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Seed Biopriming With *Trichoderma* Improves Nutrient Uptake in Rajmash (*Phaseolus vulgaris* cv HUR-137) in Varanasi Region of Uttar Pradesh

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ABSTRACT

Red kidney bean plants were treated with different grades of recommended dose of fertilizer (RDF) along with biopriming with *Trichoderma harzianum* in greenhouse. Results represented that T_2 showed maximum growth attributes while T_5 showed comparable growth followed by T_4, T_3, T_6 and T_1. Biopriming improved nutrient uptake with lesser fertilizer doses comparable to RDF in relation to nitrogen, phosphorus and potassium. Plants treated with RDF without bio-treatments was found the best as per growth but the plants treated with 90% RDF combined with biopriming was comparable and suggests that the use of bio-agents can be used significantly to supplement the nutritional needs of the crop which is reduced as a part of the nutrients. Also, the plants treated solely with the bio-agent represented good rhizospheric growth without the use of inorganic inputs suggesting the role of biopriming in development of healthy root growth and increase in root biomass.

Keywords Biopriming, Nutrient uptake, Rajmash, Dry bean.

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INTRODUCTION

Incorporation of pulse crop in the cropping system is getting momentum after the new initiative, resolutions made in 2016 as FAO nominated the year as International Year of Pulses to heighten public awareness towards the nutritional benefits of pulses. India is the largest producer and consumer of pulses in the world. Latest reported acreage in India under pulses is 25.26 Mha as per 2015-16 (DAC and FW 2016-17). The Indian production contribution of dry beans is 34% (IISc 2016). The domestic production is often less than the estimated demand i.e., 23-24 million tons. Thus the average gap of 5MT is met through

Fig. 1. Effect of biopriming with *T. harzianum* and graded dose of N: P: K application on plant height (cm) of red kidney bean at different growth stages. (T_1: Control N: P: K @ 0:0:0 kg/ha, T_2: RDF of N: P: K @ 100: 60: 25 kg/ha, T_3: Seed treatment with *T. harzianum* + 70% N and RDF of N: P: K, T_4 : Seed treatment with *T. harzianum* + 80% RDF of N: P: K, T_5: Seed treatment with *T. harzianum* + 90% RDF of N:P: K and T_6 : Seed treatment with *T. harzianum* ; DAS-Days after Sowing ; RDF-Recommended dose of fertilizer).

imports. Due to the low productivity-low input nature, pulses are grown as residual/alternate crops on marginal lands after taking care of food/income needs from high productivity high input crops like paddy and wheat by most farmers. We can go for the organic treatments including such microbial agents which increase the pulse production sustainably and serving the purpose (Meena and Meena 2017). So, the best way to increase in the production without causing an ecological alarm is to integrate both of the organic methods and fertilizers in a judicious way.

Further, *Trichoderma harzianum* is a cosmopolitan and ubiquitous species found on a wide variety of substrates and in the last decade gained momentum in its use and popularity due to a continuous advocacy as it has the potential to heal biotic and abiotic stresses. It has been isolated from soil, rotting plant material, other fungi and recently as one of the species most commonly isolated as endophytes in the sapwood of tropical trees (Chaverri *et al.* 2015). Efficient soil microorganisms pose a great beneficial impact on soil-plant system and plant growth and uptake which help in environmental sustainability (Meena *et al.* 2014, Meena *et al.* 2015). By improving the plant height, chlorophyll, leaf area and dry matter production growth of plants can be made better and higher uptake of nutrients ensure this through combined use of biofertilizer and inorganic nutrients in a proportion which is both profitable and sustaining. Growth parameters and nutrient uptake will ultimately contribute to the production and productivity at a lower cost of cultivation. The biopriming is a process of biological seed treatment that refers to combination of seed hydration and inoculation of seed with a biological agent to protect seed, improves seed germination, seedling establishment and vegetative growth (Rakshit *et al*. 2014, Babu *et al.* 2014, Kumar *et al.* 2017). Keeping these in mind, an experiment was conducted on red kidney beans (HUR-137, Malviya Rajma) following biopriming with the microbial fungal agent *Trichoderma harzianum*.

Table 1. Effect of biopriming with *T. harzianum* and graded dose of N: P: K application on plant height (cm) of red kidney bean at different growth stages. (T_1 : Control, T_2 : RDF, T_3 : 70%RDF+Biopriming, T_4 : 80% RDF + Biopriming, T_5 : 90% RDF+Biopriming, T_6 : Control+Biopriming). Means with the same letter are not significantly different.

Treatments	Vegetative stage	Pod formation	Maturation stage
T_1	9.875^{a}	29.175^{a}	31^{a}
T_2	13.675^{c}	36.825^{c}	35.675^{b}
T_3	12.525^{bc}	31.95^{ab}	32.675^{a}
T_4	12.95^{bc}	33.675^{abc}	33^{a}
T_5	13.525^{c}	36.175^{bc}	33.675^{ab}
T_6	11.575^{ab}	29.575^{a}	31.75^{a}

MATERIALS AND METHODS

The pot experiment was conducted during *rabi* season of 2016-2017 in the net house on alluvial soil of Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, BHU, Varanasi, UP bulk surface (0–15 cm) soil was collected from the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University,

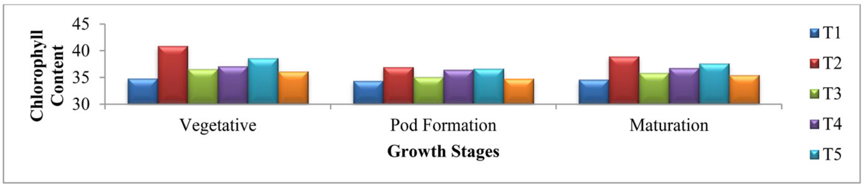

Fig. 2. Effect of biopriming with *T. harzianum* and graded levels of N: P: K application on chlorophyll content of red kidney bean at different growth stages.

Varanasi. It had available N (229 kg/ha), Available P (17 kg/ha) and Available K (230 kg/ha). For each treatment fifty seeds were taken in the petri plates. Then the microbial suspension were spread uniformly over seeds and kept for drying.

Fertilizers applied in recommended dose N : P : K @ 120 : 60 : 60 kg/ha , 1/2th N, Full P and K given at time of sowing and rest N given in 2 split dose at 25 DAS and 45 DAS. Pods were harvested after they were fully matured. The experimental design was an experiment under completely Randomized Block Design with three replications (CRD). Leaf area of the plants was measured using leaf area meter (LI-300°C) in cm^2 units at 60 and 90 days after sowing. After harvesting, plant samples were kept in paper bags and dried in hot air oven at 60 ± 2°C till the constant weight. The chlorophyll content was estimated using SPAD meter. This instrument enables non-destructive and nearly instantaneous chlorophyll measurements. It directs a beam of light corresponding to the wave length absorbed by the chlorophyll molecule through a plant leaf. Nitrogen content in plant and grain sample was determined by modified Kjeldahl method as per procedure outlined by Gupta (2007). Uptake of nutrient was calculated, to study the effect of increase/ decrease in nutrients application to soil and that different soil fertility levels on uptake of that particular nutrient by plant. Following formulae were used to calculate the total uptake of each nutrient.

Table 2. Effect of biopriming with *T. harzianum* and graded levels of N:P:K application on chlorophyll content of red kidney bean at different growth stages.

Treat-ments	Vegetative stage	Pod formation	Maturation stage
T_1	34.825[a]	34.4[a]	18.125[a]
T_2	40.925[b]	36.95[a]	24.625[b]
T_3	36.6[a]	35.125[a]	22.825[ab]
T_4	37.125[a]	36.5[a]	23.325[ab]
T_5	38.625[ab]	36.675[a]	23.925[ab]
T_6	36.15[a]	34.8[a]	20.075[ab]

Uptake (kg ha^{-1})= percent nutrient in grain × yield grain or straw (q ha^{-1})

The analysis of data was carried out using STAR. One way ANOVA for CRD was performed to compare the means of different treatments and significant differences. Duncan Multiple Range Test (DMRT) to differentiate the treatment means at $p \leq 0.5$.

RESULTS AND DISCUSSION

Plant height

Among the treatments T_2 gave the maximum plant height (Table 1, Fig. 1). It was followed by $T_{5,}$ T_4, T_3, T_6 and T_1. However, at 90 DAS significant increase in plant height was recorded with the treatment T_2

Table 3. Effect of biopriming with *T. harzianum* and graded levels of N: P: K application on leaf area (cm^{-2}) in red kidney bean at 30 and 60 DAS.

Treatments	Vegetative stage	Pod formation
T_1	71.725[a]	249.6[a]
T_2	85.1[b]	397.5[b]
T_3	78.5[ab]	293.4[ab]
T_4	80.225[ab]	338[ab]
T_5	80.425[ab]	390.725[b]
T_6	73.575[ab]	267.325[a]

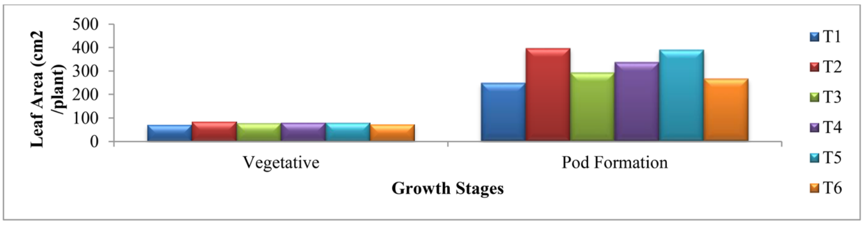

Fig. 3. Effect of biopriming with *T. harzianum* and graded levels of N application on leaf area of red kidney bean at 30 and 60 DAS.

(35.675 cm). At 90 DAS plant height ranged between, 36.33 to 63.00 and 44.50 to 47.12 cm in different treatments. In case of effect of *T. harzianum* and different graded dose of NPK application, plant height was indicated in following order : $T_2 > T_5 > T_4 > T_3 > T_6 > T_1$ in all the growth stages of red kidney bean. Enhanced plant height by *Trichoderma* inoculation can be attributed to production of secondary metabolites which may act as an auxin compound and other secondary metabolites such as harzianolide and anthroquinoues. Similar results were also reported by Vinale *et al.* (2008) in wheat, Molla *et al*. (2012), Azarmi *et al.* (2011), Rudresh *et al.* (2005), Inbar *et al.* (1994), Bjorkman *et al*. (1998). However, Mwangi *et al.* (2009) in also found increment in plant height in tomato and napier but increment was found to be non-significant and attributed the increase in plant height to production of growth hormones (Mwangi *et al.* 2009, Windham *et al.* 1986, Reddy *et al.* 1996). A 10.55% increase was observed in plant height on inoculation with the fungus over control (Khan *et al.* 2001). Phytohormones like auxin and gibberellins are produced by *Trichoderma* and solubilization of nutrients like phosphorus, iron, manganese, zinc have been found to be responsible for improvement in plant height (Kakabouki *et al.* 2021, Elkelish *et al.* 2020, Smith and Reddy 2010).

Chlorophyll content

At 30 DAS maximum chlorophyll content was observed in T_2 (40.925) as shown in Table 2, Fig. 2 followed by T_5 (38.625), T_4 (37.125) and T_3 (36.6). At 60 DAS trend of chlorophyll content was in the order i.e., $T_2 > T_5 > T_4 > T_3 > T_6 > T_1$. At 90 DAS maximum chlorophyll content was observed in T_2 (24.625). The chlorophyll content followed the order : $T_2 > T_5 > T_4 > T_3 > T_6 > T_1$. Throughout the growth duration of the crop, chlorophyll content was minimum in T_1 i.e., control with values 34.825, 34.4 and 18.125 at vegetative (30 DAS), pod formation (60 DAS) and maturation stages (90 DAS) respectively. Data of chlorophyll content at 60 DAS of plants was significantly affected due to application of graded doses of fertilizer with combination of seed biopriming by *T. harzianum*. This happened due to the fact that this soil has better potential with application of different dose of N application with seed biopriming by *T. harzianum* (Singh and Singh 2011, Meena

Table 4. Effect of biopriming with *T. harzianum* and graded levels of NPK application on dry matter production (g plant^{-1}) of red kidney bean.

Treatments	Vegetative stage	Pod formation	Maturation stage
T_1	0.1225^{a}	0.123333^{c}	1.0175^{c}
T_2	0.225^{a}	0.306667^{a}	1.425^{a}
T_3	0.1675^{abc}	0.206667^{bc}	1.1275^{bc}
T_4	0.1875^{ab}	0.236667^{ab}	1.21^{b}
T_5	0.1925^{ab}	0.266667^{a}	1.2775^{ab}
T_6	0.1575^{bc}	0.19^{bc}	1.21^{b}

Table 5. Effect of biopriming with *T. harzianum* and graded levels of NPK application on nutrient uptake of red kidney bean.

Treatments	Nitrogen uptake	Phosphorus uptake	Potassium uptake
T_1	0.74^{c}	0.30^{c}	14.07^{c}
T_2	1.82^{a}	0.54^{a}	31.34^{a}
T_3	1.00^{c}	0.39^{b}	20.38^{bc}
T_4	1.13^{bc}	0.44^{b}	25.84^{ab}
T_5	1.47^{ab}	0.47^{ab}	28.16^{ab}
T_6	1.03^{c}	0.43^{b}	20.80^{abc}

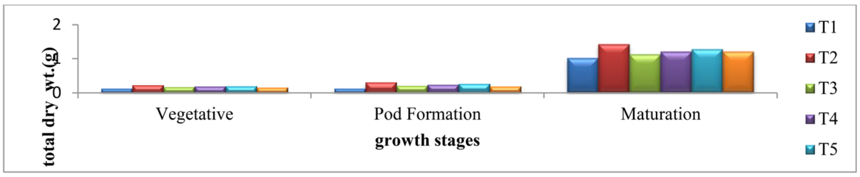

Fig. 4. Effect of biopriming with *T. harzianum* and graded levels of N application on dry matter production of red kidney bean at different growth stages.

et al. 2016). Higher chlorophyll content leads to higher photosynthetic efficiency as a result of higher nutrient uptake and translocation from roots to aerial parts with some growth regulators (Azarmi *et al.* 2011) and due to production of VOCs (Hung *et al.* 2013). It also suppresses chlorophyll losses in drought conditions (Shukla *et al.* 2012). Hexon *et al.* (2009) demonstrated increase in photosynthetic pigments in *Trichoderma* inoculated *Arabidopsis thaliana* based on the fact that *Trichoderma* increased root biomass leading to better nutrient acquisition and in turn more photosynthetic pigments. Similar results were encountered in maize plant by Akladious and Abbas (2014).

Leaf area of red kidney bean at different growth stages

A gradual and consistent increase in leaf area was observed up to 60 DAS and there after it decreased. Maximum leaf area was recorded with T_2 in both growth stages of red kidney bean.Maximum leaf area increase was recorded between 30 DAS to 60 DAS. At all growth stages maximum leaf area was recorded in treatment T_2. At 30 DAS, treatment T_2 has maximum leaf area (85.1 cm^2 plant^{-1}) and minimum was recorded in T_1. T_6 is significantly different from T_2 with leaf area 73.575 cm^2 plant^{-1} (Table 3, Fig. 3). At 60 DAS treatment T_2 has maximum leaf area (397.5 cm^2 plant^{-1}. Increase in leaf area of T_2 over control was 13.375 and 147.9 cm^2 plant^{-1} at 30 and 60 DAS respectively. Similar extent of increase in leaf area by the application of *Trichoderma harzianum* with T_3 and T_2 suggested role of *Trichoderma harzianum* in solubilizing several plant nutrients (Altomare *et al.* 1999) improving the plant root system which have been manifested in above ground biomass. *Trichoderma* inoculation leads to increase in rate of leaf photosynthesis (Vargas *et al.* 2009, Inbar *et al.* 1994, Yedidia *et al.* 2001, Azarmi *et al.* 2011). Bader and co-workers in a recent study showed that seed treatment with *Trichoderma harzianum* increased leaf area with effect from phytohormone production (Bader *et al.* 2020). Khan and co-workers in observed and increment in number of leaves in tomato plants inoculated with *Trichoderma* (Khan *et al.* 2001).

Dry matter production

The rate of increase in DMP was enhanced rapidly between 30 to 60 DAS. At 30 DAS, T_2 caused significantly higher dry matter production (0.225 g plant^{-1}) and this was significant over rest other treatments. T_1 had minimum dry matter production with 0.122 g plant^{-1}. At 60 DAS significantly higher dry matter production was recorded in treatment T_2 (0.3067 g plant^{-1}) followed by T_5, T_4, T_3, T_6 and T_1. At 90 DAS, the dry matter production increased as compared to 30 to 60 DAS and the significantly higher dry matter production was recorded with the treatment T_2 (1.425 g plant^{-1}). Lowest dry matter production was recorded with T_1 (Table 4, Fig. 4). At 90 DAS dry matter production ranged between 1.0175, 1.425, 1.1275, 1.21, 1.2775 and 1.21 g plant^{-1} respectively in different treatments. Result clearly illustrated that dry matter production of red kidney bean plant was boosted by the combined use of *Trichoderma harzianum* and N : P : K. It may also be ascribed due to adequate supply of nutrients due to mineralization of nutrients by increased population of *Trichoderma harzianum*. Significant increase in dry matter of plant by the combined use of biofertilizer and N : P : K in experiments conducted in Bangladesh

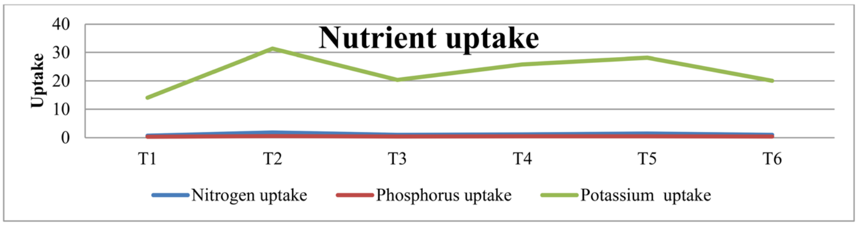

Fig. 5. Effect of biopriming with *T. harzianum* and graded levels of N application on nutrient of red kidney bean at different growth stages.

(Molla *et al.* 2012, Haque *et al.* 2012). *Trichoderma* spp. enhancing plant growth has been reported in several crop plants and has been attributed to auxin (Conteras-Cornejo *et al.* 2009). Besides, nutrient acquisition is improved enhancing indirect growth promotion due to better nutrient supply and uptake (Bjorkman *et al.* 1998, Rudresh *et al.* 2005). Some workers affirmed the improvement in root and shoot growth production in corn inoculated with *Trichoderma* backed by the fact that it can produce auxin (IAA) which initiate and promote root elongation and shoot growth reflected in the dry matter production of the crop (Zhang *et al.* 2012).

Nutrient uptake

At 30 DAS, T_2 caused significantly higher nitrogen uptake (1.82) and T_1 had minimum nitrogen uptake with 0.74. For phosphorus uptake it was higher recorded in treatment T_2 followed by T_5, T_4, T_3 and T_1 (Table 5, Fig. 5). For potassium uptake was recorded with the treatment T_2 (0.54). Potassium uptake ranged between 0.30, 0.54, 0.39, 0.44, 0.47and 0.43 respectively in different treatments.Result clearly illustrated that nutrient uptake of red kidney bean plant was boosted by the combined use of *Trichoderma harzianum* and N: P: K. The increase in nutrient uptake of shoot may be due to increased volume of root biomass enabling large volume of soil exploitation of the plant which could increase the chance for nutrients uptake through maximum access to use mineral nutrients. Higher N uptake may be due to the microbial inoculants which is an ensuring unit with the capacity to promote the plant growth, enhance nutrient availability and uptake and support the health of plant due to production of growth promoting substances (Adesemoye *et al.* 2009, Singh and Singh 2011, Azarmi *et al.* 2011, Rudresh *et al.* 2005).

CONCLUSION

The research data supports the points that :

a) Biopriming of the crop with *Trichoderma harzianum* improved the plant height, leaf area, chlorophyll content, dry matter production and nutrient uptake.

b) Full doze of fertilizer was best for the productivity of dry bean followed by 90% RDF+biopriming with *T. harzianum*.

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REFERENCES

Adesemoye AO, Torbert HA, Kloepper JW (2009) Plant growth-promoting rhizobacteria allow reduced application rates of chemical fertilizers. *Microb Ecol* 58 : 921—929.

Akladious SA, Abbas SM (2014) Application of *Trichoderma harzianum* T_{22} as a biofertilizer potential in maize growth. *J Pl Nutri* 37(1) : 30—49. DOI: 10.

80/01904167.2013.829100.

Altomare C, Norwell WA, Bjorkman T, Harman GE (1999) Solubilization of phosphates and micronutrients by the plant-growth-promoting and biocontrol fungus *Trichoderma harzianum* Rifai 1295-22. *Appl Environ Microbiol* 65 (7) : 2926—2933.

Anonymous (2017) Annual report 2016-2017. Department of Agriculture Cooperation and Farmers Welfare Government of India.

Azarmi R, Hajieghrari B, Giglou A (2011) Effect of Trichoderma isolates on tomato seedling growth response and nutrient uptake. *Afr J Biotechnol* 10 (31) : 5850—5855.

Babu AG, Shim J, Bang KS, Shea PJ, Oh BT (2014) *Trichoderma virens* PDR-28: A heavy metal-tolerant and plant growth-promoting fungus for remediation and bioenergy crop production on mine tailing soil. *J Environ Manag* 132 : 129—134.

Bader NA, Salerno GL, Covacevich F, Consolo VF (2020) Native *Trichoderma harzianum* strains from Argentina produce indole-3 acetic acid and phosphorus solubilization, promote growth and control wilt disease on tomato (*Solanum lycopersicum* L.). *J King Saud Univ Sci* 32 : 867—873.

Bjorkman T, Blanchard LM, Harman GE (1998) Growth enhancemnent of shrunken-2 (sh2) sweet corn by *Trichoderma harzianum* 1295-22 : Effect of environmental stress. *J Am Soc Hortic Sci* 123 (1) : 35—40.

Chandran MDS (2016) The pulses of life. *Ind Inst Sci, Bangalore* 62 : 65—80.

Chaverri P, Branco-Rocha F, Jaklitsch W, Gazis R, Dekenkolb T, Samuels GJ (2015) Systematics of the *Trichoderma harzianum* species complex and the re-identification of commercial biocontrol strains. Mycologia 107 (3) : 558—590.

Contreras-Cornejo HA, Macías-Rodríguez L, Cortés-Penagos C, López-Bucio J (2009) *Trichoderma virens*, a plant beneficial fungus, enhances biomass production and promotes lateral root growth through an auxin-dependent mechanism in *Arabidopsis*. *Pl Physiol* 149 : 1579—1592.

Elkelish AA, Alhaithloul HAS, Qari SH, Soliman MH, Hasanuzzaman M (2020) Pretreatment with *Trichoderma harzianum* alleviates water logging induced growth alterations in tomato seedlings by modulating physiological, biochemical and molecular mechanisms. *Environ Exp Bot* 171 : 103946.

Gupta PK (2007) Soil, plant, water and fertilizer analysis. Agrobios, Jodhpur, India.

Haque M, Ilias GNM, Molla AH (2012) Impact of *Trichoderma*-enriched biofertilizer on the growth and yield of mustard (*Brassica rapa* L.) and tomato (*Solanum lycopersicon* Mill.). *Agriculturists* 10 (2): 109—119.

Hung R, Lee S, Bennett JW (2013) *Arabidopsis thaliana* as a model system for testing the effect of *Trichoderma* volatile organic compounds. *Fungal Ecol* 6 : 19—26.

Inbar J, Abramsky M, Cohen D, Chet I (1994) Plant growth enhancement and disease control by *Trichoderma harzianum* in vegetable seedlings grown under commercial conditions. *Europ J Pl Pathol* 100 (5) : 337—346.

Jackson ML (1973) Soil Chemical Analysis. Prentice Hall of India Pvt Ltd, New Delhi, pp 498.

Kakabouki I, Tataridas A, Mavroeidis A, Kousta A, Karydogianni S, Zisi C, Kouneli V, Konstantinou A, Folina A, Konstantas A, Papastylianou P (2021) Effect of Colonization of *Trichoderma harzianum* on Growth Development and CBD Content of Hemp (*Cannabis sativa* L.). Microorganisms 9:518. https://doi.org/10.3390/microorganisms9030518.

Khan HU, Ahmad R, Ahmed W, Khan SM, Khan MA (2001) Evaluation of the combined effects of Paecilomyces lilacinus and *Trichoderma harzianum* against root-knot disease of tomato. *Online J Biol Sci* 1 (3) : 139—142.

Kumar A, Maurya BR, Raghuwanshi R, Meena VS, Islam MT (2017) Co-inoculation with Enterobacter and *Rhizobacteria* on yield and nutrient uptake by wheat (*Triticum aestivum* L.) in the alluvial soil under indo-gangetic plain of India. *J Pl Growth Reg* http://dx.doi.org/10.1007/s00344-016-9663-5.

Meena VS, Maurya BR,Verma JP (2014) Does a rhizospheric microorganism enhance Kþ availability in agricultural soil ? *Microbiol Res* 169 : 337—347.

Meena VS, Maurya BR, Verma JP, Aeron A, Kumar A, Kim K, Bajpai VK (2015) Potassium solubilizing rhizobacteria (KSR): Isolation, identification and K-release dynamics from waste mica. *Ecol Eng* 81 : 340—347.

Meena SK, Rakshit A, Meena VS (2016) Effect of seed biopriming and N doses under varied soil type on nitrogen use efficiency (NUE) of wheat (*Triticum aestivum* L.) under greenhouse conditions. *Biocatalysis Agric Biotechnol* 6 : 68—75.

Molla AH, Haque M, Haque A, Ilias GNM (2012) *Trichoderma*-enriched biofertilizer enhances production and nutritional quality of tomato (*Lycopersicon esculentum* Mill.) and minimizes NPK fertilizer use. *Agric Res* 1 (3) : 265—272.

Mwangi MW, Monda EO, Okoth SA, Jefwa JM (2009) Effect of *Trichoderma harzianum* and *Arbuscular mycorrhizal* fungi on growth in tomato (*Lycopersicum esculentum* Mill) seedlings, napier (*Pennisetum purpureum* L) and tea (*Camellia sinensis* L) cuttings. *Trop Sub trop Agro Ecosyst* 11 : 423 ––429.

Rakshit A, Pal S, Meena S, Manjhee B, Rai S, Rai A, Bhowmick MK, Singh HB (2014) Seed bio-priming : A potential tool in integrated resource management. *SATSA Mukhaptra Ann Techn Issue* 18 : 94—103.

Reddy PP, Rao MS, Nagesh M (1996) Management of the citrus nematode *Tylenchulus semipenetrans* by integration of *Trichoderma harzianum* with oilcakes. *Nematol Medit* 24 : 265—267.

Rudresh DL, Shivaprakasha MK, Prasad RD (2005) Effect of combined application of *Rhizobium*, phosphate solubilizing bacterium and *Trichoderma* spp. on growth, nutrient uptake and yield of chickpea (*Cicer arietenum* L.). *Appl Soil Ecol* 28 : 139—146.

Shukla N, Awasthi RP, Rawat L, Kumar J (2012) Biochemical and physiological responses of rice (*Oryza* *sativa* L.) as influenced by *Trichoderma harzianum* under drought stress. *Pl Physiol Biochem* 54 : 78—88.

Singh SP, Singh HB (2011) Effect of consortium of *Trichoderma harzianum* isolates on growth attributes and *Sclerotinia sclerotiorum* rot of brinjal. *Veg Sci* 39 (2) : 144—148.

Smith SE, Read DJ (2010) Mycorrhizal Symbiosis ; Academic Press : San Diego, CA, USA.

Vargas WA, Mandawe JC, Kenerley CM (2009) Plant-derived sucrose is a key element in the symbiotic association between *Trichoderma virens* and maize plants. *Pl Physiol* 151 (2) : 792—808.

Vinale F, Sivasithamparam K, Ghisalberti EL, Marra R, Barbetti MJ, Li H, Woo SL, Lorito M (2008) A novel role for *Trichoderma* secondary metabolites in the interactions with plants. *Physiol Mol Pl Pathol* 72 (1-3) : 80—86.

Windham MT, Elad Y, Baker B (1986) A mechanism for increased plant growth induced by *Trichoderma* spp. *Phytopathol* 76 : 518—521.

Yedidia I, Srivastava AK, Kapulnik Y, Chet I (2001) Effect of *Trichoderma harzianum* on microelement concentrations and increased growth of cucumber plants. *Pl Soil* 235 (2) : 235—242.