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Effect of Foliar Application of Phosphorus on Rhizosphere and Rhizoplane Fungal diversity in *Brassica juncea*

Walay Y. Tagade[1*], M. V. Kawale[2], R. B. Zode[3] and R. P. Thakre[4]

[1,3] *Department of Botany, C.J. Patel College, Tirora, Dist- Gondia, Maharashtra-441911*

[2]*Department of Botany, Dhote Bandhu Science College, Gondia, Maharashtra-441614*

[4]*Department of Botany, RTM Nagpur University, Nagpur, Maharashtra- 440033*

[*]*Corresponding author Email: walaytagade@gmail.com*

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ABSTRACT

The microbial communities, also called as microhabitat, play an important role in the growth and development of the plants. The rhizosphere fungal diversity is always different from the non-rhizosphere fungal diversity. The foliar application of fertilizers has significant effect on fungal diversity of rhizosphere. Hence, a study was conducted to understand the effect of foliar application of phosphorus on the rhizosphere and rhizoplane fungal diversity of cultivar line EH-3 and *varuna* variety of *Brassica juncea*. The foliar application of potassium dihydrogen phosphate as a source of phosphorus was used at the concentration of 0.5 and 1%. The foliar application of phosphorus resulted in considerable changes in the fungal diversity of treated plants as compared to the control plants. During the study in all 36 fungal species were isolated from rhizosphere and non-rhizosphere soil. The number of fungal colonies were found to be more during the flowering stage as compared to seedling and maturity stage. *Aspergillus* sp. was found to be significantly dominant compared to other rhizosphere fungal diversity as it was documented to account for 30-40% rhizosphere fungal microbes followed by *Fusarium* sp. which was around 15%. Apart from these, remaining all fungi documented were found to account for less than 10% of the fungal population. The rhizoplane study also revealed that the per cent occurrence of *Aspergillus* sp. was more in control as well as in treated plants of EH-3 and variety *varuna*.

KEYWORDS: EH-3, Foliar application, phosphorus, rhizoplane, rhizosphere, fungal diversity.

INTRODUCTION

The rhizosphere is an ecological niche of the soil, adjacent to root system of plants. It provides the microhabitat for the aerobic and anaerobic microorganism. Interactions between soil microorganisms and plant roots satisfy important nutrient requirements for both plant and associated microorganisms. Similarly, rhizoplane is an immediate external surface of plant roots together with closely adhering soil particles or root debris. The striking influence that root exert on the rhizosphere is the stimulation for various types of microorganisms such as algae, bacteria and fungi and this effect is known as rhizosphere effect. It generally depends on the release of organic substances by plant roots which stimulate the growth of microorganisms (Liljeroth and Baath, 1988).

Addition of plant nutrients in soil or foliar application of nutrients on plant causes variation in the exudation of some chemicals by the plant roots. The altered root exudation also changes the pattern of rhizosphere microflora both on qualitative and quantitative basis (Raaijmakers *et.al.,* 2009). The application of micronutrients (Cu, Fe, Mn and Zn) at the rate of 500 mg/liter has been reported to significantly increase wheat straw yield and grain quality (Seadh *et.al.,* 2009). Phosphorus is one of the important macronutrients for the growth and development of plants (Hameeda *et.al.,* 2008). It plays an important role in many biological processes. However, the strong adsorption of phosphorus by minerals in the soil is reported to decrease its availability to plants, therefore reducing the productivity of agricultural and forest ecosystems (Kafle *et.al.,* 2019). Hence, the foliar application of potassium dihydrogen phosphate (KH_2PO_4) in the form of phosphorus is normally given to alter the rhizosphere fungal diversity.

Dhedhi *et. al.,* (1990) studied the rhizosphere and rhizoplane of wilted and root-rot diseased plant of Chickpea and suggested that the diseased and healthy plants show considerable variation in rhizosphere and rhizoplane fungal diversity. Jha and Jalali (2006) documented and evaluated the biocontrol potential of the fungal isolates from Pea (*Pisum sativum*) rhizosphere against *Fusarium solani* f. sp. *pisi*. Likewise there are many studies on soil microbes and fungi of non-rhizosphere, rhizosphere and rhizoplane but there is little study on the fungal diversity of rhizosphere and rhizoplane of *Brassica juncea*. In view of this the present study has been undertaken on variety *varuna* (containing high amount of glucosinolate and susceptible to white rust) and selection line EH-3 (Early Heera, containing very low amount of glucosinolate and resistant to white rust) of *Brassica juncea*.

MATERIALS AND METHODS

Description of the study area: To investigate the rhizosphere and rhizoplane fungal diversity of *Brassica juncea*, variety *varuna* and cultivar line EH-3 was selected to conduct the experiments. The seeds for this purpose were procured from the Dhara Vegetable Oil and Foods Company Ltd. (**DOFCO**) sponsored project, Department of Botany, R.T.M. Nagpur University, Nagpur, Maharashtra, India. The seeds were grown in the field and foliar applications were done so as to alter the rhizosphere and rhizoplane fungal diversity (**Fig. 1**).

Potassium dihydrogen phosphate treatment: Foliar application of the 0.5 and 1% phosphorus was given by using potassium dihydrogen phosphate purified (KH_2PO_4) at three different stages, i.e. seedling, flowering and maturity stage.

Collection of rhizosphere soil samples: Three soil samples were collected during the different stages of plant growth (i.e. seedling, flowering and maturity) from the experimental field of Post Graduate Teaching Department of Botany; RTM Nagpur University Campus Nagpur, Maharashtra, India. Roots of healthy plants with adhering soil and NRS (non-rhizosphere soil) were collected and transferred to the sterile plastic bags and brought to the laboratory for examination.

Isolation of Fungi: Rhizospheric fungal microorganisms

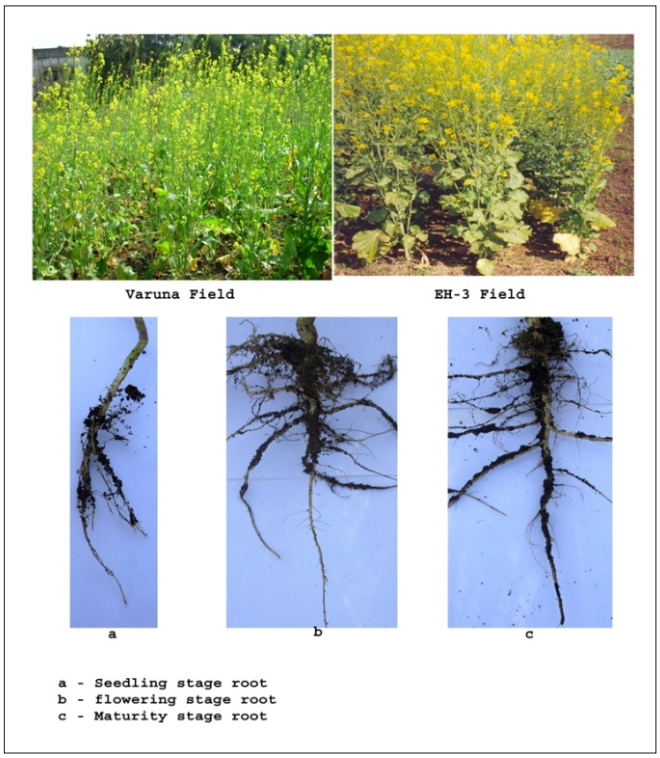

Fig.1. Experimental field and roots with rhizosphere oil.

were isolated by serial dilution plate technique (Johnson and Curl, 1972) using Czepak's Dox agar medium. After incubation, the number of colonies which appeared on plates, were counted and per cent occurrence of particular fungus was calculated. Likewise, the rhizosphere effect was studied employing the method given by Katznelson (1946). A numerical value and the R:S ratio was used to compare the fungal microorganisms present in the rhizosphere with the fungal population present outside of the rhizosphere soil.

1. **Isolation of rhizoplane fungi**: The rhizoplane fungi were isolated by serial-root washings technique (Harley and Waid, 1955).

2. **Identification of fungi**: The fungi isolated from rhizosphere and rhizoplane were identified by consulting standard literature (Nagmani *et.al*., 2006; Booth, 1977; Raper and Fennell, 1965; Raper and Thom, 1949).

RESULTS

Rhizosphere fungi: The foliar application of phosphorus resulted in considerable changes in fungal diversity documented in the rhizosphere of cultivar EH-3 and variety *varuna* as compared to the control plants. During the investigation, total 36 fungal species were isolated from NRS and rhizosphere of control and treated plants of cultivar EH-3 and variety *varuna*. The different fungi isolated were *Absidia* sp., *Alternaria alternata, Alternaria* sp., *Aspergillus clavatus A. fischeri A. flavipes, A. flavus, A. fumigatus, A. nidulans, A. niger, A. ochraceus, A. sulphureus, A. sydowii, A. terreus, A. wentii, Chaetomium globosum, Cladosporium* sp., *Curvularia lunata, Curvularia* sp., *Drechslera* sp., *Fusarium graminearum, F. oxysporum, Fusarium* sp., *Helminthosporium* sp., *Penicillium citrinum, P. purpurogenum, P. lilacinum, P. oxalicum, P. multicolor, Penicillium* sp. 1, *Penicillium* sp. 2, *Phoma* sp., *Rhizopus stolonifer, Syncephalastrum* sp., *Trichoderma viride* isolate I and II.

In all 22 fungal species were obtained from the non-rhizosphere soil (NRS). These are *Absidia* sp., *Alternaria alternata, Alternaria* sp., *Aspergillus flavus, A. fumigatus, A. niger, A. ochraceus, A. sulphureus, A. sydowii, A. terreus, A. wentii, Cladosporium* sp., *Curvularia lunata, Fusarium graminearum, F. oxysporum, Penicillium citrinum, P. lilacinum, P. multicolor, P. oxalicum, Penicillium* sp., *Rhizopus stolonifer* and *Syncephalastrum* sp. Likewise, in all 27 and 28 species of fungi were isolated from rhizosphere of control plants of cultivar EH-3 and variety *varuna*, respectively. Amongst the 27 species isolated from the rhizosphere of cultivar EH-3; *Aspergillus clavatus, Chaetomium globosum, Fusarium* sp., *Helminthosporium* sp., *Penicillium* sp. 2 and *Phoma* sp. were not observed in NRS. Apart from these fungi, *Aspergillus wentii, Fusarium graminearum, Penicillium* sp. 1 and *Syncephalastrum* sp. were isolated from NRS but not from control plants of cultivar EH-3. Similarly, out of 28 fungi isolated from variety *varuna* rhizosphere; *Aspergillus fischeri, A. flavipes, A. nidulans, Chaetomium globosum, Curvularia* sp., *Drechslera* sp., *Fusarium* sp. *Helminthosporium* sp., and *Penicillium purpurogenum* were not observed in non-rhizosphere soil. However, fungal species like *Aspergillus sydowii, A. terreus, A. wentii* and *Penicillium* sp. 1 were isolated from NRS but not observed in the rhizosphere of variety *varuna*.

The foliar application of phosphorus was found to significantly alter the rhizospheric fungal diversity. The total fungi isolated from 0.5 and 1% P treated cultivar EH-3 plants were 27 and 24, respectively. Specially *Fusarium graminearum, Penicillium purpurogenum, Trichoderma viride* isolate I and II were observed in 0.5% P treated plants of cultivar EH-3 while, *Aspergillus ochraceous, A. sydowii, Cladosporium* sp., *Penicillium* sp. 2 were not documented but were found to be present in control. Similarly, *Fusarium graminearum, Syncephalastrum* sp. and *Trichoderma viride* isolate II were isolated from the 1% P treated plants of cultivar EH-3 while *Aspergillus sydowii, Fusarium* sp. were not documented but were present in control.

In variety *varuna*, in all 29 and 30 fungal species were documented in the rhizosphere of 0.5 and 1% P treated plants, respectively. *Aspergillus clavatus, A. sydowii, A. terreus, A. wentii, Penicillium* sp. 2, *Trichoderma viride* isolate I and II were isolated from 0.5% P treated plants however, fungi like *Asprgillus fischeri, A. sulphureus, Cladosporium* sp., *Penicillium purpurogenum* and *Syncephalastrum* sp. were found to be absent but these were present in the rhizosphere of control plants. Similarly, in 1% P treated plants of variety *varuna*, fungi like *Aspergillus sydowii, A. terreus, A. wentii, Trichoderma viride* isolate I and II were observed whereas, fungi like *Cladosporium* sp., *Penicillium oxalicum* and *Syncephalastrum* sp. were altogether absent but these were isolated from the rhizosphere of control plants. On overall basis fungi like *Aspergillus* sp. and *Penicillium* sp. were

found to dominate throughout the study. Total 12 *Aspergillus* species were isolated from the rhizosphere and non-rhizosphere soil. *Aspergillus flavus, A. fumigatus* and *A. niger* were constantly isolated from the rhizosphere soil and NRS. Similarly 7 *Penicillium* sp. were obtained from rhizosphere soil and NRS. *Penicillium citrinum* was the most constant species obtained throughout (**Table 1**).

Table 1: Incidence of Fungi in NRS and rhizosphere of treated plants of cultivar EH-3 and variety *varuna*

Sr. No.	Fungal species	NRS	Cultivar EH-3			Variety *varuna*		
			C	0.5% P	1%P	C	0.5% P	1%P
1.	*Absidia* sp.	+	+	+	+	+	+	+
2.	*Alternaria alternata*	+	+	+	+	+	+	+
3.	*Alternaria* sp.	+	+	+	+	+	+	+
4.	*Aspergillus clavatus*	-	+	+	+	-	+	-
5.	*Aspergillus fischeri*	-	-	-	-	+	-	+
6.	*Aspergillus flavipes*	-	-	-	-	+	+	+
7.	*Aspergillus flavus*	+	+	+	+	+	+	+
8.	*Aspergillus fumigatus*	+	+	+	+	+	+	+
9.	*Aspergillus nidulans*	-	+	+	-	+	+	+
10.	*Aspergillus niger*	+	+	+	+	+	+	+
11.	*Aspergillus ochraceus*	+	+	-	+	+	+	+
12.	*Aspergillus sulphureus*	+	+	+	+	+	-	+
13.	*Aspergillus sydowii*	+	+	-	-	-	+	+
14.	*Aspergillus terreus*	+	+	+	+	-	+	+
15.	*Aspergillus wentii*	+	-	-	-	-	+	+
16.	*Cladosporium* sp.	+	+	-	+	+	-	-
17.	*Chaetomium globosum*	-	+	+	+	+	+	+
18.	*Curvularia lunata*	+	+	+	+	+	+	+
19.	*Curvularia* sp.	-	+	+	+	+	+	+
20.	*Drechslera* sp.	-	+	+	+	+	+	+
21.	*Fusarium graminearum*	+	-	+	+	+	+	+
22.	*Fusarium oxysporum*	+	+	+	+	+	+	+
23.	*Fusarium* sp.	-	+	+	-	+	+	+
24.	*Helminthosporium* sp.	-	+	+	+	+	+	+
25.	*Penicillium citrinum*	+	+	+	+	+	+	+
26.	*Penicillium liliacinum*	+	+	+	-	+	+	+
27.	*Penicillium multicolor*	+	+	-	-	+	-	+
28.	*Penicillium oxalicum*	+	+	+	+	+	+	-
29.	*P. purpurogenum*	-	-	+	-	+	-	+
30.	*Penicillium* sp. 1	+	-	-	-	-	-	-
31.	*Penicillium* sp. 2	-	+	-	-	-	+	-
32.	*Phoma* sp.	-	+	+	+	+	+	+
33.	*Rhizopus stolonifer*	+	+	+	+	+	+	+
34.	*Syncephalastrum* sp.	+	-	+	+	+	-	-
35.	*Trichoderma viride* isolate I	-	-	+	-	-	+	+
36.	*Trichoderma viride* isolate II	-	-	+	+	-	+	+

The 36 fungal taxa isolated from rhizosphere and NRS were found to be belonging to 14 fungal genera. *Aspergillus* sp., were most abundant both in the rhizosphere and non-rhizosphere soil and represented 30-40% of the documented fungi followed by *Fusarium* sp. which were around 15%. Apart from these, fungi like *Alternaria* sp., *Curvularia* sp., *Penicillium* sp., were almost around 10% while all other species were around 5% in both the treatments of EH-3 and variety *varuna. Drechslera* sp., *Chaetomium globosum, Phoma* sp., and *Helminthosporium* sp. were not isolated from non-rhizosphere soil but isolated from the rhizosphere soil of control plants of cultivar EH-3 and variety *varuna*. However, *Trichoderma* sp. were not isolated from both the control plants as well as NRS but it was present in P sprayed plants. Moreover, the per cent occurrence of most of the fungi was more in the soil sprayed with 0.5%P in comparison to those sprayed with 1%P (**Fig. 3 and 4**).

The rhizosphere study revealed that the maximum number of colonies were there during the flowering stage in comparison to a maturity and seedling stage in control as well as treated plants. It also revealed that maximum fungal

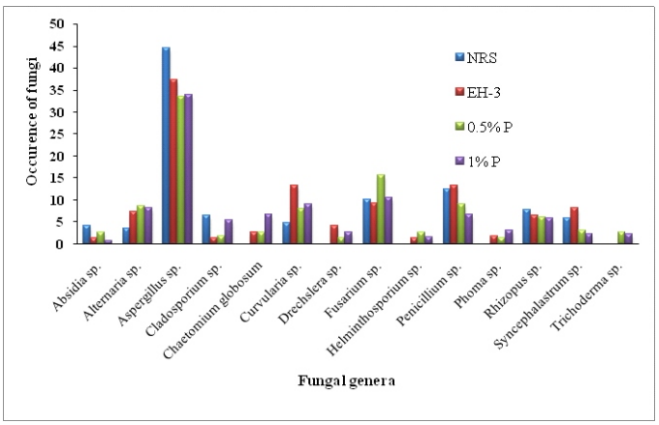

Fig. 2 Per cent Occurrence of Fungi in rhizosphere of EH-3 and NRS.

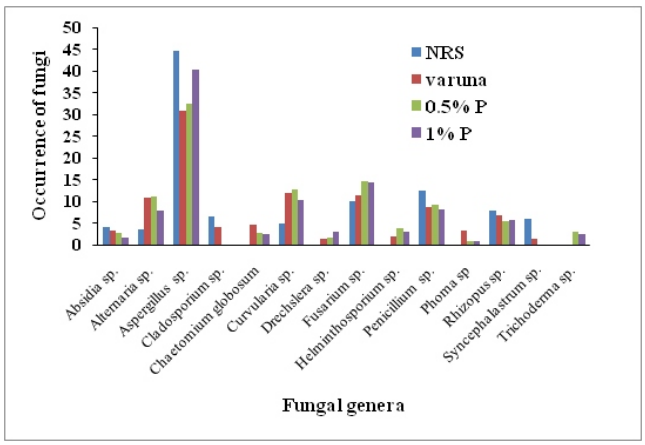

Fig. 3 Per cent occurrence of rhizosphere fungi in varuna and NRS.

diversity was there in rhizosphere soil as compared to NRS (**Fig. 4**). Even maximum rhizosphere effect was observed during the flowering stage as compared to the seedling and maturity stage of the control and treated plants. The rhizosphere effect was higher in plants which were given

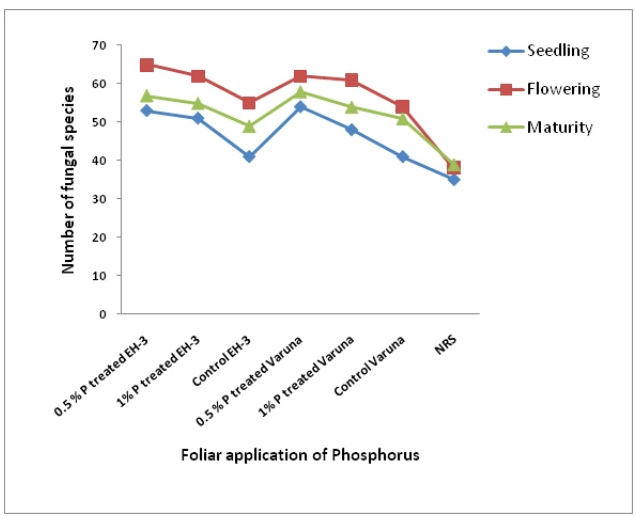

Fig. 4 Rhizosphere mycoflora found in different growth stages of EH-3 and variety *varuna.*

Table 2: Rhizosphere effect at different stages of plant growth in control and treated plants

Sr. No.	Foliar Treatments	Concentration (in %)	Cultivar EH-3			Variety *varuna*		
			S	F	M	S	F	M
1	Phosphorus	0.5	1.51 (±0.03)	1.70 (±0.08)	1.47 (±0.05)	1.53 (±0.09)	1.63 (±0.11)	1.50 (±0.07)
2	Phosphorus	1	1.45 (±0.06)	1.63 (±0.04)	1.43 (±0.09)	1.36 (±0.05)	1.60 (±0.07)	1.40 (±0.08)
3	Control	-	1.17 (±0.05)	1.43 (±0.10)	1.26 (±0.04)	1.17 (±0.06)	1.42 (±0.06)	1.33 (±0.05)

0.5%P treatment as compared to control as well as those given 1%P treatment (**Table 2**).

Rhizoplane fungi: Total 11 genera were isolated from the rhizoplane of treated and control plants of cultivar EH-3 and variety *varuna*. Per cent occurrence of *Aspergillus* spp. was most common in comparison to all other fungi isolated. *Alternaria* sp. *Curvularia* sp. and *Fusarium* sp. were also quite common amongst the rhizoplane mycota. However, the important point to be noted is that *Penicillum* spp., which was prominently present amongst the rhizospheric fungi, was found to be altogether absent in the rhizoplane during the study. There were other fungi also which were present but in very less proportion in comparison. However, there are few fungi which were absent in control but observed in phosphorus treated plants. These are *Absidia* sp., *Helminthosporium* sp., *Phoma* sp., *Trichoderma* sp. (**Table 3**).

DISCUSSION

The results obtained at different stages of plant growth clearly indicate that the rhizospheric fungal diversity is quite rich in microbial population in comparison to non-rhizospheric fungal diversity. Nagaraju and Manoharachary (2017) reported quite a good number of fungal species in NRS and rhizosphere soil. While investigating the rhizosphere and rhizoplane of *Brassica juncea* for microbial population Tagade and Thakre (2013) stated that the rhizosphere is quite rich in fungal diversity in comparison to the non-rhizosphere soil. Likewise, Bhattacharya and Bora (1995) also reported the highest fungal population in the rhizosphere as compared to non-rhizosphere soil. The reason for this could be the root exudates secreted by the plants which attract greater number of microorganisms towards roots and regulate the soil fungal community and diversity (Broeckling *et.al.,* 2008)

The highest number of colonies of different fungi in both the presently investigated taxa were found at flowering stage. It clearly indicates that flowering is the perfect stage when highest number of fungi get attracted towards the plant root. This observation is in conformity with Deb and Bora (2004), who revealed that the rhizosphere fungal population of leguminous crops like *Arachis hypogea* and *Vigna radiata* is more at flowering stage. Presently *Aspergillus* species were observed as the most dominant fungal microbes both in the rhizosphere of control and foliar treated plants of cultivar EH-3 and variety *varuna* as has been observed presently. Wakelin *et. al.,* (2004) also stated that *Aspergillus* spp. along with *Penicillium* are the dominant P-solubilizing filamentous fungi found in the rhizosphere. However, during the present study of the rhizoplane of cultivar EH-3 and variety *varuna Penicillium* species was documented. Wahid *et.al.,* (1997) also reported the highest number of *Aspergillus* and *Penicillium* species in the rhizoplane of Tomato. Wadhwani and Mehrotra (1982) also reported the specific fungi in rhizosphere and rhizoplane of smut infected plants of *Cynodon dactylon*.

Table 3: Total percent occurrence rhizoplane mycota of Brassica *juncea* in control and phosphorus treated plants.

S. No.	Fungal isolates	Control		Cultivar EH-3		Varety *varuna*	
		EH-3	*varuna*	0.5% P	1% P	0.5% P	1% P
1	*Absidia* sp.	0.0	0.0	5.1	0.0	2.6	3.4
2	*Alternaria* sp.	7.9	13.7	13.2	10.8	20.7	17.6
3	*Aspergillus* spp.	45.1	32.8	29.9	26.2	23.7	34.6
4	*Curvularia* spp.	22.8	20.7	9.5	12.3	17.4	11.5
5	*Drechslera* sp.	0.0	2.2	0.0	4.7	2.7	3.7
6	*Fusarium* spp.	17.8	21.0	22.9	17.5	13.0	12.2
7	*Helminthosporium* sp.	0.0	0.0	4.7	7.9	4.6	3.7
8	*Phoma* sp.	0.0	0.0	1.9	3.8	1.3	1.9
9	*Rhizopus* sp.	6.3	8.6	9.1	8.4	8.1	10.3
10	*Trichoderma viride*	0.0	0.0	3.1	3.0	6.1	1.2
11	Mycelia sterilia	0.0	1.1	0.7	5.3	0.0	0.0

Siddiqui *et. al.,* (2008) studied the cumulative effect of soil and foliar application of nitrogen, phosphorus and sulfur on rapeseed-mustard genotypes and stated that it enhances parameters like yield, fatty acid composition, etc. They further emphasized that ready supply of the required nutrients to the leaves (site of their metabolism) would more than compensate for the 'hidden hunger' of the growing crop for N and P. Likewise foliar application of phosphorus during the present investigations might have significantly affected the rhizospheric and rhizoplane fungal diversity and resulted in more fungal population in comparison to control plants.

Most of the fungi isolated from rhizosphere and rhizoplane are largely the same. Fungi like *Absidia* sp., *Alternaria* spp., *Aspergillus* spp., *Curvularia* spp., *Drechslera* sp., *Fusarium* spp., *Helminthosporium* sp., *Phoma* sp., *Rhizopus* sp., and *Trichoderma viride* are found to be present in both rhizosphere and rhizoplane of *Brassica juncea* of cultivar line EH-3 and variety *varuna*. To increase the availability of phosphorus, plant roots have developed a range of mechanisms. Amongst these, organic acids like citrate are reported to be released by roots and proteoid roots to solubalise ions such as phosphate and iron (Jones and Darrah, 1994; Jones *et al*., 1996). It is a well-established fact that plants absorb P from the soil in the form of soluble orthophosphate anions (Pi, H_2PO_4- or HPO_{4-2}), which are not readily available in the soil (Goldstein, 1987) and soil microflora play an important role in the release of such non available nutrients into the soil solution from where these are absorbed by the plant roots along with sap.

CONCLUSION

Foliar application of phosphorus significantly changes the rhizosphere and rhizoplane fungal diversity. The study throws light on the diversity of fungi present in the rhizosphere and rhizoplane of *Brassica juncea* cultivar line EH-3 and *varuna* variety and the associated positive effect. The foliar spray of 0.5 and 1% P increased the diversity and per cent occurrence of fungal microbes in the rhizospheric and rhizoplane region of the plants used for experimentation. The effect of such

microbes on plant growth parameters like root length, shoot length, plant height, etc. needs further investigation.

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REFERENCES

Bhattacharya, M. and Bora, K. 1995. Rhizosphere microflora of tea in relation to age of the plants. *Indian J. Mycol. Pl. Pathol*. **25**(3): 263-265.

Booth, C. 1977. *The genus Fusarium*. CMI, Kew, Surrey, England, 1-237.

Broeckling, C.D. *et al.,* 2008. Root exudates regulate soil fungal community composition and diversity. *Applied and environmental microbiology* 738-744.

Deb, B. and Bora, K. 2004. Influence of rhizosphere mycopopulation on root nodule formation in leguminous crop. *J. Mycol. Pl. Pathol.* **34**(2): 628-630.

Dhedhi, B.M., Gupta, O. and Patel, V.A. 1990. Association of microorganisms in rhizosphere and rhizoplane of healthy and wilted chickpea plants. *Indian J. Mycol. Pl. Pathol*. **22**(1): 72-73.

Goldstein, A.H. 1987. Phosphate starvation inducible excretion of acid phosphatase by cells of *Lycopersicon esculentum* in suspension culture. *J. Cell. Biochem.* **11**(B): 38-42.

Hameeda, B. *et al.,* 2008. Growth Promotion of maize by phosphate solubilizing bacteria isolated from compost and macrofauna. *Microbiological research*. **163**(2): 234-242.

Harley, J.L. and Waid, J.S. 1955.A method of studying active mycelia on living roots and other surfaces in the soil. *Trans. Br. Mycol. Soc*. **38**: 104-118.

Jha, P. K. and Jalali, B. L. 2006. Biocontrol of pea root rot incited by *Fusarium solani* f. sp. *pisi* with rhizosphere mycota. *Indian Phytopath.* **59**(1): 41-43.

Johnson, L.F. and Curl, E.A. 1972. *Methods for research on the ecology of soil-borne pathogens,* Burgess Publishing Company. Pp.7-15.

Jones, D.L., Darrah, P.R. and Kochian, L.V. 1996. Critical evaluation of organic acid mediated dissolution in the rhizosphere and its potential role in root iron uptake. *Plant Soil* **180**: 57-66.

Jones, D.L. and Darrah, P.R. 1994. Role of root derived organic acids in the mobilization of nutrients from the rhizosphere. *Plant Soil* **166**: 247-257.

Kafle, A. *et al.,* 2019. Harnessing soil microbes to improve plant phosphate efficiency in cropping systems. *Agronomy* **9**(127): 1-15.

Katznelson, H. 1946. The rhizosphere effect of mangels on certain groups of soil microorganisms. *Soil Sci*. **62**: 343-354.

Liljeroth, E. and Baath, E. 1988. Bacteria and fungi on roots of different barley varieties (*Hordeum vulgare* L). *Biol. Fert. Soil.* **7**: 53-57.

Nagaraju, D. and Manoharachary, C. 2017. Fungi associated with non-rhizosphere soil, rhizosphere soil and rhizoplane of *Vitex negundo* from Telangana. *Kavaka* **49**: 59-64.

Nagmani, A., Kunwar, I.K. and Manoharachary, C. 2006. *Hand book of Soil fungi*, I. K., International Private limited. 1-496pp.

Raaijmakers, J.M., Paulitz, T.C., Steinberg, C., Alabouvette, C. and Moënne-Loccoz, Y. 2009. The rhizosphere: a playground and battlefield for soilborne pathogens and beneficial microorganisms. *Plant Soil* **321**: 341–36.

Raper, K.B. and Fennell, D.I. 1965. *The genus Aspergillus*. The Williams and Wilkins Company, Baltimore 1-686pp.

Raper, K.B. and Thom, C. 1949. *A manual of the Penicillia*. Williams & Wilkins Company, Baltimore 1-875pp.

Seadh, S.E. *et al*. 2009. Influence of micronutrient foliar application and nitrogen fertilization on wheat yield and quality of grain and seed. *J. Biol. Sci.* **9**: 851-858.

Siddiqui, M. H. *et al.,* 2008. Cumulative effect of soil and foliar application of nitrogen, phosphorus, and sulphur on growth, physic-biochemical parameters, yield attributes, and fatty acid composition in oil of erucic acid-free rapeseed-Mustard genotypes. *Journal of plant nutrition* **31**:1284-1298.

Tagade, W.Y. and Thakre, R.P. 2013. Rhizosphere and rhizoplane mycota of *Brassica juncea* cv *varuna* and EH-3. *Journal of plant disease sciences* **8**(1): 92-95.

Wadhwani, K. and Mehrotra, N. 1982. Fungi associated with roots of smut infected plants of *Cynodon dactylon*. *Indian Phytopath*. **35**: 722 - 724.

Wahid, O.A.A., Moushtafa, A.F. and Ibrahim, M.E. 1997.Soil mycota in tomato fields. *Mycoscience* **38**: 237-241.

Wakelin, S.A. *et al*. 2004. Phosphate solubilization by *Penicillium* spp. closely associated with wheat roots. *Biol. Fertil. Soils.* **40**: 36-43.