2020. According to them such conditions promote balanced development of source and sink organs and positively affect potato productivity.

Tuber yield enhancement in Kufri Surya and HT/7-1105 as response to CO_2 enrichment was much more pronounced than in other genotypes. This may be due to source limited yield in these genotypes under ambient conditions as higher CO_2 concentration is known to enhance photosynthesis and enhanced carbohydrate availability at the source leaves (Kumar *et al.*, 2018). No negative impact of higher temperature + CO_2 on tuber yield of Kufri Surya, HT/7-1105 and HT/7-1329 could be attributed to their growth pattern particularly during tuber bulking phase when requirement of photosynthates is highest to obtain higher yield. Considering the yield potential, heat tolerance and superiority in other tuber traits, potato genotype HT/7-1329 has recently been released as "Kufri Kiran" for commercial cultivation in the country.

Impact of elevated CO_2 alone and with high temperature on important yield associated traits

Tuber yield and its response to temperature and CO_2 conditions, besides other, depend upon yield associated traits also *e.g.* leaf temperature, photosynthesis, stomatal conductance and transpiration. So, the impact of elevated CO_2 and temperature on these traits was studied and are presented in Table 1. It was observed that elevated

Table 1. Impact of elevated CO_2 alone and with high temperature on various physiological traits in potato genotypes.

Genotype	CO_2 + Temp.	CO_2	Ambient	$CD_{0.01}$
Leaf Temperature (°C)				
Kufri Badshah	27.10±1.50	23.15±1.55	18.95±0.95	NS
Kufri Surya	26.70±0.70	23.20±1.10	19.60±1.00	4.42
HT/7-1105	27.84±1.15	24.70±1.40	18.40±2.20	NS
HT/7-1329	28.00±0.80	24.54±0.75	18.95±1.95	6.02
Net photosynthesis (µmol CO_2 $m^{-2}s^{-1}$)				
Kufri Badshah	29.2±2.3	34.4±1.4	22.6±0.2	7.4
Kufri Surya	32.9±2.1	32.9±0.6	25.4±0.4	5.9
HT/7-1105	38.0±3.1	36.0±3.6	26.4±0.7	NS
HT/7-1329	32.5±0.9	35.4±1.9	27.0±2.8	NS
Stomatal conductance (mmol CO_2 $m^{-2}s^{-1}$)				
Kufri Badshah	0.31±0.06	0.54±0.24	0.64±0.08	NS
Kufri Surya	0.32±0.10	0.41±0.01	0.85±0.03	0.30
HT/7-1105	0.50±0.03	0.55±0.13	1.18±0.22	NS
HT/7-1329	0.29±0.11	0.43±0.10	1.00±0.04	0.43
Transpiration (mmol H_2O $m^{-2}s^{-1}$)				
Kufri Badshah	4.18±1.05	3.69±0.50	3.01±0.10	NS
Kufri Surya	4.10±1.30	3.40±0.40	3.69±0.40	NS
HT/7-1105	6.34±0.60	4.62±0.15	3.53±0.80	NS
HT/7-1329	4.27±0.80	4.04±1.00	3.69±1.00	NS

CO_2 and temperature do have a significant impact on leaf temperature in Kufri Surya and HT/7-1329 over ambient conditions. The values of leaf temperature under CO_2 alone and CO_2 + temperature in aforesaid varieties were at par within themselves. In other two varieties the impact on leaf temperature was non-significant. In case of photosynthesis the values of net photosynthesis were significantly higher in elevated CO_2 alone and elevated CO_2 + temperature conditions over ambient in Kufri Badshah and Kufri Surya. These values were 29.2 and 34.4 µmol CO_2 $m^{-2}s^{-1}$ under elevated CO_2 + temperature, and 32.9 and 32.9 µmol CO_2 $m^{-2}s^{-1}$ under elevated CO_2 conditions for former and later varieties. For other two varieties this impact was non-significant. Exposure to high temperature (around 3°C) and CO_2 during growing season reduced photosynthesis rate of Kufri Badshah, nevertheless, it sustained higher than control. In Kufri Surya exposure to high temperature and CO_2 did not reduced the photosynthesis rate compared to elevated CO_2 conditions but was higher than control. So far as stomatal conductance was concerned, a significant impact of elevated CO_2 and temperature was observed in two genotypes only i.e. Kufri Surya and HT/7-1329. The conductance was at par within elevated CO_2 + temperature and elevated CO_2 alone but was significantly lower than the ambient conditions. A non-significant impact of micro climatic conditions was noticed in case of transpiration.

Impact of elevated CO_2 alone and with high temperature on rate of photosynthesis and consequently tuber yield was estimated separately (figure 3). The results revealed a higher average rate of photosynthesis in elevated CO_2 (34.69 µmol CO_2 $m^{-2}s^{-1}$) followed by CO_2+ 3°C temperature elevation (33.19 µmol CO_2 $m^{-2}s^{-1}$) and ambient conditions (25.39 µmol CO_2 $m^{-2}s^{-1}$). The average tuber yield also followed similar trend with values being 44.86, 35.10 and 35.03 t/ha for CO_2

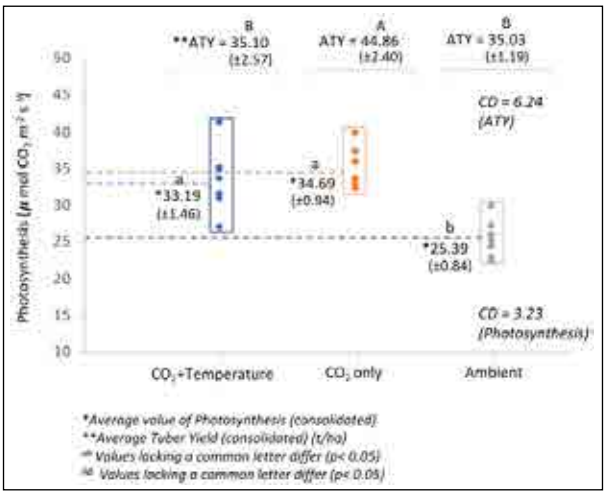


Fig. 3: *Impact of elevated CO_2 with high temperature and CO_2 alone on rate of photosynthesis in potato genotypes as compared to ambient condition.*

Table 2. Tuber yield as influenced by various yield associated traits in different potato genotypes under elevated CO_2 alone and with high temperature.

Independent variable (*X*)	Dependent variable (*Y*)	Regression equation	Coefficient of determination (R^2)
Net photosynthesis	Tuber yield	*Y*(Kufri Badshah) = 0.66*X* + 24.69	0.34
		Y(Kufri Surya) = 1.29*X* + 3.51	0.71
		Y(HT/7-1105) = 0.48*X* + 30.51	0.41
		Y(HT/7-1329) = 1.26*X* + 11.30	0.99
Stomatal conductance	Tuber yield	*Y*(Kufri Badshah) = 20.96*X* + 33.35	0.29
		Y(Kufri Surya) = -17.23*X* + 51.74	0.55
		Y(HT/7-1105) = -8.62*X* + 53.12	0.50
		Y(HT/7-1329) = -11.92*X* + 58.16	0.68
Transpiration	Tuber yield	*Y*(Kufri Badshah) = -2.99*X* + 54.62	0.07
		Y(Kufri Surya) = -8.27*X* + 73.54	0.20
		Y(HT/7-1105) = 0.69*X* + 43.39	0.04
		Y(HT/7-1329) = 12.68*X* + 0.56	0.48
Leaf Temperature	Tuber yield	*Y*(Kufri Badshah) = -0.54*X* + 56.28	0.11
		Y(Kufri Surya) = 0.87*X* + 22.56	0.22
		Y(HT/7-1105) = 0.49*X* + 35.15	0.25
		Y(HT/7-1329) = 0.83*X* + 31.56	0.49

alone, CO_2 + temperature elevation and ambient conditions, respectively.

In order to understand the association of these physiological traits with yield, regression analysis for each trait and for each genotype was done (Table 2). A few of these equations can be used to predict tuber yield on the basis of these yield associated physiological traits. These equations reflect a +ve linkage of tuber yield with net photosynthesis. In other traits the influence was mixed (+ve as well as -ve in some varieties)

CONCLUSION

Briefly, it can be concluded that like other agricultural crops, potato crop is also vulnerable to climate change. So, the understanding and impact assessment of this anticipated climate change on potato production of different genotypes, revealed in the present investigation, can prove to be crucial to frame future food security policies in general and potato production in particular. Two heat tolerant and one commercial genotype evaluated in the present study can counter the anticipated impact of climate change in coming decades. One of the heat tolerant potato genotype HT/7-1329 has already been released for commercial cultivation.

LITERATURE CITED

Abebe A, Pathak H and Singh SD (2016) Growth and yield of wheat (*Triticum aestivum* L.) with elevated atmospheric carbon dioxide and temperature in north-west India. *Current Advances in Agricultural Sciences*. **8**(1): 24-27

Anonymous (1989) Potato research in India. ICAR-Report of the 1988; External Review. pp. 3-4

Anonymous (2019) https://www.fao.org/faostat/en/#data/QCL. (Accessed on 30.11.2021).

Bushnell J (1925) The relation of temperature to growth and respiration in the potato plant. Minnesota Agricultural Experimental Station Technical Bulletin, Minnesota, USA.

Hogy P and Fangmeier A (2009) Atmospheric CO2 enrichment affects potatoes: tuber quality traits. *European Journal of Agronomy* **30**: 85–94

Inter-governmental Panel on Climate Change (2007) The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Intergovernmental Panel on Climate Change. Cambridge University Press.

Inter-governmental Panel on Climate Change (2013) Fifth assessment report on climate change- 2013. Working Group 1. Geneva: IPCC secretariat.

Jackson ML (1973) Soil chemical analysis. Englewood Cliffs, New Jersey, NJ: Prentice Hall Inc

Kaur P, Kaur H, Singh H and Sandhu SS (2019) Effect of elevated temperature regimes on growth and yield of rice cultivars under temperature gradient tunnel (TGT) environments. *Journal of Agrometeorology* **21**(3): 241-248

Kumar Prince, Minhas JS, Sharma Jagdev, Dua VK, Kumar Devendra, Saha Sunayan and Gupta YK (2018) Impact of elevated CO_2 level on growth, tuber yield and mineral content of Indian potato cultivars. *Potato Journal* **45**(2): 123-130

Kumar Prince, Trehan SP, Shah MA and Singh Pargat (2020) Package of Practices for Potato Production in Punjab. Extension folder. ICAR – Central Potato Research Institute, Shimla (HP). 10p

Kumari M, Verma SC, Bhardwaj SK and Thakur AK (2017) Impact of elevated CO_2 and temperature on quality and biochemical parameters of bell pepper (*Capsicum annuum*) crop. *Indian Journal of Agricultural Sciences* **87**(2): 179–184

Lee YH, Sand WG, Baek JK, Kim J H, Shin P, Seo M C and Cho J (2020) The effect of concurrent elevation in CO_2 and temperature on the growth, photosynthesis and yield of potato crop. *PLoS One* **15**(10): e0241081

Madhu M and Hatfield JL (2016) Dry matter partitioning and growth analysis of soybean grown under elevated CO_2 and soil moisture levels. *Current Science* **111**(6): 981-984

Minahs JS and Kumar Prince (2015) Global climate change : A threat for potato production. *Green Farming Strategic Vision* **30** (6)

Minhas JS, Kumar D, Joseph TA, Raj BT, Khurana SMP, Pandey SK, Singh S V, Singh B P and Naik P S (2006) Kufri Surya: a new heat-tolerant potato variety suitable for early planting in north-western plains, peninsular India and processing into french fries and chips. *Potato Journal* **33**(1 - 2) : 35-43

Minhas JS, Kumar Prince, Kumar Devendra, Dua VK and Gupta YK (2018) Response of potato to elevated CO_2 under short days: Growth, physiological parameters and tuber yield. *Indian Journal of Horticulture* **75**(1): 82-86

Olsen SR (1954) Estimation of available phosphorus in soils by extraction with sodium bicarbonate, 403–30. Washington, DC: US Department of Agriculture

Pinheroa RG, Wadugea RN , Liub Q, Sullivanc JA, Tsaob R, Bizimungud B, Yadaa RY (2016) Evaluation of nutritional profiles of starch and dry matter from early potato varieties and its estimated glycemic impact. *Food Chemistry* **203**: 356-366

Subbiah BV and Asija GL (1956) A rapid procedure for the determination of available nitrogen in soils. *Current Science* **25**: 259–60

Thinh NC, Shimono H, Kumagai E and Kawasaki M (2017) Effects of elevated CO_2 concentration on growth and photosynthesis of Chinese yam under different temperature regimes. *Plant Production Science*. [doi: 10.1080/1343943X.2017.1283963].

Walkley A and IA Black (1934) Estimation of soil organic carbon by the chromic acid titration method. *Soil Science* **37**(1): 29–38

Zarzecka K, Gugała M, Mystkowska I, Zarzecka M (2015) Chemical composition of edible potato tubers in retail outlets in east-central Poland. *Journal of Ecological Engineering* **16**(1): 57-61

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A STUDY ON SOURCES, MANAGEMENT AND REPLACEMENT OF POTATO (*SOLANUM TUBEROSUM* L.) SEED IN WESTERN UTTAR PRADESH

Pynbianglang Kharumnuid[1]*, NK Pandey[1] and Dhiraj K Singh[2]

ABSTRACT: Presently in India, the actual potato yield is far below the potential yield. Enhancing the seed replacement rate is one of the important strategies to narrow the gap between the actual and potential yields. Hence, the present study was conducted to examine the sources, replacement rate and management of potato seed and constraints for availing quality seed in Western Uttar Pradesh. The primary data was collected from 85 randomly selected farmers of Bulandshahar and Meerut districts. The study revealed that the Kufri Bahar, Kufri Pukhraj and Kufri Khyati were the major potato varieties. Local varieties were still prevalent among farmers. The major seed sources were farm saved seeds, fellow farmers and formal sources like department of agriculture, SAUs and research institutes. Farmers have good knowledge of seed management activities like maintenance of spacing, seed rate, seed retention period and followed them properly. The overall seed replacement rate for certified seed was around 39 percent. There was a direct relationship between seed replacement rate and farm size. The overall seed replacement rate of seed of improved potato varieties was about 92 percent. The identified constraints were high cost of quality seed, poor quality of seed, lack of proper storage and transportation facilities, lack of seed of required varieties and lack of information about improved varieties. The study suggested that extension strategies and institutional mechanisms should be formulated for popularization of the new varieties and reliable seed sources and for regular supply of certified and quality seeds to all categories of farmers to enhance the seed replacement rate.

KEYWORDS: Potato seed, Seed replacement rate, Seed sources, Certified seed, Constraint analysis

INTRODUCTION

Potato was designated as "Food for Future" by Food and Agriculture Organization (FAO) in 2008, to reflect its importance as a food crop to address future global food and nutrition security (FAO, 2008). In term of human consumption, it is the third most important food crops after rice and wheat. It also plays a very important role in Indian agriculture as it alone contributes about 21.0 percent of the total vegetable area and 28.0 percent of total vegetable production of India (DAC&FW, 2018). India has achieved a phenomenal growth in potato production in the past seven decades. The production has increased from around 1.5 million tons in 1950-51 to over 48.5 million tons during 2019-20. Although there has been a remarkable achievement in potato production, the present productivity in India is still low when compared with most of the potato growing developed countries, and is still far below India's potential yield of about 400 q/ha. Due to increase in population, changes in lifestyle and economy, it is estimated that by the year 2050, India would require about 125.0 million tons of potato from an area of 3.6 million ha (CPRI, 2015). Increasing potato productivity from current status i.e., about 23.0 t/ha to 34.5 t/ha in 2050 would be a herculean task to achieve. At present level of farm management practices, India actually able to harvest only 42.0-45.0 percent of the achievable yield, which could be improved to 80.0 percent by efficient and

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effective dissemination and implementation of improved technologies (CPRI, 2015).

The quality seeds of improved potato varieties are the basic and crucial determinants of productivity and account for 30.0-40.0 percent of the total potato production cost (Kharumnuid *et al*., 2018). The use of good quality seed of improved varieties along with other improved technologies will play a major role narrowing the yield gaps. It is estimated that the direct contribution of quality seed alone to the total production is about 15.0-20.0 percent, depending upon the crop and it can be further raised up to 40.0-50.0 percent with effective management (Singh and Singh, 2016, Singh, 2013; Natrajan *et al*., 2009). As potato seed degenerates quickly due to viral infection, it should be replaced every 4 years to avoid yield reduction. In the Indian context, for ages, seed requirement of farmers is mainly met by farm saved seed, i.e., still 65.0 percent of the farmers are using their own saved seed (DSR, 2015), leading to low seed replacement rate (SRR) in most crops. Against this background, the present study was undertaken to examine the sources and management of potato seed, seed replacement rate and major constraints in availing certified and quality seeds of improved potato varieties in Western Uttar Pradesh.

MATERIALS AND METHODS

Sampling procedure and sources of data

The *Ex-post facto* research design was implemented for this study. We purposively selected Uttar Pradesh state of India, since it is the highest potato producer in the country, producing more than 30 percent of total potato production. The primary data pertaining to 2017-18 crop season, was collected by personal interview with 85 randomly selected potato growers of Western Uttar Pradesh (43 growers from Unchgaon, Jahangirabad and Syana blocks of Bulandshahar district and 42 potato growers of Kharkhoda, Macchara and Daurala blocks of Meerut district) using a pre-structured interview schedule, which consisted of both close-ended and open-ended questions. The sampled farmers were later stratified into 5 strata on the basis of their size of operational holdings. They were marginal (below 1 ha), small (1-2 ha), semi-medium (2-4 ha), medium (4-10 ha) and large (10 ha & above) farmers. The final sample consisted of 7 marginal, 16 small, 25 semi-medium, 24 medium and 13 large farmers.

Measurement of variables

The SRR for potato crop was worked out for certified seed and seed of improved varieties separately. SRR is defined as the percentage of area sown with certified/quality seeds out of the total cultivated area under a crop in a season (Singh and Chand, 2011). It is calculated using the following equations:

$$SRR = \frac{C \times 100}{A \times K}$$

(a) Certified seed:

Where, SRR=Seed replacement rate, C=Certified seeds used by the farmers (in quintal), A=Area under the potato crop (ha), and K=Seed rate per unit of area (quintal/ha)

$$SRR = \frac{V \times 100}{A \times K}$$

(b) Seed of improved varieties:

Where SRR, A and K stand for the same notations as in above equation and V=seed of improved varieties used by the farmers (in quintal).

Furthermore, we also identified the seed sources and salient management of potato seed by direct questioning method. Thirdly, the constraints faced by farmers in availing/ procuring the potato seed was identified by asking the respondents to indicate the extent

of their agreement to each constraint related statement on a three-point continuum scale. The ranking of constraints was done based on Weighted Mean Score (WMS) which was calculated by the formula $WMS = \frac{F_i W_i}{F_i}$, where F is the frequency of farmers; W is weight of each scale; i =3 for most severe; 2 for severe and 1=for not severe).

RESULTS AND DISCUSSION

Variety wise area and quantity allocation for potato

The variety wise area and quantity allocation of seed for potato crop in the study areas was analyzed and presented in the Table 1. The Table revealed that Kufri Bahar

Table 1. Variety wise area (ha) and quantity (q) allocation for potato crop in Western Uttar Pradesh (N=85)

Varieties	Year of release	Marginal		Small		Semi-Medium		Medium		Large		Overall	
		Area (ha)	Qty (q)	Area (ha)	Qty (q)	Area (ha)	Qty (q)	Area (ha)	Qty (q)	Area (ha)	Qty (q)	Area (ha)	Qty (q)
Kufri Bahar	1980	1.66 (62.37)	59.40 (65.74)	4.66 (44.31)	165.30 (44.44)	11.29 (32.44)	374.85 (31.93)	19.43 (28.73)	761.48 (29.82)	38.28 (43.65)	1361.56 (42.64)	75.32 (37.05)	2722.59 (36.88)
Kufri Pukhraj	1998	0.32 (12.17)	12.00 (13.28)	1.54 (14.64)	45.60 (12.26)	10.36 (29.77)	361.60 (30.80)	18.30 (27.05)	694.27 (27.19)	12.26 (13.98)	473.58 (14.83)	42.78 (21.04)	1587.05 (21.50)
Kufri Khyati	2008	0.20 (7.61)	6.00 (6.64)	1.21 (11.50)	41.40 (11.13)	4.05 (11.64)	146.64 (12.49)	10.04 (14.84)	402.08 (15.75)	8.90 (10.15)	340.98 (10.68)	24.41 (12.00)	937.10 (12.69)
Kufri Chipsona-1	1998	0.00 (0.00)	0.00 (0.00)	0.32 (3.08)	14.40 (3.87)	1.01 (2.90)	34.80 (2.96)	0.69 (1.02)	20.40 (0.80)	14.69 (16.75)	474.21 (14.85)	16.71 (8.22)	543.81 (7.37)
S-4	Not known	0.23 (8.82)	6.96 (7.70)	1.17 (11.12)	45.30 (12.18)	1.34 (3.84)	39.60 (3.37)	4.45 (6.58)	153.05 (5.99)	3.36 (3.83)	149.41 (4.68)	10.55 (5.19)	394.32 (5.34)
Kufri Chipsona-3	2006	0.00 (0.00)	0.00 0.00)	0.20 (1.90)	7.50 (2.02)	0.65 (1.87)	21.00 (1.79)	2.06 (3.05)	61.20 (2.40)	7.16 (8.17)	303.42 (9.50)	10.07 (4.95)	393.12 (5.32)
302	Not known	0.00 (0.00)	0.00 0.00)	0.81 (7.70)	30.00 (8.06)	2.71 (7.79)	87.30 (7.44)	2.87 (4.24)	98.22 (3.85)	0.00 (0.00)	0.00 (0.00)	6.39 (3.14)	215.52 (2.92)
Kufri Garima	2012	0.04 (1.52)	1.50 (1.66)	0.32 (3.08)	12.00 (3.23)	0.81 (2.33)	12.00 (1.02)	0.65 (0.96)	21.62 (0.85)	3.04 (3.46)	90.00 (2.82)	4.86 (2.39)	137.12 (1.86)
Kufri Frysona	2009	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.28 (0.81)	10.50 (0.89)	3.77 (5.57)	139.51 (5.46)	0.00 (0.00)	0.00 (0.00)	4.05 (1.99)	150.01 (2.03)
2001	Not known	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.70 (4.88)	50.50 (4.30)	1.01 (1.49)	37.51 (1.47)	0.00 (0.00)	0.00 (0.00)	2.71 (1.33)	88.01 (1.19)
Kufri Pushkar	2005	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	2.02 (2.99)	75.02 (2.94)	0.00 (0.00)	0.00 (0.00)	2.02 (0.99)	75.02 (1.02)
Kufri Surya	2006	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.34 (1.98)	59.42 (2.33)	0.00 (0.00)	0.00 (0.00)	1.34 (0.66)	59.42 (0.80)
Kufri Anand	1999	0.00 0.00)	0.00 (0.00)	0.28 (2.66)	10.50 (2.82)	0.00 (0.00)	0.00 (0.00)	1.01 (1.49)	29.53 (1.16)	0.00 (0.00)	0.00 (0.00)	1.29 (0.63)	40.03 (0.54)
Kufri Sadabahar	2008	0.20 (7.61)	4.50 (4.98)	0.00 (0.00)	0.00 (0.00)	0.20 (0.58)	6.00 (0.51)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.40 (0.20)	10.50 (0.14)
S-1	Not known	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.40 (1.15)	29.10 (2.48)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.40 (0.20)	29.10 (0.39)
Total	-	2.66 (100.0)	90.36 (100.0)	10.52 (100.0)	372.00 (100.0)	34.80 (100.0)	1173.9 (100.0)	67.64 (100.0)	2553.31 (100.0)	87.69 (100.0)	3193.15 (100.0)	203.31 (100.0)	7382.72 (100.0)

Note: Figures in parentheses indicate the percentage of the total area/quantity of particular varieties in respective farmers' categories

was the most popular variety and covered about 37.05 percent of total potato area of the sampled farmers, which was followed by Kufri Pukhraj (21.01%). A recently released variety Kufri Khyati (12.69%) was the third major potato variety. Processing varieties like Kufri Chipsona-1 (7.37%) and Kufri Chipsona-3 (5.34%) also covered significant potato area. Local and unnotified varieties like S-4, 302, 2001 and S-1 are still adopted by farmers. Similar percentage was seen in the variety wise allocation of quantity for potato seed by the farmers. It is evident that about 90.00 percent area were under improved varieties developed by ICAR-Central Potato Research Institute. The trend was almost similar for all the categories of farmers. Younger varieties like Kufri Garima and Kufri Frysona are covered only small areas, which may be due to the unavailability of seeds.

Sources of potato seeds

The important seed sources of farmers in the study areas were analyzed and presented in Table 2. The analysis revealed that the most important seed source was farm saved seeds, which was used by about 38.90 percent of farmers and covered about 48.10 percent of potato area. Using of self-retained seeds by farmers may be due to lack and high cost of quality seed of required varieties. As mentioned earlier, potato seed is very expensive; the marginal and small farmers could not afford to purchase them. The second important source was the seed exchanged or purchased from fellow farmers (23.30% farmers, 15.60% potato area). Thus, it is evident that informal seed sources contributed more to potato seed supply in the study area. About 22.00 percent of farmers procured certified/quality seeds of improved varieties from formal sources like State Agriculture/ Horticulture Departments, State Agricultural Universities, Krishi Vigyan Kendras (KVKs) and research institutes. The farmers perceived that quality of seeds form formal sources was excellent, however, their quantity was limited and the cost was comparatively higher than the seeds sold by the village traders. Mostly, progressive farmers who were having good knowledge about seed sources and varieties and have good contact with the extension agents could get such seed. Besides these, some farmers also purchased seeds from other seed sources like local seed dealers, private companies and commercial seed producers. Therefore, government should take measures to ensure regular supply of quality seeds at prices affordable by all categories of farmers, and extension activities like trainings, frontline demonstrations, etc. should also be organized for farmers on scientific production of quality seeds.

Table 2. Sources of potato seeds of sampled farmers (N=180)

Seed Sources	Farmers		Area (Ha)	
	f	%	Area	%
Farm saved seeds	70	38.90	97.70	48.10
State agricultural department, SAUs, KVKs	38	21.10	54.60	26.80
Fellow farmers' seeds	42	23.30	31.60	15.60
Seed traders/local markets	22	12.20	7.70	3.80
Commercial seed growers	6	3.30	5.30	2.60
CPRI	2	1.10	6.40	3.10
Total	180	100	203.3	100

Note: Total farmers=180, since some farmers procured seeds from more than two sources, f=frequencies of farmers

Salient seed management practices

The important seed management practices of farmers in Western Uttar Pradesh have been presented in Table 3. It is evident that sampled farmers in the study areas properly followed the recommended seed management practices. On an average, the seed rate was found to be about 34.92 quintal of seed per hectare. This is because farmers mostly used whole seed rather than cut potato seed. The

Table 3. Salient potato seed management practices followed by sampled farmers in Western Uttar Pradesh.

Farm size categories	Seed rate (q/ ha)	Seed retention period in year (% of farmers)					Use of seed potato (% of farmers)		Spacing (cm)	
		1	2	3	4	≥ 5	Whole	Cut	Row-Row	Plan-Plan
Marginal	33.36	42.86	14.29	28.57	0.00	14.29	71.43	28.57	61	20
Small	35.50	31.25	18.75	37.50	0.00	12.50	81.25	18.75	61.75	20.25
Semi-Medium	33.97	32.00	12.00	36.00	8.00	12.00	88.00	12.00	56.64	18.96
Medium	35.75	33.33	12.50	37.50	8.33	8.33	91.67	8.33	56.67	18.87
Large	36.04	15.38	7.69	46.15	15.38	15.38	92.30	7.70	61	19.61
Total	34.92	30.59	12.94	37.65	7.06	11.76	87.06	12.94	59.42	19.53

findings revealed that overall, about 88.20 percent of sampled farmers replaced seeds within the recommended 4 years period. In potato cultivation, it is recommended to use whole seed tubers rather than cut tubers to prevent the crop from spread of seed borne diseases from one tuber to others. This practice of planting whole seed tuber was again followed by majority (87.06%) of the sampled farmers. It is observed that there is a direct relationship between utilization of whole seed and farm size; the larger the farm size, the more is the utilization of whole tuber seed. In the case of maintenance of spacing, on an average the row-to-row spacing was about 59.43 cm and the plant-to-plant spacing was 19.50 cm, which is almost equal to the recommended spacing. This is because, majority of farmers used tractor operated planters for planting of potato in the study areas. Overall, the seed management practices were properly followed by farmers, which may be due to high extension contacts because of the presence of various research institutes and agricultural departments near the study areas.

Seed replacement rate of potato

The SRR for certified seed and seed of improved varieties used by farmers was analyzed separately and presented in Table 4. In case of certified seed, the overall SRR of the selected farmers was 29.88 percent which is quite good, since the recommended SRR for potato crop should be more than 25 percent. However, the farm category-wise analysis revealed a direct relationship between SRR and farm-size. The SRR for certified seed was found to be 0.00, 12.69, 8.13, 21.89 and 45.82 for marginal, small, semi-medium, medium and large farmers, respectively. This may be due to better financial conditions of larger farmers to purchase seeds from formal sources and also of their good contacts with extension agents in the seed system. Most of the farmers, especially the marginal and small farmers, reported the high price of certified seed as their major constraints in potato production. The overall SRR of seed of improved potato varieties in the study areas was high at about 91.80 percent. This is because majority of farmers adopted improved potato varieties during 2017-18. There is no specific relationship between farm

Table 4. Seed replacement rate of potato crop of sampled farmers in Western Uttar Pradesh (N=85)

Farm size categories	Certified seed	Seed of improved varieties
Marginal	0.00	93.89
Small	12.69	79.45
Semi-Medium	8.13	81.82
Medium	21.89	87.89
Large	45.82	96.29
Overall	29.88	91.78

size and SRR in the case of seed of improved varieties. The SRR of seed of improved varieties was found to be 93.89, 79.45, 81.82, 87.89 and 96.29 percent for marginal, small, semi-medium, medium and large farmers, respectively.

Major constraints in availing of certified seeds and seed of improved varieties

Finally, we analyzed the constraints faced by farmers in availing the certified seed and seed of improved varieties and presented in Table 5. It is evident from the table that high cost of quality seeds with an overall weighted mean score (WMS) of 2.25 was ranked as the first major constraint in the study areas. Since the cost of potato is very high, poor farmers, especially the marginal and small farmers have to either use their self-retained seeds or poor-quality seeds from the local traders, leading to low productivity. The second constraint was poor quality of seed sold by the village traders (WMS=2.16). Some farmers reported that the seeds sold by local traders are not of good quality, and they did not want to use them even if they have money at their disposal. The farmers also experienced the lack of proper storage and transportation facilities (WMS=2.01). Due to lack of transportation facility or high transportation cost, farmer found it difficult to purchase seed from the formal sources which are generally located either in the district headquarter or in faraway places. Lack of seed of required varieties (WMS=1.94) was the fourth constraint, because of which, farmers have to stick to same old varieties. Moreover, many seed agencies did not supply seed in time, so farmers have to cultivate their own farm saved seeds. Lack of information about improved varieties (WMS=1.84) was another constraint that hinder farmers form obtaining good quality seeds.

Table 5. Major constraints in procuring certified seeds and seed of improved varieties in Western Uttar Pradesh during 2017-18 (N=85)

Constraints	WMS	Rank
High cost of quality/certified seeds	2.25	I
Poor seed quality of available varieties	2.16	II
Lack of storage and transportation facilities	2.01	III
Lack of seed of required varieties	1.94	IV
Lack of information about improved varieties	1.84	V

CONCLUSION

The study revealed that majority of farmers adopted improved varieties, however, more area was under older varieties. The informal seed sources like farm saved seeds, peer farmers, and local seed traders formed the major sources which provided seed to about 70.00 percent of sampled farmers. The study also revealed that the formal seed sources also played an important role in the supply of certified and good quality seeds; however, their supply is limited. The overall SRR for certified seed was around 30.00 percent. The farm category-wise analysis revealed a direct relationship between seed replacement rate and farm size. The overall SRR of seed of improved potato varieties was high at about 92.00 percent. Furthermore, the findings revealed that the sampled farmers faced some constraints in availing certified/quality potato seeds, which lead to low seed replacement rate. Thus, extension strategies and institutional mechanisms like frontline demonstrations, popularization of new varieties and reliable seed sources, capacity building of farmers for production of quality seeds, creation of community seed villages and encouragement of PPP in quality seed production and dissemination, are recommended for enhancing the seed replacement rate for improving potato productivity and farmers' income.

LITERATURE CITED

CPRI (2015) Vision 2050. Central Potato Research Institute (Indian Council of Agricultural Research), Shimla, Himachal Pradesh, India, 26p

DAC&FW (2018) Horticultural Statistics at a Glance 2018. Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India, New Delhi, India, 458p

DSR (2015) Vision 2050. Directorate of Seed Research (Indian Council of Agricultural Research), Kushmaur, Mau, Uttar Pradesh, 19p

FAO (2008) Potatoes, nutrition and diet. FAO's Nutrition and Consumer Protection Division, Rome, Italy Available at http://www.fao.org/potato 2008/en/potato/factsheets.html, 1p

Kharumnuid P, Pandey NK and Singh DK (2018) An analysis of farm-level adoption of improved potato production technologies in Western Uttar Pradesh, *J AgriSearch* **5**(4):276-281

Natrajan S, Jacob SR and Mandal AB (2009) Quality seed production. Glimpses of success stories. Directorate of Seed Research (Indian Council of Agricultural Research), Kushmaur, Mau, Uttar Pradesh

Singh H and Chand R (2011) The Seeds Bill 2011: Some reflections. *Econ Polit Wkly* **51**: 22-25

Singh RP (2013) Issues and strategies to correct missing links in seed sector of India. *J Res (BAU),* **25**(1): 1-15

Singh RP and Singh S (2016) Optimising seed replacement rates in Jharkhand: Present scenario, challenges and opportunities, Jharkhand *J Dev Manag Stud* **14** (2): 6987-7007

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INFLUENCE OF INTEGRATED CROP MANAGEMENT TECHNOLOGY ON POTATO PRODUCTIVITY, PROFITABILITY, ENERGY DYNAMICS AND CARBON FOOTPRINTS IN NORTH-WESTERN HIMALAYAS

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ABSTRACT: An '*on-farm*' adaptive research study was conducted during 2006-2011 in wet-temperate north-western Himalayas to evaluate the effects of integrated crop management (ICM) technology on potato tuber productivity, profitability, energy dynamics and carbon footprints. This '*On-farm*' field study revealed that the ICM technology imbedded with improved potato varieties like Kufri Shailja and Kufri Giriraj along with balanced nutrition (120:80:60 kg NPK/ha & 20 t FYM/ ha) and proper crop management and plant protection measures manures, led to higher productivity (27.8%), net returns (34.5%) and bio-energy production (58.1%) compared to farmers' practice (FP). The ICM resulted in slightly higher carbon footprints (0.08 kg CE kg^{-1} fresh potato tuber yield) compared to FP (0.069 kg CE kg^{-1} fresh potato tuber yield) due to better crop management and higher input-use. However, the total carbon output under ICM was ~31.3% higher over FP, indicating that ICM may prove as a viable mitigation strategy to climate-change. Overall, ICM is a better option over FP w.r.t. potato productivity, profitability, net-income gains, bio-energy and carbon output in wet-temperate north-western Himalayas.

KEYWORDS: Bioenergy, crop management, carbon footprints, Himalayas, potato, tuber productivity.

INTRODUCTION

India is the 2nd largest producer of potato (*Solanum tuberosum*) in the world after China, accounting for ~12% of global potato production (CPRI, 2019-20). Total area under potato in India is ~2.16 million ha (m ha) with the production of 51.3 million tonnes (mt) and average productivity of 23.8 t ha^{-1} far behind China (FAOSTAT, 2021). During last 3 decades, India has achieved a cumulative annual growth rate (CAGR) of ~4.57%; however, our potato productivity could achieve a CAGR of merely ~1.39%. Since, potato is an important food and industrial crop in India, playing a vital role in national food and nutritional security besides backing-up industrial applications. Hence, we have to sincerely focus on its yield enhancement through improved cultivars, improved crop management technology and its horizontal expansion in the conventional and non-conventional areas. In India, potato is grown throughout the nation with comparatively higher yield in Indian plains due to better technology dissemination and adoption compared to hill and mountain ecosystems, where it is mostly grown as summer/*Kharif* crop with comparatively low yields. Thus, we need to focus equally on enhancing the potato productivity in these hill and mountain ecosystems through appropriate technology development and its dissemination for higher adoption rates in order to boost to national potato production as a whole.

Potato assumes greater importance in Indian Himalayas especially north-western

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Himalayas (NWH) where hill farmers grow it in mid and high-hills (Choudhary *et al*., 2010; 2013), but poor edaphic factors coupled with poor crop management lead to low potato yields (17.4 t ha^{-1}) compared to national averages (Paul *et al*., 2016). Most of the arable area under potato in NWH is rainfed, where high rainfall in *Kharif* potato season leads to nutrient run–off losses and soil organic matter (SOM) depletion in hilly topography which lead to low crop productivity and unhealthy soils (Choudhary *et al*., 2013; Paul *et al*., 2016). Furthermore, non-adoption of improved cultivars, balanced plant nutrition, improved crop management technology, are some of the major factors which result in poor potato productivity in NWH (Choudhary *et al*., 2013). As, potato requires higher doses of plant nutrition due to its high yield potential in a shorter cycle, thus, sustaining the potato productivity and soil health is again a challenging task for resource-poor small-holder hill farmers who already lack awareness about advanced farm technology (Paul *et al*., 2016). Thus, the development and dissemination of site-specific integrated crop management (ICM) technology imbedded with improved potato cultivars, balanced plant nutrition, improved crop and water management, pest and disease management is highly essential to boost the potato productivity in NWH and collateral agro-ecosystems. Thus,'on-*farm*' experimentation was undertaken to assess the comparative performance of some potato cultivars under proven integrated crop management (ICM) technology in wet temperate region of Himachal Pradesh w.r.t. potato productivity, profitability and water-use efficiency besides its energy and carbon footprint estimation for its long-term sustainability in wet-temperate NW Himalayas. In addition, an intensive technology transfer programme was also aimed at higher technology adoption for improved potato productivity and income gains in NWH.

MATERIALS AND METHODS

Study area and climate

Current study comprising technology gap analysis, '*on-farm*' experimentation, technology adoption and its impact assessment, was conducted during *Kharif* 2006-2011 in Himachal Pradesh, India. The Mandi district of Himachal Pradesh geographically located centrally in the state [31°13`20`` to 32°04`30``N latitude; 76°37'20" to 77°23'15" E longitude; 700 to 4000 m altitude], was selected as the study district with high-hill wet-temperate region of this district as the study area covering its Sundernagar, Sadar, Darang, Karsog, Gohar and Seraj Blocks. First of all, the gap analysis by employing PRA technique was done during 2006-2008 on the adoption of improved potato production technology in the high-hill wet-temperate region of this district (Sundernagar, Sadar, Darang, Karsog, Gohar and Seraj Blocks) (Table 1). Thereafter, one representative block Seraj in Mandi district was selected randomly for the current '*on-farm*' experimentation in Reyara village (Janjehli) of Seraj block by the CSK HPKV, Farm Science Centre, Mandi (HP). The soil of experimental site was silty-clay loam in texture, acidic in reaction (pH 5.4) with soil organic carbon 9.6 g kg^{-1} soil besides available nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) to the tune of 241.8, 12.2 and 393.9 kg ha^{-1}, respectively. Rainfall and temperature data was recorded at '*Agro-Meteorological Observatory*' of CSK HPAU, Farm Science Centre, Sundernagar, India (Fig. 1). The study area receives an average annual rainfall of 1700 mm ~75% of which is received during July–Sept., and the rest is received during Dec.–Feb. The hottest months are May to July with mean daily

Table 1. Gap in adoption of improved potato production technology in high hill wet temperate zone (Under rainfed situation).

S. No.	Technology package	Integrated crop management technology	Existing farmers' practice	Gap in adoption (F/P/N)*
1.	Sowing time	March-April	March-April	N
2.	Sowing method	In furrows (50 cm 20 cm)	In furrows (50 cm 20 cm)	N
3.	Varieties	Kufri Jyoti, Kufri Giriraj	Kufri Jyoti	N
4.	Seed rate/ha	25 q/ha	20 q/ha	P
5.	Tuber treatment	Indofil M-45 @ 0.05%	Not done	F
6.	FYM (t/ha)	20 t/ha	10 t/ha	P
7.	Fertilizers (kg/ha) ($N:P_2O_5:K_2O$)	120:80:60	60:60:30	P
8.	Fertilizer placement	In furrows	In furrows	N
9.	Chemical weed management	Isoproturon 75WP @ 1.0 kg a.i./ha or Oxiflorofen (Goal 23.5 EC) @ 0.5 kg a.i./ha	Not done	F
10.	Manual weed management	One hand-weeding + earthing-up at 30 DAP One hand-weeding + earthing-up at 50 DAP	When plants attains a height of 15-20 cm	P
11.	Pest management (White grub)	Furadan 3 G @ 2.5 kg/ha	Not done	F
12.	Disease management (Late blight)	Two sprays of Redomil MZ -72 WP or Metamyl 0.25% at 15 days interval followed by 4 sprays of Indofil M-45 @ 0.25% at weekly interval	Use of non recommended fungicides 2 sprays)	F

*F-Full gap; P-Partial gap; N-No gap

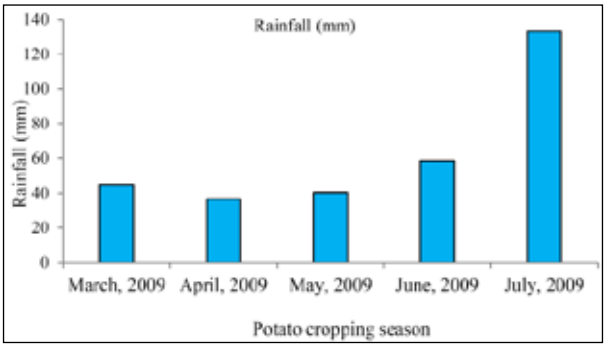


Fig. 1. Average monthly rainfall (mm) during potato growing period.

maximum temperature ranging between 32–35^{0}C, whereas December to February are the coldest months, with mean daily minimum temperature ranging between 2.6–3^{0}C.

Experimental and treatment details

On the basis of the gap analysis, the integrated crop production technology for potato was standardized by the CSK HPKV, Farm Science Centre, Sundernagar, Mandi (HP) during 2007-2008 at its Research farm. Thereafter '*on-farm*' experimentation was conducted during summer (March–July) seasons of 2009 under two crop management scenarios' *viz*. integrated crop management (ICM) technology and farmers' practice (FP) using improved potato cultivars *viz*. Kufri Himalini, Kufri Giriraj, Kufri Shailja alongwith Kufri Jyoti (as check) in Reyara village (Janjehli) of Seraj block, Himachal Pradesh in randomized block design replicated five times with the plot size of 2.5 m 3.2 m (8 m^2) each, for analysis of variance (ANOVA) following standard procedures (Rana *et al.*, 2014). Under ICM technology and the FP, the compete crop management schedule covering the entire field operations right from sowing of improved potato cultivars, balanced plant nutrition, improved crop and water management to pest and disease management till harvesting, is mentioned in Table 1.

Crop management

The potato crop was planted in 2nd week of March both in ICM and FP in respective plots/locations (Table 1), under rainfed conditions. On an average, the potato growing season during the study had 312.8 mm rainfall during March to July, 2009. The seed tubers weighing ~50 g each and having minimum two eyes were planted on raised–beds at 50 cm 20 cm spacing. Nutrient management was done strictly as per treatment plan and well-rotten FYM was added during land preparation in respective treatments on fresh weight basis (av. 35% moisture), which contained N, P, K to the tune of 0.86, 0.41 and 0.68% (on oven dry-weight basis), respectively. The half N and entire P and K were applied basally at planting time through urea (46% N), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O), respectively; while remaining half N was top dressed near potato rows in 2-equal splits at 1st and 2nd earthing-up operations. Weeds were controlled by using Oxiflorofen 23.5 EC @ 0.5 kg a.i. ha^{-1} as per treatment plan in ICM. Two hand-weeding (HW) followed by two earthing-up were done at 30 and 50 days after planting (DAP). Both ICM and FP plots, received plant protection practices as per treatment plan (Table 1), throughout the cropping season. Yield of net plot was recorded. Since, the experimental plot size was small; thus, crop was managed properly besides precise samplings' for maintaining the heterogeneity of low level in studied parameters.

Potato tuber yield and economics

The experimental observations on tuber yield were recorded following standard procedures (Rana *et al*., 2014). The economic analysis was done using tuber yield, cost of cultivation incurred and prevailing market price of potato.

Energy calculations

Energy sources in farming systems include both direct (operational) and indirect (non-operational) energy sources (Kumar *et al.,* 2021). The direct energy sources directly release the energy *viz*. fuel, diesel, farm machinery, manual human labour and animal draft, etc. Indirect energy sources do not release energy directly but dissipate energy during conversion processes *viz*. seed, fertilizers, microbial inoculants, crop residues and manures, pesticides, etc. Energy for synthesis, manufacturing, transportation and distribution is considered as energy sequestered in these indirect energy sources. Both direct and indirect energy sources can again be classified as renewable and non-renewable energy sources. Direct energy sources like animate, solar, wind and water are classified as direct renewable energy sources. Diesel and electricity are classified as direct non-renewable energy sources. Indirect energy sources like manures are classified as indirect renewable energy sources. Fertilizer, chemical and machinery come under indirect non-renewable sources of energy. Hence, primary data on various farm inputs and potato management practices were used for computation of energy consumption using energy equivalents (Table 2). Energy output from the products (potato tuber and haulm yield) was calculated by multiplying the respective production levels with their respective energy equivalents (Table 2). According to the energy input and output, cost of cultivation and potato yield, the energy-use indices were calculated using standard procedures as given by Devasenapathy *et al.* (2008, 2009) and Kumar *et al.* (2021) as follows:

Energy input (MJ ha^{-1}) = A

Energy output (MJ ha^{-1}) = B

Net energy or energy return or energy balance (MJ ha^{-1}) = B – A

$$\text{Energy-use efficiency} = \frac{\text{Energy output (MJ/ha)}}{\text{Energy input (MJ/ha)}}$$

Table 2. Energy equivalent of inputs and outputs in agricultural operations used in present study.

S. No.	Particulars	Units	Equivalent Energy (MJ)	Reference
A.	*Input*			
	Farm Machinery	kg	62.7	Devasenapathy *et al.* (2008, 2009); Paramesh *et al.* (2019)
	Knapsack sprayer	h	0.17	Kumar *et al.* (2021)
2.	Diesel	L	47.8	Pishgar-Komleh *et al.* (2012); Paramesh *et et al.* (2019)
3.	Human power	man-hour	1.96	Kumar *et al.* (2021)
5.	Fertilizers			
	Nitrogen (N)	kg	60.6	Devasenapathy *et al.* (2009)
	Phosphorus (P_2O_5)	kg	11.1	Devasenapathy *et al.* (2008
	Potassium (K_2O)	kg	6.7	Devasenapathy *et al.* (2008
	FYM	kg	0.30	Paramesh *et al.* (2019)
6.	Chemicals			
	Herbicides	kg	85	Pishgar-Komleh *et al.* (2012)
	Fungicide	kg	295	Pishgar-Komleh *et al.* (2012)
	Insecticides	kg	115	Pishgar-Komleh *et al.* (2012)
7.	Planting material			
	Potato tuber	kg	3.6	Pishgar-Komleh *et al.* (2012)
B.	*Output*			
1.	Potato tuber	kg	3.6	Pishgar-Komleh *et al.* (2012)

$$\text{Energy productivity (kg MJ}^{-1}) = \frac{\text{Economic yield (kg/ha)}}{\text{Energy input (MJ/ha)}}$$

$$\text{Energy profitability} = \frac{\text{Net energy (MJ)}}{\text{Energy input (MJ/ha)}}$$

$$\text{Specific energy} = \frac{\text{Energy input}}{\text{Potato tuber yield (kg/ha)}}$$

Carbon footprints and carbon budgeting

Carbon equivalents (CE) were estimated by multiplying the inputs (potato tubers, fuel, FYM, fertilizers, pesticides, etc.) with their respective carbon emission coefficients as given in Table 3. Emission coefficient for each herbicide/fungicide/pesticide is unavailable; so, it was assumed that emission during the processes of production, transportation, storage, and field application are same for all pesticides within a class (Lal, 2004). Total carbon input and output were calculated as sum of carbon equivalents of all inputs and outputs of potato crop.

Carbon output: Carbon output of potato crop was calculated as per methodologies given by Kumar *et al.* (2021) as given below:

Table 3. Estimates of equivalent carbon emissions for agricultural inputs used in presented study.

Input	Unit	Emission factors (kg CO_2-e/unit)	References
Human labour	man-h	0.70	Houshyar *et al.* (2015).
Machinery	h	3.32	Deng (1982); Yadav *et al.* (2018)
Diesel	litre	3.32	Deng (1982); Yadav *et al.* (2018)
Nitrogen (N)	kg	1.3	Kumar *et al.* (2021)
Phosphorus (P)	kg	0.2	Kumar *et al.* (2021)
Potassium (K)	kg	0.15	Kumar *et al.* (2021)
Farmyard manure (FYM)	kg	0.029 kg/kg	Bellarby *et al.* (2008)
Insecticide	kg a.i.	5.1	Lal (2004)
Herbicide	kg a.i.	6.3	Lal (2004)
Fungicide	kg a.i.	3.9	Lal (2004)

Carbon output (kg CE ha^{-1}) = Total biomass (grain yield + by-product yield) 0.44*
**Plant biomass contains on an average 44% carbon content as given by Lal (2004).*

Carbon efficiency: Carbon efficiency of potato crop was calculated as the ratio of total carbon output to carbon input: Carbon efficiency = Total carbon output/total carbon input

Carbon footprints: Carbon footprints of potato crop were calculated as per methodologies given by Kumar *et al.* (2021) hereunder:
Carbon footprints (kg CE/kg potato tuber) = Total carbon emission or input (kg CE/ha)/tuber yield (kg/ha).

Carbon sustainability index (CSI): The CSI of potato crop was estimated by computing the difference between total carbon output and total carbon input of potato crop and dividing it by the total carbon inputs of potato crop as given by Kumar *et al.* (2021) hereunder:
CSI = (Total carbon output – total carbon input)/total carbon input

Technology tranfer methodologies

In order to achieve the objectives of technology transfer on potato cultivation using ICM and improved varieties and its adoption in the study area in NWH, various technology transfer tools were used in current study during 2009-2010. Besides conductining '*On–farm*' experimentation, the farmers (n=68) of participating and sorrounding villages were also trained through hands-on training on potato cultivation using ICM through method demonstrations. Farmers' specialized trainings and field conventions for time-to-time technical back-up; were the technology-transfer efforts of CSK HPKV, FSC-Sundernagar (HP).

Knowledge upgradation, technology adoption and impact assessment

A thorough study was undertaken during 2009-2011 with well structured interview schedules (pre– & post–training) to assess the knowledge levels and knowledge upgradation of trainee farmers (n=68) in Seraj block of Mandi (HP). Extent of adoption of ICM under potato cultivation was assessed after one year of '*On-farm*' experimentation i.e. year 2010 while the net-income gains by the potato growers were assessed after two years i.e. year 2011 in the Seraj block of Mandi (HP) using participatory rural appraisal (PRA) technique, interview schedules and group dynamics method to have reliable and valid information (Choudhary *et al.,* 2013).

2.4. Statistical analysis

The experimental design was randomised block design (RBD) replicated five times and the statistical analysis was done by the standard procedure suggested by Gomez and Gomez (1984). Significance of differences among different treatments was tested using the standard F-test. Least significance difference (LSD) values at P = 0.05 were used to determine the significant differences between treatment means.

RESULTS AND DISCUSSION

Gap analysis on potato production technology in wet-temperate NW Himalayas

The data in Table 1 revealed that full gap was observed in potato seed tuber treatment, chemical weed management, pest management and disease management practices against the recommended practices in high-hill wet-temperate agro-ecological situations in the study area of Mandi district in NWH. Further, partial gap was observed in the practices like potato sowing method, seed rate, organic manure application and mechanical weed management. However, no gap was found in the time of planting and varieties grown by the farmers. It was revealed that Kufri Jyoti is the predominant variety grown by the potato farmers in high-hill wet-temperate NWH. Lack of awareness,

technical know-how and non-availability of disease resistant (Late blight) variety planting material could be the possible reasons for the non-adoption of improved potato production technology in the region (Choudhary and Rahi, 2018). Hence, CSK HPKV, Farm Science Centre, Sundernagar, Mandi (HP) assessed the performance of new potato cultivars in Mandi district in high-hill wet-temperate NWH.

Potato tuber yield and economics

The results pertaining to the potato tuber yield and haulm yield differed significantly among the potato varieties with highest yield under Kufri Shailja with yield trend of Kufri Shailja > Kufri Giriraj > Kufri Jyoti> Kufri Himalini in current study (Fig. 2), indicating that the genetic yield potential of these varieties, differential tolerance to late blight of potato and their suitability to hill region of NWH led to this variation. Likewise, the integrated crop management (ICM) technology showed its superiority over the farmers' practice (FP) among all the varieties, due to balanced plant nutrition and crop management under ICM (Paul *et al.*, 2016; Varatharajan *et al.*, 2019a, 2019b). The integration of organic sources and chemical

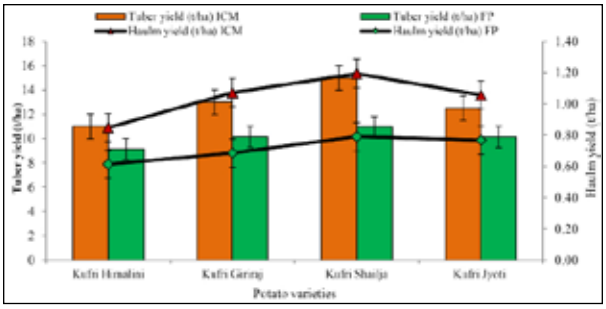


Fig. 2. Effect of ICM technology on tuber and haulm yield of potato cultivars in wet-temperate NW Himalayas. Vertical bars indicate LSD (P = 0.05).

fertilizers alongwith proper crop management under ICM provided optimum and balanced nutrition; in addition, the supply of plant nutrients remained synchronised with the crop growth (Choudhary *et al.*, 2013); hence resulting in higher yields. The gross returns, net returns and B: C ratio also followed the similar trend as that of potato tuber yield where ICM showed its superiority among all the varieties following the trend of Kufri Shailja > Kufri Giriraj > Kufri Jyoti> Kufri Himalini at both the management levels (ICM and FP) in current study (Fig. 3). This may again be attributed to the yield variation under ICM technology and the farmers' practice (Choudhary and Rahi, 2018).

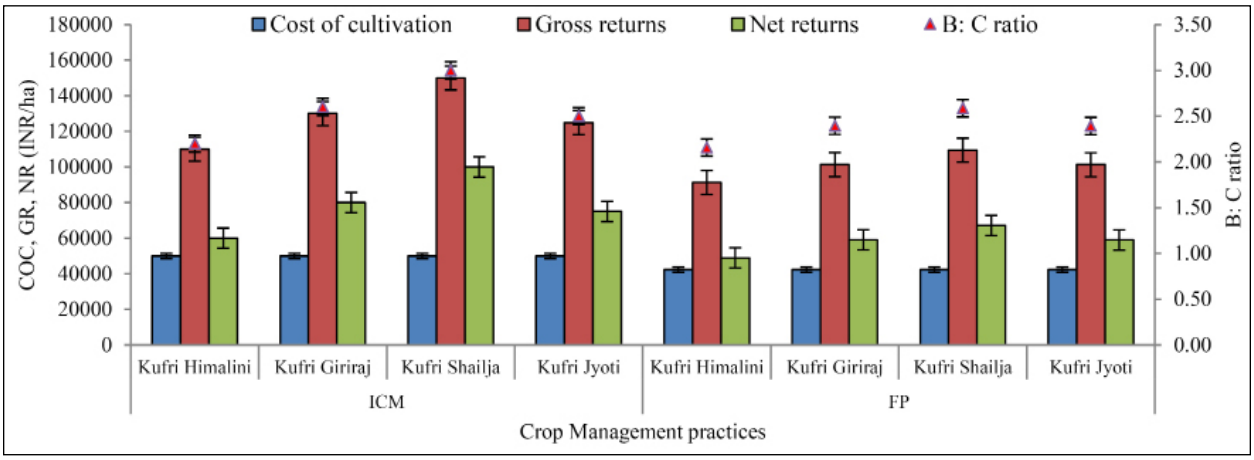


Fig. 3. Effect of ICM technology on profitability of potato cultivars in wet-temperate NW Himalayas. Vertical bars indicate LSD (P = 0.05). (COC: Cost of cultivation, GR: Gross returns, NR: Net returns).

Energy dynamics

The source- and operation-wise energy use pattern was computed for potato crop (Fig. 4 and 5). The mean total energy of 32538 and 20583 MJ ha^{-1} was consumed in this crop under ICM and FP, respectively (Fig. 4). Overall, the seed tubers contributed highest input energy followed by NPK fertilizers, FYM and then land preparation. Seed tubers and fertilizer application were the major contributors of total energy consumption in the crop. This may be attributed to high tuber rate @ 20 and 25 q/ha under ICM and FP, respectively. In ICM management, source-wise energy input pattern followed the trend of seed tubers>fertilizer>FYM>diesel>human>agro-chemicals>machinery>human power (Fig. 5). Under FP, source-wise energy input pattern followed the trend of seed tubers>fertilizer>diesel>FYM>human> machinery>agro-chemicals (Fig. 5). Seed tubers comprised higher amount of the total energy consumption mainly due to its huge quantity used and the respective energy equivalents (Pishgar-Komleh *et al.*, 2012). Furthermore, fertilizer application was the second major input both in ICM and FP plots. Source-wise energy input pattern also revealed that the share of indirect renewable was the highest over the indirect non-renewable, direct renewable and direct

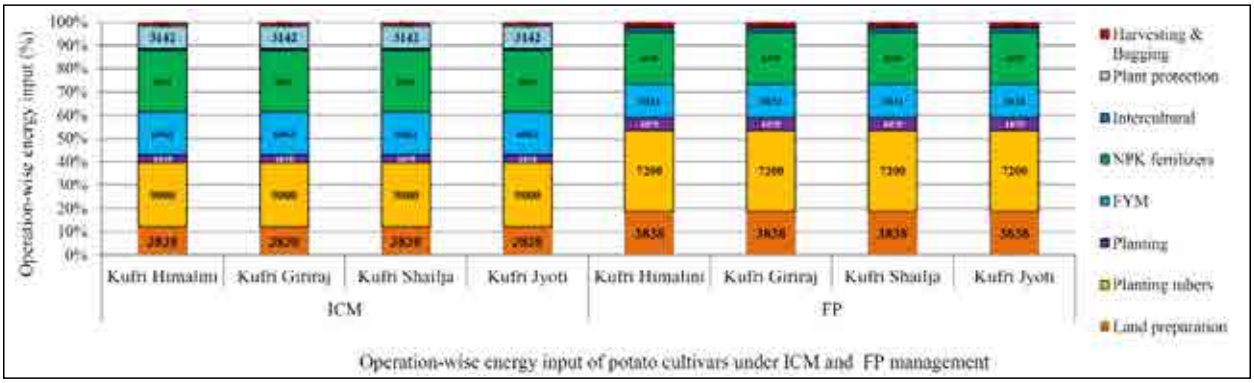


Fig. 4. Operation-wise energy input (%, MJ/ha) of potato cultivars under ICM and FP management in wet temperate NW Himalayas.

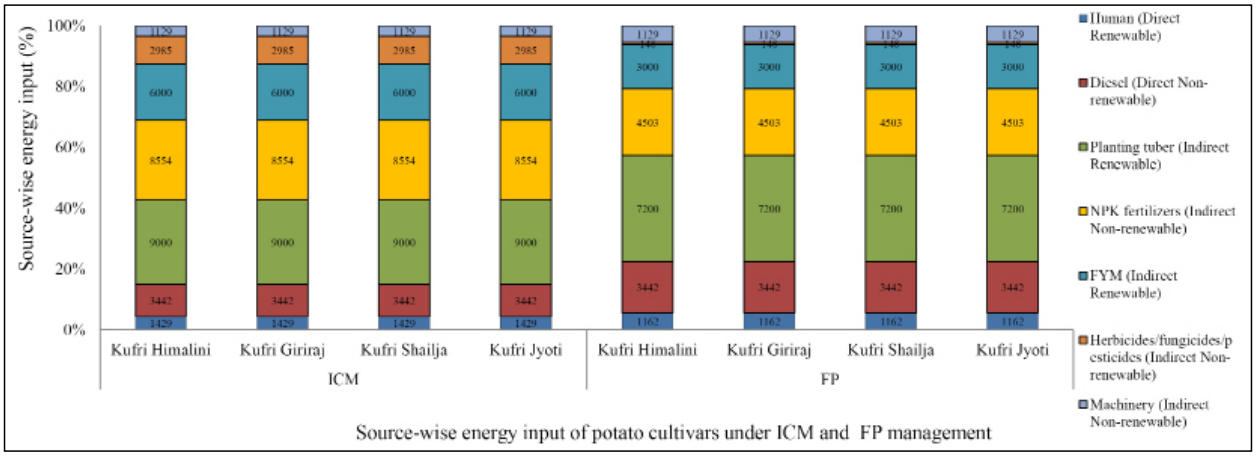


Fig. 5. Source-wise energy input (%, MJ/ha) of potato cultivars under ICM and FP management in wet temperate NW Himalayas.

non-renewable sources of energy both in ICM and FP (Fig. 5).

Energy-use indices

Total bio-energy output in potato crop under all the tested potato varieties ranged from 20583 to 32538 MJ/ha with highest magnitude under ICM compared to FP; while energy output varied from 46161–63235 MJ ha^{-1} under ICM and 37613–45534 MJ ha^{-1} under FP under different potato varieties (Table 4). On an average, proper crop management under ICM noticed higher net energy (21879 MJ/ha) and specific energy (2.56 MJ/kg) owing to higher productivity (Kumar *et al.*, 2021). However, the energy-use efficiency (2.03), energy productivity (0.49 kg/MJ) and energy profitability (1.03) were higher under FP, due to comparatively less energy consumption (Choudhary *et al.*, 2017).

Greenhouse gas emissions and carbon footprints

On an average, highest total greenhouse gas (GHG) emission equivalents from the inputs were observed under ICM (3738.1 CO_2-e kg ha^{-1}) compared to FP (2541.4 CO_2-e kg ha^{-1}) with respective field level emissions of 249.2–339.8 and 232.1–278.4 CO_2-e kg Mg^{-1} for fresh tuber yield, and 1298–1827 and 1149–1481 CO_2-e kg Mg^{-1} for tuber dry matter yield basis, respectively (Table 5). On an average, highest share of total emissions was computed for the seed tubers (34-40%) and the N_2O emissions from the farm (17-23%) both in ICM and FP (Fig. 6). This may be attributed to high seed rate and the high use of organics and N-fertilization (60-120 kg N/ha) in current study (Choudhary *et al.*, 2014; Rajpoot *et al.*, 2021).

On an average, highest total carbon input were observed with treatment ICM (1020 kg CE ha^{-1}) compared to FP which had the least total carbon input (693 kg CE ha^{-1}) in this study (Table 6). As, high use of chemical fertilizers, FYM and agro-chemicals was done under ICM compared to FP, thus, it led to higher GHG-emissions and total carbon input (Gan *et al.*, 2009; Goglio *et al.*, 2014). Under ICM, total carbon output varied between 1273 to 1792 kg CE ha^{-1} among different varieties with carbon footprints of 0.068–0.093 kg CE kg^{-1} of fresh tuber yield and 0.354–0.498 kg CE kg^{-1} of tuber dry matter yield among different

Table 4. Effect of crop management practices and potato cultivars on energy-use indices in potato crop.

Crop management practices	Potato cultivars	EI (MJ/ha)	EO (MJ/ha)	NE (MJ/ha)	EUE	EP (kg/MJ)	EPR	SE (MJ/kg)
ICM	Kufri Himalini	32538	46161	13623	1.42	0.34	0.42	2.96
	Kufri Giriraj	32538	55095	22557	1.69	0.40	0.69	2.50
	Kufri Shailja	32538	63235	30697	1.94	0.46	0.94	2.17
	Kufri Jyoti	32538	53177	20639	1.63	0.38	0.63	2.60
	Mean	32538	54417	21879	1.67	0.40	0.67	2.56
FP	Kufri Himalini	20583	37613	17030	1.83	0.44	0.83	2.25
	Kufri Giriraj	20583	41802	21219	2.03	0.49	1.03	2.03
	Kufri Shailja	20583	45534	24951	2.21	0.53	1.21	1.88
	Kufri Jyoti	20583	42384	21801	2.06	0.49	1.06	2.03
	Mean	20583	41833	21250	2.03	0.49	1.03	2.05

Note: EI-Energy input, EO-Energy output, NE-Net energy, EUE-Energy use efficiency, EP-Energy productivity, EI-Energy intensiveness, EPR-Energy profitability, SE-Specific energy.

Table 5. Effect of crop management practices and potato cultivars on carbon footprints of potato cultivation.

Crop management practices	Potato cultivars	GHG-emissions (CO_2-e kg ha^{-1})									CFy (CO_2-e kg Mg^{-1})	
		Machinery	Diesel	Human labour	Planting tubers	NPK fertilizers	FYM	Herbicides/ fungicides/ pesticides	N_2O from farm	Total	Fresh tuber yield basis	Dry tuber yield basis
ICM	Kufri Himalini	59.8	239	510.3	1275	580	181.0	51	842	3738.1	339.8	1827.0
	Kufri Giriraj	59.8	239	510.3	1275	580	181.0	51	842	3738.1	287.5	1445.0
	Kufri Shailja	59.8	239	510.3	1275	580	181.0	51	842	3738.1	249.2	1298.0
	Kufri Jyoti	59.8	239	510.3	1275	580	181.0	51	842	3738.1	299.0	1465.9
FP	Kufri Himalini	59.8	239	415.1	1020	290	94.5	2	421	2541.4	278.4	1480.6
	Kufri Giriraj	59.8	239	415.1	1020	290	94.5	2	421	2541.4	250.6	1326.1
	Kufri Shailja	59.8	239	415.1	1020	290	94.5	2	421	2541.4	232.1	1149.0
	Kufri Jyoti	59.8	239	415.1	1020	290	94.5	2	421	2541.4	251.0	1184.0

Table 6. Carbon budgeting and carbon footprints as influenced by crop management and potato cultivars.

Inputs	ICM					FP				
	Kufri Himalini	Kufri Giriraj	Kufri Shailja	Kufri Jyoti	Mean	Kufri Himalini	Kufri Giriraj	Kufri Shailja	Kufri Jyoti	Mean
Total carbon input (kg CE ha^{-1})	1020	1020	1020	1020	1020	693	693	693	693	693
Total carbon output (kg CE ha^{-1})	1273	1610	1792	1587	1566	1025	1144	1321	1282	1193
Carbon efficiency	1.25	1.58	1.76	1.56	1.54	1.48	1.65	1.91	1.85	1.72
Carbon sustainability index	0.25	0.58	0.76	0.56	0.54	0.48	0.65	0.91	0.85	0.72
Carbon footprint (kg CE kg^{-1} tuber dry matter yield)	0.498	0.394	0.354	0.400	0.412	0.404	0.362	0.313	0.323	0.350
Carbon footprint (kg CE kg^{-1} fresh tuber yield)	0.093	0.078	0.068	0.082	0.080	0.076	0.068	0.063	0.068	0.069

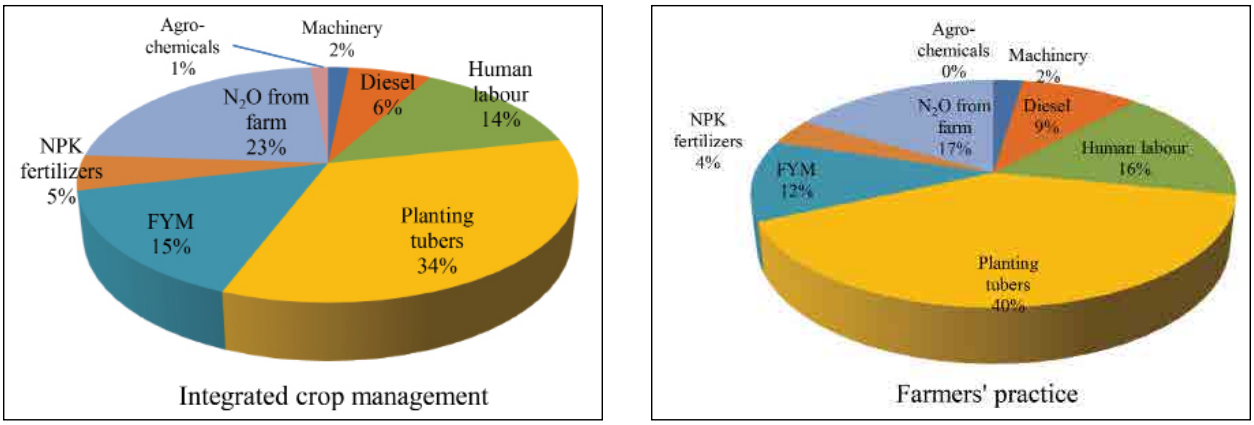


Fig. 6. Influence of integrated crop management technology on carbon footprints of potato cultivation in NW Himalayas.

potato varieties with least footprints under Kufri Shaija. On the other hand, FP exhibited carbon footprints of 0.063–0.076 kg CE kg^{-1} of fresh tuber yield and 0.313–0.404 kg CE kg^{-1} of tuber dry matter yield among different potato varieties with least footprints again under Kufri Shaija due to its higher productivity. On an average, FP observed higher carbon-efficiency (1.72) and carbon sustainability index (0.72) mainly due to lower carbon input used here (Choudhary *et al.,* 2017). However, ICM resulted in slightly higher carbon footprints (0.08 kg CE kg^{-1} fresh potato tuber yield) compared to FP (0.069 kg CE kg^{-1} fresh potato tuber yield) due to higher carbon inputs used in balanced plant nutrition, crop management and plant protection measures under ICM (Gan *et al.,* 2009; Goglio *et al.,* 2014; Choudhary *et al.,* 2017; Kumar *et al.,* 2021).

Pre- and post-training knowledge behaviour and impact assessment

Data presented in Table 7 on pre-training knowledge assessment of 68 farmers of Seraj block of Mandi district (Study area) revealed that their respective knowledge about potato crop management and improved varieties varied between 28–88 and 43–65%; whereas, the training interventions led to post-training knowledge enhancement of these farmers (n=68) by 89–100 and 92–97%, respectively. This pre-training assessment was done using well structured interview schedule using questionnaire as mentioned in Table 7.

The technology adoption rate after one year of study completion (year 2010) varied between 72–98% for different components of ICM in potato farming. Similarly, the technology adoption rate about improved potato cultivars varied between 71–83% (Table 7), due to regular technology transfer efforts (Choudhary *et al*., 2013).

The assessment of net income gains (NIGs) after two year of *'on-farm'* experimentation i.e. year 2011 in the study area revealed that by the adoption of ICM technology and improved potato cultivars, the average

Table 7. Assessment of knowledge upgradation (Av. values) and technology adoption (%) among trainee farmers (n=68) in Seraj block of Mandi district in Himachal Pradesh (Study area).

Technology component	Pre-training (%)	Post- Training (%)	Technology adoption rate after one year of study completion (%) (n=68)*
Potato crop management			
ICM in potato cultivation and its benefits	56	100	88
Potato tuber selection	58	95	86
Field preparation for tuber planting	78	95	91
Plant spacing	68	95	85
Integrated nutrient management	58	91	88
Weed management and plant protection measures	28	91	72
Intercultural operations	88	100	98
Haulm cutting	35	89	75
Harvesting time and methodology	84	100	91
Improved potato cultivars			
Knowledge & adoption of improved potato varieties	43	92	71
Knowledge about planting time	65	95	80
Knowledge about harvesting time	61	97	83

Note: *Technology adoption rate of 68 trained farmers after one year of study i.e. 2010.

Table 8. Net income gains by the adoption of ICM coupled with improved potato cultivars (n = 68) in wet-temperate region of Mandi district (study area).

Potato farming	Number of farmers (n=68*)	Net returns (INR/ha)		Percent (%) increase in NIGs
		Range	Average	
ICM coupled with improved potato cultivars	n = 68	58500–75800	66480	41.3%
FP using conventionally grown variety 'Kufri Jyoti'	n = 68	43780–57600	47065	–

*Note: n is the number of potato growers.

net income was INR 66480/ha with 41.3% higher net income gains (NIGs) among potato growers (n=68) over the conventionally grown variety 'Kufri Jyoti' under farmers' practice (Table 8).

CONCLUSION

This '*On-farm*' field study clearly demonstrated that the integrated crop management (ICM) technology imbedded with improved potato varieties like Kufri Shailja and Kufri Giriraj along with balanced nutrition (120:80: 60 kg NPK/ha & 20 t FYM/ha) as well as proper crop management and plant protection measures; may lead to higher potato productivity, profitability and bio-energy production. Since, the ICM resulted in slightly higher carbon footprints (0.08 kg CE kg^{-1} fresh potato tuber yield) compared to FP (0.069 kg CE kg^{-1} fresh potato tuber yield) due to better crop management and input-use. However, the total carbon output under ICM was ~31.3% higher over FP, indicating that ICM adoption may be a possible mitigation strategy to climate change. Overall, ICM is a better option over FP w.r.t. potato productivity, profitability, net-income gains, bio-energy and carbon output in diverse potato production systems of wet-temperate NW Himalayas and collateral agro-ecologies across the globe.

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The authors gratefully acknowledge the technical and financial support of the CSK Himachal Pradesh Agricultural University, Palampur, India. The ICAR-CPRI Shimla (HP) is also acknowledged for the scientific support for assessing the energy dynamics and carbon footprints of this study carried out by the CSK Himachal Pradesh Agricultural University, Farm Science Centre, Sundernagar (HP), India.

LITERATURE CITED

Bellarby J, Foereid B, Hastings A, Smith P (2008) Cool farming: Climate impacts of agriculture and mitigation potential. www.greenpeace.at/uploads/media/Cool_Farming_Report_Final_web.pdf. (Retrieved on 25.12.2021).

Choudhary A.K, Rahi S, Singh A, Yadav DS (2010) Effect of vermicompost and biofertilizers on productivity and profitability in potato in north–western Himalayas. *Current Advances in Agricultural Sciences* **2**: 18-21.

Choudhary AK and Rahi S (2018) Organic cultivation of high yielding turmeric (*Curcuma longa* L.) cultivars: A viable alternative to enhance rhizome productivity, profitability, quality and resource-use efficiency in monkey–menace areas of north-western Himalayas. *Industrial Crops and Products* **124**: 495-504.

Choudhary AK, Thakur SK, Suri VK (2013) Technology transfer model on integrated nutrient management technology for sustainable crop production in high value cash crops and vegetables in north-western Himalayas. *Communications in Soil Science and Plant Analysis* **44**: 1684-1699.

Choudhary M, Rana KS, Bana RS, Ghasal PC, Choudhary GL, Jakhar P, Verma RK (2017) Energy budgeting and carbon footprint of pearl millet-mustard cropping system under conventional and conservation agriculture in rainfed semi-arid agro-ecosystem. *Energy* **141**: 1052-1058.

CPRI (2019-20) Annual Progress Report of CPRI, Shimla (HP).

Deng JL (1982) Grey controlling system. *Cent. Inst. Technol*. **10**: 9-18.

Devasenapathy P, Ramesh T, Gangwar B (2008) Efficiency indices for agriculture management research. New Delhi, India: New India Publishing Agency. p 87.

Devasenapathy P, Senthilkumar G, Shanmugam PM (2009) Energy management in crop production. *Indian Journal of Agronomy* **54**(1):80-90.

FAOSTAT (2021) FAOSTAT data of the year 2020 (Retrieved on 25.12.2021).

Gan YT, Campbell CA, Jansen HH, Lemke R, Liu LP, Basnyat P, McDonald CL (2009) Carbon input to soil by oilseed and pulse crops in semiarid environment. *Agricultural Ecosystems and Environment* 132: 290-297.

Goglio P, Grant BB, Smith WN, Desjardins RL, Worth DE, Zentner R, Malhi SS (2014) Impact of management strategies on the global warming potential at the cropping system level. *Science of the Total Environment* **490**: 921-933.

Gomez KA and Gomez AA (1984) Statistical Procedure for Agricultural Research. John Wiley and Sons, New York, USA.

Houshyar E, Dalgaard T, Tarazkar MH, Jørgensen U (2015). Energy input for tomato production what economy says, and what is good for the environment. *Journal of Cleaner Production* **89**: 99-109.

Kumar A, Rana KS, Choudhary AK, Bana RS, Sharma VK, Prasad S, Gupta G, Choudhary M, Pradhan A, Rajpoot SK, Kumar A, Kumar A and Tyagi V (2021) Energy budgeting and carbon footprints of zero-tilled pigeonpea–wheat cropping system under sole or dual crop basis residue mulching and Zn-fertilization in a semi-arid agro-ecology. *Energy* **231**: 120862.

Lal R (2004) Carbon emissions from farm operations. *Environment International* 30: 981-990.

Paramesh V, Parajuli R, Chakurkar EB, Sreekanth GB, Chetan Kumar HB, Gokuldas PP, Mahajan GR, Manohara KK, Reddy KV, Ravisankar N (2019) Sustainability, energy budgeting, and life cycle assessment of cropdairy-fish-poultry mixed farming system for coastal lowlands under humid tropic condition of India. *Energy* 188: 116101.

Paul J, Choudhary AK, Sharma S, Savita, Bohra M, Dixit AK, Kumar P (2016) Potato production through bio–resources: Long–term effects on tuber productivity, quality, carbon sequestration and soil health in temperate Himalayas. *Scientia Horticulturae* **213**: 152-163.

Pishgar-Komleh SH, Ghahderijani M, Sefeedpari P (2012) Energy consumption and CO2 emissions analysis of potato production based on different farm size levels in Iran. *Journal of Cleaner Production* **33**: 183-191.

Rajpoot SK, Rana DS, Choudhary AK (2021) Crop and water productivity, energy auditing, carbon footprints and soil health indicators of Bt-cotton transplanting led system intensification *Journal of Environmental Management* **300**: 113732.

Rana KS, Choudhary AK, Sepat S, Bana RS and Dass A (2014) Methodological and Analytical Agronomy, Post Graduate School, IARI, New Delhi, pp 276.

Varatharajan T, Choudhary AK, Pooniya V, Dass A and Harish MN (2019b) Integrated crop management practices for enhancing productivity, profitability, production-efficiency and monetary-efficiency of pigeonpea (*Cajanus cajan)* in Indo-Gangetic plains region. *Indian Journal of Agricultural Sciences* **89**(3): 559-563.

Varatharajan T, Choudhary AK, Pooniya V, Dass A, Meena MC, Gurung B, Harish MN (2019a) Influence of integrated crop management practices on yield, photosynthetically active radiation interception, resource-use-efficiency and energetics in pigeonpea (*Cajanus cajan*) in north Indian plains. *Journal of Environmental Biology* **40**(6): 1204-1210.

Yadav GS, Das A, Lal R, Babu S, Meena RS, Saha P, Singh R, Datta M (2018) Energy budget and carbon footprint in a no-till and mulch based rice-mustard cropping system. *Journal of Cleaner Production* 191: 144-157.

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EVALUATION OF NEWER INSECTICIDES FOR THE MANAGEMENT OF *MYZUS PERSICAE* (SULZER)

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ABSTRACT: Green peach aphid, *Myzus persicae* (Sulzer) (Aphididae: Hemiptera) is one of important pest which causes direct and indirect losses to many horticultural crops. To deal with this pest insecticide application remains the principal method to avoid its losses. Therefore, the present study was aimed to evaluate two insecticides with novel mode of action as an alternative to the existing insecticides used for management of *M. persicae*. Further leaf dip method was followed to evaluate the test chemicals against *M. persicae*. Probit analysis and LC_{50} data suggest that flonicamid is as effective as imidacloprid. The flonicamid also has different mode of action and can be used as an alternate chemical to manage *M. persicae* in potato and other crop ecosystems. This is the first study that indicates insecticidal resistance in *M. persicae* population in India.

KEYWORDS: *Myzus persicae, mtCOI,* Imidacloprid, Flonicamid, Pymetrozine, Probit analysis, LC50.

INTRODUCTION

Green peach aphid, *Myzus persicae* (Sulzer) (Aphididae: Hemiptera) is an extremely polyphagous aphid species which has been reported to feed on more than five hundred species of host plants belongs to at least forty different families including several important agricultural crops (Van Emden and Harrington, 2007). The *M. persicae* causes direct yield losses to many vegetable crops by sucking the plant sap as well as indirect losses by transmitting plant viruses (Naga et al., 2020). Virus transmission abilities of *M. persicae* are generally considered to be more economically important as it is known to transmit more than 100 plant viruses mainly in non-persistence manner (Blackman and Eastop, 2000). The *M. persicae* is also known to be a major pest in potato and which cause significant yield losses indirectly by transmitting many plant viruses that leads to degeneration of the seed tubers (Kreuze et al. 2020). The potato crop is mainly grown using seed plot technique in Indo-gangetic plains during winter season. However, crops which are grown beyond the seed plot technique require insecticide protection. Imidacloprid is widely used to manage many sucking pests including *M. persicae* and this intensive use may lead various problems like insecticide resistance, resurgence and toxicity to non-target. The resistance problem has emerged in many countries to insecticides from four different modes of action subgroups: carbamates (1A), organophosphates (1B), synthetic pyrethroids (3A), and neonicotinoids (4A) (Bass et al. 2014). The resistance to insecticides has also been recorded with various intensities in the Indian population of *M. persicae* (Halder et al. 2007; Gavkare et al. 2013; Halder and Rai 2018).

In the present study we have evaluated the two newer insecticides flonicamid and pymetrozine against *M. persicae* populations collected from potato. These chemicals have a unique mode of actions where flonicamid

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acts as modulator of chordotonal organ and pymetrozine acts as chordotonal organ TRPV channel modulators (IRAC, mode of action classification scheme, Version 10.1). Due to this unique mode of action these insecticides were chosen in the present study where the efficacy of these chemicals was compared with the recommended chemical imidacloprid.

MATERIALS AND METHODS

Materials used for bioassay

Bioassay of insecticides was carried out against two *M. persicae* populations and both the populations were collected from Jalandhar, (Punjab). Out of these populations one was collected during 2013 and since then was being maintained on Chinese cabbage, *Brassica pekinensis* since 2013 at ICAR-CPRI, Shimla under glasshouse. This population since its collection has not been exposed to insecticides and called as laboratory population.

The second population was collected during the January, 2021 form the same location and called it as Jalanadhar population in this set of experiment. The *M. persicae* population collected from Jalandhar, Punjab (India) was identified morphologically using taxonomic keys. The identification was further confirmed by sequencing the mitochondrial cytochrome oxidase 1 gene (*mtCOI*) using method previously established by Folmer *et al.* (1994). The Polymerase Chain Reaction (PCR) reaction was performed with slight modification as described below, the reaction consisted of 2x EmeraldAmp® GT PCR Master Mix 10 µl, 1 µl each forward and reverse primers, DNA template (30 ng) and nuclease free water was added to make the total reaction volume of 20 µl. PCR was carried out with an initial denaturation at 94°C for 4 min followed by 35 cycles of 94°C for 30 s, 50°C for 45 s, 72°C for 1 min, and a final extension at 72°C for 10 min. Mitochondrial sequence (*mtCOI*) of *M. persicae* and sequences retrieved from GenBank, NCBI were subjected to multiple sequence alignment with using clustalW followed by construction of phylogenetic tree using Neighbor-Joining method (Saitou and Nei, 1987).

Insecticides evaluated against the *M. persicae* have been mentioned in table 1. The Jalandhar population was only evaluated against imidacloprid and flonicamid.

Insecticidal bioassay

Leaf dip method was followed to evaluate the test chemicals against *M. persicae* as described by IRAC Test method (https://irac-online.org/content/uploads/2009/09/Method_001_v3_june09.pdf).

Appropriate test dilutions of each formulations was prepared in 0.01% Triton x-100 with a staring from dose 10 fold higher from the field recommended dose (mentioned in table 1) (De Little and Umina 2017) and five serial dilutions were prepared. Leaf discs of 4 cm diameter were excised using the surgical blades from fresh uninfected Chinese cabbage leaves. These leaves discs were

Table 1. Insecticides details used for bioassay against *M. persicae*

Test chemical	Field recommended dose (gms of a.i/ ha)	MoA (IRAC, mode of action classification scheme, Version 10.1)
Imidacloprid 17.8% SL	25	Nicotinic acetylcholine receptor (nAChR) competitive modulators
Flonicamid 50% WG	75	Chordotonal organ Modulators undefined target site
Pymetrozine 50% WG	150	Chordotonal organ TRPV channel modulators

allowed to dip in the insecticide dilutions of test chemicals for about 10 sec and dried in incubator at 25°C for about 45 minutes. The control leaf discs were only dipped into 0.01% Triton x-100.

Further these leaf discs were placed over a agar base in about 4,2 cm diameter vials and covered with muslin cloth after releasing the test insect. A drop of water was also poured over the agar base in each vial to keep the leaf discs hydrated. About 30 aphids (from synchronized populations) were released over the leaf discs and incubated at 21°C in incubator.

The aphid response was assessed after 24h in case of imidacloprid (IRAC test method 1) and after 120h in case of flonicamid and pymterozine (IRAC test method 19). The aphid responses were observed as live, morbid and dead. Adults were considered live if they moved and held themselves normally, and morbid if their movement or posture was abnormal. Results were expressed as percentage mortality and for untreated mortality corrected using Abbott's formula (Abbott, 1925). The mortality data were subjected to probit analysis using Polo plus and after Finney, (1971). A resistance ratio was also calculated by dividing the LC_{50} of field population by LC_{50} of the lab population.

The resistance for the population was scaled as follows: < twofold, no resistance; 2- to 10-fold, very low resistance; 11- to 20-fold, low resistance; 21- to 50-fold, moderate resistance; 51- to 100-fold, high resistance; >100-fold, very high resistance (TorreseVila *et al.,* 2002; Saddiq *et al.,* 2014).

RESULTS AND DISCUSSION

Molecular identification of aphid species

The aphids identified as *M. persicae* based on the molecular analysis. Multiple sequence alignment with reference sequence revealed the aphid species as *M. persicae*. The *mtCOI* sequence of aphid had shown 100 percent similarity with reference sequences (Accessions no. KM577343.1, MK396780.1) at NCBI database and the representative *mtCOI* sequence of *M. persicae* has been submitted at NCBI (Accession no. MK814190.1).

Insecticidal bioassay

A signification differences in the responses of *M. persicae* populations to test chemicals, indicating a change of sensitivity against insecticides in the Jalandhar population.

The flonicamid had shown highest toxicity with LC_{50} as 1.195 ppm which was however on par with the LC_{50} of imidacloprid (4.214 ppm) (Table 2). Pymetrozine was found to be the least effective chemical against *M. persicae* with LC_{50} 142.77 ppm (fiducial limit 31.214- 1511.8 ppm) (Table 2).

Bioassay of the flonicamid and imidacloprid were also revealed similar responses in Jalandhar population as observed with the lab population (Table 3). The flonicamid had shown higher toxicity with LC_{50} of 28.420 ppm which was however at par with the LC_{50} of imidacloprid (53.345 ppm) (Table 3). Previous reports also

Table 2. Laboratory evaluation of Insecticides against *M. persicae* adults laboratory population

Test chemical	n	LC_{50} (95% CI) (ppm)	Chi-Square	df*	Heterogeneity	SE	Slop
Imidacloprid	180	4.214 (1.087-12.451)	0.369	4	0.092	0.094	0.552
Flonicamid	180	1.195 (0.163-4.407)	2.022	4	0.506	0.082	0.401
Pymetrozine	180	142.77 (23.849-3101.7)	1.051	4	0.263	0.059	0.249

n = numbers of insects used for bioassay; CI, confidence intervals; *df = degrees of freedom; SE= Standard Error

Table 3. Laboratory evaluation of Insecticides against *M. persicae* adults, Jalandhar population.

Test chemical	n	LC_{50} (95% CI) (ppm)	Chi-Square	df*	Heterogeneity	SE	Slop	RR
Imidacloprid	357	53.345 (21.328 -145.631)	0.467	4	0.131	0.057	0.432	12.6
Flonicamid	400	28.420 (9.280 -106.384)	0.327	4	0.082	0.053	0.337	23.7

n = numbers of insects used for bioassay; CI, confidence intervals; *df = degrees of freedom; SE= standard error, RR= resistance ratio.

suggested similar level of response (LC_{50}) to laboratory population *M. persicae* (Gavkare et al. 2013). The bioassay of pymetrozine against Jalandhar population could not be performed as the collapsed due to parasitoids infestation arrived along with field samples. Our finding of flonicamid efficacy against *M. persicae* is supported by previous workers where it has found more effective then imidacloprid, thiamethoxam and acetamiprid (Chandi and Gill, 2019; Sretenovic et al., 2019). The flonicamid has been also found highly effective against aphid and whitefly in cotton ecosystem (Ghelani *et al*., 2014).

The resistance ration of imidacloprid and flonicamid were 12.6 and 23.7 respectively, revels change in response of *M. persicae* against these chemicals in the field population (table 3). The resistance ratio indicates a low level of resistance against imidacloprid and moderate resistance prevalent against flonicamid in the Jalandhar population (TorreseVila *et al.*, 2002; Saddiq et al., 2014). Altered response of *M. persicae* against imidacloprid has been previously recorded by Halder and Rai (2018). The slight change in the sensitivity of *M. pericae* has been recorded in the Greece by (Ntantos 2020).

Intensive use of insecticides over many years has led to the development of widespread and multiple forms of resistance. The first report of resistance *M. persicae* species dates back to 1955 (Anthon, 1955). Resistance in *M. persicae* now reported to most classes of insecticide, including the organophosphates, carbamates, pyrethroids, cyclodienes, and neonicotinoids.

The *M. Persicae* employs seven independent mechanisms of resistance against the insecticides (Puinean *et al.*, 2010; Bass *et al.*, 2014). Hence there is a need to continuously evaluate the effective chemicals having different mode of action against *M. persicae* to manage the insecticide resistance populations.

CONCLUSION

Overall this study highlights that the flonicamid is as effective as imidacloprid which has different mode of action and can be used as an alternate chemical to manage *M. persicae* in potato and other crops ecosystems. Apart from the effectiveness of the chemical the results also highlights the change in the sensitivity of the imidacloprid and flonicamid in the field population (Jalandhar, Punjab) so there is a need to continuous monitoring of the filed population for resistance monitoring.

LITERATURE CITED

Abbott, W S (1925) A method for computing effectiveness of an insecticide. *J Econ Entomol* **18**: 265-267

Anthon EW (1955) Evidence for Green Peach Aphid Resistance to Organo-Phosphorous Insecticides. *J Econ Entomol* **48**:56–57

Bass C, Puinean AM, Zimmer CT, et al (2014) The evolution of insecticide resistance in the peach potato aphid, *Myzus persicae*. *Insect Biochem. Mol Biol* **51**: 41–51

Chandi RS and Gill BS (2019) Efficacy of safer insecticides against aphid on celery. *Agric Sci Dig - A Res J* **39**: 70-72

de Little SC, Umina PA (2017) Susceptibility of Australian *Myzus persicae* (Hemiptera: Aphididae)

to three recently registered insecticides: Spirotetramat, Cyantraniliprole, and Sulfoxaflor. *J Econ Entomol* **110**: 1764–1769

Finney, D. J. 1971. Probit analysis 3rd ed. Cambridge University, London, 333 p.

Folmer O, Black M, Hoeh W, et al (1994) DNA primers for amplification of mitochondrial cytochrome c oxidase subunit I from diverse metazoan invertebrates. *Mol Mar Biol Biotechnol* **3**(5): 294-299

Gavkare OM, Kumar S, Sharma NI and Sharma PL (2013) Evaluation of some novel insecticides against *Myzus persicae* (Sulzer). *The Bioscan* **8**(3): 1119-1121

Ghelani MK, Kabaria BB and Chhodavadia SK (2014). Field efficacy of various insecticides against major sucking pests of *Bt* cotton. *J. Biopestic* 7: 27

Halder J and Rai AB (2018) Aphidicidal activity of some systemic insecticides and change in susceptibility level of *Myzus persicae* Sulzer in vegetable ecosystem in Varanasi, India. *Pestic Res J* **30**(2): 219-223

Halder J, Dhingra S, Ganesh K S and Bhandari JKS (2007). Relative toxicity of some synthetic insecticides with special reference to change in susceptibility level of *Myzus Persicae* Sulz over a Decade. *Pestic Res J* **19**(1): 76-78

Kreuze JF, Souza-Dias JA, Jeevalatha A, Figueira AR, Valkonen JP and Jones RA (2020). Viral diseases in potato. In, The potato crop. Springer, Cham, 389-430p

Naga KC, Buckseth T, Subhash S, et al (2020) Transmission efficiency of potato leaf roll virus (Plrv) by potato aphid, *Aulacorthum solani* and green peach aphid *Myzus persicae* . *Indian J Entomol* **82**:68

Ntantos P (2020) Evaluation of insecticide resistance in Greek populations of *Myzus persicae.* Department of Sustainable Agriculture and Business, International Hellenic University, Greece. M.Sc. 42p

Puinean AM, Denholm I, Millar NS, et al (2010) Characterisation of imidacloprid resistance mechanisms in the brown planthopper, *Nilaparvata lugens* Stål (Hemiptera: Delphacidae). *Pestic Biochem Physiol* **97**: 129–132

Saddiq B, Shad SA, Khan HA, Aslam M, Ejaz M and Afzal MB (2014) Resistance in the mealybug Phenacoccus solenopsis Tinsley (Homoptera: Pseudococcidae) in Pakistan to selected organophosphate and pyrethroid insecticides. *Crop Prot* **66**: 29-33

Saitou N, Nei M (1987) The neighbor-joining method: a new method for reconstructing phylogenetic trees. *Mol Biol Evol* **4**: 406–425

Saitou N, Nei M (1987) The neighbor-joining method: a new method for reconstructing phylogenetic trees. *Mol Biol Evol* **4**: 406–425

Sretenovic M, Miletic N and Tamas N (2019) Efficacy of different insecticides for the control of green peach aphid (*Myzus persicae* sulzer) in nectarine orchards. P*akistan J Agric Sci* **56**: 661–668

Torres-Vila LM, Rodriguez-Molina MC, Lacasa-Plasencia A, Bielza-Lino P and Rodriguez-Rincon A (2002) Pyrethroid resistance of *Helicoverpa armigera* in Spain: current status and agro ecological perspective. *Agric Ecosyst Environ* **93:** 55-66.

Van Emden HF and Harrington R (2007). Aphids as crop pests. CAB International

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EFFICACY AND ECONOMIC OF SULFOXFLOR 12% SL AGAINST SUCKING INSECT PESTS OF POTATO

Anuj Bhatnagar

ABSTRACT: The field efficacy of sulfoxaflor 12% SL insecticide was evaluated against sucking insect pests (whiteflies and leafhoppers) on seven popular potato cultivars (Kufri Chipsona-1, Kufri Anand, Kufri Chipsona-3, Kufri Surya, Kufri Neelkhant, Kufri Bahar and Kufri Khyati) during 2018-19 and 2019-20. Results showed that, sulfoxaflor 12% SL exhibited excellent activity against *Bemisia tabaci* (Gennadius) and *Amrasca beguttula beguttula* Isida during both the years. The whitefly and leaf hopper population were low on protected potato cultivars as compared to unprotected cultivars. Similarly, highest pooled mean tuber yield (49.33 t/ha) was recorded of K. Khyati when crop was protected by three sprays of sulfoxaflor 12% SL followed by K. Anand (46.90 t/ha) and K. Bahar (40.56 t/ha). By working out cost benefit ratio it is evident that K. Khyati ranked first indicating the maximum return of Rs. 3.18 per rupee invested followed by K. Chipsona-3 with Rs.2.54 and K. Anand Rs.2.47. The present study suggests the use of sulfoxaflor 12% SL is preferred insecticide and could be incorporated in integrated pest management of sucking insect pests of potato.

KEYWORDS: Potato cultivars, whiteflies, leafhoppers, sulfoxflor 12% SL

INTRODUCTION

Potato (*Solanum tuberosum* Linn.) is considered very important tuber crop in India. It is cultivated under different eco-environmental conditions for local consumption and available throughout the year (Rana and Pandey, 2007). The potato is presently produced 53.02 million tonnes from 2.16 million ha area with an average productivity of 24.54 t/ha (Annual report, 2019). Whitefly and leafhoppers are highly polyphagous insect pests, feeding on many horticultural and agricultural crops throughout India (Bhatnagar, 2007; Bhatnagar, 2008; Chandel *et al*. 2013;Bhatnagar, 2013). The leafhoppers and whitefly are most important due to sucking the sap directly from tender parts and transmitting important viral diseases, resulting degeneration of potato. However, whitefly is already established as a vector and transmitting potato apical leaf curl New Delhi virus in potato especially in Western India. Several insecticides belonging to different groups, mainly chlorinated hydrocarbons and organophosphate have been recommended for their control but farmers generally complain the effectiveness of these insecticides against *whitefly* and *leafhoppers* on potato crop. Several conventional and synthetic insecticides have been tried against whitefly, leafhoppers and aphids on various crops in the past (Thakur *et al*., 1991, Singh and Gupta, 1993). Sulfoxaflor 12% SL is a new insecticide used against sap-feeding insects belonging to the family of sulfoximine; that act as nicotinic acetyl choline receptor (nAChR) competitive modulators. Sulfoxaflor binds tonAChR in place of acetylcholine and acts as an allosteric activator of nAChR. Sulfoxafloracts on the same receptors of neonicotinoids as nicotine and butenolides, but it binds differently. It binds to insects nAChRs more strongly than to mammals' ones, so it is much less toxic for mammals and man (Bacci *et al*., 2018)

The major problem in the productivity of potato varieties is its perpetual insect pest infestation throughout crop growth. The new insecticides are playing very important role in

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reducing pest damage with least disturbance to eco-system. Hence, the present study was carried out to evaluate the 7 promising potato cultivars (Kufri Anand, Kufri Surya, Kufri Chipsona- 1, Kufri Neelkhant, Kufri Chipsona -3, Kufri Bahar and Kufri Khyati) against whitefly and leafhoppers harboring on crop under sprayed and unsprayed conditions beside the population buildup of whitefly and leafhoppers on potato cultivars, yield and its yield attributing factors.

MATERIALS AND METHODS

Field trials were conducted to evaluate the efficacy of new insecticide sulfoxflor 12% SL against whitefly, *Bemisia tabaci* (Gennadius) and leafhoppers *Amrasca beguttula beguttula* Isida on potato cultivars at ICAR-Central Potato Research Institute Campus, Modipurum, Meerut (U.P.) during two consecutive years 2018-2019 and 2019-20. The experiment was laid out in a randomized block design with plot size of 3 m x 3 m. Potato cultivars, T1- Kufri Chipsona-1, T2- Kufri Anand, T3- Kufri chipsona-3, T4- Kufri Surya, T5-Kufri Neelkhant, T6-Kufri Bahar, and T7- Kufri Khyati were planted in the 1st week of November during main crop season with three replications. All the agronomical package and practices recommended for the region were followed in raising a good crop. There sprays of Sulfoxaflor 12% SL @ 0.03% (3ml/10 lit of water) were given when crop was 30, 45 and 55 days old at 15 days interval.

The observations on the population buildup of whitefly and leafhoppers were recorded on 05 randomly selected plants covering upper, middle and lower leaves of each plant at before and 24hrs and 48hrs after each spray from both sprayed and unsprayed potato cultivars. The yield data was recorded from net plot after removing halum in the first week of February during both the years. The other plant growth parameters like % germination (30 days old crop), average plant height, average compound leaves/ plant and % apical leaf curl diseased plants (50 days old crop) along with other yield attributing characters like percent & total over size, seed size and small size tubers were recorded at the time of harvest in sprayed and unsprayed plots. Benefit-Cost analysis was expressed in terms of Benefit: Cost ratio by using the following formula

$$\text{Cost benefit : ratio} = \frac{\text{Net return (Rs. ha}^{-1})}{\text{Cost of treatment (Rs. ha}^{-1})}$$

The data was further subjected to statistical analysis. Similarly, the % increase in tuber yield over unsprayed crop was calculated as follows-

$$\text{\% Increase in tuber yield} = \frac{\text{Tuber yield in sprayed plot - Tuber yield in unsprayed plot}}{\text{Tuber yield in unsprayed plot}} \times 100$$

RESULTS AND DISCUSSION

Population buildup of Whitefly, *B. tabaci* and leafhoppers *A. beguttula beguttula* on potato cultivars

A day before spray the mean population of whitefly and leafhoppers was almost uniform across the experimental plots on potato cultivars (2.33-3.67/ 5plants) and (1.67-4.33/ 5plants), respectively. It did not differ significantly one and two days after first spray on potato cultivars during both the years. The lowest number pooled mean of whitefly per 05 plant was recorded in the K. Khyati (0.50 whiteflies/ 05 plant) followed by K. Chipsona-1, K.Nilkhant and K.Surya (0.83 /5 plants) in sprayed plot of sulfoxaflor 12% SL (Fig 1 & 2). Similarly, no significant difference among the sprayed potato cultivars was noticed even after second spray of Sulfoxaflor when crop was 45 days old. However, one day before second spray again non-sprayed potato cultivars showed no significant difference with respect to number of whiteflies and leafhoppers. The lowest

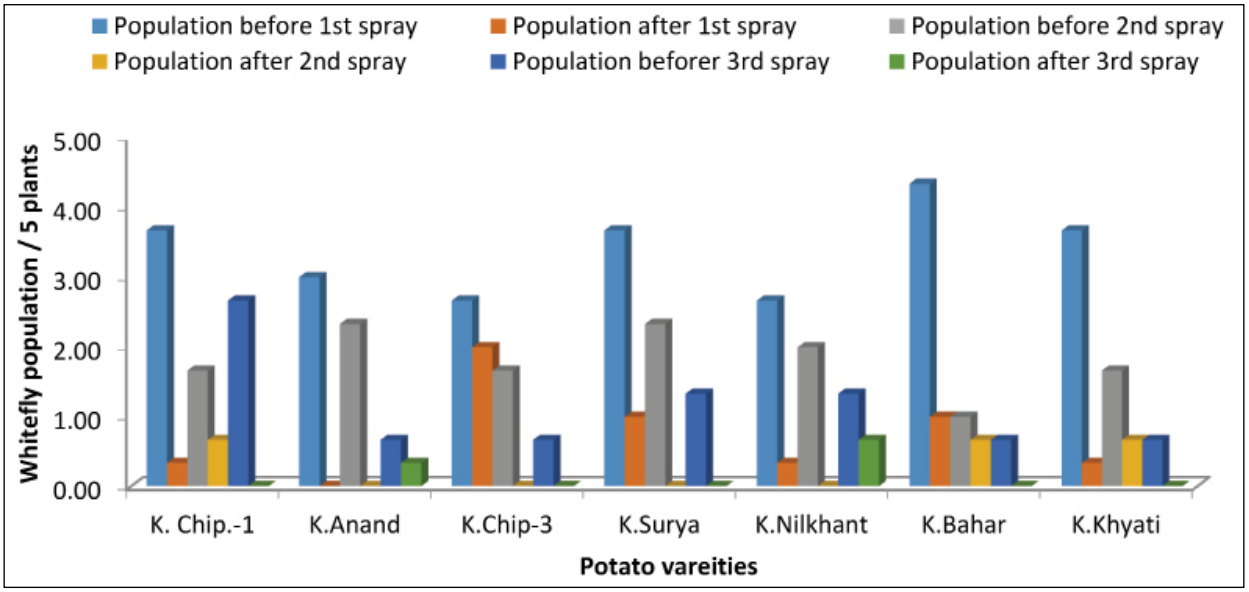


Fig. 1. Mean population buildup of whiteflies on potato cultivars (sprayed and unsprayed) under field conditions (pooled data of 2018-19 and 2019-20)

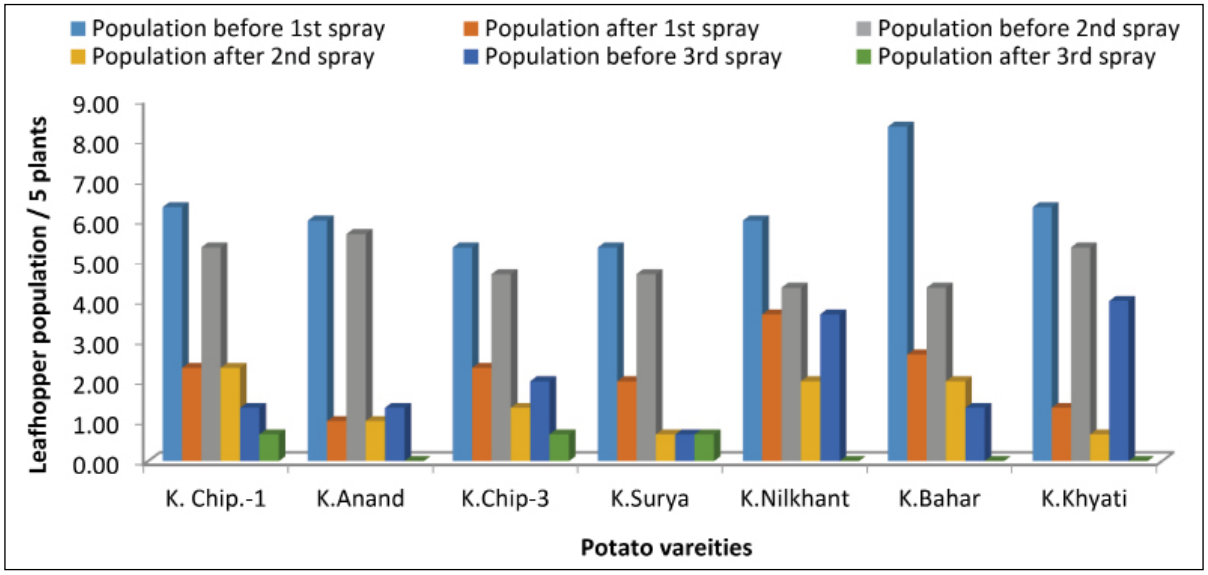


Fig. 2. Mean population buildup of leafhoppers on potato cultivars (sprayed and unsprayed) under field conditions (pooled data of 2018-19 and 2019-20)

number of pooled mean of whitefly per 05 plant was recorded in the K. Chipsona-3 and K. Nilkhant (0.0 whiteflies/ 05 plant) followed by K. Surya and K. Anand (0.33/5 plants) in sprayed plots. Similarly, it was 0.67/ 05 plants for leafhoppers on K. Khyati followed by K. Surya and K. Bahar (1.0/ 05 plants). The maximum number of pooled mean of whiteflies and leafhoppers population were (1.0/ 05 plants) and (2.66/ 05 plants), respectively on K. Khyati and K. Chipsona-1 in sprayed crop. No significant difference of whitefly population was noticed among sprayed potato cultivars before and after

third spray in 55 days old crop. However, significant difference was recorded before third spray against leafhopper population on potato cultivars while no differences was noticed one day and second day after third spray. There was decline of temperature after third week of December, resulting slightly lower population of whitefly and leafhopper on main potato crop during the experimental period. However, Bhatnagar *et al.,* 2013 also reported that sharp decrease in temperature after mid-November decreased whitefly and leafhoppers population drastically. Incidence of whitefly and leafhoppers population did not differ significantly in relation to plant protection treatments on potato crop.

Gradual reduction in percentage of whitefly and leafhoppers population as a result of sulfoxflor insecticide treatments on potato cultivars were recorded during both the years (Tables 1). The highest pooled mean reduction percentages of whitefly were recorded on K. Chipsona-3 followed by K. Surya where the mean reduction percentages were 84.19%, 78.72%, 76.81%, 71.62% and 61.36%% on K. Nilkhant, K. Chipsona-1, K. Khyati, K. Bahar and K. Anand, respectively. The least pooled mean reduction percentage of whitefly population was recorded on K. Anand where the mean reduction percentages were 58.38 and 64.37% during the years 2018-19 and 2019-20, respectively. Similarly, field evaluation of Sulfoxaflor on potato cultivars against leafhoppers revealed that the highest pooled mean reduction percentages 87.21 and 79.66 were achieved on K. Khyati and K. Bahar, where the mean reduction percentages were 81.51% and 92.81% and 70.66% and 88.20% during the respective years. The least mean pooled reduction percentage was recorded on K. Chipsona-1. The earlier results indicate that, neonicotinoids provide excellent control of many sucking pests including leafhoppers and whitefly (Bhatnagar, 2007). Our results are in agreement of Bacci *et al*., 2018 who reported that sulfoxaflor was effective against sap-feeding insect pests that are resistant to other classes of insecticides, including many that are resistant to the neonicotinoids.

The population of *B. tabaci* and *A. beguttula beguttula* was active on potato crop throughout the crop growth. The incidence of whitefly and leafhoppers population were resulted on main potato crop from residue population from natural host and weeds in the vicinity of the crop. However, the populations of whitefly and leafhoppers were remains low on sprayed potato cultivars when crop was protected by three sprays of sulfoxflor.

Table 1: Mean (%) reduction of whitefly and leafhoppers on different potato cultivars after each spray during main crop season (pooled data)

Potato cultivars	Mean reduction of whiteflies over unsprayed (%)				Mean reduction of leafhoppers over unsprayed (%)			
	1st spray	2nd spray	3rd spray	Mean	1st spray	2nd spray	3rd spray	Mean
K. Chipsona-1	80.83	55.33	100.0	78.72	75.65	39.49	68.98	61.38
K. Anand	73.89	84.80	25.38	61.36	61.67	65.22	100.0	75.63
K. Chipsona-3	62.54	100.0	100.0	87.52	68.95	71.52	73.20	71.23
K. Surya	73.81	87.64	100.0	87.15	75.97	79.30	71.24	75.51
K. Nilkhant	77.38	100.0	75.19	84.19	28.55	69.29	92.66	63.50
K. Bahar	64.86	50.00	100.0	71.62	71.35	79.30	88.33	79.66
K. Khyati	90.32	40.11	100.0	76.81	86.60	87.42	87.59	87.21

Three sprays of sulfoxaflor 12% SL (3ml/10 lit of water) 30, 45 and 55 days old potato crop

The higher mean incidence of whitefly and leafhoppers was recorded in unsprayed potato cultivars due to change of environmental condition i.e., increase of temperature, decline of R.H. and maturity of seven potato cultivar. Low temperature and rains in the months of November and December also influenced the buildup of whitefly and leafhoppers on potato crop (Bhatnagar *et al*., 2016). A perusal of whitefly incidence data revealed that whitefly has become a severe threat to potato crop by not only sucking the sap directly from the tender parts of potato plant and also transmitting important APCLV, resulting quick degeneration of potato seed (Bhatnagar, 2007 and Chandla *et al*., 2001). Similarly, the incidence of leafhoppers has responsible for hopper burn especially in warmer region of the country.

Per cent germination, Av. Plant height and number of compound leaves, disease incidence, per cent different size of tubers, tuber yield and its attributing characters of potato cultivars along with its economic

Pooled per-cent mean germination data did not differ significantly among sprayed and unsprayed (89.0-100.0%) potato cultivars. However, pooled mean data on Plant height, number of compound leaves and % numbers of oversize tubers did differ statistically among the seven potato cultivars under both the conditions during the respective years (Table 2). Similarly, the pooled per cent mean disease incidence varied from 0.0-0.33% among the protected cultivars while it was from 1.13-1.38% among the unprotected cultivars (Table 3). The maximum pooled mean disease incidence (1.38%) was recorded in unsprayed K. Nilkhant. However, minimum mean disease incidence (0.0%) was recorded in sprayed potato cultivars of K. Khyati and K. Chipsona-1.

Table 2. Yield attributing plant and tuber characters of different potato cultivars (sprayed and unsprayed) under field conditions (pooled data of 2018-19 and 2019-20)

Potato cultivars	Yield and tuber characters of potato under sprayed condition								Yield and tuber characters of potato unsprayed condition							
	% Emergence	Av. Plant height/ plant (cm)	Av. Number of comp. leaves / plant	Over size tubers (t/ha)	Seed size tubers (t/ha)	Small size tubers (t/ha)	% Over size tubers	% Seed size tubers	% Small size tubers	% Emergence	Av. Plant height/ plant (cm)	Av. Number of comp. leaves / plant	Over size tubers (t/ha)	Seed size tubers (t/ha)	Small size tubers (t/ha)	% Over size tubers	% Seed size tubers	% Small size tubers
K. Chip.-1	96.00	63.27	16.87	8.65	21.40	2.75	13.07	57.91	28.07	94.63	62.50	16.27	8.59	19.20	2.44	11.72	59.97	27.69
K. Anand	99.57	69.87	16.80	18.42	24.23	2.54	16.97	59.31	23.60	100.0	68.0	15.53	18.72	21.45	3.16	17.88	55.67	26.77
K.Chip.-3	100.0	67.67	15.93	9.75	26.50	2.73	10.78	65.93	23.23	99.10	66.10	16.33	11.49	21.65	2.24	19.15	57.57	25.32
K. Surya	99.53	62.07	13.67	9.06	18.91	2.43	10.74	59.11	28.58	98.63	59.60	13.53	9.30	15.55	2.15	14.07	59.17	26.72
K. Nilkhant	99.57	64.13	15.20	11.50	22.85	3.68	11.80	52.50	36.03	100.0	60.73	14.07	11.64	20.33	3.34	13.31	56.13	30.51
K. Bahar	89.00	56.80	14.93	14.26	23.56	2.71	15.71	61.17	23.58	89.53	53.63	14.73	13.20	21.41	2.11	15.75	62.37	21.84
K. Khyati	98.63	61.27	18.80	31.92	17.51	1.54	30.87	47.33	20.90	98.17	57.67	17.33	27.48	16.14	1.42	27.81	48.63	20.13
S. Em±	3.95	2.22	0.57	2.72	1.79	0.29	3.34	3.13	3.02	4.21	1.78	0.64	3.00	1.84	0.48	5.01	4.27	2.65
CD @ 5%	NS	6.91	1.79	8.49	5.60	0.90	10.4	9.76	NS	NS	5.56	2.01	9.36	NS	NS	6.68	NS	NS

Three sprays of sulfoxaflor 12% SL (3ml/10 lit of water) 30, 45 and 55 days old potato crop

Highest pooled mean tuber yield (49.33 t/ha) was recorded of K. Khyati when crop was protected by three sprays followed by K. Anand (46.90 t/ha) and K. Bahar (40.56 t/ha) (Table 3). However, maximum (12.24 %) increase in tuber yield was recorded in K. Surya followed by K. Chipsona-3 (10.19) and K. Khyati (9.45) (Table 3). By working out cost benefit ratio it is evident that K. Khyati ranked first indicating the maximum return of Rs. 3.18 per rupee invested followed by K. Chipsona-3 with Rs.2.54 and K. Anand Rs.2.47. The maximum C: B ratio 1:3.18 was recorded in K. Khyati due to its high yield potential and protection against insect vectors. Jaykar *et al*. (2019) also reported that K. Khyati, K. Anand and K.Garima were recorded the highest tuber yield under protected conditions. Bhatnagar (2013) also confirmed that soil application of insecticides and two to three sprays of insecticides were required for complete protection of potato crop against insect's pests under field conditions.

CONCLUSION

Three sprays of Sulfoxaflor could be incorporated in spray schedule against sucking pests especially whiteflies and leafhoppers for getting potential yield of seven potato cultivars. The use of pesticides from the emergence of potato crop to 55 days old was effectively reduced the whitefly and leafhopper population, percent disease intensity and significantly increased tuber yield. It can be concluded that, sulfoxaflor is the preferred insecticides with less toxicity to the mammals and can be used to control sucking insect pests in potato IPM programs.

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Table 3. Yield and cost benefit ratios of different potato cultivars (sprayed and unsprayed) under field conditions (pooled data of 2018-19 and 2019-20)

Potato cultivars	% Diseased plants in sprayed plots (50 days old crop)	% Diseased plants in unsprayed plots (50 days old crop)	Mean Tuber yield in unsprayed crop (t/ha)	Mean Tuber yield in sprayed crop (t/ha)	Economics of treatments						
					% Increase in yield over control	increase in yield over control (t/ha)	*Cost of increase yield potato (Rs.)	**Cost of plant protection (Rs.) (1)	Net profit (Rs.) (2)	Benefit: Cost Ratio (1/2)	Rank
K. Chip.-1	0.0	1.27	30.08	32.80	9.04	2.72	19040	7128	11912	1:1.67	7
K. Anand	0.33	1.27	43.36	46.90	8.16	3.54	24780	7128	17652	1:2.47	3
K. Chip.-3	0.33	1.27	35.41	39.02	10.19	3.61	25270	7128	18142	1:2.54	2
K. Surya	0.33	1.27	27.02	30.39	12.24	3.37	23590	7128	16462	1:2.30	4
K. Nilkhant	0.33	1.38	35.24	38.02	7.88	2.78	19460	7128	12332	1:1.73	6
K. Bahar	0.33	1.27	37.68	40.56	7.64	2.88	20160	7128	13032	1:1.82	5
K. Khyati	0.0	1.13	45.07	49.33	9.45	4.26	29820	7128	22692	1:3.18	1
SEm±	0.1	0.11	2.26	1.79	-	-	-	-	-	-	-
CD (p=0.05)	NS	NS	7.05	5.58	-	-	-	-	-	-	-

Note: Three sprays of sulfoxaflor 12% SL (3ml/10 lit of water) 30, 45 and 55 days potato old crop * Cost of potato Rs. 7000/ t ** (Cost of plant protection- Labor+ spray product + Machine)

LITERATURE CITED

Annual Progress Report (2019). Annual progress report of Central Potato Research Institute, Shimla 156p.

Bacci L, Convertini S and Rossaro B (2018) Class of insecticides with a broad range of action against many insect pests. *Journal of Entomological and Acarological Research* **50**:7836

Bhatnagar A (2007) Incidence and succession of thrips, leafhoppers and whitefly in combination of planting dates and potato varieties. *Annals of Plants Protection Sciences* **15** (1): 101-105

Bhatnagar A (2008) Insect associated with potato in Madhya Pradesh. *Pest Management in Horticultural Ecosystem* **13** (2): 21-24

Bhatnagar A (2013) Management of sap sucking and soil insect pests of potato with insecticides, *Pesticide Research Journal* **30**(1): 1-4

Bhatnagar A, Sharma V and Singh BP (2016) Climate change and population buildup of whitefly on potato cultivars in North western India, *Int. j. Agricult. Stat. Sci.*, **12** (1):199-203

Chandel RS, Chandla VK, Verma KS and Pathania M (2013) Insect pest of potato in India: biology and management. In: (eds) Giordanengo P, Alyokhin A and Vincent C, Insect pests of potato, global perspectives on biology and management. Elsevier, Waltham, MA, USA, 227-265 pp.

Jaykar Singh, Bhatnagar A, Kumar M, Singh U and Kumar A (2019). Evaluation of promising potato cultivars against *Bemicia tabaci, Annals of Plants Protection Sciences* **27** (2): 303-305

Rana RK and Pandey SK (2007) In India: An analysis of industry demand. Processed Food Industry, **10:** 26-35

Singh R and Gupta GP (1993) Effect of insecticidal schedules on intermittent population of jassid and whitefly and yield of cotton. *Pesticide Res. J.*, **16**: 432-433

Thakur BS, Dhaanork BK and Puri SN (1991) Bio-efficacy of some insecticides against whitefly infesting cotton. *J. Maharashtra Agril. Univ.,* **16**: 432-433

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UPDATES ON MOLECULAR MARKERS LINKED TO POTATO VIRUS Y (PVY) RESISTANCE GENES IN POTATO

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ABSTRACT: Potato is the leading non-grain food product in the world and stands third important food crop after wheat and rice. It is a future crop for ensuring food security in the developing world but it is affected by several biotic and abiotic factors which reduce the total yield. Among the biotic stresses, PVY is also the worldwide problem in potato causing serious damage. PVY^{O}, $PVY^{N,}$ and PVY^{C} are the main strains of PVY causing losses to potato cultivation. The complex strains of the PVY are responsible for different foliar and tuber symptoms in potato. The recombination between different strains creates new harmful strains (PVY^{NTN}, $PVY^{N:O}$, PVY^{N-Wi}) which from the last many years becomes a serious problem. Two types of resistance genes (HR and ER) are mapped on different potato species for PVY strains. Extreme resistance genes are reported in *S. tuberosum gp. andigenum* (Ry_{adg}), *S. stoloniferum* (Ry_{sto} and Ry_{fsto}) and *S. chacoense* (Ry_{chc}). Likewise, hypersensitive response (HR) genes are found in *S. tuberosum* (Ny_{tbr}, *Ny-1*, and *Ny-2*), *S. sparsipilum* (Nc_{spl}), and Sarpo Mira (*Ny-Smira*). Ry_{adg} and *Ny-2* genes were reported on chromosome no XI, Ry_{sto} and Ry_{fsto} on chromosome no XII, Ny_{tbr} and Nc_{spl} chromosome no IV, and Ry_{chc}, *Ny-1*, and *Ny-Smira* on chromosome no IX. Till now various molecular markers (AFLP, SCAR, RAPD, STS, CAPS, and RGL) linked to different PVY resistance genes are reported in various populations. Marker-based selection in the breeding programme can hasten the breeding process and reduce dependency on taking up chemical or other management practices.

KEYWORDS: Potato virus Y (PVY), extreme resistance (ER), Hypersensitive resistance (HR)

INTRODUCTION

Potato is the leading non-grain food product in the world and stands third important food crop after wheat and rice (Spooner & Hetterscheid, 2016) and a future crop for ensuring food security in the developing world (Tiwari et al., 2020). The area under potato worldwide is 19.2 Mha with a 376.8 MT annual production (Tiwari et al., 2021). More than 50 viruses affect potato production worldwide (Lal et al., 2021) but out of all, six viruses Potato leaf roll virus (PLRV), Potato virus Y (PVY), potato virus X (PVX), potato virus A (PVA), potato virus S (PVS), and potato virus M (PVM), is the most important viruses in terms of distribution and their effect on yields (Ahmadvand et al., 2012).

PVY problem in potato is worldwide and it is mainly transmitted through aphids in a non-persistent manner. It was reported to affect more than 9 families including 14 genera of the Solanaceae, such as potato, pepper, tomato, brinjal, tomato. PVY is a type member of the genus Potyvirus, family Potyviridae. The virus has a positive-sense single-stranded linear RNA genome responsible for coding for a large polyprotein. The yield losses by PVY in potato varies between 30 to 80% (Ahmadvand et al., 2012) depending upon the genotype. Globally, it's a common problem in most potato-producing areas especially in seed potato production because of the strict tolerance limit for certification. The virus is transmitted to the next generation through its vegetative mode of propagation from infected material. Under field conditions, it

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is transmitted naturally by several species of aphids i.e., more than 50 species with varying efficiency (Ragsdale et al., 2001). The common symptoms are yellowing of leaflets, mottling, vein necrosis, plant dwarfing, leaf-dropping, lower quality tubers, and under heavy infection premature plant death (Slater et al., 2020). Potyvirus is known for their tendency to evolve more rapidly through recombination's which might be to gain the selective advantage in a specific host/ in a given environment (Gibbs et al., 2017a)and it almost certainly originated in the Andes, where its hosts were domesticated. We have inferred the phylogeny of the published genomic sequences of 240 PVY isolates collected since 1938 worldwide, but not the Andes. All fall into five groupings, which mostly, but not exclusively, correspond with groupings already devised using biological and taxonomic data. Only 42 percent of the sequences are not recombinant, and all these fall into one or other of three phylogroups; the previously named C (common. The strains of PVY are distinguished based on their reactions toward a series of resistance genes present in potato. If a strain is eliciting hypersensitive (HR) response in genotypes of potato carrying the Ny gene, like 'Desiree' and 'Maris Bard' it was named as PVY^{O}. On the other hand, if the genotype, such as 'King Edward' carrying the *Nc* gene elicits HR response, the strain was as PVY^{C}. The strains not eliciting HR responses toward these two genes (*Ny* and *Nc*) in potato genotypes were named PVY^{N} (Jones 1990; Singh et al., 2008; Valkonen et al., 1997).

Till now various PVY strains (PVY^{O}, PVY^{N}, PVY^{NTN}, $PVY^{N\text{-}Wi}$, PVY^{C}, PVY^{Z}, PVY^{E}) are recognized which causes heavy losses to potato cultivation (Lacomme *et al*., 2017; Singh *et al*., 2008). The PVY^{O} and PVY^{C} strains were distinguished by their reactions with the potato Ny and Nc hypersensitivity genes (Gibbs *et al*., 2017b). The ordinary strain PVY^{O} is most prevalent in the majority of the potato growing areas. The symptoms and severity of PVY^{O} vary with potato cultivars, but generally, it causes mosaic, leaf necrosis followed by the leaf drop. The recombinant strains of PVY i.e., PVY^{NTN}, $PVY^{N\text{-}Wi}$ an $PVY^{N:O}$ induces characteristic veinal necrosis in tobacco, and therefore they are called necrotic strains. These strains are often associated with tuber syndromes i.e., potato tuber necrotic disease (PTNRD) in susceptible cultivars of potato (Beczner *et al*., 1984; Glais *et al*., 2002) and canoe-shaped cracks (Benedict *et al*., 2015) and hence pose a real threat for potato production. Since potato crop is mainly propagated through tuber so chances of virus spread across generations is more through infected tubers. Host resistance is the ultimate solution of this virus so many resistance genes are reported in wild and cultivated species. So the development of resistant variety by incorporating these resistance genes in a breeding programme is the most effective way to control this virus (Ana C. Fulladolsa *et al*., 2015). The utilization of wild species in potato breeding programme have already an intricate history due to their large secondary gene pool (Sood *et al*., 2021).

Mapping of resistance genes in potato species

Various extreme resistance (ER) and hypersensitive response (HR) genes are mapped for PVY resistance in potato. Hypersensitive response genes are effective against a single strain of PVY, related to cell death, and prevent the spreading of virus-cell to cell and extreme resistance genes are effective of all strains of PVY with strong suppression. Extreme resistance genes are reported in *S. tuberosum sp. Andigenum* (Ry_{adg}) (Dalla Rizza et al., 2006a; Kasai et al., 2000)based on nucleotide differences within

resistance gene-like fragments isolated from a potato plant carrying the Ry adg gene, which confers extreme resistance to potato Y potyvirus (PVY, *S. stoloniferum* (Ry_{sto} and Ry_{fsto}) (I. Cernák et al., 2008; Song & Schwarzfischer, 2008) and *S. chacoense* (Rychc) (Hosaka *et al*., 2001; Sato *et al*., 2006). Likewise hypersensitive response (HR) genes are found in *S. tuberosum* (Nytbr, Ny-1 and Ny-2) (Celebi-Toprak *et al*., 2002; K Szajko *et al*., 2008; Katarzyna Szajko *et al*., 2014), *S. sparsipilum* (Ncspl) (Moury *et al*., 2011) and Sarpo Mira (Ny-Smira) (Tomczyńska *et al*., 2014). Ryadg and Ny-2 genes were reported on chromosome no XI (Katarzyna Szajko *et al*., 2014), Rysto and Ryfsto on chromosome no XII (Flis *et al*., 2005; Milbourne *et al*., 1998), Nytbr and Ncspl chromosome no IV (Celebi-Toprak *et al*., 2002; Moury *et al*., 2011) Rychc, Ny-1 and Ny-Smira on chromosome no IX (Hosaka *et al*., 2001; Tomczyńska *et al*., 2014). These genes are used in the various breeding programme at the global level according to the prevalence of different PVY strains.

Molecular markers linked to different resistance genes

Till now various molecular markers linked to different PVY resistance genes are reported in different populations. Kasai et al. 2000 reported SCAR marker (RYSC3) linked to Ry_{adg} gene, likewise AFLP (TG 508, M45) marker (Dalla Rizza *et al*., 2006a; Hämäläinen *et al*., 1997), CAPS (ADG2) marker (Sorri *et al*., 1999), RGL (ADG1 and ADG2) marker (Hämäläinen *et al*., 1998) were also reported linked to this gene which are mentioned in table no 1. SSR (STM0003), AFLP (M35, M45), STS (YES3-3A and YES3-3B), SCAR ($SCAR_{ysto4}$), and CAPS (GP122) markers were reported by various workers which linked to extreme resistance gene Ry_{sto} in different potato populations (Brigneti *et al*., 1997; István Cernák *et al*., 2008; Dalla Rizza *et al*., 2006a; Heldák *et al*., 2007; Milbourne *et al*., 1998; Song *et al*., 2005; Song & Schwarzfischer, 2008). One CAPS (GP122) and ISSR marker (UBC857) linked to Ry_{fsto} gene were reported by Flis *et al*. 2005; Witek *et al*. 2006. Celebi-Toprak *et al*. 2002 reported RFLP marker (TG506) was linked to hypersensitive response Ny_{tbr} gene. For Ry_{chc} gene Hosaka *et al*. 2001 reported RAPD marker (38-530) linked to this gene. Szajko *et al*. 2008, 2014 reported SCAR (SC895) and CAPS marker (S1d11) linked to *Ny-1* gene and one CAPS marker (B11.6) linked to *Ny-2* gene. Tomczyńska *et al*. 2014 reported STS marker (Ry186) linked to *Ny-Smira* gene.

Use of linked markers in the breeding programme

Slater *et al*. 2020 screened Australian parental collection for PVY resistance gene *Ryadg* or *Rysto* with the help of STM0003, M45, and RYSC3 linked marker. These markers differentiate all the parental cultivars for PYV resistance and they concluded that these markers can be used in marker-assisted selection (MAS) for the breeding programme. Whitworth et al. 2009 evaluate *S. tuberosum ssp. Andigena* derived accessions for multiple PVY strains (PVY^{NTN}, $PVY^{N:O}$, PVY^{O}, PVY^{N}) with the help of ADG2, RYSC3 and RYSC4 linked markers. The presence of the marker was also in close agreement with potato virus Y (PVY) resistance in the cultivars/ clones. This study is helpful for breeders for the development of variety which will show durable resistance to PVY and pyramiding of divergent resistance genes. Dalla Rizza et al. 2006beye depth, shape screened potato germplasms for extreme resistance to PVY with the help of two molecular markers (RYSC3 and M45) and out of total germplasm 44% of accessions shown extreme resistance genes. Ottoman et al. 2009 evaluate segregating population of potato for Ry_{adg}

Table 1: Molecular marker linked to different PVY resistance genes

Gene	Species	Resistance response (HR/ER)	Chromosome location	Linked marker	Type of marker	Reference
Ry_{adg}	*S. tuberosum sp. Andigenum*	ER	XI	RYSC3	SCAR	Kasai et al., 2000
				TG508	AFLP	Hämäläinen et al., 1997
				ADG2	CAPS (*BbvI*)	Sorri et al., 1999
				ADG1	RGL	Hämäläinen et al., 1998
				ADG2	RGL	Hämäläinen et al., 1998
				M45	AFLP	Dalla Rizza et al., 2006a
Ry_{sto}	*S. stoloniferum*	ER	XII	STM0003	SSR	Milbourne et al., 1998; Song et al., 2005
				M35	AFLP	Brigneti et al., 1997
				M45	AFLP	Dalla Rizza et al., 2006a
				YES3-3A	STS	Song & Schwarzfischer, 2008
				YES3-3B	STS	Song & Schwarzfischer, 2008
				SCARysto4	SCAR	István Cernák et al., 2008
				GP122	CAPS (*Eco*RV)	Heldák et al., 2007
Ry_{fsto}	*S. stoloniferum*	ER	XII	GP 122	CAPS (*Eco*RV)	Flis et al., 2005
				UBC857	ISSR	Flis et al., 2005
				GP122	CAPS (*Eco*RV)	Witek et al., 2006
Ny_{tbr}	*S. tuberosum*	HR	IV	TG506	RFLP	Celebi-Toprak et al., 2002
Ry_{chc}	*S. chacoense*	ER	IX	38-530	RAPD	Hosaka et al., 2001; Sato et al., 2006
Ny-1	*S. tuberosum*	HR	IX	$SC895_{1139}$	SCAR	K Szajko et al., 2008
				S1d11	CAPS (*Mn/I*)	Katarzyna Szajko et al., 2014
Ny-2		HR	XI	$B11.6_{1600}$	CAPS (*Eco*RI)	Katarzyna Szajko et al., 2014
Nc_{spl}	*S. sparsipilum*	HR	IV			Moury et al., 2011
Ny-Smira	Sarpo Mira	HR	IX	Ry186	STS	Tomczyńska et al., 2014

gene, artificially inoculated with PVY^{O} strain via two molecular markers (RYSC3 and ADG2) and their results showed close agreement with ELISA assay. So the use of molecular markers can be an alternative tool to ELISA for the detection of PVY strain. Valkonen et al. 2008 Solanum stoloniferum, carries a dominant gene, Ry_{sto}, which confers extreme resistance (ER used two molecular markers (GP122 and STM00003) for the detection of Ry_{sto} gene in F_1 diploid populations which were derived from *S. stoloniferum* accession and these markers detected those populations which expressed ER to PVY. Likewise, Fulladolsa et al. 2015 used YES3-3B and RYSC3 markers linked to genes Ry_{sto} and Ry_{adg} respectively in their breeding population. Bhardwaj et al. 2015 screened 119 genotypes of potato for Ry_{sto} and Ry_{adg} gene via STM0003 and RYSC3 marker respectively and concluded that RYSC3 was the better marker for diagnostic of PVY resistance. A similar type of study was done by Sharma et al. 2014; Kneib et al. 2017; Bhardwaj et al. 2019; Fulladolsa et al. 2019; Byarugaba et al. 2021late blight, viruses and nematodes are

the most devastating. Varieties resistant to individual stress have been deployed but the production remained limited because of other biotic stresses affecting the crop. Potato cultivars having multiple disease resistance are urgently required to boost production. Resistance to late blight is both qualitative and quantitative while extreme resistance to PVY can be imparted by the single dominant genes Ryadg and Rysto. Likewise resistance to potato cyst nematode is mainly imparted by the single dominant H1 and Gro1-4 genes. All these genes have been mapped and tightly linked molecular markers are available to perform marker-assisted selection (MAS in different breeding populations for detection of PVY resistance via various linked molecular markers. Elison et al. 2020 used three linked markers (RYSC3, YES3-3B, and RY186) for simultaneous detection of three independent genes (Ry_{adg}, $Ry_{sto,}$ and Ry_{chc}) in multiplex PCR and concluded that this assay allows higher throughput and simplicity in developing varieties with multiple Ry genes.

CONCLUSION

It is now clear that different recombinant strains of PVY virus are emerging which can cause severe damage in the future. So, screening of more wild species for mapping of other resistance genes and used them in a breeding programme is the need of the hour. Using wild species where resistance genes were already mapped in a regular breeding programme is in the infancy stage. If they are not crossable to cultivated species breeder should them by either manipulating their ploidy level or by protoplast fusion techniques. The use of molecular markers linked to resistance genes will reduce time or cost compared to conventional phenotypic screening. Potato has a large secondary gene pool as compared to other crops so a new source of resistance should search in other wild species to broaden our experimental gene pool.

LITERATURE CITED

Ahmadvand, R., Takács, A., Taller, J., Wolf, I., & Polgár, Z. (2012). Potato viruses and resistance genes in potato. In *Acta Agronomica Hungarica* (Vol. 60, Issue 3, pp. 283–298). Akadémiai Kiadó. https://doi.org/10.1556/AAgr.60.2012.3.10

Beczner, L., Horváth, J., Romhányi, I., & Förster, H. (1984). Studies on the etiology of tuber necrotic ringspot disease in potato. *Potato Research*, *27*(3), 339–352. https://doi.org/10.1007/BF02357646

Benedict, C. A., McMoran, D. W., Inglis, D. A., & Karasev, A. V. (2015). Tuber Symptoms Associated with Recombinant Strains of Potato virus Y in Specialty Potatoes Under Western Washington Growing Conditions. *American Journal of Potato Research*, *92*(5), 593–602. https://doi.org/10.1007/s12230-015-9472-6

Bhardwaj, V., Sharma, R., Dalamu, Srivastava, A. K., Baswaraj, R., Singh, R., & Singh, B. P. (2015). Molecular characterization of potato virus Y resistance in potato (Solanum tuberosum L.). *Indian Journal of Genetics and Plant Breeding*, *75*(3), 389–392. https://doi.org/10.5958/0975-6906.2015.00062.0

Bhardwaj, V., Sood, S., Kumar, A., Vanishree, G., Sharma, S., Sundaresha, S., Raigond, B., Kumar, R., Bairwa, A., Lal, M., & Chakrabarti, S. K. (2019). Efficiency and reliability of marker assisted selection for resistance to major biotic stresses in potato. *Potato Journal*, *46*(1), 56–66.

Brigneti, G., Garcia-Mas, J., & Baulcombe, D. C. (1997). Molecular mapping of the potato virus Y resistance gene Ry(sto) in potato. *Theoretical and Applied Genetics*, *94*(2), 198–203. https://doi.org/10.1007/s001220050400

Byarugaba, A. A., Mukasa, S. B., Barekye, A., & Rubaihayo, P. R. (2021). Prevalence of R Genes for Resistance to Potato Viruses in Uganda Germplasm. *Potato Research*, *64*(2), 267–276. https://doi.org/10.1007/s11540-020-09477-7

Celebi-Toprak, F., Slack, S. A., & Jahn, M. M. (2002). A new gene, Nytbr, for hypersensitivity to Potato virus Y from Solanum tuberosum maps to chromosome IV. *Theoretical and Applied Genetics*, *104*(4), 669–674. https://doi.org/10.1007/s001220100749

Cernák, I., Taller, J., Wolf, I., Fehér, E., Babinszky, G., Alföldi, Z., Csanádi, G., & Polgár, Z. (2008).

Analysis of the applicability of molecular markers linked to the PVY extreme resistance gene Rysto, and the identification of new markers. *Acta Biologica Hungarica*, *59*(2), 195–203. https://doi.org/10.1556/ABiol.59.2008.2.6

Cernák, István, Decsi, K., Nagy, S., Wolf, I., Polgár, Z., Gulyás, G., Hirata, Y., & Taller, J. (2008). Development of a locus-specific marker and localization of the Ry sto gene based on linkage to a catalase gene on chromosome XII in the tetraploid potato genome. *Breeding Science*, *58*(3), 309–314. https://doi.org/10.1270/jsbbs.58.309

Dalla Rizza, M., Vilaró, F. L., Torres, D. G., & Maeso, D. (2006a). Detection of PVY extreme resistance genes in potato germplasm from the Uruguayan breeding program. *American Journal of Potato Research*, *83*(4), 297–304. https://doi.org/10.1007/BF02871590

Dalla Rizza, M., Vilaró, F. L., Torres, D. G., & Maeso, D. (2006b). Detection of PVY extreme resistance genes in potato germplasm from the Uruguayan breeding program. *American Journal of Potato Research*, *83*(4), 297–304. https://doi.org/10.1007/BF02871590

Elison, G. L., Hall, D. G., Novy, R. G., & Whitworth, J. L. (2020). Development and Application of a Multiplex Marker Assay to Detect PVY Resistance Genes in Solanum tuberosum. *American Journal of Potato Research*, *97*(3), 289–296. https://doi.org/10.1007/s12230-020-09777-1

Flis, B., Hennig, J., Strzelczyk-Żyta, D., Gebhardt, C., & Marczewski, W. (2005). The Ry-f sto gene from Solanum stoloniferum for extreme resistant to Potato virus Y maps to potato chromosome XII and is diagnosed by PCR marker GP122 718 in PVY resistant potato cultivars. *Molecular Breeding*, *15*(1), 95–101. https://doi.org/10.1007/s11032-004-2736-3

Fulladolsa, Ana C., Navarro, F. M., Kota, R., Severson, K., Palta, J. P., & Charkowski, A. O. (2015). Application of Marker Assisted Selection for Potato Virus Y Resistance in the University of Wisconsin Potato Breeding Program. *American Journal of Potato Research*, *92*(3), 444–450. https://doi.org/10.1007/s12230-015-9431-2

Fulladolsa, Ana Cristina, Charkowski, A., Cai, X., Whitworth, J., Gray, S., & Jansky, S. (2019). Germplasm with Resistance to Potato virus Y Derived from Solanum chacoense: Clones M19 (39–7) and M20 (XD3). *American Journal of Potato Research*, *96*(4), 390–395. https://doi.org/10.1007/s12230-019-09719-6

Gibbs, A. J., Ohshima, K., Yasaka, R., Mohammadi, M., Gibbs, M. J., & Jones, R. A. C. (2017a). The phylogenetics of the global population of potato virus y and its necrogenic recombinants. *Virus Evolution*, *3*(1), 1–12. https://doi.org/10.1093/ve/vex002

Gibbs, A. J., Ohshima, K., Yasaka, R., Mohammadi, M., Gibbs, M. J., & Jones, R. A. C. (2017b). The phylogenetics of the global population of potato virus y and its necrogenic recombinants. *Virus Evolution*, *3*(1). https://doi.org/10.1093/ve/vex002

Glais, L., Tribodet, M., & Kerlan, C. (2002). Genomic variability in Potato potyvirus Y (PVY): Evidence that PVYNW and PVYNTN variants are single to multiple recombinants between PVYO and PVYN isolates. *Archives of Virology*, *147*(2), 363–378. https://doi.org/10.1007/s705-002-8325-0

Hämäläinen, J. H., Sorri, V. A., Watanabe, K. N., Gebhardt, C., & Valkonen, J. P. T. (1998). Molecular examination of a chromosome region that controls resistance to potato Y and A potyviruses in potato. *Theoretical and Applied Genetics*, *96*(8), 1036–1043. https://doi.org/10.1007/s001220050836

Hämäläinen, J. H., Watanabe, K. N., Valkonen, J. P. T., Arihara, A., Plaisted, R. L., Pehu, E., Miller, L., & Slack, S. A. (1997). Mapping and marker-assisted selection for a gene for extreme resistance to potato virus Y. *Theoretical and Applied Genetics*, *94*(2), 192–197. https://doi.org/10.1007/s001220050399

Heldák, J., Bežo, M., Štefúnová, V., & Galliková, A. (2007). Selection of DNA markers for detection of extreme resistance to potato virus Y in tetraploid potato (Solanum tuberosum L.) F1 progenies. *Czech Journal of Genetics and Plant Breeding*, *43*(4), 125–134. https://doi.org/10.17221/2074-cjgpb

Hosaka, K., Hosaka, Y., Mori, M., Maida, T., & Matsunaga, H. (2001). Detection of a simplex RAPD marker linked to resistance to potato virus Y in a tetraploid potato. *American Journal of Potato Research*, *78*(3), 191–196. https://doi.org/10.1007/BF02883544

Kasai, K., Morikawa, Y., Sorri, V. A., Valkonen, J., Gebhardt, C., & Watanabe, K. N. (2000). Development of SCAR markers to the PVY resistance gene Ry adg based on a common feature of plant disease resistance genes. *Genome*, *43*(1), 1–8. https://doi.org/10.1139/g99-092

Kneib, R. B., Kneib, R. B., Pereira, A. da S., & Castro, C. M. (2017). Allele dosage of PVY resistance genes in potato clones using molecular markers. *Crop Breeding*

and Applied Biotechnology, *17*(4), 306–312. https://doi.org/10.1590/1984-70332017v17n4a47

Lacomme, C., Glais, L., Bellstedt, D. U., Dupuis, B., Karasev, A. V., & Jacquot, E. (2017). Potato virus Y: Biodiversity, pathogenicity, epidemiology and management. In *Potato Virus Y: Biodiversity, Pathogenicity, Epidemiology and Management*. https://doi.org/10.1007/978-3-319-58860-5

Lal, M. K., Tiwari, R. K., Kumar, R., Naga, K. C., Kumar, A., Singh, B., Raigond, P., Dutt, S., Chourasia, K. N., Kumar, D., Parmar, V., & Changan, S. S. (2021). Effect of potato apical leaf curl disease on glycemic index and resistant starch of potato (Solanum tuberosum L.) tubers. *Food Chemistry*, *359*, 129939. https://doi.org/10.1016/j.foodchem.2021.129939

Milbourne, D., Meyer, R. C., Collins, A. J., Ramsay, L. D., Gebhardt, C., & Waugh, R. (1998). Isolation, characterisation and mapping of simple sequence repeat loci in potato. *Molecular and General Genetics*, *259*(3), 233–245. https://doi.org/10.1007/s004380050809

Moury, B., Caromel, B., Johansen, E., Simon, V., Chauvin, L., Jacquot, E., Kerlan, C., & Lefebvre, V. (2011). The helper component proteinase cistron of Potato virus Y induces hypersensitivity and resistance in Potato genotypes carrying dominant resistance genes on chromosome IV. *Molecular Plant-Microbe Interactions*, *24*(7), 787–797. https://doi.org/10.1094/MPMI-10-10-0246

Ottoman, R. J., Hane, D. C., Brown, C. R., Yilma, S., James, S. R., Mosley, A. R., Crosslin, J. M., & Vales, M. I. (2009). Validation and implementation of marker-assisted selection (MAS) for PVY resistance (Ryadg gene) in a tetraploid potato breeding program. *American Journal of Potato Research*, *86*(4), 304–314. https://doi.org/10.1007/s12230-009-9084-0

Ragsdale, D. W., Radcliffe, E. B., & DiFonzo, C. D. (2001). Epidemiology and Field Control of PVY and PLRV. *Virus and Virus-like Diseases of Potatoes and Production of Seed-Potatoes*, 237–270. https://doi.org/10.1007/978-94-007-0842-6_22

Sato, M., Nishikawa, K., Komura, K., & Hosaka, K. (2006). Potato virus Y resistance gene, Rychc, mapped to the distal end of potato chromosome 9. *Euphytica*, *149*(3), 367–372. https://doi.org/10.1007/s10681-006-9090-y

Sharma, R., Bhardwaj, V., Dalamu, D., Kaushik, S. K., Singh, B. P., Sharma, S., Umamaheshwari, R., Baswaraj, R., Kumar, V., & Gebhardt, C. (2014). Identification of elite potato genotypes possessing multiple disease resistance genes through molecular approaches. *Scientia Horticulturae*, *179*, 204–211. https://doi.org/10.1016/j.scienta.2014.09.018

Singh, R. P., Valkonen, J. P. T., Gray, S. M., Boonham, N., Jones, R. A. C., Kerlan, C., & Schubert, J. (2008). Discussion paper: The naming of Potato virus Y strains infecting potato. In *Archives of Virology* (Vol. 153, Issue 1, pp. 1–13). Springer. https://doi.org/10.1007/s00705-007-1059-1

Slater, A. T., Schultz, L., Lombardi, M., Rodoni, B. C., Bottcher, C., Cogan, N. O. I., & Forster, J. W. (2020). Screening for resistance to PVY in Australian potato germplasm. *Genes*, *11*(4), 429. https://doi.org/10.3390/genes11040429

Song, Y. S., Hepting, L., Schweizer, G., Hartl, L., Wenzel, G., & Schwarzfischer, A. (2005). Mapping of extreme resistance to PVY (Rysto) on chromosome XII using anther-culture-derived primary dihaploid potato lines. *Theoretical and Applied Genetics*, *111*(5), 879–887. https://doi.org/10.1007/s00122-005-0010-7

Song, Y. S., & Schwarzfischer, A. (2008). Development of STS markers for selection of extreme resistance (Ry sto) to PVY and maternal pedigree analysis of extremely resistant cultivars. *American Journal of Potato Research*, *85*(2), 159–170. https://doi.org/10.1007/s12230-008-9012-8

Sood, S., Kumar, A., Singh, B., S, S., & Bhardwaj, V. (2021). Cytoplasmic genome of Indian potato varieties and breeding lines vis a vis prospects in potato breeding. *Heliyon*, *7*(3), e06365. https://doi.org/10.1016/j.heliyon.2021.e06365

Sorri, V. A., Watanabe, K. N., & Valkonen, J. P. T. (1999). Predicted kinase-3a motif of a resistance gene analogue as a unique marker for virus resistance. *Theoretical and Applied Genetics*, *99*(1–2), 164–170. https://doi.org/10.1007/s001220051221

Spooner, D. M., & Hetterscheid, W. L. A. (2016). 13. Origins, Evolution, and Group Classifi cation of Cultivated Potatoes. In *Darwin's Harvest* (pp. 285–307). Columbia University Press. https://doi.org/10.7312/motl13316-014

Szajko, K, Chrzanowska, M., Witek, K., Strzelczyk-Zyta, D., Zagórska, H., Gebhardt, C., Hennig, J., & Marczewski, W. (2008). The novel gene Ny-1 on potato chromosome IX confers hypersensitive

resistance to Potato virus Y and is an alternative to Ry genes in potato breeding for PVY resistance. *Theoretical and Applied Genetics*, *116*(2), 297–303. https://doi.org/10.1007/s00122-007-0667-1

Szajko, Katarzyna, Strzelczyk-□yta, D., & Marczewski, W. (2014). Ny-1 and Ny-2 genes conferring hypersensitive response to potato virus Y (PVY) in cultivated potatoes: Mapping and marker-assisted selection validation for PVY resistance in potato breeding. *Molecular Breeding*, *34*(1), 267–271. https://doi.org/10.1007/s11032-014-0024-4

Tiwari, R. K., Bashyal, B. M., Shanmugam, V., Lal, M. K., Kumar, R., Sharma, S., Vinod, Gaikwad, K., Singh, B., & Aggarwal, R. (2021). Impact of Fusarium dry rot on physicochemical attributes of potato tubers during postharvest storage. *Postharvest Biology and Technology*, *181*, 111638. https://doi.org/10.1016/j.postharvbio.2021.111638

Tiwari, R. K., Kumar, R., Sharma, S., Naga, K. C., Subhash, S., & Sagar, V. (2020). Continuous and emerging challenges of silver scurf disease in potato. In *International Journal of Pest Management* (pp. 1–13). Taylor & Francis. https://doi.org/10.1080/09670874.2020.1795302

Tomczyńska, I., Jupe, F., Hein, I., Marczewski, W., & Śliwka, J. (2014). Hypersensitive response to Potato virus Y in potato cultivar Sárpo Mira is conferred by the Ny-Smira gene located on the long arm of chromosome IX. *Molecular Breeding*, *34*(2), 471–480. https://doi.org/10.1007/s11032-014-0050-2

Valkonen, J. P. T., Wiegmann, K., Hämäläinen, J. H., Marczewski, W., & Watanabe, K. N. (2008). Evidence for utility of the same PCR-based markers for selection of extreme resistance to Potato virus Y controlled by Rysto of Solanum stoloniferum derived from different sources. *Annals of Applied Biology*, *152*(1), 121–130. https://doi.org/10.1111/j.1744-7348.2007.00194.x

Whitworth, J. L., Novy, R. G., Hall, D. G., Crosslin, J. M., & Brown, C. R. (2009). Characterization of broad spectrum potato virus Y resistance in a Solanum tuberosum ssp. andigena-Derived population and select breeding clones using molecular markers, grafting, and field inoculations. *American Journal of Potato Research*, *86*(4), 286–296. https://doi.org/10.1007/s12230-009-9082-2

Witek, K., Strzelczyk-żyta, D., Hennig, J., & Marczewski, W. (2006). A multiplex PCR approach to simultaneously genotype potato towards the resistance alleles Ry-fsto and Ns. *Molecular Breeding*, *18*(3), 273–275. https://doi.org/10.1007/s11032-006-9021-6

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STRENGTHENING THE INTELLECTUAL PROPERTY MANAGEMENT AND COMMERCIALIZATION PORTFOLIO OF INSTITUTE POTATO TECHNOLOGIES

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ABSTRACT: An ecosystem of vibrant intellectual property (IP) creation and commercialization will not only promote the culture of creativity and innovation among researchers but also enhance the economic development of the country. The value and economic reward for the owners of IP rights come only from their commercialization and there is need to promote the public sector initiative for IP commercialization. In the recent decade, ICAR-CPRI has made concerted efforts for the creation of IP assets, their maintenance and commercialization. IP protection status of the institute comprises the registration and protection of 22 potato varieties through PPV&FRA, filing of 22 patents, 12 designs and two trademarks. In the last decade, after the establishment of the institute technology management unit (ITMU), the institute has licensed around 16 technologies to more than 75 entrepreneurs & earned revenue of around 22 million INR. More and more entrepreneurship should be encouraged, so that the financial value of IPRs protection may be captured. This study demonstrates the intellectual property management and commercialization status of the institute in the last decade.

KEYWORDS: Intellectual property, commercialization, potato variety, patent, technologies

INTRODUCTION

Agriculture science has been the engine of growth and led to quantum jumps in productivity in the past. The agriculture and allied sector contributes 20.2% share in India Gross Domestic Product (GDP) in 2020-21 (NSO, 2021). Potato came to India nearly 400 years ago and it contributed <1% of the global production till mid 20th Century. In India, the R&D in potato completely changed the scenario in the last 7 decades and potato institute has played an important role to make the country self-reliant in potato production. After the introduction of high yielding potato varieties and development of location-specific crop practices by the institute triggered rapid growth in potato production. India is the second-largest potato producer and presently contributing nearly 12% of global production (51.2% million tons) (CPRI, 2019). The institute has 5 divisions, six regional stations and 23 All India Coordinated Research Project (Potato) centres in different climatic locations of the country for conducting multi-location testing. Researchers of the institute have contributed immensely to the increased productivity of potato crop by application of conventional breeding and cutting edge biotechnological tools. Beside this, *in vitro* propagation, genomics, proteomics, protoplast fusion, plant diagnostic, high tech seed production, post harvest processing, development of farm machineries and farm practices has strengthened the research output of the institute (CPRI, 2020).

Till date, 66 potato varieties have been developed and released by the institute. All the varieties has been tested for cultivation under diverse agro-climatic conditions of the

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country, which possesses multiple resistances to different biotic and abiotic stresses and 7 of them are suitable for processing. Prior to establishment of institute technology management unit (ITMU) in 2006, several technologies developed by the institute in last seven decade including seed plot technique, potato varieties etc. were already transferred in public domain to fulfill the national demand pertaining to nutritional and food security (Singh *et al.*, 2018). Growing trends in the creation and filing of IP in recent years has expanded also in agricultural institutions. The awareness of IP management in recent past has also increased among the researchers in national agricultural research system. The R&D pertaining to potato has been an innovative area; much of the IP created remains unprotected. The main cause of poor IP portfolio is lack of awareness among researcher and the perception that IP protection is either not required or that the process to obtain it is unnecessarily complicated. A vibrant intellectual property ecosystem will not only stimulate the economic development in country, but also enhance public welfare by protecting the rights of all creators and innovators in the research organizations. A strong IPR portfolio will play a big role in attracting investment into the country along with boosting local business ecosystem. Indian Council of Agricultural Research (ICAR) has framed the guidelines on IPR in 2006 and recently revised in 2018. These IP guidelines will definitely help to nurture the IP culture in agriculture based organizations. The creators and inventors engaged in this agriculture sector will realize their potential for generating, protecting and utilizing IPRs which would contribute to revenue creation and business development (NIPRP, 2016). This article describes the working framework of ITMU and their role in the IP management and technology transfer/commercialization at institute level.

Role of national policy for IP management

The 21st century belongs to the knowledge era and is driven by the knowledge economy. A strong IPR regime led to fostering creativity, an innovation that thereby promotes entrepreneurship, enhances socio-economic and cultural development in the country. In India, the national intellectual property rights (IPR) policy was developed the first time by the Ministry of Commerce and Industry, Govt. of India in 2016 with the holistic slogan "Creative India; Innovative India". Public sector R&D working in the country has also developed and revised their IPR guidelines as per the national IPR policy. The ICAR has revised their guidelines in 2018 as per the national IPR policy 2016 (ICAR, 2018 & NIPRP, 2016). Effective implementation of IPRs legislation and related policies led to enhance the significant outputs from R&D in the national agricultural research system.

Structure of IP management & technology commercialization in ICAR

Commercialization strategies involve profiting from IPRs through external exploitation which represents a fundamental avenue for creating IP value for organization. The ICAR has created the channel for management of IPR portfolio and technology transfer/commercialization for its institutions as per the prevailing national IPR and other related laws and policies. ICAR has constituted the intellectual property & technology management unit (IP&TM) at headquarter level to act as the central facilitating decision making body to coordinate and monitor the IP portfolio of its institutes as per the ICAR guidelines for IPM and technology transfer/commercialization, 2018. This unit allocates the budget to each ITMU for IP protection, maintenance and commercialization of developed technologies. The main responsibility of this unit is to

monitor the IP matters and provide necessary advice and support to their institutes. The ICAR has constituted central technology management committee (CTMC) and its secretariat situated at ICAR headquarters and Director General of the council designated as chairman of the committee. At the zone level, zonal technology management committee (ZTMC) has been constituted to take decision for the IP and technology management of the concerned ICAR institutions. The respective director of the zonal institute designated as chairman of the ZTMC. The main role of ZTMC is to advise the institutions which are under their jurisdiction for the matter related to IP, technology management and commercialization (Table 1). The institute technology management committee (ITMC), constituted at institute level and chaired by the director of the respective institute and working as the decision making body for IP related issues or concern at institute level. ITMU act as the secretariat for the respective ITMCs and execute the day to day matters concerned to IP management of the institute (ICAR, 2018).

Components of technology managements & commercialization

Role of institute technology management unit

The main objective for establishment of ITMU in each ICAR institutes is to create an effective IP environment in order to strengthen the IP portfolio at institute level. This unit also assists in streamlining the institute knowledge and technological products through commercial, cooperative and open public routes. This unit of the institute is playing an important role as facilitator and advises in several techno-regulatory and policy matters related to intellectual property and technology management. The ITMU of the institute acts as catalyst to transform the original innovative research ideas into commercial ventures in real sense. This unit also facilitates the researchers of the institute for effective management of IPRs by availing the services of IP attorneys for drafting, filing, prosecution & maintenance of patents, trademark, design and other IPRs (Fig. 1). This unit ensures effective coordination at all the stages to ensure meeting the stringent time-lines of the procedural activities which are crucial for ensuring successful grant and maintenance of patents and other forms of IPR. The ITMU has played an important role to motivate, promote and facilitates about registration of potato varieties under 'The Protection of Plant Variety and Farmers Right Act, 2001'. This unit also assists the researcher of the institute for drafting, filing and prosecution of potato variety application and their protection in plant variety and farmer rights authority, New Delhi (PPV&FRA, 2001).

Table 1. Structure of intellectual property management and technology commercialization in ICAR-CPRI, Shimla

Secretariat of committees		Types of IP management committees in ICAR		Chairman of committees
Agro-Technology Management Center (ATMC)	←	Central Technology Management Committee (CTMC)	→	Director General, ICAR
↓		↓		↓
Zonal Technology Management Unit (ZTMU)	←	Zonal Technology Management Committee (ZTMU)	→	Director General, ICAR-IIVR, Varanasi
↓		↓		↓
Institute Technology Management Unit (ITMU)	←	Institute Technology Management Committee (ITMC)	→	Director, ICAR-CPRI, Shimla



Fig. 1 ITMU deals with the different forms of Intellectual Property Rights

Process of IP management in ITMU:

Intellectual property refers to creation of the mind such as inventions, literary and artistic works, designs, symbols, names and images used in commerce. IPR comprises patent, design, trademark, copyright, geographic indications, trade secrets, integrated circuits, layout design and plant variety protection (WIPO, Geneva). The majority of applications executed by institute ITMU comprise patents, designs, plant varieties protection and trademarks (Fig.1). Patent is an exclusive right granted by patent office after the disclosure of the details of an invention. Patent is also called a techno-legal document granted after fulfilling the important criteria's viz. novelty, non-obviousness and industrial utility. There are certain non-patentable restrictions under section [3(h) & 3 (j)] of the Patent Act, 1970 related to grant of agricultural & horticulture inventions (The Patent Act, 1970). In India, the patent is granted for 20 years from the date of filing the application in patent office. After the grant of patent, the applicant needs to renew it up to 20 years by paying the prescribed annuities otherwise the patent will supposed to be revoked.

The IP protection and maintenance procedure generally handled & monitored by ITMU of the institute. After creation of authentic research data and to fulfill the above mentioned 3 important criteria's, the inventor needs to submit the information's in prescribed invention disclosure form (IDF) along with prior art search report to the ITMU. On the basis of shared information's by inventor, ITMU conduct the ITMC meeting for review and approval. After approval, ITMU proceed the case by availing the services of IP attorney for drafting and filing the application in patent or IP office which depends upon the type of intellectual property. Beside this, if the inventor utilizes the bioresources of Indian origins in his/her invention are required to seek approval from the National Biodiversity Authority, Chennai (Fig.2).

Methodology involved in commercialization of institute technologies

The inventor of the technology need to share the details with ITMU in the prescribed

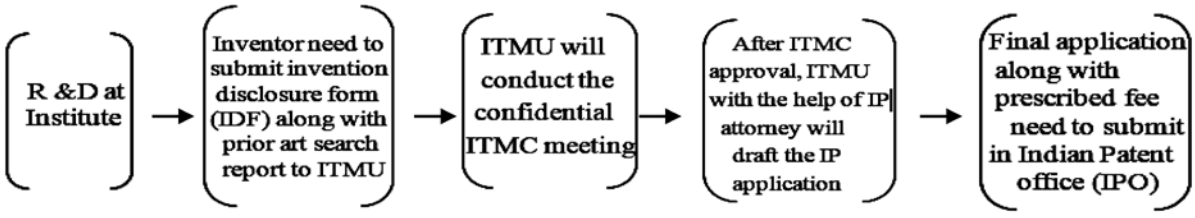


Fig. 2 Flow chart of IP management at institute level

disclosure form along with the costing sheet of technology which comprises the details of budget and manpower involved for generation of respective technology. The ITMU of the institute need to submit the filled technology disclosure form (TDF) and costing sheet in Agrinnovate (AgIn) India Ltd. The AgIn team will fix the technology-commercial assessment committee meeting for assessment & valuation of technology. The commercial assessment committee which comprises director of the concerned institute, inventor of the technology, member secretary of ITMU, commercialization expert, chief executive officer of AgIn and other concerned expert nominated by AgIn. After in-depth deliberation and discussion, the committee will approve the standard terms for licensing the technology and the same are supposed to upload in the web portal of AgIn. After that advertisement, business development and due diligence for clients will be performed by Agrinnovate. The interested party needs to place the online indent for the technology and experts from AgIn signed the tripartite terms of trade (ToT) document. Finally AgIn will draft and sign the tripartite technology license agreement between licensee, concerned Institute and themselves after the deposit of licensing fee as mentioned in ToT (ICAR, 2018) (Fig. 3).

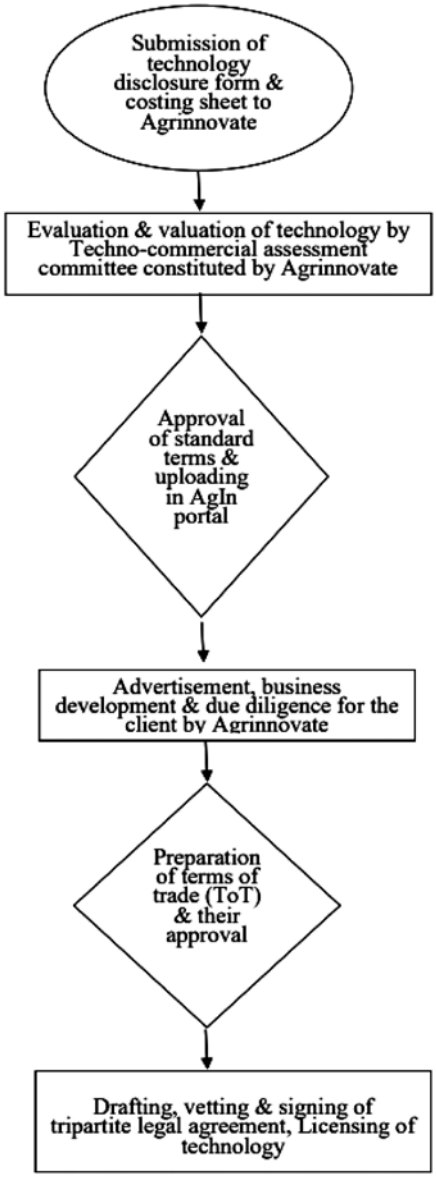


Fig. 3 Standard operating framework for commercialization of ICAR-CPRI technologies

Present commercialization status of institute technologies:

Till date, institute has filed 22 patents, 12 designs and 2 trademarks applications in respective IP office. Six patents, 9 designs and one trademark has been granted to the institute by IP office. Out of 34 IP, 16 has been commercialized and still open for licensing to the public, private and industry partners from national and overseas. The ITMU of the institute has licensed the technologies to more than 75 partners and earned around 22 million INR revenue to the institute. All the technologies licensed by signing the non-exclusive agreement for 5 years with the provision of royalty and further renewal for same duration. More than 20 non-IP technologies developed in past by the institute has been transferred and available in public domain (Singh *et al.*, 2020; Singh *et al.*,2021) (Table 2).

Table 2. List of technologies developed, IP protection and transfer/commercialization by ICAR-CPRI

S. No.	IP protected technologies of CPRI	Technologies of CPRI available in public domain
1.	Automated hydroponic system for potato microtuber production *in vitro*	Seed Plot technique
2.	Boifertilizer-cum-biofungicide/ biobactericide composition B5	Evaporatively cooled potato Store
3.	DNA insert plug loading system for pulse field Gel Electrophoresis	Seed treatment with boric acid against seed borne diseases
4.	Aeroponics for potato-seed production & fabrication	An improved heap storage technology
5.	Genetically modified potato with reduced level of reducing sugars and improved cold chipping attribute	Storage of processing potatoes at 10-12°C
6.	Potato custard powder	Computer aided advisory system for potato crop scheduling
7.	Dipstick assay kit for detection of potato viruses at farmers fields	Potato pest manager, Regional level potato acreage and production estimation
8.	Plant holding and lifting system	Seedling transplant crop from TPS
9.	Plant holding unit &Grow box	Seedling tuber production from TPS
11.	Dehydration of tubers	Potato growing season descriptor
12.	Dipstick for estimation of glucose in potato tubers and methods thereof	Late blight forecasting system
13.	Design & development of a tractor drawn cutter bar type of potato haulm cutter	Hi–Tech seed production through micropropagation
14.	Processing of potatoes into chips, French fries and other products	Seed soaking for Phosphorus economy in potato
15.	Modular structure for covering an area	Fertilizer drill cum line marker-tractor drawn
16.	Process for potato daliya, Semolina and Flour	Design development and testing of manually drawn four-in-one implement for potato cultivation
17.	Potato based gluten free cookies	Automatic potato planter-tractor drawn
18.	*in vitro* plant acclimatization	Passive blade potato digger-tractor drawn
19.	Kufri FryoM	Modified sprayer tractor operated
20.	VEGFAST	Oscillating type potato digger-tractor mounted
21.	Counting Machine	Rubber roller potato grader power operated
22.	Devices for hydroponic culture of plants	
23.	Combine harvester	

Status of CPRI technologies in Agrinnovate India Ltd.:

The AgIn will operate with functional autonomy and flexibility to facilitate the IP management and technology transfer/ commercialization pursuits of ICAR. It will efficiently liaise with ICAR technology users in private, cooperative, non-governmental and public sectors. The AgIn will execute technology disclosure shared by respective institute and its processing for commercialization, valuation, pricing, licensing, patent/IP watch, market watch, preventive and legal action to safeguard/ defend the IP. It will also facilitate in licensing of proprietary research tools and explore licensing of ICAR's IP abroad. Presently, 7 technologies pertaining to ICAR-CPRI are now available in the web portal of AgIn. All the above mentioned potato technologies developed in this institute viz. Kufri FryoM, Aeroponic technology, Dehydration of tubers, Modular structure for covering an area with a net, *in vitro* plant acclimatization,

Device for hydroponic culture of plants, Advanced potato processing hybrids are open for licensing to entrepreneurs of national and overseas. These technologies have been commercialized to more than 12 entrepreneurs/clients through tripartite licensing agreement on non-exclusive basis and some of them are in the process of licensing. The value and economic reward for the owners of IP rights comes only after their commercialization. It is necessary to interlink the investors and IP creators so that the entrepreneurship can be encouraged to capture the financial value of IPRs.

Protection of institute potato varieties:

The Govt. of India enacted The Protection of Plant Varieties & Farmers Rights (PPV&FRA) Act in 2001 & adopted *Sui generesis* system. Indian legislation is not only in conformity with international union for the protection of new varieties of plants (UPOV, 1978, but also have sufficient provisions to protect the interest of public sector breeding institutions and farmers. To implement the provisions of the Department of Agriculture, Cooperation and Farmer Welfare, Ministry of Agriculture and Farmer Welfare, GoI has established the Protection of Plant Varieties and Farmers Right Authority on 11th Nov. 2005 in New Delhi. The constitution of PPV&FRA, a statutory body created by an Act of Parliament by Ministry of Agriculture and Farmers welfare, Govt. of India. The PPV&FRA will provide an effective system for protection of plant varieties, the rights of farmers and plant breeders and to encourage the development of new varieties of plants. It has been considered necessary to recognize and protect the right of the farmers in respect of their contribution made at any time in conserving, improving and making available plant genetic resources for the development of the new plant varieties. Moreover, to accelerate agricultural growth & to stimulate investment in R&D, it is necessary to protect plants breeders' right for the development of new plant varieties. A variety is eligible for registration under the act if it fulfils the criteria of distinctiveness, uniformity and stability (DUS). The candidate variety must be distinguishable by at least one essential characteristic from all varieties of common knowledge in any country at the time of filing the application. Further candidate variety should have sufficiently uniform in expression of its essential characteristics which would remain unchanged even after repeated propagation. The variety should also have a single and distinct denomination (PPV&FRA, 2001).

PPV&FRA categorizes the varieties i.e. new, essentially derived variety (EDV), extant notified, extant variety of common knowledge (VCK) & farmer's variety. Till date, ITMU has facilitated the inventors of the institute to file 22 applications of potato varieties in PPV&FRA, New Delhi. Out of 22 applications, 20 have been granted and 2 are under examination and in the process of DUS testing. Two varieties of potato have been registered as new variety, 18 registered as extant notified variety and 2 are as extant VCK variety (Table 3).The actual journey of potato varietal development by institute started in year 1958 with the release of Kufri Kisan, K. Kuber, K. Kumar, K. Kundan, K. Red and K. Safed in India(Bhardwaj *et al.,* 2017; Singh *et al.,* 2018). The numbers pertaining to varieties development have significantly improved over the years. After the establishment of potato institute, it has developed 68 varieties of potatoes for the different agro-climatic conditions of the country.

Agri-business incubation (ABI):

Agri-business incubation program is an initiative of ICAR under its national agriculture innovation fund (NAIF) and one ABI unit has been allotted to CPRI. The ABI is a place where

Table 3. Status of potato varieties protection of ICAR-CPRI in PPV& FRA

Type of variety	Name of variety	Year of filing	Date of certificate issue	Duration of protection	Fees of variety protection for individual entity
New variety	Kufri Garima	2013	22.10.2016	21.10.2031	7,000/each
	K. Gaurav	2013	22.10.2016	21.10.2031	
Essentially derived variety (EDV)	--	--	--	--	--
Extant notified variety	K. Shailja	2011			2,000/each
	K. Sadabahar	2011	21.05.2014	17.07.2023	
	K. Himsona	2011	27.05.2014	25.12.2023	
	K. Pukhraj	2011			
	K. Khyati	2011	27.05.2014	25.12.2023	
	K. Pushkar	2011	27.05.2014	24.04.2021	
	K. Kanchan	2011	27.05.2014	14.11.2016	
	K. Giriraj	2011	27.05.2014	25.10.2014	
	K.Surya	2011	27.05.2014	24.04.2021	
	K. Arun	2011			
	K. Anand	2011	27.05.2014	25.10.2014	
	K. Himalini	2011	27.05.2014	24.04.2021	
	K. Girdhari	2011	27.05.2014	17.07.2023	
	K. Chipsona-3	2011	27.05.2014	24.04.2021	
	K. Chipsona-2	2011			
	K. Chipsona-1	2011	17.01.2020	11.08.2025	
	K. Mohan	2019	17.01.2020	05.12.2031	
	K. Frysona	2019	17.01.2020	11.08.2025	
Extant VCK variety	K. Elaar	2019	Awaited	Under examination	7,000/each
	K. Atal	2019	Awaited	Under examination	
Farmers variety	---	--	--	---	--

the process of starting agri-business venture is catalyzed by supporting the entrepreneurs with agriculture technologies, business consultancy, networking with management experts, venture capital funding, infrastructure and other necessary facilities. The objective of ABI is to disseminate technologies and products by creating venture and providing consultancies so that these technologies can be used for creating more and more viable business. The other mandate of ITMU & ABI unit of the institute is to promote entrepreneurship development in potato sector by transfer of technologies to individuals/ end users/corporate. The ABI unit also assists in imparting consultancy and training for nurturing prospective entrepreneurs and creation of skilled manpower. In past 2 years, ABI unit of ICAR-CPRI established in our Jalandhar station is promoting the VEGFAST technology by imparting training and signed around 38 license agreements with incubatees and entrepreneurs.

Successful commercialization of aeroponic system technology- a case study

In order to ensure disease-free planting material, the institute has standardized the

micro-propagation technique for micro-/mini-tubers production. ICAR-CPRI has developed a programmed air mist based potato culturing technique based on aeroponic technology. This technique allows us to grow plants in an air mist environment without the use of soil or any other aggregate medium. This technology has several beneficial features like fast multiplication of high quality initial planting material producing 35-60 minitubers per tissue culture plantlet, easy to operate & can be installed in non-arable and water scarce areas. The minitubers produced by this technique will be free from many soil borne pathogens of potato. The aeroponic system technology has revolutionized potato seed industry in the country and the technology has already been commercialized to 19 private and public partners. Installation of more and more units of aeroponic would expedite multiplication of seeds of potato to meet the rapidly growing demand. This technology is IP protected by institute and presently available for licensing to all private and public partners through Agrinnovate India Ltd. (Bhardwaj *et al.,* 2017) (Fig.4).



Fig. 4 Aeroponic system for potato mini tuber production; a) plant shoots and b) plant roots under aeroponic conditions.

CONCLUSION

The role of IPRs is also significant in the protection of the outcome of research. There is need to enhance the awareness campaign among researchers about IP protection & filing which ultimately led to successful transfer/commercialization of novel technologies. A nation-wide program of promotion should be launched with an aim to improve the awareness about the benefits of IPRs and their value to the rights-holders and innovators. Such programs will build an atmosphere where creativity and innovation are encouraged in national agriculture research system. This will ultimately led to strengthen the culture of IP generation, protection and convert into technology transfer & commercialization. IP management in agriculture requires broad portfolio management and need to link IPR protection with incubation, licensing, up-scaling and commercialization. IPR are not just up to the grant of the patent alone but subsequent maintenance, prosecution enforcement and commercialization of these rights are equally important. If the post filing and grant efforts when monitored properly and it will help to harvest more benefits from IP. Measures to check counterfeiting and piracy also need to be identified and undertaken. There is need to overcome the technology transfer gap among lab to stakeholders or entrepreneurs for the adoption of new latest technologies developed by the potato institute. Activities related to IP management and their successful transfer and commercialization will definitely

needs to strengthen and this will finally boost the R&D activities for sustainable growth of Indian potato industry.

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LITERATURE CITED

Bhardwaj V, Gopal K, Sharma R and Chakrabarti SK (2017). Technologies developed and Transferred/ Commercialized Mannual, ICAR-Central Potato Research Institute, Shimla, India. Technical bulletin-107: 32 p.

CPRI (2019). Annual report 2018-19. ICAR-Central Potato Research Institute, Shimla, India: iiip

CPRI (2020). Annual report 2019-20. ICAR-Central Potato Research Institute, Shimla, India: 3p

ICAR (2018). ICAR Guidelines for Intellectual Property Management and Technology Transfer/ Commercialization (Revised in 2018) Indian Council of Agricultural Research, New Delhi: 9-10p

NIPRP (2016). Department of Industrial Policy & Promotion, Ministry of Commerce & Industry, Govt. of India. https://dpiit.gov.in/sites/default/files/national-IPR-Policy2016-14October2020.pdf 20 December, 2021

NSO (2021) Ministry of Statistics & Program Implementation, (GoI), New Delhi. https://www.pib.gov.in/PressReleasePage.aspx?PRID=1741942 10 December, 2021

PPV&FRA (2001). Frequently asked questions on The Protection of Plant Varieties and Farmers Right Act, 2001 New Delhi, 19-20p

Singh R, Bhardwaj V and Pandey NK (2021) Intellectual property protection & commercialization portfolio of ICAR-CPRI, Shimla (HP). Paper presented in International Potato e-conference-2021, Shimla, 23-26 November 2021

Singh R, Gopal K, Bhardwaj V and Chakrabarti SK (2020) Facets of Technology transfer: ICAR-CPRI status. Poster presented in Global Potato Conclave-2020 Gandhinagar, Gujarat, 28-31 January 2020

Singh AK, Janakiram T, Chakrabarti SK, Bhardwaj V and Tiwari JK (2018). Indian Potato varieties. ICAR-Central Potato Research Institute, Shimla (HP) ix-xiip.

The Patent Act 1970 (2020). Universal LexisNexis, Gurgaon: 6-7 p, ISBN-13 : 999 9 99999 9P0 5.

WIPO (2021). World Intellectual Property Organization, Geneva. https://www.wipo.int/about-ip/en/ 20 December, 2021

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CORRIGENDUM

Date of Submission and Acceptance of Articles; Potato Journal 47(1 & 2), 2020

S. N.	Title of manuscript	Date of submission	Date of acceptance
	Potato Journal : 47(1) 2020		
1.	Kufri Neelkanth: purple skin coloured speciality potato variety of India	9.8.2020	14.7.2021
2.	Preliminary analysis of genotypic and phenotypic correlation of traits in drought tolerant potato under moisture deficit areas of North-Western Ethiopia	24.3.2020	19.7.2021
3.	Kufri Thar-2: a new drought tolerant table potato variety	10.12.2020	20.7.2021
4.	Kufri Thar-3: a water use efficient medium maturing potato variety for North Indian plains	10.7.2020	1.9.2021
5.	Present status of wart disease of potato in Darjeeling and Kalimpong districts of West Bengal	31.12.2020	26.2.2021
6.	Genetic diversity of different carotenoid containing Indian potato cultivars as revealed by SSR markers	22.10.2019	9.7.2021
7.	Screening for hollow heart in potato (*Solanum tuberosum* L.) genotypes	25.9.2019	19.7.2021
8.	Potato variety: a web based tool for search on potato varieties	3.3.2020	1.9.2021
9.	Investigating the best suitable nuclear isolation buffer for potato flow cytometry	13.3.2020	16.3.2020
10.	Development of SSR fingerprints of interspecific potato somatic hybrids	18.3.2020	17.7.2021
11.	Storability and organoleptic performance of indigenous and exotic potato collections	1.9.2020	13.7.2021
12.	First report of *Haplothrips tenuipennis* bagnall (thysanoptera, phlaeothripidae) on potato in north western hills of India	16.4.2020	2.11.2020
	Potato Journal : 47(2) 2020		
1.	Kufri Karan-first multiple disease resistant, high yielding potato variety for cultivation in hills and plateaux of India	18.1.2021	19.7.2021
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10.	Effectiveness of *Bacillus thuringiensis* subsp. kurstaki (Btk) and dried *Lantana camara* L. foliage against Potato Tuber Moth (*Phthorimaea operculella*) under local storage condition of Meghalaya	1.9.2020	17.8.2021
11.	Potato productivity and nutrient use efficiency as influenced by NPK fertilizer omissions in Central India	25.9.2020	17.8.2021
12.	Dynamics of *Bemisia tabaci* on potato cultivars grown under organic and inorganic conditions in North-Western India	20.7.2021	21.9.2021

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Anonymous (2010) Agribusiness in India: green shoots. *Economist* **394**(13-19 March): 65-66

Chakravarty C and Pandey B (2005) Growing roots in farmlands: an interview with Ms Indra Nooyi, worldwide president and CFO, PepsiCo. *Econ Times* 29 August 2005

Online sources

FAO (2008) Potato world: Africa-international year of the potato 2008. Food and Agriculture Organisation, Rome. http://www.potato2008.org/en/world/africa.html, 31 December 2008

Hirtle PB (2008) Copyright renewal, copyright restoration, and the difficulty of determining copyright status. *D-Lib Magazine* **14**(7-8), DOI:10.1045/july2008-hirtle

Anonymous (2008) *Encyclopaedia Britannica*. http://search.eb.com, 6 May 2008

E-Views (2006) E-Views quantitative software. http://www.eviews.com, 28 September 2006

Book and book chapter

Guenthner J (2001) The International Potato Industry. Woodhead Publishing Limited, Cambridge: 312p, ISBN-13: 978 1 85573 465 4

Adiyoga W and Norton GW (2009) Costs and benefits of Bt potato with resistance to potato tuber moth in Indonesia. In, Projected Impacts of Agricultural Biotechnologies for Fruits and Vegetables in the Philippines and Indonesia. Norton GWH (ed), Los Banos, Philippines: 105-40

Annual report, bulletin or working paper

CPRI (2010) Annual report 2009-10. Central Potato Research Institute, Shimla, India: 203p

Chand R (2003) Government intervention in food grain markets in the new context. National Centre for Agricultural Economics and Policy Research, New Delhi. Policy paper-19: 118p

CPRI (1999) Package of practices of ware and seed potato production in central Indo-Gangetic plains. Central Potato Research Institute, Shimla, India. Extension bulletin-16: 9p

Theisen K and Thiele G (2008) Implementing CIP's vision: impact targeting. International Potato Center (CIP), Lima, Perú. Working paper 2008-4: 24p

Conference presentation

Haq I, Farooq K and Mahmood MM (2008) Screening of potato genotypes for late blight resistance/ tolerance in Pakistan. Poster presented in Global Potato Conference-2008, New Delhi, 9-12 December 2008

Bachem C, de Boer J, Borm T and Visser R (2008) Potato genome sequencing: status report. Paper presented in Global Potato Conference-2008, New Delhi, 9-12 December 2008

Raman KV (2000) Integrated pest management in potato production. In, Potato, Global Research & Development (Proceedings of the Global Conference on Potato, New Delhi, 6-11 December 1999) Khurana SMP, Shekhawat GS, Singh BP and Pandey SK (eds) **1**: 345-51

Bradshaw JE (2008) Have we reached yield plateau: a genetic perspective. In, Abstracts: Global Potato Conference-2008. Indian Potato Association, Shimla, India: 3-4

Thesis

Kaur RJ (2004) Effect of nitrogen management through organic and inorganic sources in potato. Department of Agronomy, Punjab Agricultural University, Ludhiana, India, Ph.D. thesis: 99p

Encyclopaedia or dictionary

Kinni TB (2004) Walt Disney (1901-1966): founder of the Walt Disney company. Encyclopaedia of Leadership. Sage Publications, Thousand Oaks, CA: **1**: 345-49

Cowie AP (1989) Oxford Advanced Learner's Dictionary, 2nd ed. Oxford University Press, Oxford

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Gram	g	Minute	min
Hectare	ha	Nanometre	nm
Kilogram	kg	Second	s
Litre	l	Square cm	cm^2
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