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Effect of potassium and zinc solubilizing microorganisms on nutrient availability in soil, nutrient uptake by groundnut, soil microbial population and yield of groundnut in coastal zone of Karnataka

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Abstract

Background: Groundnut is the second most annual oil seed crop. It has 45 to 49 per cent oil content and 26 per cent protein in kernel. Hence, groundnut is called as ‘king of oil seeds’ and ‘poor man’s cashew nut’.
Methods: Field experiment was conducted during summer season of 2021 at ZAHRS, Brahmavara, KSNUAHS, Shivamogga, Field experiment consisted of eight treatments were replicated thrice and laid out in RCBD.
Result: Among treatments tried, significantly higher microbial population registered in treatments which received RDF with seed treatment with KSB and ZnSB either alone (T_3 or T_4) or in combination (T_5 and T_6). Significantly, higher soil available nutrient status at harvest (N: 242 kg ha, P_2O_5:103.75 kg ha^{-1}, K_2O: 96.6 kg ha^{-1} and Zn: 0.83 mg kg^{-1}), recorded in treatment recommended dose of fertilizer + seed treatment with KSB + ZnSB (T_5). Higher number of pods plant^{-1} (29.1), pod weight plant^{-1} (21.9 g) were recorded with recommended dose of fertilizer + seed treatment with KSB + ZnSB (T_5). The better values of these indices in T_5 resulted in higher pod yield (1675 kg ha^{-1}) of groundnut.

Keywords: KSB, microbial population, seed treatment and ZnSB

Introduction

Groundnut is an important oilseed crop is being cultivated during summer followed by rice in coastal Karnataka, with an area of 2050 ha and production 4625 ton (Anon., 2020) [2]. In this region, groundnut is mainly growing under residual nutrients which applied to previous *kharif* paddy crop. Application of major nutrients to preceding paddy crop has lead to exploitation of native soil micronutrients as a result making soil deficit in with respect to micro-nutrients in general and Zn in particular. And also heavy rainfall in the region leads to leaching of potassium that creates acidity in soil which fixes the potassium and zinc nutrients in soil. It may lead to low productivity because potassium is the most important plant nutrient after nitrogen and phosphorus that has a key role in the growth, metabolism and development of plants.

In addition to increasing plant resistance to diseases, pests, and abiotic stresses, K is known to involved in the activation of over 80 different enzymes responsible for plant and animal physiological processes such as energy metabolism, starch synthesis, nitrate reduction, photosynthesis and sugar degradation. However, Potassium is found in relatively large quantities in most soils. Ironically, the unavailable form of potassium varies from 95 to 98 per cent of the total soil potassium, which includes insoluble K bearing rocks and minerals *viz.*, feldspar, mica, etc., followed by slowly available form (1-10%) and readily available form (1-2%) (Parmer and Sindu, 2016) [18]. The total pool of soil K is highly complex, and this can be solubilized by rhizosphere microorganisms through the production of acids and thereby made available for plants (Ullaman *et al.*, 1996) [31]. Zinc, one of the important micronutrients, is required in small proportion for the proper growth and development of living organisms (Hafeez *et al*., 2013) [7]. In plants, specifically, it is involved in carbohydrate and auxin metabolism (Alloway, 2004) [1] also acts as a significant anti-oxidant. Zinc-finger transcription factors play an important role in the normal development of floral tissues, flowering, fertilization and fruiting (Epstein and Bloom, 2005) [6]. Plants take up zinc as divalent cation but only a very minor portion of total zinc present in soil is in soluble form.

The rest of the zinc is in the form of insoluble complexes and minerals. To alleviate zinc deficiency, various methods have been applied since long. Zinc fertilization in the form of zinc sulphate (White and Broadly, 2005) [33] or Zn-EDTA (Karak *et al*., 2005) [11] have been used, but their usage puts an economical and environmental pressure and these are transformed into insoluble complex forms within seven days of fertilizer application (Rattan and Shukla, 1991) [23].

To overcome nutrient deficiencies, biofertilizers as solubilizer are better option in view of their cost-effectiveness, contribution to crop productivity, soil sustainability and eco-friendly nature. Biofertilizer is one of the important components of integrated nutrient management practices to supplement the chemical fertilizers leading to sustainable agriculture. Biofertilizers include nitrogen-fixing bacteria, phosphate solubilizing bacteria (PSB), phosphate mobilizers, plant growth-promoting biofertilizers, potassium solubilizing bacteria and zinc solubilizing bacteria.

In this context, use of solubilizing beneficial rhizosphere microorganisms as bio inoculants to increase nutrient availability by converting unavailable form of nutrients to available form and to achieve the objective of low external input sustainable agriculture is need of the day (He *et al*., 2010). In the background of the facts above, the study was taken up to know the effect of potassium and zinc solubilising microorganisms on nutrient availability in soil, nutrient uptake and soil microbial population in groundnut under Coastal Zone of Karnataka.

Material and Methods

A field study was carried out during summer 2020-21 at Zonal Agricultural and Horticultural Research Station, Brahmavara, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga. The experimental site soil was low in available nitrogen (270 kg ha^{-1}), medium in available phosphorous (41.65 kg ha^{-1}), low in available potassium (88.42 kg ha^{-1}) and deficit in available zinc (0.42 mg ha^{-1}). The experiment consisting eight treatments *viz*.,: T_1: Absolute control, T_2: POP (25:75:37.5) kg NPK ha^{-1}+ $ZnSO_4$@ 10 kg ha^{-1}), T_3: T_2 + Seed treatment with Potassium Solubilising Bacteria (KSB), T_4: T_2 + Seed treatment with Zinc Solubilising Bacteria (ZnSB), T_5: T_2 + Seed treatment with both KSB and ZnSB, T_6: RDNP +75% RD of K and $ZnSO_4$ + Seed treatment with both KSB and ZnSB, T_7: RDNP + 50% RD of K + $ZnSO_4$ + Seed treatment with both KSB and ZnSB, T_8: RDNP Seed treatment with both KSB and ZnSB.

Potassium Solubilizing Bacteria (KSB), *Frateuria aurantia* used in the experiment is an acidophile, rod shaped, gram negative and belongs to proteobacteria, indentified by colourless zone of solubilization in Aleksandrow agar media. Zinc Solubilizing Bacteria (ZnSB) used was *Psudomonas* spp (ZnSB-4 strain) which can be identified by brownish zone of solubilization in Mineral salt supplemented ZnO agar media.

The groundnut variety used in the experiment was TMV-2. It is a Spanish bunch type derived by the mass selection from 'Gudhiathum bunch' released in 1946. The duration of the crop is 110-115 days, with yield of 1200- 1400 kg ha^{-1} and oil content of 49 per cent.

Soil analysis

Available nitrogen (Kjeldal distillation method), phosphorous (Spectrophotometer), potassium (Flame photometer) and zinc (Atomic absorption spectrophotometer) were analysed by adopting standard protocols.

Plant analysis

Plant nitrogen, phosphorous, potassium and zinc content were estimated by tri-acid, di-acid (P and K) and DTPA extractable method, respectively.

The nutrient uptake by the crop was calculated using the following formulae given below.

$$\text{Nutrient uptake (kg ha}^{-1}) = \frac{\text{Nutrient Concentration (\%)} \times \text{Dry matter (kg ha}^{-1})}{100}$$

(For N, P and K)

$$\text{Zn uptake (g ha}^{-1}) = \frac{\text{Zn Concentration (ppm)} \times \text{Dry matter (kg ha}^{-1})}{1000}$$

Result and Discussion

Effect on soil microbial population

The results revealed that numerically higher bacteria, fungi and actinomycetes population was found in treatment which received nutrients through application of RDF + KSB + ZnSB (125.15× 10^{5}g^{-1} soil), fungi (28.00× 10^{3}g^{-1} soil) actinomycetes (15.52 × 10^{2}g^{-1} soil) over RDF alone (Table. 1) due to application of microbial inoculants or biofertilizers which act as inoculums for multiplication of microbe in the soil. However, the microbial population decrease as the age of the crop advances due to reduced root activities like root exudation and rhizosphere microbial activity. Similarly, Ektakumari *et al*. (2018) [5] have also counted significantly higher microbial population by the use of different microbes.

The results on potassium solubilizing bacteria revealed the maximum population with the application of RDF + KSB + ZnSB (35.95 × 10^4 g^{-1} soil) over RDF (Table 1). These results are in conformity with findings of Karande and Khot (2007) [12].

The results showed that higher zinc solubilizing bacteria population was found in treatment RDF + KSB + ZnSB (38.60 × 10^4 g^{-1} soil) over RDF (Table 1). It is due to the multiplication of applied zinc solubilizing bacteria bioinoculant in rhizosphere soil which act as seed material. Higher ZnSB population found at 45 DAS was due to higher root activity in rhizosphere soil and decline in later stages. Ingle *et al*. (2003) [10] also concluded that the rhizobial and total microbial population was increased from 30 days onwards and reached the peak at 50 DAS.

Table 1: Effect of Potassium and Zinc Solubilizing Microorganisms on total soil microbial population after 45 DAS of groundnut

Treatments		Total bacteria (CFU ×10^5 g^{-1} of soil	Total fungi (CFU ×10^3 g^{-1} of soil)	Total actinomycetes (CFU ×10^2 g^{-1} of soil)	KSB (CFU × 10^4 g^{-1} of soil)	ZnSB (CFU × 10^4 g^{-1} of soil)
		45 DAS	45 DAS	45 DAS	45 DAS	45 DAS
T_1	Absolute control	65.00	13.00	6.16	5.67	7.66
T_2	RDF	110.00	20.00	9.08	14.58	15.00
T_3	RDF + ST with KSB	115.28	23.16	12.20	31.60	25.83
T_4	RDF + ST with ZnSB	117.96	23.50	12.50	26.25	35.92
T_5	RDF + ST with KSB + ZnSB	125.15	28.00	15.52	35.95	38.60
T_6	RDNP + 75% RD of K and $ZnSO_4$ + ST with KSB and ZnSB	125.00	27.30	15.36	33.01	37.80
T_7	RDNP + 50% RD of K and $ZnSO_4$ + ST with KSB and ZnSB	123.33	26.33	14.40	32.34	36.30
T_8	RDNP + ST with KSB and ZnSB	120.19	25.28	14.00	32.00	36.00
S.Em.±		3.62	0.67	0.38	0.84	0.94
C.D.@ 5%		10.68	1.99	1.13	2.47	2.79

Note: FYM at 10 tons per ha and *Rhizobium* seed treatment is common for all treatments except T_1.
RDF- Recommended dose of fertilizer (25:75:37.5) NPK kg ha^{-1}+ $ZnSO_4$@ 10 kg ha^{-1}.
ST- Seed treatment KSB- Potassium solubilizing bacteria (*Frateuria aurantia*)
ZnSB – Zinc solubilizing bacteria

Effect on soil nutrient availability

Potassium and zinc solubilizing bacteria can dissolve fixed nutrients in soil and from K-bearing minerals and release nutrients through the production of various organic acids such as oxalic acid, tartaric acids, gluconic acid, 2-ketogluconic acid, citric acid, malic acid, succinic acid, lactic acid, propionic acid, glycolic acid, malonic acid, fumaric acid, etc. (Sheng and He, 2006; Prajapati *et al*., 2012 and Prajapati *et al*., 2013) [26, 20, 21]. These acids will release fixed nutrients and make them available to plants. Significantly higher available nitrogen in the soil was noticed in treatment RDF + seed treatment with KSB and ZnSB (242.40 kg ha^{-1}) which was closely followed by T_6 (Table. 2).This may be due to the synergetic effect of *Rhizobium* + KSB + ZnSB, which improved the nitrogen availability in soil. Similarly, better phosphorous availability in soil was obtained with treatments RDF + seed treatment with KSB and ZnSB (101.18 kg ha^{-1}) closely followed by RDNP + 75% RD of K and $ZnSO_4$ + Seed treatment with both KSB and ZnSB (T_6) (Table. 2). These results confirmed the findings of Sugumaran and Janarthanam (2007) [28], who recorded higher P and K availability due to inoculation of *B. mucilaginosus* (KSB) compared to control in groundnut.

Significantly higher available potassium in soil was recorded with treatment RDF + seed treatment with KSB and ZnSB (96.6 kg ha^{-1}), closely followed by RDNP +75% RD of K and $ZnSO_4$ + seed treatment with both KSB and ZnSB (T_6) over RDF alone (Table. 2). Potassium solubilizing microorganism improves the potassium availability in soil by mineralizing/solubilizing the fixed potassium in soil. The major mechanism of K mineral solubilization is by the production of organic and inorganic acids and production of protons through acidolysis mechanism (Maurya *et al.*, 2014 and Meena *et al*., 2015) [14, 16]. These results were proved with findings of Supanjani *et al*. (2006) [29] who recorded increased K availability from 13 to 15 per cent with the potassium solubilizing bacteria in *Capsicum annuum*.

Improvement in Zn availability was realized in treatment of RDF + seed treatment with KSB and ZnSB (0.83 mg kg^{-1}) followed by RDNP + 75% RD of K and $ZnSO_4$ + seed treatment with both KSB and ZnSB (0.81 mg kg^{-1}) which are on par. These results are line with the findings of Suganya and Saravanan (2014) [27] who reported irrespective of soil and moisture regime, the zinc solubilizing bacteria enhanced the available zinc content of the soils.

Table 2: Effect of potassium and zinc solubilizing microorganisms on nutrient availability in soil

Treatments		Nutrient availability (kg ha^{-1})			mg kg^{-1}
		N	P_2O_5	K_2O	Zn
T_1	Absolute control	176.0	28.2	54.6	0.13
T_2	RDF	204.4	77.0	62.4	0.66
T_3	RDF + ST with KSB	216.7	88.0	88.2	0.72
T_4	RDF + ST with ZnSB	210.3	84.8	82.3	0.76
T_5	RDF + ST with KSB + ZnSB	242.4	103.8	96.6	0.83
T_6	RDNP + 75% RD of K and $ZnSO_4$ + ST with KSB and ZnSB	233.0	101.2	92.3	0.81
T_7	RDNP + 50% RD of K and $ZnSO_4$ + ST with KSB and ZnSB	210.6	98.3	62.7	0.68
T_8	RDNP + ST with KSB and ZnSB	209.4	92.2	52.3	0.49
S.Em.±		8.86	4.96	3.28	0.03
C.D.@ 5%		25.74	14.41	9.53	0.08

Note: FYM at 10 tons per ha and *Rhizobium* seed treatment is common for all treatments except T_1.
RDF- Recommended dose of fertilizer (25:75:37.5) NPK kg ha^{-1}+ $ZnSO_4$@ 10 kg ha^{-1}.
ST- Seed treatment KSB- Potassium solubilizing bacteria (*Frateuria aurantia*) ZnSB – Zinc solubilizing bacteria

Effect on nutrient content and uptake

Nutrient uptake by any crop depends on nutrients availability in soil and it is the product of nutrient content in the plant (%) and dry matter production. Under favorable conditions higher the available nutrient status in the soil more the uptake by plant. Transformation of the unavailable form of nutrients to the available form is mainly carried out by microorganisms like nutrient solubilizers.

In the present study, seed treatment with KSB and ZnSB along with RDF has recorded significantly higher nitrogen uptake (44.19, 35.32, 79.50 kg ha^{-1} by haulm, kernel and total, respectively) closely followed by seed treatment with KSB and ZnSB along with 100 per cent NP + 75% recommended K and Zn (43.57, 34.43 and 78 kg ha^{-1}, respectively, in haulm, kernel and total) (Table. 4). Higher nitrogen uptake in these treatments is due to higher nutrient content (Table 3) in haulm and kernel (T_5: 1.68 and 2.84%, respectively) and (T_6: 1.66 and 2.82%, respectively) over RDF (0.87 and 1.32%, respectively). It is also due to the priming effect of potassium on nitrogen uptake in those treatments where seeds were treated with KSB and ZnSB either alone or in combination. Similarly, Han *et al.* (2006) [8] have realized higher P and K availability and uptake of N, P and K by shoot and root in pepper and cucumber. Further, Sheng and Haung (2002) [26] have reported higher biomass and nutrient contents of P and K due to Potassic bacteria.

Significantly higher total P uptake was noticed with the treatment of RDF + seed treatment with KSB + ZnSB (T_5) (8.94, 5.35 and 14.29 kg ha^{-1} by haulm, kernel and total, respectively) closely followed by seed treatment with KSB and ZnSB along with RDNP + 75% RD of K and Zn (T_6) over RDF alone (Table.4). Higher nutrient uptake is attributed for higher nutrient content and higher biomass (Table 3). This is concomitant to the findings of Badr *et al.* (2006) [4] who obtained 48, 71 and 41 per cent higher dry matter, P and K uptake than control due to KSB in sorghum.

Similarly, higher potassium uptake by groundnut was realized with T_5 *i.e.,* KSB and ZnSB seed treatment along with 100 per cent RDF (45.51, 32.11 and 77.62kg ha^{-1} by haulm, kernel and total, respectively) closely followed by RDNP + 75% RD of K and $ZnSO_4$ + Seed treatment with both KSB and ZnSB (T_6) over RDF alone (Table.4). Similarly, Sheng (2005) [25] reported 30-36 cent higher potassium content and biomass in cotton and rapeseed while Ramarethinam *et al.* (2005) [22] in chilli. Higher uptake in Treatment T_5 is attributed to high K content (Table. 3) in haulm (1.74%) and kernel (2.58%). Similarly, Zinc uptake by groundnut was significantly higher in treatment which received nutrients through application of RDF + seed treatment with KSB + ZnSB (53.58, 61.32 and 110.59 g ha^{-1} respectively, in haulm, kernel and total) over RDF (Table.4). Higher uptake of Zinc is due to better mineralization of potassium and zinc in soil by KSB and ZnSB which caused for higher availability and high zinc content (Table. 3). Significantly enhanced total dry biomass (12.96 g plant^{-1}) and higher N (2.268%), K (2.0%), Mn (60 ppm) and Zn content (278.8 ppm) were also obtained by Kumar *et al.* (2013) [13] with seed bacterization of ZnSB @ 10 g kg^{-1}. Tariq *et al.* (2007) [30] also reported that PGPR inoculation significantly increased concentration of Zn (23.6 mg kg^{-1}) in the rice grain over the control (9.2 mg kg^{-1}).

Table 3: Effect of potassium and zinc solubilizing microorganisms on nutrient content in haulm and kernel of groundnut

Treatments		Nitrogen (%)		Phosphorous (%)		Potassium (%)		Zinc (ppm)	
		Haulm	Kernel	Haulm	Kernel	Haulm	Kernel	Haulm	Kernel
T_1	Absolute control	0.87	1.32	0.16	0.27	0.91	1.6	13.46	39.44
T_2	RDF	1.58	2.72	0.28	0.36	1.58	2.48	18.20	45.49
T_3	RDF + ST with KSB	1.65	2.81	0.31	0.37	1.72	2.52	17.36	46.42
T_4	RDF + ST with ZnSB	1.64	2.79	0.30	0.38	1.70	2.49	18.83	48.23
T_5	RDF + ST with KSB + ZnSB	1.68	2.84	0.34	0.43	1.74	2.58	20.32	49.27
T_6	RDNP + 75% RD of K and $ZnSO_4$ + ST with KSB and ZnSB	1.66	2.82	0.33	0.41	1.73	2.53	20.28	48.77
T_7	RDNP + 50% RD of K and $ZnSO_4$ + ST with KSB and ZnSB	1.61	2.80	0.32	0.40	1.66	2.44	19.40	44.35
T_8	RDNP + ST with KSB and ZnSB	1.59	2.70	0.32	0.39	1.55	2.26	16.52	43.28
S.Em.±		0.07	0.09	0.01	0.01	0.06	0.04	0.69	1.53
C.D.@ 5%		0.21	0.25	0.04	0.03	0.17	0.11	2.09	4.44

Note: FYM at 10 tons per ha and *Rhizobium* seed treatment is common for all treatments except T_1.
RDF- Recommended dose of fertilizer (25:75:37.5) NPK kg ha^{-1}+ $ZnSO_4$@ 10 kg ha^{-1}.
ST- Seed treatment KSB- Potassium solubilizing bacteria (*Frateuria aurantia*)
ZnSB – Zinc solubilizing bacteria

Table 4: Effect of potassium and zinc solubilizing microorganisms on nutrient uptake by groundnut

Treatments		Nitrogen (kg ha^{-1})			Phosphorous (kg ha^{-1})			Potassium (kg ha^{-1})			Zinc (g ha^{-1})		
		Haulm	Kernel	Total	Haulm	Kernel	Total	Haulm	Kernel	Total	Haulm	Kernel	Total
T_1	Absolute control	17.42	8.60	26.02	3.22	1.73	4.95	18.29	10.36	28.65	27.05	25.53	64.97
T_2	RDF	32.51	30.56	63.07	6.84	4.01	10.85	38.67	27.87	66.48	44.31	51.10	96.59
T_3	RDF + ST with KSB	42.94	32.83	75.77	7.94	4.44	12.38	43.52	29.44	72.96	48.20	54.23	102.43
T_4	RDF + ST with ZnSB	41.49	31.90	73.39	7.59	4.24	12.13	43.43	28.50	71.93	49.08	55.21	104.29
T_5	RDF + ST with KSB + ZnSB	44.19	35.32	79.50	8.94	5.35	14.29	45.51	32.11	77.62	53.58	61.32	110.59
T_6	RDNP + 75% RD of K and $ZnSO_4$ + ST with KSB and ZnSB	43.57	34.43	78.00	8.68	5.02	13.70	45.40	30.97	76.37	53.29	59.68	108.45
T_7	RDNP + 50% RD of K and $ZnSO_4$ + ST with KSB and ZnSB	37.47	29.43	66.91	7.45	4.25	11.70	38.64	25.73	64.37	40.33	46.75	91.10
T_8	RDNP + ST with KSB and ZnSB	37.06	27.34	64.38	7.35	3.87	11.22	35.96	22.64	58.60	38.40	43.35	86.63
S.Em.±		1.05	1.33	2.38	0.48	0.54	1.02	1.06	0.61	1.67	1.27	1.97	3.24
C.D.@ 5%		3.05	3.86	6.91	1.39	1.57	2.96	3.07	1.76	4.84	3.69	5.73	9.42

Note: FYM at 10 tons per ha and *Rhizobium* seed treatment is common for all treatments except T_1.
RDF- Recommended dose of fertilizer (25:75:37.5) NPK kg ha^{-1}+ $ZnSO_4$@ 10 kg ha^{-1}.
ST- Seed treatment. KSB - Potassium solubilizing bacteria (*Frateuria aurantia*), ZnSB – Zinc solubilizing bacteria

Effect on yield and yield parameters of groundnut

Any new experiment aims to increase the quantity of the product to meet the food security.

Higher number of pods (29.2 plant^{-1}) and pod weight (21.9 g plant^{-1}) recorded in treatment RDF + Seed treatment with KSB + ZnSB (T_5). These higher yield parameters results significantly higher pod yield of 1675 kg ha^{-1} and kernel yield of 1245 kg ha^{-1} was recorded with treatment RDF + Seed treatment with KSB + ZnSB (T_5). This was closely followed by treatment RDNP +75% RD of K and $ZnSO_4$ + Seed treatment with both KSB and ZnSB (T_6) 1654 and 1224 kg ha^{-1}, pod and kernel yield, respectively (Table 5). Higher yield with KSB and ZnSB seed treatment was due to role of inoculums in increasing of microbial population in soil thereby increases the nutrient availability, nutrient uptake by crops and better utilization of native K and Zn and also influence the positive effect on uptake of other nutrients. Similar results were obtained by Verma *et al.* (2016) [32], Prajapati and Modi (2016) [18], Meena *et al*. (2013) [15], Nomen *et al*. (2015) [17], due to the application of Zn bio-fertilizer, have recorded 4.7 per cent higher pod yield of groundnut, over control. Archana *et al*. (2008) [3] reported that all the inoculated bacterial isolates increased plant growth, nutrient uptake, and yield component of maize plant significantly over absolute fertilizer control.

Table 5: Effect of Potassium and Zinc Solubilizing microorganisms on yield and yield parameters of groundnut

Treatments		Total pods plant^{-1}	Pod weight g plant^{-1}	Pod yield kg ha^{-1}	Kernel yield kg ha^{-1}
T_1	Absolute control	19.00	10.5	950	622
T_2	RDF	27.00	20.2	1545	1104
T_3	RDF + ST with KSB	27.5	20.5	1600	1168
T_4	RDF + ST with ZnSB	27.8	20.8	1590	1145
T_5	RDF + ST with KSB + ZnSB	29.2	21.9	1675	1245
T_6	RDNP + 75% RD of K and $ZnSO_4$ + ST with KSB and ZnSB	28.3	21.4	1654	1224
T_7	RDNP + 50% RD of K and $ZnSO_4$ + ST with KSB and ZnSB	26.3	19.8	1480	1054
T_8	RDNP + ST with KSB and ZnSB	25.9	18.3	1440	1002
S.Em.±		0.63	0.54	46.00	37.00
C.D.@ 5%		1.89	1.61	135.70	107.30

Note: FYM at 10 tons per ha and *Rhizobium* seed treatment is common for all treatments except T_1.
RDF- Recommended dose of fertilizer (25:75:37.5) NPK kg ha^{-1}+ $ZnSO_4$@ 10 kg ha^{-1}.
ST- Seed treatment KSB- Potassium solubilizing bacteria (*Frateuria aurantia*)
ZnSB – Zinc solubilizing bacteria

Conclusion

From the study, it is concluded that seed treatment with potassium and zinc solubilizing microorganisms which act as seed inoculums resulted in improvement microbial population in soil. The organic acids released by the microbes will augment the nutrient availability for the crop. Thus, seed treatment of potassium and zinc solubilizing microorganisms along with state recommended fertilizer resulted in improvement in plant nutrient content and nutrient uptake by groundnut to the magnitude of 26.05, 31.70, 16.75 and 14.49 per cent, N, P, K and Zn, respectively and higher pod yield of 8.41 per cent over RDF alone in groundnut.

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