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Short communication

Evaluation of potato cultivars for phosphorus efficiency under Nilgiris conditions

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ABSTRACT

Field experiments were conducted at ICAR-Central Potato Research Station, Muthorai, the Nilgiris, Tamil Nadu for three years with seven potato varieties under four levels of phosphorus to evaluate its efficiency. Varieties Kufri Neelima and Kufri Swarna were found more P efficient because of their higher relative biomass production, tuber yield efficiency index, harvest index, agronomic use efficiency (AUE) and P uptake efficiency. These two varieties produced higher tuber yields under no P and at P_{max} of standard variety. The varieties Kufri Girdhari, Kufri Jyoti and Kufri Himalini proved P responsive as they responded well to P application and produced very low yields under no P application. Higher root biomass in these two efficient varieties could be the reason behind their higher P use efficiency as compared with other genotypes. The two P efficient potato varieties also happen to be resistant to potato cyst nematodes, which is very common and serious problem in the Nilgiris. The mechanism to have resistance against PCN, whose cysts emerge only in the presence of root exudates of susceptible potato varieties, could also have benefitted those cultivars to show more efficiency in native P utilization. Further investigations are required to find out the exact mechanism of P efficiency in these two PCN resistant genotypes.

Key words: Agronomic use efficiency, phosphorus use efficiency, potato cultivars, P uptake, tuber yield efficiency.

Most of the P (>80%) is obtained from nonrenewable sedimentary deposits. Phosphorus use efficiency is generally very low at <30% in potato. Cultivated soils contain good reserves of P and its availability to the plants is seized because of transformations to other forms depending upon soil pH. P is limiting because of its chemistry, *i.e.*, low solubility of phosphates and their rapid transformation to insoluble forms (Smil, 9). Al, Fe, Ca, K, and Mg can all react with fertilizer P and produce relatively insoluble compounds (Smil, 9). Potato is classified as "inefficient responder" to P application (Miyasaka and Habte, 8). Hence, the need to improve P use efficiency is more important in the future due to economic environmental, and mineral resource availability pressures.

Plants take up P in the form of orthophosphates which is a very small proportion in the soil when compared with the total P. But the P efficient plants or cultivars are supposed to have the ability to convert soil P into orthophosphates or other available forms through some sort of mechanism which may include higher root biomass, root/shoot ratio, root exudates which can dissolve the phosphates or some other mechanism of that sort. Lee *et al*. (7) reported that the cultivar adaptation to low-P stress growing conditions depends on various traits, such as mobilization of insoluble phosphates, utilization of limited bioavailable P sources, and P-uptake efficiency. An elite genotype that can adapt to P-limiting growing conditions needs to be excellent in each of the above traits. If such cultivars are identified and their mechanism is known then it becomes easier to breed varieties with higher P efficiency through improved biotechnological tools. Potato is widely grown in Nilgiris with large doses of P application under lateritic soil conditions. If P efficient cultivars are identified and recommended, it can avoid soil build up of P, thereby eutrophication of water bodies and environmental pollution. Hence, the present investigation was carried.

A field experiment was conducted at CPRS, Muthorai, the Nilgiris, Tamil Nadu during 2010 to 2012 by planting seven potato varieties under four different levels of P (0, 50, 100 and 150 kg P_2O_5 per hectare). The seven varieties tried were Kufri Swarna, K. Jyoti, K. Neelima, K. Girdhari, K. Shailja, K. Giriraj and K. Himalini, which differ in their maturity periods under Nilgiri conditions (equinox). The trials were planted during summer season (April to August) under rainfed conditions as the region receives good amount of (800 mm) rainfall during South-West monsoon. The plot size adopted was 2.4 x 2.0 m with four rows of potato having 10 plants in each row (at 60 x 20 cm spacing). Standard cultural practices were followed

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for inter-culture and harvesting by cutting the haulms 15 days before harvest. The soil type in experimental plot was sandy loam with high available N and P and medium at K. The soils of the Nilgiris are rich in P but the availability is very less because of the transformation of P to Fe and Al phosphates.

Per cent emergence of different varieties under four levels of P application was estimated after one month of planting. At 45 days, plant height, shoot number and number of leaves per plant were recorded by selecting five plants per plot at random. Shoot weight, root length and root biomass were estimated at 90 days after planting. Tuber number and yield was estimated in different size grades (<25, 26-50, 51-75 and >75 g) after separation. Tuber yields were recorded net plot wise in all the three years in four different size grades. The total biomass of plants were recorded at 90 days and the tuber yield at 120 days. Harvest index was calculated in all the varieties at different P levels. P uptake was estimated in different plant parts at 90 days after planting by drawing samples from five plants in each plot. Phosphorus content in tubers was estimated at harvest. Soil samples were analysed for nutrient status using standard procedures before and after the conduct of the experiment. The following nutrient efficiency indices like Tuber yield efficiency index, tuber harvest index, agronomic use efficiency (AUE), and phosphorus uptake efficiency (PUE) were estimated. The pooled data of three years was used to fit quadratic models for yield estimation in seven varieties and the *Pmax* was estimated for standard variety Kufri Jyoti using the procedure suggested by Govindakrishnan *et al.* (4). The yields of different varieties at *Pmax* were estimated using the quadratic equations developed.

Plant height, number of shoots per plant and leaf number was significantly affected by P application in potato varieties. The two varieties, namely, Kufri Swarna and Kufri Neelima performed better in terms of plant height, number of shoots and leaf number than rest of the varieties. Efficiency of the above two varieties in utilization of P could be witnessed from the initial stage itself as the plant growth parameters were superior in them (Table 1). Potato being a heavy feeder requires higher levels of nutrients from the initial stage itself. Non availability of required quantities of P might have caused imbalance in many of the treatments leading to reduction in growth and related parameters. Shortage of phosphate supply was found to increase mainly the ratio of root length per weight of plants (Fist 2; Jungk *et al*., 6; Trehan and Sharma, 10). The regulating mechanism is reported to be root cell elongation (Anuradha and Narayanan, 1).

The yield produced by Kufri Neelima and Kufri Swarna without P application was higher than all other cultivars even at their highest levels of P application except for Kufri Girdhari at 100 kg P that too it was higher than Kufri Swarna at zero level of P application. This indicates that these two varieties are highly efficient in utilization of native P under Nilgiri conditions. The varieties Kufri Swarna (31.3 t/ha) and Kufri Neelima (32.9 t/ha) produced very high yields

Table 1. Growth parameters, yield components and efficiency indices of potato varieties.

Variety	Pl. ht. (cm)	No. of shoots	No. of leaves	Yield/ net plot (kg)	Tuber No. / net plot	P content in tubers (%)	Plant P conc. (%)	P uptake in stems (kg/ ha)	Stem DMP (t/ ha)	Tuber DMP (t/ ha)	AUE
K. Jyoti	22.76	2.58	17.69	4.49	62	0.28	0.14	2.02	1.44	4.65	150.13
K. Swarna	33.53	3.05	23.12	6.64	65	0.29	0.10	2.21	2.21	6.91	222.98
K. Girdhari	24.97	2.87	18.31	4.83	65	0.29	0.13	2.02	1.56	5.03	162.13
K. Shailja	12.47	1.45	10.85	1.16	19	0.28	0.14	0.51	0.36	1.21	38.90
K. Himalini	22.73	2.41	15.20	3.58	68	0.29	0.14	1.57	1.12	3.73	120.39
K. Giriraj	18.01	2.26	14.43	2.78	42	0.29	0.10	0.90	0.90	2.90	93.42
K. Neelima	31.19	2.69	23.03	6.79	80	0.29	0.12	2.80	2.33	7.07	228.06
$LSD_{0.05}$	2.711	0.311	2.356	0.607	7	0.00					
P0	20.31	2.26	15.31	3.59	50	0.27	0.12	1.39	1.16	3.74	120.77
P50	24.99	2.64	18.43	4.59	61	0.29	0.13	1.99	1.53	4.78	154.19
P100	25.15	2.58	18.59	4.72	60	0.29	0.13	2.05	1.57	4.92	158.71
P150	24.21	2.40	17.75	4.37	58	0.30	0.14	2.10	1.50	4.55	146.84
$LSD_{0.05}$	2.050	0.235	1.781	0.462	5	0.00					

under no application of P and the varieties Kufri Jyoti, Kufri Himalini and Kufri Girdhari responded very well to the application of P at different levels (Tables 1, 2 & 3). Efficiency of the above two varieties in utilization of soil available P could result in increased tuber yield even at zero level of P application under acidic soil conditions of the Nilgiris.

This gives an indication about the efficiency of a particular cultivar to yield efficiently under non application and high level of application of a particular nutrient in comparison with other varieties. Tuber yield efficiency index was high in Kufri Swarna and Kufri Neelima as they could produce more yield at P deficient conditions. Among the seven cultivars tested Kufri Shailja and Kufri Giriraj were the least P efficient (Fig. 1). Varieties Kufri Girdhari, Kufri Himalini and Kufri Jyoti were intermediate and P responsive. This shows that the varieties Kufri Neelima and Kufri Swarna were highly effective in utilizing the native P in comparison with other varieties under testing.

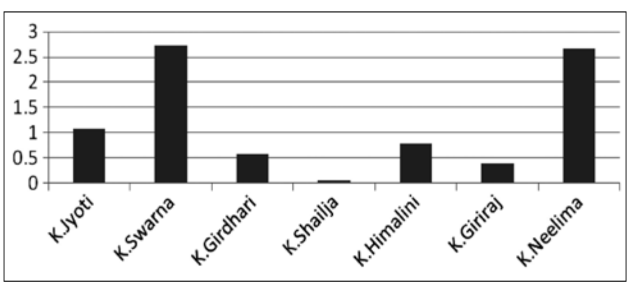
Harvest index represents conversion efficiency of vegetative source to economical part. The cultivars Kufri Neelima and Kufri Swarna recorded the highest values for harvest index indicating that they are the most P efficient and the HI increased with increase in P level upto 150 kg per hectare (Fig. 1). That means these two varieties are more efficient in converting source into economical parts. The two varieties Kufri Neelima (228) and Kufri Swarna (222) had shown higher Agronomic Use Efficiency (AUE) when compared with other varieties and Kufri Girdhari (162), Kufri Jyoti (150) and Kufri Himalini (120) showed moderate values for AUE. The least AUE values were recorded for K. Shailja (38) and K. Giriraj (93) (Table 1). Trehan and Sharma (10) reported that Kufri Pukhraj was the most N, P and K efficient cultivar among ten cultivars tested in the absence as well as

Table 2. Tuber yield per net plot (kg) in potato varieties.

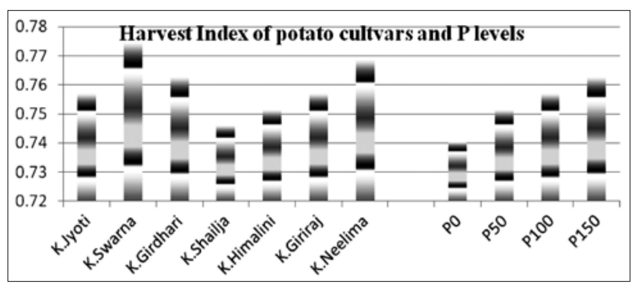
Variety	P0	P50	P100	P150
K. Jyoti	3.3783	4.6433	4.8133	5.0367
K. Swarna	6.0200	6.6583	6.7517	7.1100
K. Girdhari	3.4783	5.0267	6.2700	4.5283
K. Shailja	0.9483	1.4167	1.2467	1.0150
K. Himalini	2.5667	4.1450	3.8367	3.7850
K. Giriraj	2.4383	3.1733	3.0183	2.4900
K. Neelima	6.3250	7.0633	7.1317	6.6283

Table 3. ANOVA for tuber yield.

Source	DF	Type III SS	Mean square	F value	Pr>F
Rep (year)	3	2.4639107	0.8213036	0.73	0.5380
year	2	154.4015512	77.2007756	68.23	<.0001
variety	6	591.4661988	98.5776998	87.12	<.0001
P_level	3	32.1779833	10.7259944	9.48	<.0001



a. Tuber yield efficiency index



b. Harvest index

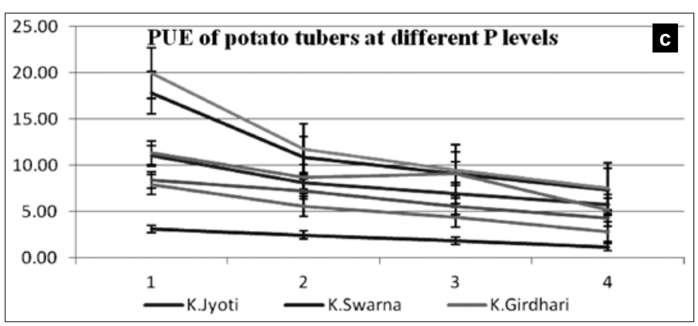


Fig. 1. Tuber yield efficiency, (a) harvest index (b) and phosphorus uptake efficiency (c) of potato cultivars under different P levels.

Table 4. Yield at economic optimum, P_{Max}, no P and dry root biomass of potato varieties.

Variety	Quadratic equation	Econ Opt (kg/ ha)	Yd at Econ opt P (t/ ha)	Yd at Max P of std variety (t/ ha)	Yd at no P (t/ ha)	Root dry wt. (g /plant)
K. Jyoti	$y = -0.0005x^2 + 0.135x + 17.895$ $R^2 = 0.8935$	132	27.4	27.0	17.9	1.72
K. Swarna	$y = -0.0005x^2 + 0.0884x + 31.14$ $R^2 = 0.7459$	85	35.0	40.2	31.1	3.07
K. Girdhari	$y = -0.0017x^2 + 0.3028x + 17.418$ $R^2 = 0.8539$	88	30.9	26.5	17.4	2.61
K. Shailja	$y = -0.0004x^2 + 0.055x + 5.0894$ $R^2 = 0.6745$	65	6.9	14.2	5.9	1.54
K. Himalini	$y = -0.0008x^2 + 0.1622x + 13.926$ $R^2 = 0.6822$	99	22.1	23.0	13.9	2.52
K. Giriraj	$y = -0.0007x^2 + 0.0987x + 12.834$ $R^2 = 0.4901$	68	16.3	21.9	12.8	1.98
K. Neelima	$y = -0.0006x^2 + 0.1072x + 32.968$ $R^2 = 0.9475$	87	37.7	42.1	32.9	3.14

(Econ opt = Economic optimum, Yd = Yield); P opt (kg/ ha) =- (cp-b) /2c; Cp: cost of P fertilizer per kg/ Price of potatoes per tonne = (37.5/12000) = 0.003125

presence of green manure. They also reported that the efficient cultivars gave higher tuber yield under N, P and K stress (*i.e.* with less dose of N, P and K fertilizer) and had higher Agronomic Use Efficiency (AUE) than less efficient cultivars.

The P uptake efficiency indices recorded higher values at no P application in Kufri Neelima and Kufri Swarna indicating their efficiency to convert native P to available forms. Other varieties showed very low uptake efficiency at no application and the values were lower at higher levels of P application (Fig. 1). The variation in phosphorus efficiency of different potato cultivars was due to both their capability to use absorbed P to produce potato tubers (PUE) and to their capacity to take up more P per unit soil. Trehan and Singh (12) reported that Kufri Pushkar is more P efficient than Kufri Pukhraj. Quadratic models were developed for all the cultivars and from them the optimum P dose was estimated (economic optimum). The tuber yield at economic optimum was 37.7 t/ha in Kufri Neelima and 35.0 t/ha in Kufri Swarna. The varieties next in order were Kufri Girdhari (30.9), Kufri Jyoti (27.4), Kufri Himalini, Kufri Giriraj (16.3) and Kufri Shailja (6.9) (Table 4). The P_{Max} for standard variety Kufri Jyoti (135 kg/ha) is estimated using the technique developed by Govindakrishnan *et al.* (4). The yields at P_{Max} and at no P also followed similar trend.

The root biomass (dry) produced in Kufri Neelima (3.14 g/plant) and Kufri Swarna (3.07 g/plant) were significantly higher on an average at all the levels of P application substantiating their efficiency in utilizing soil available and applied P resources. Further, these two varieties are resistant to PCN infection, which makes them maintain healthier roots without any cysts when compared with other varieties. This could also have been contributed for their better P use efficiency. Lee *et al.* (7) reported that 'Harley Blackwell' and 'Satina' cultivars of potato showed greater P mobilization ability in soils without supplemental P than the other five cultivars tested.

The ability to uptake more P from soil available level made the cultivars Kufri Neelima and Kufri Swarna more efficient in producing better tuber yields in comparison with other cultivars. Nutrient efficient plants are defined as those plants, which produce higher yields per unit of nutrient, supplied or absorbed than other plants (standards) under similar agro-ecological conditions (Trehan and Singh, 12). The main properties that affect the uptake of nutrients from soil are kinetics of ion absorption by roots, the size of root system and morphological root properties as reported by Jungk and Claassen (6). Earlier, Gahoonia (3) also reported that phosphate availability could be influenced by root induced changes of soil pH. Kufri Girdhari, K. Jyoti and K. Himalini responded greatly to the application of P and proved most P responsive varieties. Investigations are required to confirm the actual reasons for P efficiency.

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