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Effect of nitrogen levels and seed bio-priming on root infection, growth and yield attributes of wheat in varied soil type

Sunita Kumari Meena[a,b,*], Amitava Rakshit[a], Harikesh B. Singh[c], Vijay Singh Meena[a,d,*]

[a] Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi 221005, Uttar Pradesh, India
[b] Division of Soil Science and Agricultural Chemistry, ICAR-Indian Agriculture Research Institute, New Delhi 110012, India
[c] Department of Mycology and Plant Pathology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi 221005, Uttar Pradesh, India
[d] ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora 263601, Uttarakhand, India

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ABSTRACT

There is increasing interest in the use of beneficial microbes as alternatives to chemical fertilizers and plant growth promoters in agricultural production. Judicious application of *Trichoderma* sp. with chemical nitrogenous (N) fertilization to seeds will be an efficient mechanism for placement into varied soil type (alluvial, red and black) where they enhance the colonize seedling roots and establishment of the plant. Significantly higher leaf area was recorded with T_2 (RDF of NPK @ 120-60-60 kg ha^{-1}) in both growth stage of wheat as compared to rest of the treatments. Data at 30 days after sowing (DAS) revealed that leaf area range significantly varied between ~ 59 to 86, 15 to 26 and 26 to 55 cm^2 $plant^{-1}$ under alluvial, red and black soils, respectively. Results clearly indicated that the root infection was significantly varied at 30 DAS from 5% to 18%, 6% to 23% and 5% to 14% for alluvial, red and black soils, respectively under different treatment combinations. It was significantly higher with T_1 (Control NPK @ 0-0-0 kg ha^{-1}) and the values were respectively for ~ 18%, 23% and 14% in alluvial, red and black soils. However, the combined application of N and seed bio-priming resulted in highest root infection incidence in the red (14.87%) followed by alluvial (12.40%) and black (8.73%) soils. Significantly higher grain yield was recorded with T_2 (RDF of NPK @ 120-60-60 kg ha^{-1}) followed by T_3, T_4, T_5 and T_1 treatments. It was varied significantly between 0.56 to 6.35, 0.20 to 2.65 and 0.36 to 5.12 g pot^{-1} under alluvial, red and black soils, respectively. The combined application of *T. harzianum* with chemical N fertilization will be one of the sustainable solutions for improving the ability of seed bio-priming to establish and function consistently in the field for sustainable crop production.

1. Introduction

Global increases in food production achieved in recent decades with changing climatic scenario have required large (15–20 times) increases in the use of synthetic pesticides to control pests, pathogens and weeds of crops (Oerke, 2006; Meena et al., 2017b) meanwhile, the increasing use of synthetic agrochemicals (Adesemoye et al., 2009; Ahmad et al., 2016). Strong consumer pressure has resulted in the withdrawal of many synthetic agrochemicals, the lowering of maximum residue limits and changes in the regulatory environment that favour more environmentally benign control options (Meena et al., 2014). The search for alternative and eco-friendly solutions for agriculture has prompted researchers to take a second look at the range of efficient microbes long known to provide benefits to agricultural production and is driving rapid growth in markets for biopesticides (Meena et al., 2017a; Meena and Meena, 2017). Seed is a basic and vital input for sustained growth in agricultural productivity and production ~ 90% of the food crops are grown from seed (Kloepper et al., 1989; Meena et al., 2017b).

In sustainable, low-input cropping systems the roles of microbes in maintaining soil fertility, improving plant nutrition and biocontrol of plant pathogens may be more important than in conventional agriculture in which high inputs of agrochemicals are used (Kumar et al., 2017; Meena et al., 2017c). Numerous studies have reported that the application of beneficial microbes may represent a reliable alternative to reduce the application of agrochemicals in modern agriculture (Meena et al., 2016). The combination of microbes having multiple positives and complementary functions could be more beneficial for increasing growth and yield and may provide plant protection under different conditions (Harman, 2006). The bio-priming is a process of biological seed treatment that refers combination of seed hydration and inoculation of seed with beneficial biological agent to protect seed, improves seed germination, seedling establishment and vegetative

* Corresponding authors at: Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi 221005, Uttar Pradesh, India.
E-mail addresses: sumeena66@gmail.com (S.K. Meena), vijayssac.bhu@gmail.com, vijay.meena@icar.gov.in (V.S. Meena).

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growth (Rakshit et al., 2014; Babu et al., 2014; Kumar et al., 2017).

In the sustainable agriculture production system, vesicular arbuscular mycorrhizal (VAM) fungi are one of the important beneficial microbes in the rhizospheric soils and have potential use in forestry for promoting plant growth and productivity. VAM fungi play a dominant role in increasing phosphorus solubilization and uptake of phosphorus (P), nitrogen (N), calcium (Ca), sulphur (S), potassium (K) and micronutrients by plants. *Trichoderma* sp. has been described as fungal biocontrol agents, acting by either, the production of antimicrobial compounds or parasitism of fungal plant pathogens (Singh et al., 2003; Kumar et al., 2017). Conversely, mycorrhiza formation can affect the microbial population in the rhizosphere directly or indirectly through changes in root exudation (composition and quantity) patterns, or through fungal exudates (Kumar et al., 2011; Rakshit et al., 2015).

The use of microbes with the aim of improving nutrients availability for plants is an important practice and necessary for agriculture (Meena and Meena, 2017). Efficient use of *Trichoderma*-enriched biofertilizer may increase yield, reduce the uses of N fertilizers, reduce soil borne pathogens and improve soil health (Haque et al., 2012). *Trichoderma* also interacts with beneficial root inhabiting fungi like mycorrhizae. The interaction of *Trichoderma* species with mycorrhizal fungi is different as during interaction with VAM different signaling cascades are activated that lead to a synergistic action. Several studies have noted the beneficial effects of the arbuscular mycorrhizal (AM) fungi and *Trichoderma* sp. to improve plant productivity and soil quality (Rakshit et al., 2014; Meena et al., 2017b). Synergistic effects of both fungi on plant growth as well as on the control of various plant diseases have been previously shown (Martínez-Medina et al., 2011; Contreras-Cornejo et al., 2014). The ability of *Trichoderma* sp. to impede colonization of plant roots by AM fungal species appears to be dependent on the order of inoculation of the fungi. The seed bio-priming then becomes a system rather than merely a component added to seeds. At last, it can be said that seed bio-priming must be an initial step of raising crop and has a pivotal role in sustainable crop production which cannot be ignored. Thus, for an optimal management of microbial consortia, it is necessary to thoroughly understand the interaction between these two fungi to guarantee these successful applications under field condition which may help in the development of sustainable agricultural practices. Information regarding root infection, growth and yield attributes of wheat in varied soil type is limited. In this study, an attempt has been made to quantitatively estimate root infection as affected by seed bio-priming and chemical N fertilization with the following objectives: (i) to determine the effects of seed bio-priming and chemical N management on yield and yield attributes of wheat crop under varied soil types, and (ii) to assess root infection and root growth attributes that influences growth, development and productivity of wheat crop.

2. Materials and methods

2.1. Experimental soils

The present investigation on wheat was carried out in pots in the net house of the Department of Soil science and Agricultural Chemistry, Institute of Agriculture Sciences, Banaras Hindu University, Varanasi, India situated at an altitude of ~ 80 mts above mean sea level and at 25°18′ North latitude and 80°36′ East longitudes. Seed bio-priming with *T. harzianum* along with gradual application of nitrogen were applied in the three types of soils. The soils of three orders; Entisol, Inceptisol and Alfisol were collected. The Alluvial soil sample was collected from the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. The red soil was collected from the Semara village in Shahabganj, Mirzapur and black soil was collected from Arziline block Sehansapur, Varanasi, initial soil properties of experimental soils present in Table 1.

Table 1
Initial physicochemical properties of experimental soils.

Physical Parameter	Alluvial Soil	Red Soil	Black Soil
Bulk Density ($Mg\ m^{-3}$)	1.4	1.3	1.5
Particle density ($Mg\ m^{-3}$)	2.6	2.5	2.6
Water holding capacity (%)	39.9	38.9	44.9
Sand (%)	48.8	46.0	11.7
Silt (%)	30.5	32.8	52.7
Clay (%)	20.4	21.5	35.6
Soil Texture	Sandy loam	Silty clay loam	Clayey
Electro-chemical and Chemical properties			
pHw (1:2.5)	7.2	6.4	7.4
EC ($dS\ m^{-1}$)	0.4	0.3	0.6
CEC (C mol (p^{+}) kg^{-1})	29.0	18.0	30.9
Organic carbon ($g\ kg^{-1}$)	3.7	3.1	3.9
Available N ($kg\ ha^{-1}$)	229.0	173.0	236.0
Available P ($kg\ ha^{-1}$)	17.0	8.0	13.0
Available K ($kg\ ha^{-1}$)	230.0	109.0	235.0

2.2. Experimental and treatment details

The experiment has been under taken on three different soil types at the Institute of Agricultural Sciences, Banaras Hindu University, during December 2012 to April 2013, under net house conditions, bio-primed seed of wheat-234 with *T. harzianum* along with different levels recommended fertilizer doses was grown. *Trichoderma* strain was isolated from different regions of Uttar Pradesh by Department of Mycology and Plant Pathology, Institute of Agricultural Science, BHU, Varanasi and characterized for their plant growth promotion activity. The most efficient and compatible *Trichoderma* isolates *Trichoderma harzianum* BHU51 (Gene Bank accession no. JN 618343) was used in this study. A total five treatments were applied and theses are as follows: T_1: Control NPK @ 0-0-0 $kg\ ha^{-1}$; T_2: RDF of NPK @ 120-60-60 $kg\ ha^{-1}$; T_3: Bio-priming with *T. harzianum* + ¾th N and RDF of PK; T_4: Bio-priming with *T. harzianum* + ½ N and RDF of PK; T_5: Bio-priming with *T. harzianum* + ¼th N and RDF of PK. During the various crop growth stages recommended agronomical practices were followed for better crop production.

Table 2
Effect of soil types, seed bio-priming and graded levels of N application on leaf area of wheat crop at 30 and 60 days after sowing.

Treatment[a]		Soil types			
		Alluvial soil ($cm^2\ plant^{-1}$)	Red soil		Black soil
30 DAS	T_1	59.5	14.6		25.8
	T_2	85.7	25.7		54.5
	T_3	71.2	21.7		53.2
	T_4	63.2	13.3		44.3
	T_5	62.7	10.3		36.3
		SEm ±		CD $p < 0.05$	
	Treatment	0.62		2.40	
	Soils type	0.34		1.32	
	Interaction	1.07		4.16	
60 DAS	T_1	65.1	30.2		46.5
	T_2	188.0	119.2		142.2
	T_3	181.3	110.9		136.9
	T_4	155.9	86.0		123.2
	T_5	83.1	73.0		63.5
		SEm ±		CD $p < 0.05$	
	Treatment	5.60		21.78	
	Soils type	3.07		11.93	
	Interaction	9.70		37.72	

[a] T_1: Control NPK @ 0-0-0 $kg\ ha^{-1}$; T_2: RDF of NPK @ 120-60-60 $kg\ ha^{-1}$; T_3: Bio-priming with *T. harzianum* + ¾th N and RDF of PK; T_4: Bio-priming with *T. harzianum* + ½ N and RDF of PK; T_5: Bio-priming with *T. harzianum* + ¼th N and RDF of PK.

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