



INM in chilli in Vertisols with Biofertilizers, *Trichoderma viride* and VAM on yield and seedling vigour

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ABSTRACT

Soil contains considerable amount of Phosphorus and Potassium but these elements are present in insoluble form. Hence, these nutrients cannot be absorbed by plants. To overcome this deficiency in soils, use of PSB and KSB as inoculants increases P and K uptake by plants and thus play an important role in plant nutrition. The beneficial effects of combined application of chemical fertilizers with biofertilizers are universally known. A balanced application of inorganic (NPK) fertilizers along with biofertilizers and bio control agents appear to be an ideal proposition to meet nutrient requirements of crops rather than single application. In view of this, the present investigation was undertaken to assess the effect of bio fertilizers, bio control agents in combination with different doses of RDF. The trial was conducted with eight treatments consisting of bio fertilizers, bio control agents in combination with different doses of RDF in Randomized block design with three replications. Among the treatments, T₄ (75% RDF +Bio fertilizer + *Trichoderma viride* +VAM) recorded maximum yield (125.2 q/h) being on par with T₂ (118.3q/ha) and T₁ (113.3q/h). Plant height was significantly maximum in T₄ (97.7cm) being on par with T₂ (95.6cm), T₃ (90.3cm) and T₁ (88.1cm). Number of branches was significantly maximum in T₄ (4.6) being on par with T₂ (3.9). Number of fruits were significantly maximum in T₄ (189.7) being on par with T₂ (187.5), T₁ (167.3), T₃ (162.7) and T₅ (164.5). with regard to number of seeds per pod T₄ recorded more number of seeds per pod (92.3) where as seed yield /pod was also significantly maximum in T₄ (88.7gm).With regard to seed characters, among the treatments, T₄ recorded maximum germination % (88.0), shoot length (3.7cm) , root length(6.2 cm) SVI-I (874.3) and SVI-II(115.9).

Keywords: PSB and KSB, INM, biofertilizers, *Trichoderma viride*, VAM, yield, shoot length, root length, SVI-I, SVI-II.

INTRODUCTION

Chilli (*Capsicum annuum* L.) is one of the important commercial crops of India. It is grown both in tropical and sub-tropical regions and requires a warm humid climate. Though, chilli can be grown in many types of soils, well-drained loamy soils rich in organic matter is best suited for its cultivation. Due to its commercial importance, farmers are using higher doses of chemical fertilizers to realize more yields. But this resulted in to deterioration of soil characters (Kukereja *et al.*, 1991). During cultivation of chilli indiscriminate and continuous application of chemical fertilizers resulted in ecological imbalance with consequent ill effects on soil as well as environment and increases the cost of cultivation. Chilli production has to be increased primarily from enhancing the productivity with a combination of high yielding plant types, standard agronomic practices like seed priming and balanced plant nutrition attained through integrated nutrient management (INM). Since chemical fertilizers alone will not be able to sustain the productivity, balanced nutrition is one of the most important factor that affecting the growth and productivity of chilli. Phosphorus and potassium are major essential macronutrients for plant growth and development. Potential bacteria such as phosphate Solubilizing bacteria and Potassium solubilizing bacteria could dissolve successfully non-readily available forms of soil phosphorus and also potassium and play an essential role in providing it to plants. Therefore, direct application of phosphate and potassium solubilizing bacteria may be more useful and environmentally safer than chemical P and K fertilizers (Parmar & Sindhu 2013). Paul and Thomas 1985 reported that, most of

the potassium in soil exists in the form of silicate minerals. The phosphorus and potassium can become available to the plants when minerals are solubilized. Generally in soils, the total K per plant was greatly increased if soluble potassium was added, but this increment was higher when the soil was inoculated with the strain PSB-2 and KSB -5. Lin *et al.* (2002) demonstrated that bacterial inoculation could result in growth promotion and higher K contents of plant components. Hence off late, lot of importance is given to integrated nutrient management. Seedling establishment is an important component of successful chilli production. Germination percentage and seedling vigour provide early indicators of the physiological performance of seed. Seedling vigour index-I is conventionally calculated from germination percentage and seedling length, while seedling vigour index-II incorporates seedling dry weight. However, limited information is available on the combined effect of reduced RDF with a consortium comprising bacterial biofertilizers, *T. viride* and VAM on both early seedling performance and subsequent field productivity of chilli. Therefore this study was conducted to assess the nutrient requirement of the crop by integration of inorganic and biofertilizers which helps not only to increase the yield but also maintains the soil health and ecofriendly environment. In this context, the INM practice is quite encouraging.

MATERIALS AND METHODS

The present investigation was carried out at Regional Horticulture Research station, Lam to test the potentiality of biofertilizers on chilli namely Azospirillum, PSB, KSB along with *T. viride* and VAM. The experiment was laid out with eight treatments in randomized block design (RBD) with three replications. The treatment details as follows:

T1- RDF (120kg N + 24kg P + 48 kg K per acre)

T2- 75% RDF (90 kg N + 18 kg P + 36 kg K per acre) + bio fertilizers (Azospirillum + PSB + K solubilizing bacteria each @ 2kg /acre) as basal application

T3-75%RDF (90 kg N + 18 kg P + 36 kg K per acre) + biocontrol agent *Trichoderma viride*@ 2kg/acre + *Michorhiza* (VAM @ 5kg/acre) as basal application

T4-75%RDF (90 kg N + 18 kg P + 36 kg K per acre) + biofertilizers (Azospirillum + PSB+ K solubilizing bacteria each @2kg/acre) + Biocontrol agent *Trichoderma Viride* @ 2kg/acre + *Michorhiza* (VAM @ 5kg/acre) as basal application

T5- 50% RDF (60 kg N + 12 kg P + 24 kg K per acre) + Azospirillum + PSB + K solubilizing bacteria each @ 2kg /acre) as basal Application.

T6- 50%RDF (60 kg N + 12 kg P + 24 kg K per acre) + biocontrol agent *Trichoderma viride*@ 2kg/acre + *Michorhiza* (VAM @ 5kg/acre) as basal application

T7-50% NPK (60 kg N + 12 kg P + 24 kg K per acre) + biofertilizers (Azospirillum + PSB + K solubilizing bacteria each @2kg/acre) + biocontrol agent *Trichoderma viride*@ 2kg/acre + *Michorhiza* (VAM @ 5kg/acre)

T8- Application of biofertilizers only.

The seeds of chilli variety, LCA -620 Seedlings were raised under standard nursery management practices in the nursery and forty aged seedlings were transplanted in main field at spacing of 75 x 30cm at a plot size of 4.0 X 3.0.mt.

The initial soil properties should be reported as follows:

Property	Initial value
pH	[8.4]
EC (dS m ⁻¹)	[0.6]
Organic carbon (%)	[0.46]



Available N (kg ha ⁻¹)	[314 Kg N/ha]
Available P (kg ha ⁻¹)	[24 Kg/P ₂ O ₅]
Available K (kg ha ⁻¹)	[590 Kg K ₂ O/ha]
Soil texture	[Black cotton soils with heavy clay]

The recommended dose of 120:24:48 kg NPK kg/ac per acre was applied in the form of urea, single super phosphate and muriate of potash, respectively. The biofertilizers, Azospirillum, Phosphorus solubilizing bacteria, potassium solubilizing bacteria each @ 2kg/acre along with biocontrol agents, Trichoderma viride @ 2 kg/acre and Michorhiza (VAM @ 5kg/acre) and entire dose of phosphorus are applied to soil as basal application before transplanting. The recommended dose of nitrogen (as per the experimental treatment dose) and potash was applied in four splits one month after transplanting and later at twenty days interval. Necessary agronomic and timely plant protection measures were taken up to raise the healthy crop. The data on various growth parameters was recorded at the time of harvest on five randomly selected plants from each replication and the mean values were subjected to statistical analysis as per Panse and Sukhamtme (1985). The observations were recorded for the growth parameters such as plant height (cm), No. of branches/plant, No. of fruits per plant, number of seeds/pod, seed yield/plant (g), dry fruit yield (q/ha), Seed germination %, root length (cm), and shoot length (cm), SVI- I and SVI- II. Ten seedlings were randomly selected from each treatment for assessing seed quality parameters, shoot length, root length, total seedling length (cm), seedling dry weight (mg), and seedling vigor indices I and II. The root length was measured from the tip of the primary root to base of hypocotyle with the help of a scale and mean root length was expressed in centimeters. The shoot length was measured from the tip of the primary leaf to the base of the hypocotyle and mean shoot length was expressed in centimeter.

Germination percentage of the seed lot was tested and recorded following method (ISTA, 2016).

Germination percentage of the seed was calculated as detailed below:

$$\text{Germination percentage of the seed} = \frac{\text{Number of germinated seeds}}{\text{Total number of seeds}} \times 100$$

The seedling vigour index (SVI-I & SVI-II) was computed following Abdul-Baki and Anderson, (1973).

Seedling Vigour Index-I:

It evaluates elongation and physical growth capacity of seedling.

$$\text{SVI- I} = \text{seedling length (cm)} \times \text{Germination percentage}$$

Seedling Vigour Index-II (SVI-II):

It evaluates dry matter accumulation and the mobilization of food reserves from the seed. The ten normal seedlings were placed in a paper cover and dried in shade for 24 h and then, they were kept in an oven maintained at 80°C for 16 ± 1 h. The dried seedlings were weighed and the mean values were expressed in grams.

$$\text{SVI-II} = \text{seedling dry weight (gm/mg)} \times \text{Germination percentage}$$

RESULTS AND DISCUSSION

Plant height is a crucial yield-attributing trait that has a direct effect on biomass accumulation and production of fruits (Khandaker *et al.*, 2017). Plant height was recorded by measuring the length from the base of the plant (ground level) to the growing tip of the main stem from all the tagged plants and average was worked out and

expressed in centimeters. Plant height was significantly maximum in T₄ (75% RDF +BF+TV+VAM- (97.7cm) being on par with T₂ - 75% RDF + bio fertilizers (Azospirillum + PSB + K solubilizing bacteria each @ 2kg /acre) as basal application (95.6cm), T₃ (75%RDF + biocontrol agent Trichoderma viride@ 2kg/acre + Mycorrhiza (VAM @ 5kg/acre) as basal application-90.3cm) and T₁(RDF -88.1cm). Among the treatments, minimum plant height was recorded in T₈ - Application of biofertilizers alone (74.2cm).

Numbers of primary branches produced per plant were recorded from five tagged plants by counting the number of branches at harvest and average was worked out and expressed in numbers. The number of primary branches per plant was significantly maximum in T₄ (4.6) being on par with T₂ (3.9) compared to RDF (3.7) where as lowest number of primary branches per plant was recorded in T₈ (3.0). Yogaraju *et al.*, (2019) opined that, the production of more number of primary branches per plant in T₄ could be due to higher metabolic activity because of optimum nitrogen supplied by Azospirillum and VAM fertilizers resulting in higher production of carbohydrates and hormones like NAA and cytokinins might have resulted in breaking of apical dominance and accelerated higher number of branches. Similar results were reported earlier in chillies by Medhe *et al.*, (2010), Deshpande *et al.*, (2010), Hiraguli and Allolli (2005).

Numbers of pods harvested from randomly tagged five plants were recorded by counting the number of fruits at harvest and average was worked out and expressed in numbers. Number of fruits per plant was found to be significantly influenced by nutrient management treatments. A significantly higher number of pods per plant was recorded in chili T₄ (189.7) and it was statistically similar with T₂ (178.5). Whereas, significantly lowest number of fruits was recorded in T₈ (119.3). Similar results of increase in chilli pods were reported earlier by Srijana Bharati *et al.*, (2023), Kapil Shamra and Atul Sharma (2024).

The well ripened fruits from the randomly selected five plants were harvested and dried, and kept in paper bag. Seeds were extracted by beating the fruits with pliable sticks. Then, the seeds were separated and the seeds were weighed and mean value was expressed in number. Among the treatments, T₄ recorded significantly highest number of seeds per pod (92.3), being on par with T₁ (83.7), whereas, significantly lowest number of seeds per pod was recorded in T₈ (50.3). Seed yield per plant was significantly highest in T₄ (88.7 g), being on par with all the treatments except T₈ (53.4 g).

Seed yield was calculated from randomly selected five plants. The well ripened fruits were harvested and dried, and kept in paper bag. Seeds were extracted by beating the fruits with pliable sticks. Then, the seeds were separated and sieved, and the seeds were weighed and expressed in grams per plant. Among the treatments, T₄ recorded significantly maximum seed yield per plant (88.7g/pl) being on par with T₂, (83.7g/pl), T₁ (73.3g/pl) and T₃ (71.4 g/pl).

Similar trend was observed with respect to yield per hectare. Pods harvested in each plot from all pickings were measured in kilograms. Yield per hectare was calculated and expressed in tones per hectare. Among the treatments, T₄ recorded significantly maximum yield (125.2q/ha) being on par with T₂ (118.3q/ha), T₁ (113.3q/ha) and T₃ (105.3q/ha). This might be due to better physiological condition of plant, thereby enhanced availability of nutrients. Yogaraju *et al.*, (2019) reported that, higher yield could be due to the more vegetative growth leading to increase in photosynthetic area, which in turn resulted in more synthesis and accumulation of dry matter in the fruit. Moreover, presence of growth promoting substances such as auxin, gibberellins and cytokinin due to presence of biofertilizers would have also contributed in development and accumulation of sink resulting in better growth and subsequently more number of fruits per plant and maximum fruit yield per hectare. These results are agreement with the results of Kondapanaidu *et al.*, (2009), Hiraguli and Allolli (2011) and Leelarani *et al.*, (2015). The low performance in T₈, which received biofertilizers alone, further indicates that biological inputs alone were insufficient to produce the maximum yield in chilli as it requires more amounts of NPK for growth and yield. The result supports the concept that microbial inoculants should generally be viewed as complementary components of integrated nutrient management rather than universal replacements for chemical fertilizers.

The data pertaining to germination %, Shoot length, root length, SVI-I and SVI-II was presented in Table-II. The germination test was conducted by using paper towel technique. Four replicates of 100 seeds each were



germinated in germination paper and kept in germination room and at the end of fourteenth day of sowing, the number of normal seedlings in each replication was counted and the germination was calculated and expressed in percentage. Germination %, ranged from 76.0 (T₈) to 88.0 (T₄). Among the treatments, T₄ recorded significantly maximum germination % (88.0%) being on par with T₂, (86. 7%), T₁ (83. 3%) and T₃ (82.0%).

Similar trend was observed with respect to Shoot length and root length. The shoot length was measured from the point of attachment of seed to tip of the leaf and the mean values were expressed in centimeter. Among the treatments, T₄ recorded significantly maximum Shoot length (3.7 cm) being on par with T₂, (3.5cm), T₁ (3.4cm) and T₃ (3.3cm). The seedlings used for measuring shoot length were also used for measuring root length. Root length was measured from the point of attachment of seed to the tip of primary root. The mean values were calculated and expressed in centimeter. Among the treatments, T₄ recorded significantly maximum root length (6.2 cm) being on par with T₂, (5.7cm), T₁ (5.5cm) and T₃ (5.4cm). Similar results of increase in root and shoot length due to INM was reported by Shivani *et al.*, 2026 and Kanchana *et al.*, (2014) in chilli plants. Ashrafuzzaman *et al.* (2009)., Kanchana *et al.*, (2014) attributed the enhanced root growth due to inoculation with biofertilizers might be due to IAA production, improved phosphate solubilization and increased nutrient uptake, which stimulated root elongation and development of a more extensive root system.

SVI-I and SVI-II showed significant differences between the treatments. Among the treatments, T₄ recorded significantly the highest SVI-I (874.3) being on par with T₂ (803.8) and T₁ (736.3) where as T₈ recorded the lowest SVI-I (548.9). Among the treatments, T₄ recorded significantly the highest SVI-II (115.9) being on par with T₂ (110.3) and T₁ (106.7) where as T₈ recorded the lowest SVI-II (75.3). The higher germination %, Shoot length, root length, SVI-I and SVI-II under T₄ indicate improved early seedling performance. Both SVI-I and SVI-II incorporates germination, seedling length and seedling dry weight the better performance under T₄ reflects the combined contribution of a higher germination percentage and maximum seedling growth. Higher germination percentage and greater seedling growth along with higher seedling dry weight in T₄ resulted in maximum SVI-I and SVI-II. Earlier studies indicated that, *Azospirillum* has been associated with enhanced root development and mineral nutrition through multiple plant–microbe interactions. PSB contribute to phosphorus mobilization, while potassium-solubilizing microorganisms may increase potassium availability in the rhizosphere. The inclusion of *T. viride* together with VAM and bacterial inoculants may have produced a broader biological effect than individual microbial components. Similar results of increase in chilli yield with biological nitrogen fixers duly reducing chemical fertilizers to 25 to 50% was reported by Talukder and Jana (2011), Yogaraju *et al.*, (2019) in chillies.

CONCLUSION

Among the treatments, Plant height was significantly maximum in T₄ (97.7cm) being on par with T₂ (95.6cm), T₃ (90.3cm) and T₁ (88.1cm). Number of branches was significantly maximum in T₄ (4.6) being on par with T₂ (3.9). Number of fruits were significantly maximum in T₄ (189.7) being on par with T₂ (187.5), T₁ (167.3), T₃ (162.7) and T₅ (164.5). With regard to number of seeds per pod T₄ recorded more number of seeds per pod (92.3) where as seed yield /pod was also significantly maximum in T₄ (88.7gm). Among the treatments T₄ (75% RDF +BF+TV+VAM) recorded maximum yield (125.2 q/ha/h) being on par with T₂ (118.3q/ha) and T₁ (113.3q/h). With regard to seed characters, among the treatments, T₄ recorded maximum germination % (88.0), shoot length (3.7cm), root length (6.2 cm) SVI-I (874.3) and SVI-II (115.9).

The present investigation concluded that application of *Azospirillum* + PSB + KSB+ *Trochoderma viride* + VAM + along with 75% RDF has more beneficial effects in terms of growth yield and seedling characters of chilli as compared to application of recommended dose of NPK fertilizers (RDF) under field condition.

Table: Effect of INM on growth, yield attributing characters and yield in chilli

Treatment Details	Plant height (cm)	No. of primary branches	No. of fruits	No. of seed/pod	Seed y/pl (gm)	Ripe yield (Q/h)
T1- RDF (120kgN+24kgP+48kgK per	88.1	3.7	167.3	83.7	73.3	113.3



acre)						
T2- 75% RDF + bio fertilizers (Azospirillum +PSB+K solubilizing bacteria each @ 2kg /acre) as basal application	95.6	3.9	178.5	75.9	83.7	118.3
T3-75%RDF + biocontrol agent Trochoderma viride @ 2kg/acre + Michorhiza (VAM @ 5kg/acre) as basal application	90.3	3.6	162.7	64.8	71.4	105.3
T4-75%RDF + biofertilizers (Azosporillum + PSB+ K solubilizing bacteria each @2kg/acre) + biocontrol agent Trichoderma Viride @ 2kg/acre + Michorhiza (VAM @ 5kg/acre) as basal application	97.7	4.6	189.7	92.3	88.7	125.2
T5- 50% RDF+ Azospirillum +PSB + K solubilizing bacteria each @ 2kg /acre) as basal application	84.1	3.6	164.5	81.8	76.1	97.3
T6- 50%RDF+ biocontrol agent Trochoderma viride @ 2kg/acre + Michorhiza (VAM @ 5kg/acre) as basal application	83.7	3.8	152.8	74.9	72.2	91.9
T7-50% NPK + biofertilizers (Azosporillum + PSB + K-solubilizing bacteria each @2kg/acre) + biocontrol agent Trichoderma Viride @ 2kg/acre + Michorhiza (VAM @ 5kg/acre)	85.7	3.8	167.7	82.2	80	101.4
T8- Application of biofertilizer alone	74.2	3	119.3	50.3	53.4	42.2
CD	11.4	0.7	18.5	16.1	18.5	26.8
CV	7.4	10.8	14.2	12.2	14.2	15.4

Table: Effect of INM on Germination %, shoot length, root length, SVI-I and SVI-II in chilli

Treatment Details	Germination %	Shoot length(cm)	Root length (cm)	SVI-I	SVI-II
T1- RDF (120kgN+24kgP+48kgK per acre)	83.3 (65.3)	3.4	5.5	736.3	106.7
T2- 75% RDF + bio fertilizers (Azospirillum +PSB+K solubilizing bacteria each @ 2kg /acre) as basal application	86.7 (68.0)	3.5	5.7	803.8	110.3
T3-75%RDF + biocontrol agent Trochoderma viride @ 2kg/acre + Michorhiza (VAM @ 5kg/acre) as basal application	82.0 (64.9)	3.3	5.4	711.4	104.9
T4-75%RDF + biofertilizers (Azosporillum + PSB+ K solubilizing bacteria each @2kg/acre) + biocontrol agent Trichoderma Viride @ 2kg/acre + Michorhiza (VAM @ 5kg/acre) as basal application	88.0 (69.8)	3.7	6.2	874.3	115.9
T5- 50% RDF+ Azospirillum +PSB + K solubilizing bacteria each @ 2kg /acre) as	78.0 (62.0)	3.1	5.2	642.5	91.9



basal application					
T6- 50%RDF+ biocontrol agent Trochoderma viride @ 2kg/acre + Michorhiza (VAM @ 5kg/acre) as basal application	75.3 (60.2)	2.9	4.9	591.8	84.1
T7-50% NPK + biofertilizers (Azosporillum +PSB +K solubilizing bacteria each @2kg/acre) + biocontrol agent Trichoderma Viride @ 2kg/acre + Michorhiza (VAM @ 5kg/acre)	79.3 (63.0)	3.2	5.3	673.6	96
T8-Control (Application of biofertilizer alone)	76.0 (60.7)	2.7	4.5	548.9	75.3
CD	2.9	0.4	0.9	77.6	12.3
CV	2.6	6.7	9.5	6.4	7.2

(Note: Parenthetical values indicate arc-sine angular transformations for percentage data evaluation)

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