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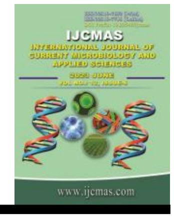

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Effect of Graded Levels of Zinc and Zinc Solubilizing Microbes on Growth Parameters and Yield of Ginger

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A B S T R A C T

The pot culture experiment was conducted during *kharif* season of 2019-20 in the Department of Soil Science and Agricultural Chemistry, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani to evaluate the response of ginger to graded levels of zinc and zinc solubilizing biofertilizers. Experiment consist of sixteen treatment combinations which includes four zinc solubilizing cultures (Control, *Pseudomonas fluorescens*, *Pseudomonas striata*, and *Trichoderma viride*) and four levels of zinc (0, 20, 30 and 40 kg ZnSO4 ha-1) in factorial complete randomized design. The results emerged out indicated significant effect of zinc solubilizing cultures particularly *Pseudomonas striata and* zinc level upto 40 kg ZnSO4 ha-1 on plant height, number of leaves, leaf area and rhizome yield of ginger over the other treatments. Effect of zinc solubilizing cultures i.e. *Pseudomonas striata* noted maximum plant height (37.06-49.59-60.84 cm for 90,150 and 210 days).The zinc level @ 40 kg ZnSO4 ha-1 was having better effect on plant height (34.83-47.38-57.84 cm for 90,150 and 210 days) zinc solubilizers influenced the number of leaves of ginger plant at various growth stages and was recorded stage wise in the range between 10.55 to 15.62, 16.64 to 21.59 and 20.50 to 25.54 at 90, 150 and 210 days respectively. Significantly highest leaf area noted in pot treated with *Pseudomonas strita* (32.11-33.33-34.76 cm^2) and significant effect of levels of zinc up to 40 kg ha^{-1} have influenced on leaf area and noted highest in 40 kg ha^{-1} $ZnSO_4$ (28.71-30.56-32.08 cm^2). The highest rhizome yield was found in pots inoculated with *Pseudomonas striata* (374.72 g pot^{-1}) and zinc level @40 kg ZnSO4 ha-1 (355.78g pot^{-1}).

Introduction

Zinc is one of the essential nutrient for the normal healthy growth and reproduction of plants, animals and humans and when supply of plant-available zinc is inadequate, crop yield are reduced and the quality of crop products is frequently impaired. Zinc occurs in plant either as a free ion, or as a complex with a variety of low molecular weight compounds. Zinc may also be incorporated as a component of protein and other macromolecules. As a component of protein, zinc act as functional, structural or regulatory cofactor of a large number of enzymes (Patrick *et al.*, 1993). It also play role in the biochemical pathway such as carbohydrate metabolism, both in photosynthesis and in conversion of sugars to starch, in protein metabolism, auxin (growth regulator) metabolism, pollen formation, maintenance of integrity of biological membranes, resistance to infection by certain pathogen. Zinc (Zn) is major metal component and activator of several enzymes involved in metabolic activities and biochemical pathway. It is a functional, structural or regulatory co-factor of a large number of enzymes and its deficiency adversely affect the growth and development of crop plant by affecting various enzymatic reactions, metabolic process and redox reactions. The multifunctionality of Zn in all living organisms provides this element key roles in basal metabolism, defense, and virulence, and to design specific Zn- related tools to trick plant attackers or/and to ameliorate plant defense (Cabot *et al.*, 2019). The problem of zinc deficiency occur in soil-plant system worldwide causing gradual reduction in crop productivity and yield and thereby affecting humans as well (Rani Nitu *et al.*, 2020).

Biofertilizers have now emerged as a promising component of nutrient supply (Ghosh *et al.*, 2001). As ginger is a long growing crop and requires more nutrients for better crop growth and yield, the steady supply of adequate nutrient is important for proper growth and yield. Biofertilizers offer a low cost, low capital intensive and ecofriendly route to boost the productivity depending upon their activity of mobilizing different nutrients. Use of biofertilizer in crop not only fixes the biological nitrogen but also solubilizes the insoluble nutrients in soil. These microorganisms play an important role in increasing the availability of N, P and K. Keeping this in view, present investigation was undertaken to find out effect of zinc solubilizing microbial cultures on growth and yield in ginger crop.

Materials and Methods

The experiment was carried out in the Department of Soil Science and Agricultural Chemistry, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani on Vertisol. The initial soil was having pH 8.10, EC 0.18 dSm-1, organic carbon 4.42 g kg-1 and calcium carbonate was 21.33 g kg-1. Available N content was 134.90 kg ha-1, available P2O5 content was 15.20 kg ha-1, available K2O content 592.4 was kg ha-1 and DTPA extractable zinc was noted as 0.60 mg kg-1, DTPA extractable iron was 2.15 mg kg-1, DTPA extractable copper was 1.10 mg kg-1 and DTPA extractable manganese was 7.21 mg kg-1. Thus, the soil was clayey in texture, moderately alkaline in reaction, medium in available nitrogen, phosphorus and sufficient in available potassium and deficient in iron and zinc. The research experiment was carried out on ginger (Variety Mahim) crop in *kharif* season during 2019-20. The experiment consists of sixteen treatments combinations replicated thrice in Factorial Complete Randomized Design. The treatments includes four zinc solubilizing cultures (Control, *Pseudomonas fluorescens*, *Pseudomonas striata* and *Trichoderma viride*) with four levels of zinc sulphate (0, 20, 30 and 40 kg ZnSO4 ha-1). For planting of the ginger, rhizomes were treated before planting with the zinc solubilizing cultures (liquid biocultures) of *Pseudomonas striata*, *Pseudomonas florescence* and *Trichoderma viride.* Rhizomes were cut into the pieces as per requirement and soaked overnight in these cultures in separate trays. On the next day the planting operation was carried out manually and recommended fertilizers along with treatment wise ZnSO4 was added by dissolving in water. The plant height, number of leaves, leaf area per plant were recorded periodically. However, yield of ginger was recorded by uprooting the plants from pots at maturity.

Results and Discussion

Plant height

Plant height of ginger was taken at 90,150 and 210 days after the planting. The data given in table 1 indicates significant influence of various zinc solubilizing microbial cultures and graded levels of ZnSO4. The plant height increased significantly due to the zinc solubilizing microbial cultures over the control. The *Pseudomonas striata* treated ginger had significantly better plant height (37.06 cm,49.59 cm and 60.84 cm for 90,150 and 210 days) as compare to other treatments followed by *Trichoderma viride* (36.07-48.90-59.14cm for 90, 150 and 210 days respectively) over uninoculated pots. Several PGPR are dynamically involved in the synthesis of auxins in pure culture and also in soil, and hence can play significant roles in the growth and development of crop. The zinc level @ 40 kg ZnSO4 ha-1 was having better effect on plant height (34.83-47.38-57.84cm) over the other levels and control due to balanced supply of nutrient in this zinc deficient soil. The higher plant height at various growth stages might be a result of required zinc supply to growing plants through soil. Egamberdiyeva *et al.,* (2004) also found that in nutrient-poor-calcisol soil, *Bacillus*, *Pseudomonas* and *Arthrobacter* strains significantly increased early growth of plant. Similarly, Shadap *et al.,* (2018) also found significant impact of applied zinc on growth of ginger plants.

Number of leaves

Results presented in table 2 indicates that the zinc solubilizers influenced the number of leaves of ginger plant at various growth stages and was recorded stage wise in the range between 10.55 to 15.62, 16.64 to 21.59 and 20.50 to 25.54 at 90, 150 and 210 days respectively. Significantly maximum numbers of leaves were produced by *Pseudomonas striata* (15.62, 21.59 and 25.54 for 90 and 150 and 210 DAS respectively) inoculated pots which was found at par with *Trichoderma viride* inoculation (14.70-20.62-24.61 at 90,150 and 210 days respectively). Due to production of organic acid in rhizosphere root system decreases soil pH which increases solubility of insoluble compound which leads to availability of nutrients for plants. Due to this availability uptake of nutrients increases by the plants. Improvement of nutrient uptake and transport from root to aerial part, together to produce plant stimulators leads to increases growth parameter. The zinc levels have also the significant results on number of leaves as having the better results of $ZnSO_4$ @40 kg ha^{-1} (14.59-20.60-24.43 for 90, 150 and 210 DAP) over other treatments due to proper and steady supply in growing period of crop. The results are similar to the Singh *et al.,* (2014) and Shadap *et al.,* (2018) who also concluded that the application of organic manure and biofertilizer and graded doses of inorganic fertilizer increases the number of leaves in ginger crop.

Leaf area

The data mentioned in the table 3 about the effect of zinc solubilizing cultures and levels of zinc have the significant effect on the leaf area of ginger. The leaf area ranged between 23.80 to 32.11 cm^2, 22.98 to33.33 cm^2 and 24.44 to 34.76 cm^2 at 90, 150 and 210 days after planting respectively. Significantly highest leaf area noted in pot treated with *Pseudomonas strita* (32.11-33.33-34.76 cm^2) followed by the *Trichoderma viride* (29.6732.93-33.99 cm^2). The significant effect of levels of zinc up to 40 kg ha^{-1} have influenced on leaf area.

The highest leaf area was noted in 40 kg^{-1} ha $ZnSO_4$ (28.71-30.56-32.08 cm^2). However the lower values of leaf area were found in control treatment. The cultures have the effect on the growth enhancement was reported by Turan *et al.,* (2014) and Tanwar *et al.,* (2013). Also Palai *et al.,* (2017) revealed that soil application of Zn@6 kg ha^{-1}+ one foliar spray @ 0.05% Zn at 25 DAS increases leaf area in baby corn.

Rhizome yield

Results found that significant effect of zinc solubilizer and graded levels of zinc on yield of ginger crop presented in table 4. The highest rhizome yield was found in pots inoculated with *Pseudomonas striata* (374.72 g pot^{-1}) which was at par with *Trichoderma viride* (345.06 g pot^{-1}). Whereas lower rhizome yield was noted in control (270.32 g pot^{-1}). *Pseudomonas* sp. increases the yield which might be due to of nitrogen fixing ability, P solubilization, Zn mobilization also the production of siderophores and growth hormone.

Table.1 Effect of different zinc solubilizing microbial cultures and zinc levels on plant height of ginger

Treatments	Plant height (cm)		
	90 DAS	150 DAS	210 DAS
Zinc solubilizers (S)			
S0: Control	23.35	36.79	44.72
S1: *Pseudomonas fluorescens*	30.17	41.75	53.08
S2: *Pseudomonas striata*	37.06	49.59	60.84
S3:*Trichoderma viride*	36.07	48.90	59.14
S.E±	0.32	0.35	0.91
C.D. at 5%	0.92	1.03	2.73
Levels of $ZnSO_4$ (Zn)			
Zn0:$ZnSO_4$ 0 kg ha^{-1}	29.50	42.04	52.71
Zn1:$ZnSO_4$ 20 kg ha^{-1}	30.65	42.91	53.27
Zn2:$ZnSO_4$ 30 kg ha^{-1}	31.67	44.69	53.96
Zn3:$ZnSO_4$ 40 kg ha^{-1}	34.83	47.38	57.84
S.E.±	0.32	0.35	0.91
C.D. at 5%	0.96	1.03	2.73
Interaction (Zn×S)			
S.E.±	0.64	0.71	1.82
C.D. at 5%	1.92	2.13	5.47

Table.2 Effect of different zinc solubilizing microbial cultures and zinc levels on number of leaves of ginger plant

Treatments	Number of leaves $plant^{-1}$		
	90 DAS	150 DAS	210 DAS
Zinc solubilizers (S)			
S0: Control	10.55	16.64	20.50
S1: *Pseudomonas fluorescens*	12.91	18.86	22.91
S2: *Pseudomonas striata*	15.62	21.59	25.54
S3:*Trichoderma viride*	14.70	20.62	24.61
S.E±	0.18	0.17	0.17
C.D. at 5%	0.54	0.51	0.51
Levels of $ZnSO_4$(Zn)			
Zn0:$ZnSO_4$ 0 kg ha^{-1}	12.51	18.42	22.39
Zn1:$ZnSO_4$ 20 kg ha^{-1}	13.28	19.29	23.24
Zn2:$ZnSO_4$ 30 kg ha^{-1}	13.41	19.40	23.50
Zn3:$ZnSO_4$ 40 kg ha^{-1}	14.59	20.60	24.43
S.E±	0.18	0.17	0.17
C.D. at 5%	0.54	0.51	0.51
Interaction (Zn×S)			
S.E±	0.37	0.34	0.34
C.D. at 5%	1.08	0.102	1.03

Table.3 Effect of different zinc solubilizing microbial inoculants and zinc levels on leaf area of ginger

Treatments	Leaf area (cm^2)		
	90 DAS	**150 DAS**	**210 DAS**
Zinc solubilizers			
S0: Control	23.80	22.98	24.44
S1: *Pseudomona fluorescens*	25.94	26.69	29.01
S2: *Pseudomona striata*	32.11	33.33	34.76
S3:*Trichoderma viride*	29.67	32.93	33.99
S.E±	0.37	0.28	0.25
C.D. at 5%	1.12	0.85	0.75
Levels of $ZnSO_4$ (Zn)			
Zn0: $ZnSO_4$ 0 kg ha^{-1}	27.05	27.14	28.39
Zn1: $ZnSO_4$ 20 kg ha^{-1}	27.65	28.62	30.25
Zn2: $ZnSO_4$ 30 kg ha^{-1}	28.11	29.62	31.47
Zn3: $ZnSO_4$ 40 kg ha^{-1}	28.71	30.56	32.08
S.E±	0.37	0.28	0.25
C.D. at 5%	1.12	0.85	0.75
Interaction (Zn×S)			
S.E±	0.74	0.57	0.50
C.D. at 5%	2.23	1.71	1.51

Table.4 Effect of zinc solubilizer and levels of zinc on rhizome weight yield

Treatments	Rhizome Yield (g pot^{-1})
Zinc solubilizers (S)	
S0: Control	270.32
S1: *Pseudomonas fluorescens*	305.04
S2: *Pseudomonas striata*	374.72
S3:*Trichoderma viride*	345.06
S.E±	7.09
C.D. at 5%	21.27
Levels of $ZnSO_4$ (Zn)	
Zn0:$ZnSO_4$ 0 kg ha^{-1}	297.85
Zn1:$ZnSO_4$ 20 kg ha^{-1}	300.38
Zn2:$ZnSO_4$ 30 kg ha^{-1}	341.14
Zn3:$ZnSO_4$ 40 kg ha^{-1}	355.78
S.E±	7.09
C.D. at 5%	21.27
Interaction (Zn×S)	
S.E±	14.19
C.D. at 5%	42.34

The results are similar to the findings of Chandrashekhar and Hore (2019) revealed that application of biofertlizer had better response to ginger crop. The effect of graded levels of zinc also found significant on rhizome yield. As the highest rhizome yield recorded @40 kg ZnSO4 ha-1 (355.78g pot^{-1}). The lowest yield recorded in control pots. Increase in yield might be a result of required zinc supply to growing plants.

Maralian (2009) concluded that foliar application of iron and zinc increased wheat seed yield. Grewal (2001) and Dileep (2019) also found that zinc treatments provides highest yield.

From the results it can be concluded that zinc solubilizing microbial cultures particularly *Pseudomonas striata* and 40 kg $ZnSO_4$ ha^{-1} had significant effect on the growth parameters like plant height, number of leaves, leaf area and rhizome yield.

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