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RICE HUSK ASH (RHA) - A POTENTIAL SOURCE FOR IMPROVING PHOSPHORUS NUTRITION IN POTATO (*S. TUBEROSUM* L.)

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ABSTRACT: Use of alternative sources of nutrients such organic manures, residues and by-products to chemical fertilizers may enhance not only the yield but cut down the fertilizers use. Therefore, present investigation was carried out to explore the possibility of using rice husk ash (RHA) as a source of phosphorus in potato crop. Two pot experiments were conducted on Kufri Jyoti and Kufri Girdhari to determine the effect of rice husk ash on phosphorus nutrition of the crop during 2020-21. Application of rice husk ash (RHA) significantly increased the plant height, haulms (leaf plus stem) biomass, root weight, chlorophyll content (SPAD value) and P content. In Kufri Jyoti, application of 20g RHA per pot significantly increased haulms biomass, tuber yield, relative leaf chlorophyll content and P content in haulms by 17.8 per cent over control. In Kufri Girdhari, application of 40g RHA/ pot also increased the P content by (14.6 %) in haulms over control besides significant increase in haulm yield, root mass and relative leaf chlorophyll content. It was observed that subjecting the crop to moisture stress by withholding the irrigation towards harvest, senescence was delayed in plants fertilized with rice husk ash. RHA application showed a significant and positive correlation with root length and tuber yield (r=0.70). The results of the present study revealed that RHA can be used as a source of phosphorus for potato crop and has potential to improve water relations and nitrogen nutrition as indicated by improved relative leaf chlorophyll content in plants fertilized with RHA.

KEYWORDS: Macro-nutrient, Potato, phosphorus, rice husk ash and tuber yield

INTRODUCTION

Potato (*S. tuberosum* L.) is third most important crop of world can play a key role in food and nutritional security of ever-increasing global population. In India, potato is grown in entire Indo-gangatic plains during the rabi season preceding by paddy (Kumar *et. al.,* 2023). Owing to its short duration cash crop and high bulking potential in plains, crop require appreciable amount of macro-nutrients NPK in readily available form and in sufficient amount (Kumar *et. al.,* 2021). Phosphorus is a yield limiting nutrient followed by nitrogen, which is applied through inorganic fertilizers to the crop.

Rock phosphate, a non-renewable resource, is the main raw material for phosphatic fertilizers and this high-grade reserves of rock phosphates are likely to be exhausted within the next 50 to 100 years. The recovery efficiency of phosphatic fertilizers is low about 25 per cent (Kumar *et. al.*, 2018), as phosphorus (P) is easily immobilized in soil. Therefore, improving P use efficiency either by exploiting genetic diversity or use of alternative sources such as crop residues/ wastes/ by-product is necessary for achieving sustainable yields.

Plants have evolved diverse strategies to cope with P deficiency and to counteract P-deficiency stress secretion of organic acid anions like malate, citrate and oxalate by plant roots is one of the effective strategy (Chen and Liao, 2016). Current evidence indicates that Silicon (Si) application strongly

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promotes the exudation of both malate and citrate by roots (Kostic *et al.*, 2017). Although the precise nature of the role still remains unclear, evidence suggests that Si plays a significant role in P nutrition and an alleviating effect of Si under P limiting conditions has been reported in rice (Hu *et al.*, 2018) in tomato (Zhang *et al.*, 2019).

Rice husk Ash (RHA) is the product of incineration of rice husk. It has the highest proportion of silica content among all plant residues and is an abundantly available and renewable agriculture by-product from rice milling in the rice-producing countries like India. In India, RHA production is estimated to be around 4.4 million tons per year and its disposal is an issue for rice mills. The rice husk contains about 50% cellulose, 25–30% lignin and 15–20% silica (Ismail and Waliuddin, 1996) and every 100 kg of husks burnt in a boiler yields about 25 kg of RHA containing about 60-70% depending up on composition of the rice husks, burning temperature and burning time. RHA besides being a rich source of silicon also contains considerable carbon and small amounts of P, K and other micronutrients. Positive effects of RHA has been reported in wheat (Kostic *et al*. 2017; Singh *et. al.*,2019) and tomato (Hu *et al.*, 2021), however, the studies on usefulness of RHA in potato crop are lacking. RHA application has shown increased soil P availability both directly (by supplying P contained in the ash) or indirectly (Gao et al., 2019).

Considering the limited reservoirs of rock phosphate used for P fertilizer production, use of agricultural residues like RHA is necessary to ensure future food production. Hence this study was carried out to generate first-hand information on its beneficial effects on potato crop with special reference to P nutrition.

MATERIALS AND METHODS

Two independent pot experiments were conducted under glass house condition during the year 2020-21 at ICAR-Central Potato Research Institute, Shimla (HP). The popular varieties of potato *viz.* Kufri Jyoti and Kufri Girdhari were chosen to investigate the effect of rice husk ash (RHA) on crop performance. In the first experiment, thoroughly washed cocopeat was used as a growing media. The first experiment on Kufri Jyoti consisted of three treatments *viz.* T_1 = Cocopeat alone; T_2 = Cocopeat + 10g RHA/pot; T_3 = Cocopeat + 20g RHA/pot. The treatments were replicated five times. Second experiment was conducted on Kufri Girdhari using acid washed sand as growing media and three doses of RHA were tested in the following treatment combinations: T_1 = Sand alone; T_2 = Sand + 10g RHA/pot; T_3 = Sand + 20g RHA/pot; T_4 = Sand + 40g RHA/pot and T_5 = Sand + RDF P/pot and the treatments were replicated three times. RHA was applied around the seed piece at the time of planting. Half dose of nitrogen (as urea) and potassium (as SOP) and full dose of micronutrients (Zn, Fe, Cu, Mn & B) was applied uniformly at planting by mixing in the respective growing media used in the experiment and remaining half dose of N and K was incorporated in the rootzone 20 days after emergence. The RHA used had a pH =9.36 (1:2 ratio) and OC = 10.2%; N = 0.01%; P = 0.30%; K = 0.52%; Ca = 0.40%; Mg = 0.12% and S = 0.08%. Observations on plant height, SPAD value were recorded 60 days after planting. Haulms (leaf plus stem) and root were harvested separately, oven dried and biomass yield is reported on oven dry weight basis. Chlorophyll content was measured indirectly by chlorophyll meter SPAD - 502 Plus. Nutrient content of RHA and potato samples (haulms and tuber) was determined as per standard methods after acid digesting the samples in nitric and perchloric acid mixture. The experiment was laid out in completely randomized design (CRD) and statistically analysed by following the methodology proposed by Gomez and Gomez, 1984.

RESULTS AND DISCUSSION

Currently residue wastes and by-products as an organic fertilizers can play an important role as complementary sources with inorganic fertilizers to improve not only the productivity but also water and nutrient use efficiency along with the soil health. In the present investigation, addition of rice husk ash had shown superiority in terms of growth and tuber yield. In the first study conducted on Kufri Jyoti in cocopeat, 10 and 20 g RHA per pot increased the biomass as well as tuber yield per pot (**Table 1 and Figure 1**). Haulm (leaf plus stem) biomass on dry weight basis was 32.47 per cent (10 g RHA per pot) and 40.00 per cent higher (20 g RHA per pot). Application of 20 g RHA per pot increased P content significantly in haulms by 17.85 per cent and statistically at par with control over control. The SPAD value was also increased significantly to the tune of 11.52 per cent and 19.63 per cent with the application of rice husk ash at the rate of 10 g and 20 g/pot, respectively, compared to the control treatment. Tuber yield also increased significantly with the application of RHA (10 g and 20 g) to the tune of 13.68 and 17.70 per cent over control with the application of 10g and 20g RHA, respectively. When the plants were subjected to moisture stress by withholding the irrigation towards harvest, the senescence was delayed in plants fertilized with RHA compared to in control treatment. The alleviating effects of Si on drought stress has been observed in a wide variety of crop plants including both monocots and dicots. Silicon enhanced water stress tolerance in *Solanum lycopersicum* L by improving root hydraulic conductance (Gong *et al*., 2005 and Thorne *et al., 2021).* The underlying mechanism by which Si alleviates oxidative damage is not clear.

Table 1. Effect of different rates of RHA on growth and yield of potato *cv* Kufri Jyoti.

Treatment number	Plant height (cm)	SPAD value	Haulms biomass (dry weight basis) (g/pot)	Haulms P (%)	Tuber yield (g/pot)
T_1	23.20	32.80	4.65	0.224	74.10
T_2	33.40	36.60	6.16	0.236	84.24
T_3	37.00	39.24	6.51	0.264	87.22
$CD_{(p=0.05)}$	2.20	1.69	0.45	0.021	4.91

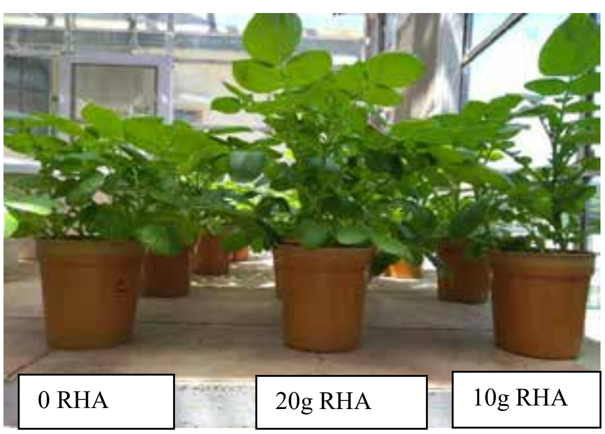

Fig. 1. Effect of RHA on growth of Kufri Jyoti in cocopeat.

In second experiment on Kufri Girdhari variety, RHA application rates of 40g per pot significantly increased (14.65) the phosphorus content in haulms, plant height and root dry weight over control (**Table 2**). The highest P concentration (0.52%) in haulms was observed in T_5 with the addition of chemical P fertilizer. The differences in plant height were more pronounced during the initial growth stage and narrowed down as the season progressed (**Figure 2**). Evidence suggests that Si plays a significant role in P nutrition, but the precise nature of that role still remains unclear. Two major mechanisms of Si-mediated alleviation of P deficiency are proposed based on different studies: (i.) increased root uptake and (ii.) enhanced utilization of P within

Table 2. Effect of different rates of RHA on growth and yield of potato *cv* Kufri Girdhari.

Treatment number	Plant height (cm)	SPAD value	Haulms biomass (dry weight basis) (g/ pot)	Haulms P (%)	Root weight (g)/ pot	Tuber yield (g)/ pot
T_1	33.07	32.20	8.00	0.41	1.648	63.36
T_2	36.27	32.93	8.25	0.42	1.722	64.67
T_3	40.17	34.43	8.53	0.45	1.802	73.87
T_4	41.97	35.40	8.64	0.47	1.815	74.88
T_5	45.60	33.77	9.55	0.52	1.857	76.74
$CD_{(p=0.05)}$	2.26	1.66	0.48	0.04	0.056	4.90

Fig 2. Effect of RHA on shoot and root growth in sand (LHS-control and RHS with RHA)

the plant tissues. Increase in P concentration and plant growth parameters due to RHA application in the present study is attributed to utilization of P present in RHA. Root biomass exhibited significant and positive relationship with haulms biomass and tuber yield (**Figure 3**). Application of rice husk ash also increased the SPAD index significantly in Kufri Girdhari (**Table 2 and Figure 4**). SPAD

Fig. 4. Effect of RHA on leaf chlorophyll in Kufri Girdhari (LHS (0RHA+P) and RHS (40g RHA alone) in sand culture

index is indirect measure of plant nitrogen status. Although, the exact mechanisms by which Si induces change in N metabolism still remain unknown, increased N uptake under suboptimal N supply mediated by Si has been reported in different plant species, e.g., cowpea (*Vigna unguiculata*) (Mali and Aery, 2008), maize (*Zea mays*) (Mabagala *et al.*, 2020) and rice (*Oryza sativa*) (Deus et al., 2020). Increased tissue concentration of N due to application of Si has been attributed enhanced transport efficiency (Sheng *et al.*, 2018).

As observed in the present study, increase in P uptake with the application of Si under P limiting conditions has been reported in wheat (Kostic *et al.*, 2017; Neu *et al.*, 2017),

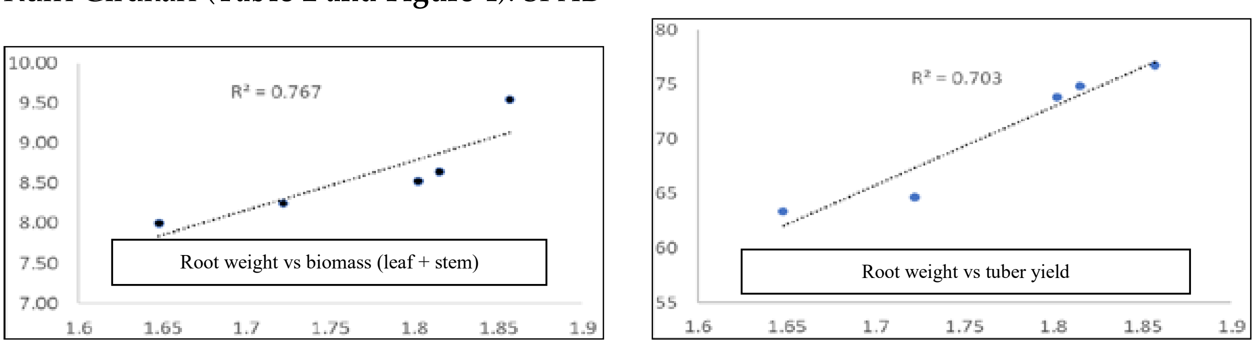

Fig.3. Relationship between root weight and haulms biomass (LHS) and tuber yield (RHS).

maize (Owino-Gerroh and Gascho, 2005), tomato (*Solanum lycopersicum*) (Zhang *et al*., 2019), rice (Ma and Takahashi, 1990; Pati et al., 2016; Hu et al., 2018) and potato (*Solanum tuberosum*) (Soltani *et al*., 2017; Soratto *et al*., 2019), although the precise nature of the role of Si plays in P nutrition still remains unclear. Priyadharshini and Seran (2009) found that RHA application @ 4.5 t ha^{-1} results the high number of nodules and nodule weight and significantly higher yield in cowpea. Application of RHA to soil increases soil P availability directly by supplying P contained in the ash and indirectly as well (Gao *et al*., 2019). Although the root exudates were not determined in present study, evidence indicates that Si application strongly promotes the exudation of both malate and citrate by roots which increases the P availability (Kostic *et al*. 2017).

CONCLUSION:

Overall, the results of the present study concluded that RHA besides being a source of nutrients like P, it also has the potential to improve drought tolerance in potato crop by positively impacting the root growth. Apart from increased nutrient uptake silicon application can be attractive approach to improving plant water status and maintaining plant water balance under drought stress conditions. Further studies should evaluate the benefits of RHA using in different types of soils under natural farm conditions to enhance our understanding of RHA for improving tuber yield and nutrient use efficiency and the underlying mechanisms by which Si alleviates oxidative damage under drought needs to be investigated in potato.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

ETHICAL STATEMENT

This article does not contain any studies with human participants or animal performed by any of the authors.

LITERATURE CITED

Chen ZC and Liao, H (2016) Organic acid anions: An effective defensive weapon for plants against aluminum toxicity and phosphorus deficiency in acidic soils. *Journal of Genetics and Genomic Research* **43**: 631–638

Deus ACF, de Mello PR, de Cássia FAR, de Oliveira, RLL and Felisberto, G (2020) Role of silicon and salicylic acid in the mitigation of nitrogen deficiency stress in rice plants. *Silicon* **12**: 997–1005

Gao S, DeLuca, TH and Clevel CC (2019) Biochar Additions Alter Phosphorus and Nitrogen availability in agricultural ecosystems: a meta-analysis. *Science of Total Environment* **654**: 463-472

Gong H, Zhu X, Chen K, Wang S and Zhang C (2005) Silicon alleviates oxidative damage of wheat plants in pots under drought. *Plant Sci.* **169**: 313–321

Gomez KA and A.A. Gomez (1984). Statistical procedures for agricultural research (2 ed.). John wiley and sons, NewYork, 680p.

Hu AY, Che J, Shao JF, Yokosho K, Zhao XQ, Shen RF *et al*. (2018) Silicon accumulated in the shoots results in down-regulation of phosphorus transporter gene expression and decrease of phosphorus uptake in rice. *Plant and Soil* **423**: 317–325

Hu AY, Xu SN, Qin DN, Li W and Zhao XQ (2021) Role of silicon in mediating phosphorus imbalance in plants. *Plants* **10**:51-65

Ismail MS and Waliuddin A (1996) Effects of rice husk ash on high strength concrete. *Construction of Building Materials* **10**: 521-526

Kostic L, Nikolic N, Bosnic D, Samardzic J and Nikolic M (2017) Silicon increases phosphorus (P) uptake by wheat under low P acid soil conditions. *Plant and Soil* **419**: 447–455

Kumar Prince, Dua VK, Sharma Jagdev, Byju G, Minhas JS and Chakrabarti SK (2018) Site specific nutrient requirements of NPK for potato (*Solanum tuberosum* L.) in western Indo-gangatic plains of India based on QUEFTS. *Journal of Plant Nutrition*. **41**(15):1988-2000

Kumar Prince, Kumar Raj, Shah M Abas, Singh RK, Sharma AK, Kumar Raj and Dua VK (2023) Tuber yield and incidence of virus-vectors in late-planted seed potato crops in north-western plains of India. *Potato Research*. https://doi.org/10.1007/s11540-022-09604-6.

Kumar Prince, Sharma J, Kumar D, Sharma V, Dua VK, Sharma A, Kumar R and Kumar M (2021) Apposite macronutrient fertilization (AMNF) – an effective modus operandi for potato crop. *Indian Journal of Agricultural Sciences* **91**(2): 244-248

Ma JF and Takahashi E. (1990) Effect of silicon on the growth and phosphorus uptake of rice. *Plant and Soil* **126**: 115–119

Mabagala FS, Geng YH, Cao GJ, Wang LC, Wang M and Zhang M L (2020) Effect of silicon on crop yield, and nitrogen use efficiency applied under straw return treatments. *Applied Ecology and Environmental Research* **18**: 5577–5590

Mali M, and Aery NC (2008) Silicon effects on nodule growth, dry-matter production, and mineral nutrition of cowpea (*Vigna unguiculata*). *Journal of Plant Nutrition and Soil Science* **171**: 835–840

Neu S, Schaller J and Dudel EG (2017) Silicon availability modifies nutrient use efficiency and content, C:N:P stoichiometry, and productivity of winter wheat (*Triticum aestivum L.*). *Scientific Reports* **7**: 40829

Owino-Gerroh C and Gascho GJ (2005) Effect of silicon on low pH soil phosphorus sorption and on uptake and growth of maize. *Communications in Soil Science and Plant Analysis* **35**: 2369–2378

Pati S, Pal B, Badole S, Hazra GC and Mandal B (2016) Effect of silicon fertilization on growth, yield, and nutrient uptake of rice. *Communications in Soil Science and Plant Analysis* **47**: 284–290

Priyadharshini J and Seran TH (2009) Paddy husk ash as a source of potassium for growth and yield of cow pea (*Vigna unguiculate* L.). *The Journal of Agricultural Sciences* **4** (2): 67-76

Sheng H, Ma J, Pu J and Wang L (2018) Cell wall-bound silicon optimizes ammonium uptake and metabolism in rice cells. *Annals of Botany* 1**22**: 303–313

Shi Y *et al*. (2016) Silicon enhances water stress tolerance by improving root hydraulic conductance in *Solanum lycopersicum* L. *Front. Plant Sci.* **7**: 196.

Singh R, Srivastava P, Singh P, Sharma AK, Singhe H, Raghubanshi AS (2019) Impact of rice-husk ash on the soil biophysical and agronomic parameters of wheat crop under a dry tropical ecosystem. *Ecological Indicators* **105**: 505-515

Soltani M, Kafi M, Nezami A and Taghiyari, HR (2017) Effects of silicon application at nano and micro scales on the growth and nutrient uptake of potato mini-tubers (*Solanum tuberosum* var. Agria) in greenhouse conditions. *Bio Nano Science* **8:** 218–228

Soratto RP, Fernandes, AM, Pilon C and Souza MR (2019) Phosphorus and silicon effects on growth, yield, and phosphorus forms in potato plants. *Journal of Plant Nutrition* **42:** 218–233

Thorne S J, Hartley S E and Maathuis FJM (2021) The effect of silicon on osmotic and drought stress tolerance in wheat landraces. *Plants* **10:** 814.

Zhang Y, Liang Y, Zhao X, Jin X, Hou L, Shi Y and Ahmed GL (2019) Silicon compensates phosphorus deficit-induced growth inhibition by improving photosynthetic capacity, antioxidant potential, and nutrient homeostasis in tomato. *Agronomy* **9**:733-749.

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