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Interaction effect of graded levels of zinc and zinc solubilizing biofertilizers on growth parameters and yield of ginger

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Abstract
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. The interaction effect of zinc solubilizing cultures and graded levels of zinc i.e. *Pseudomonas striata* + 40 kg ZnSO4 ha^{-1} noted on plant height (41.37-54.55-67.63cm for 90,150 and 210 days), number of leaves (16.29-22.32-25.93 for 90, 150 and 210 days respectively), leaf area (34.13 cm2 -35.81cm2-37.06 cm2 at 90, 150 and 210 days respectively) and rhizome yield (436.15 g pot^{-1}) over the other treatments.

Keywords: Ginger, zinc, cultures and growth parameters

Introduction
Ginger (*Zingiber officinale* Rosc) is commonly called as *'Ale'* or *'Adrak'* which is an important commercially grown crop for its aromatic rhizomes. It is used as spice, condiment and also as a medicine. It has been used as spice for over 2000 years (Bartley and Jacob, 2000) [2]. Ginger is herbaceous perennial belonging to family *Zingiberaceae* and it is believed to be native of south eastern India. It is cultivated in many tropical and subtropical countries including China, India, Australia, Jamaica and Haiti. China and India are the leading producers of ginger in world. Ginger is cultivated in tropical and subtropical part of India especially in Maharashtra, Kerala, Karnataka, Tamilnadu, West Bengal and Himachal Pradesh. Ginger is important crop as it has low toxicity and it having many properties including antitumor, antioxidant, anti-inflammatory, Antiapoptotic cytotoxic and anti-proliferative.

Zinc is one of the essential nutrient for the normal healthy growth and reproduction of plants 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) [10]. It 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. Zinc supply when inadequate in plant shows one or more important physiological functions of zinc are unable to operate normally and plant growth is adversely affected. Zinc deficiency results in the visible symptoms in plant such as stunting or reduced height, interveinal chlorosis or yellowing of leaves between veins, and so that yield may affect. Plant yield can be reduced by 20% more or without visible symptoms called hidden deficiency.

Biofertilizers has now emerged as a promising component of nutrient supply (Ghosh *et al*. 2001) [6].

These microbes produce organic acids in soil which sequester the zinc cations and decrease the pH of the nearby soil. Moreover, the anions can also chelate zinc and enhance zinc solubility. The various PGPR have shown enhanced growth and Zinc content when inoculated in plants. Microbes are potential alternate that could cater plant zinc requirement by solubilizing the complex zinc in soil. The organic based zinc nutrition is best since its Zn use efficiency is more. A bacterial based approach was devised to solve the micronutrient deficiency problem. In soil it undergoes a complex dynamic equilibrium of solubilization and precipitation that is greatly influenced by the soil pH and micro flora and that ultimately affects their accessibility to plant roots for absorption (Altomare *et al*. 1999) [1]. Microbial inoculants are important constitute an of integrated nutrient management system that helps in sustainable agriculture. Consideration, the importance of zinc application in crop in general particularly in ginger. Ginger is a long growing crop and requires more nutrient for higher rhizome yield, the supply of adequate nutrient is important.

Material 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

The interaction effect between the zinc solubilizers and zinc levels was found significant for the plant height in ginger crop as narrated in table 1. The maximum plant height was recorded in *Pseudomonas striata* X 40 kg $ZnSO_4$ ha^{-1} (41.37-54.55-67.63 cm for 90,150 and 210 days) treated pots and the minimum plant height was seen in the control treatment. It was observed that application of the zinc solubilizers and the graded dose of zinc @ 40 kg ZnSO4 ha^{-1} noted 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) [5] also found that in nutrient-poor-calcisol soil, *Bacillus*, *Pseudomonas* and *Arthrobacter* strains significantly increased early growth of plant. Similarly, Shadap *et al*. (2018) [11] also found significant impact of applied zinc on growth of ginger plants.

Table 1: Interaction effect of zinc solubilizing microbial cultures and levels of zinc on plant height (cm) of ginger plant

Treatments	Zn0: $ZnSO_4$ 0kg ha^{-1}	Zn1: $ZnSO_4$ 20 kg ha^{-1}	Zn2: $ZnSO_4$ 30 kg ha^{-1}	Zn3:$ZnSO_4$ 40 kg ha^{-1}	Mean
Plant height at 90 days after planting					
S0: Control	19.41	22.78	24.25	26.96	23.35
S1: *Pseudomonas fluorescens*	28.67	29.56	30.71	31.74	30.17
S2: *Pseudomonas striata*	34.85	36.77	35.25	41.37	37.06
S3:*Trichoderma viride*	35.06	33.47	36.48	39.25	36.07
Mean	29.50	30.65	31.67	34.83	
Interaction	S	Zn	SXZn		
S.E±	0.32	0.32	0.64		
C.D. at 5%	0.96	0.96	1.92		
Plant height at 150 days after planting					
S0: Control	34.63	35.29	37.78	39.45	36.79
S1: *Pseudomonas fluorescens*	39.78	40.45	42.44	44.34	41.75
S2: *Pseudomonas striata*	46.11	48.92	48.78	54.55	49.59
S3: *Trichoderma viride*	47.71	46.99	49.74	51.17	48.90
Mean	42.06	42.91	44.69	47.38	
Interaction	S	Zn	SXZn		
S.E±	0.35	0.35	0.71		
C.D. at 5%	1.03	1.03	2.13		
Plant height at 210 days after planting					
S0: Control	45.47	45.57	44.43	43.42	44.72
S1: *Pseudomonas fluorescens*	50.83	50.30	51.87	59.30	53.08
S2: *Pseudomonas striata*	56.10	58.37	61.27	67.63	60.84
S3: *Trichoderma viride*	58.43	58.85	58.27	61.01	59.14
Mean	52.71	53.27	53.96	57.84	
Interaction	S	Zn	SXZn		
S.E±	0.91	0.91	1.82		
C.D. at 5%	2.63	2.63	5.47		

Number of leaves: It was observed that the maximum number of leaves fond in the pot inoculated with *Pseudomonas strita* X $ZnSO_4$ 40 kg ha^{-1} (16.29- 22.32-25.93 for 90, 150 and 210 days respectively (Table 2). However it was revealed that the minimum number of leaves observed in the control treatment (Table 2). These results are in agreement with Singh *et al.* (2014) [14] and Shadap *et al.* (2018) [11] 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.

Table 2: Interaction effect of zinc solubilizing microbial cultures and levels of zinc on number of leaves of ginger plant

Treatments	Zn0: $ZnSO_4$ 0kg ha^{-1}	Zn1: $ZnSO_4$ 20 kg ha^{-1}	Zn2: $ZnSO_4$ 30 kg ha^{-1}	Zn3:$ZnSO_4$ 40 kg ha^{-1}	Mean
Number of leaves at 90 days after planting					
S0: Control	9.14	10.40	10.37	12.30	10.55
S1: *Pseudomonas fluorescens*	11.65	12.77	13.23	13.99	12.91
S2: *Pseudomonas striata*	15.87	15.25	15.07	16.29	15.62
S3:*Trichoderma viride*	13.37	14.70	14.98	15.77	14.70
Mean	12.51	13.28	13.41	14.59	
Interaction	S	Zn	SXZn		
S.E±	0.18	0.18	0.37		
C.D. at 5%	0.54	0.54	1.08		
Number of leaves at 150 days after planting					
S0: Control	15.17	16.40	16.51	18.50	16.64
S1:*Pseudomonas fluorescens*	17.63	18.77	19.19	19.85	18.86
S2: *Pseudomonas striata*	21.67	21.30	21.07	22.32	21.59
S3:*Trichoderma viride*	19.22	20.68	20.83	21.73	20.62
Mean	18.42	19.29	19.40	20.60	
Interaction	S	Zn	SxZn		
S.E±	0.17	0.17	0.34		
C.D. at 5%	0.51	0.51	0.102		
Number of leaves at 210 days after planting					
S0: Control	18.77	20.29	20.63	22.29	20.50
S1:*Pseudomonas fluorescens*	21.76	22.92	23.10	23.85	22.91
S2: *Pseudomonas striata*	25.66	25.14	25.45	25.93	25.54
S3:*Trichoderma viride*	23.37	24.63	24.83	25.64	24.61
Mean	22.39	23.24	23.50	24.43	
Interaction	S	Zn	SXZn		
S.E±	0.17	0.17	0.35		
C.D. at 5%	0.51	0.51	1.03		

Leaf area: Interaction effect of zinc solubilizing cultures and levels of zinc has a significant effect on the leaf area of ginger crop showed in table 3. The highest leaf area was noticed in the pot inoculated with *Pseudomonas striata* X $ZnSO_4$ 40 kg ha^{-1} (34.13-35.81-37.06 cm^2 at 90, 150 and 210 days respectively). However the values of uninoculted pots were noted lower leaf area. The cultures have the effect on the growth enhancement was reported by Turan *et al.* (2014) [13] and Tanwar *et al.* (2013) [12]. Also Palai, *et al.* (2017) [9] 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.

Table 3: Interaction effect of zinc solubilizing microbial cultures and levels of zinc on leaf area (cm^2) in ginger plant

Treatments	Zn0: $ZnSO_4$ 0kg ha^{-1}	Zn1: $ZnSO_4$ 20 kg ha^{-1}	Zn2: $ZnSO_4$ 30 kg ha^{-1}	Zn3:$ZnSO_4$ 40 kg ha^{-1}	Mean
Leaf area (cm^2) at 90 days after planting					
S0: Control	23.74	24.28	24.64	22.54	23.80
S1:*Pseudomonas fluorescens*	25.49	25.33	25.99	26.95	25.94
S2: *Pseudomonas striata*	29.77	32.03	32.52	34.13	32.11
S3:*Trichoderma viride*	29.22	28.94	29.30	31.22	29.67
Mean	27.05	27.65	28.11	28.71	
Interaction	S	Zn	SXZn		
S.E±	0.37	0.37	0.74		
C.D. at 5%	1.12	1.12	2.23		
Leaf area (cm^2) at 150 days after planting					
S0: Control	19.99	23.80	24.33	23.80	22.98
S1: *Pseudomonas fluorescens*	25.68	26.37	26.56	28.17	26.69
S2: *Pseudomonas striata*	31.30	32.27	33.93	35.81	33.33
S3:*Trichoderma viride*	31.58	32.04	33.65	34.45	32.93
Mean	27.14	28.62	29.62	30.56	
Interaction	S	Zn	SXZn		
S.E±	0.28	0.28	0.57		
C.D. at 5%	0.85	0.85	1.71		
Leaf area (cm^2) at 210 days after planting					
S0: Control	21.33	25.51	25.59	25.32	24.44

S1: *Pseudomonas fluorescens*	27.17	28.43	29.96	30.47	29.01
S2: *Pseudomonas striata*	32.77	33.80	35.41	37.06	34.76
S3:*Trichoderma viride*	32.30	33.26	34.92	35.48	33.99
Mean	28.39	30.25	31.47	32.08	
Interaction	S	Zn	SXZn		
S.E±	0.25	0.25	0.50		
C.D. at 5%	0.75	0.75	1.51		

Rhizome yield: The interaction effect of zinc solubilizing cultures and levels of zinc found significant for yield of ginger crop depicted in Table 4. The highest yield was recorded in pots treated with *Pseudomonas striata* X 40 kg ZnSO4 ha^{-1}. (436.15 g pot^{-1}) at par with the fungal treatment of *Trichoderma viride* X 40 kg ZnSO4 ha^{-1}. However the lowest yield was recorded in control pots. Increase in yield might be a result of required zinc supply to growing plants. The results are similar to the findings of Chandrashekhar and Hore (2019) [3] revealed that application of biofertlizer had better response to ginger crop. Maralian, (2009) concluded that foliar application of iron and zinc increased wheat seed yield. Grewal (2001) [7] and Dileep (2019) [4] also found that zinc treatments provides highest yield.

Table 4: Interaction effect of zinc solubilizer and levels of zinc on rhizome yield in ginger

Treatments	**Rhizome yield (g pot^{-1})**				
	Zn0: $ZnSO_4$ 0kg ha^{-1}	**Zn1: $ZnSO_4$ 20 kg ha^{-1}**	**Zn2: $ZnSO_4$ 30 kg ha^{-1}**	**Zn3:$ZnSO_4$ 40 kg ha^{-1}**	**Means**
S0: Control	241.53	227.16	322.22	290.37	270.32
S1: *Pseudomonas fluorescens Pseudomonas fluorescens*	277.81	314.81	319.78	307.77	305.04
S2: *Pseudomonas striata*	352.91	326.73	383.10	436.15	374.72
S3:*Trichoderma viride*	319.17	332.81	339.45	388.82	345.06
Mean	297.85	300.38	341.14	355.78	
Interaction	S	Zn	SXZn		
S.E±	7.09	7.09	14.19		
C.D. at 5%	21.27	21.27	42.34		

Conclusion

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

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