ROLE OF VESICULAR-ARBUSCULAR MYCORRHIZAL FUNGI ON RICE CROP WITH DIFFERENT DOSE OF FERTILIZER TO SAVE SUSTAINABILITY

ABSTRACT

The word "sustainability" has recently come to find itself pushed forward into the limelight and attached as a modifier to nouns with which it formerly had no more than a nodding acquaintance. "Sustainable development," for example, has been with us for some time, but more recent pairings are now commonplace: sustainable agriculture, sustainable design, sustainable energy, sustainable tourism, and sustainable living, to name a few. Remind of view sustainability my research works carried out to solve this problem to save sustainable development. An experiment was conducted during rainy (Kharif) season 2015, to find out the effect of fungal isolates with different dose of fertilizer on growth yield attributes of rice. The experiment comprises three replication and seven treatment combinations. The rice variety–PB1509 was transplanted with pot experiment. The results showed that application of T_1 (N_0 P_0 K_0) (control), T_2 (N P K), T_3 ($N_{3/4}$ $P_{3/4}$ K), T_4 ($N_{1/2}$ $P_{1/2}$ K), T_5 ($N_{1/2}$ $P_{1/2}$ K + VAMV-SI/4), T_6 (N½ P½ K + VAMV-SII/5) and T_7 (N½ P½ K+ VAM-SIII/3) gave significantly yield attributes were also higher in this treatment (T_5) over control and other treatments.

Keywords: Sustainability; basmati-rice; growth; yield; vesicular-arbuscular mycorrhiza; kharif.

INTRODUCTION

The word mycorrhizae is derived from two Greek words, mycos and rhizos, meaning fungus and root, respectively. Mycorrhizal association forms a very dynamic and beneficial relationship that exists between arbuscular mycorrhizal fungi (AMF) and roots of higher plants (vascular plants). More than 80% of terrestrial plants form association with mycorrhizal fungus except some

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Commented [D2]: Mention updated references plants belonging to non-mycorrhizal families like Amaranthaceae, Brassicaceae, Caryophyllaceae, Chenopodiaceae, Polygonaceae, and Urticaceae [1,2]. In addition, AMF play a vital role in wide range of functions from stress reduction to bioremediation in soils polluted with heavy metals [3]. They are also involved in diverse functions such as soil health improvement, plant health improvement, and protection of plants against pathogen. In this situation, we must go for a combined use of both organic and inorganic fertilizers in judicious combination based on soil nutrient status to improve and sustain the soil fertility and productivity which is called as integrated nutrient management (INM). One of the major components in INM practices is the use of bio-fertilizers which are prepared from many beneficial microbial inoculants ([4,5,6,7], Kumar et al. 2015, 2016b; Ahmad et al. 2016).

MATERIALS AND METHODS

VAM from water samples and cultured from soil samples were examined microscopically for identification on the basis of morphological characters. Identification was done after Desikachary, 1959. Separate algal spectrum was prepared for soil samples and water samples collected at 35th and 75th day of transplantation. On the basis these data a common algal spectrum was prepared, finally. The pot experiments with rice were kept with soil. Uniform dose of N, P_2O_5, K_2O @ 120:60:40 were applied in pot experiment. Pot experiment conducted during kharif 2015. Ten kilogram soil was mixed thoroughly with required quantity of amendments (as per treatment) and filled in each earthen pot. There after water was applied to pot to saturation. The treated pots were left for 15 days. After that half dose nitrogen (60 kg ha^{-1}) through urea (0.58g pot^{-1}) was applied at the time of transplantation of rice seedlings. Remaining half amount of nitrogen was applied in two equal instalments after 20 days and 45 days after transplanting (DAT), i.e., tillering and panicle initiation stage respectively. Total amount of P_2O_5 and K_2O was applied as basal application through tricalcium phosphate (0.54g pot^{-1}) and muriate of potash (0.29g pot^{-1}), respectively. Thirty five days old seedlings of rice variety Pusa Basmati PB 1509 were transplanted @ three seedlings per hill and in total three hills were planted in each pot. Care was taken about the need for irrigation and weeding throughout the experimental period.

RESULTS AND DISCUSSION

The data regarding the effect of use of different VAM fungi isolates with recommended fertilizer dose on Tillers, Effective tillers, Plant height, Panicle length, Grain yield, Straw yield and Test weight are given in this chapter and discussed under following heads.[8]

Tillers

Number of tillers per pot presented in Table 1 revealed that affected by fertilizer dose and different isolates of VAM fungi was increased significantly and varies from 25.3 tillers per pot in absolute control to 36.9 tillers per pot in the treatment T_5 ($N_{½}$ $P_{½}$ K + VAM-SI/4) which received half dose of N, P and full dose of K with VAM isolates VAM-SI/4. Further the increase in N and P fertilizer dose from 50% to 75% and 100% increased the total number of tillers per pot significantly over absolute control. Full dose of fertilizer cause 14.19% increase in number of tillers over the absolute control. VAM fungi isolates tested at 50% N and P showed significant increase in number of tillers. The highest increase in number of tillers (21.78%) was recorded with VAM-SI/4 increase in number of tillers over control (without isolate).

Table 1. Effect of VAM fungi on tiller growth of rice

Treatment	Tillers/pot
T_1($N_0P_0K_0$) (control)	25.3
T_2 (N P K)	35.6
T_3 ($N_{¾}$ $P_{¾}$ K)	33.3
T_4 ($N_{½}$ $P_{½}$ K)	32
T_5 ($N_{½}$ $P_{½}$ K + VAM-SI/4)	36.9
T_6 ($N_{½}$ $P_{½}$ K + VAM-SII/5)	35.3
T_7 ($N_{½}$ $P_{½}$ K+ VAM-SIII/3)	35.6
CD (P=0.05)	1.48
CV	4.23

Effective Tillers/Pot

Number of effective tillers per pot presented in Table 2 revealed that affected by fertilizer dose and different isolates of VAM fungi was increased

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significantly and varies from 20 effective tiller per pot in absolute control to 32.0 tiller per pot in the treatment T_2 (N P K) with full dose of fertilizer and T_5 ($N_{½}$ $P_{½}$ K + VAM-SI/4) which received half dose of N P and full does of K and N P and full dose of K with fungal isolates VAM-SI/4 . Further the increase in N and P fertilizer dose from 50% to 75% and 100% increased the total number of effective tillers per pot significantly over absolute control. Full does of fertilizer caused 26.08% increase in number of effective tillers over the absolute control. Fungal isolates tested at 50% N, P and full dose of K showed significant increase in number of effective tillers. The highest increase in number of effective tillers (21.67%) was recorded with VAM-SI/4 increase in number of effective tillers over without isolate.

Table 2. Effect of VAM fungi on effective tiller growth of rice.

Treatment	Effective tillers/pot
T_1($N_0P_0K_0$) (control)	20.3
T_2 (N P K)	31.9
T_3 ($N_{¾}$ $P_{¾}$ K)	27.3
T_4 ($N_{½}$ $P_{½}$ K)	26.3
T_5 ($N_{½}$ $P_{½}$ K + VAM-SI/4)	31.9
T_6 ($N_{½}$ $P_{½}$ K + VAM-SII/5)	30.6
T_7 ($N_{½}$ $P_{½}$ K+ VAM-SIII/3)	30
CD (P=0.05)	1.17
CV	3.94

Plant Height

Plant height presented in Table 3 revealed that affected by fertilizer dose and different isolates of VAM fungi was increased significantly and varies from 80.3 cm plant height in absolute control to 102.6 cm in the treatment T_7 ($N_{½}$ $P_{½}$ K + VAM-SIII/3) which received half dose of N, P and full does of K with fungal isolates VAM-SIII/3. Further the increase in N and P fertilizer dose from 50% to 75% and 100% increased the plant height significantly over absolute control. Full dose of fertilizer caused 24.53% increase in plant height over the absolute control. Fungal isolates tested at 50% N, P and full dose of K increased significantly in plant height with all isolates. The highest increase in plant height (58.08%) was recorded with isolates VAM-SIII/3 increase in plant height over without isolate.

Table 3. Effect of VAM fungi on plant height of rice

Treatment	Plant height (cm)
T_1($N_0P_0K_0$) (control)	80.3
T_2 (N P K)	100
T_3 ($N_{¾}$ $P_{¾}$ K)	66.3
T_4 ($N_{½}$ $P_{½}$ K)	64.9
T_5 ($N_{½}$ $P_{½}$ K + VAM-SI/4)	100.9
T_6 ($N_{½}$ $P_{½}$ K + VAM-SII/5)	101.3
T_7 ($N_{½}$ $P_{½}$ K+ VAM-SIII/3)	102.6
CD (P=0.05)	4.11
CV	4.44

Panicle Length

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Panicle length presented in Table 4 revealed that affected by different fertilizer dose with isolates of VAM fungi was increased significantly and varies from 13.6 cm in absolute control to 17.6 cm in the treatment T_5 ($N_{½}$ $P_{½}$ K + VAM-SI/4) which received half dose of N, P and full dose of K with fungal inoculant VAM-SI/4. Further the increase in N and P fertilizer dose from 50% to 75% and 100% increased the panicle length significantly over absolute control. Full dose of fertilizer caused 24.28% increase in panicle length over the absolute control. Fungal isolates tested at 50% N, P and 100% of K increased significantly in panicle length. The highest increase in panicle length (23.07%) was recorded with inoculant VAM-SI/1 increase panicle length over without isolate.

Table 4. Effect of VAM fungi on panicle length of rice

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Treatment	Panicle Length (cm)
T_1($N_0P_0K_0$) (control)	13.6
T_2 (N P K)	16.9
T_3 ($N_{¾}$ $P_{¾}$ K)	17.3
T_4 ($N_{½}$ $P_{½}$ K)	14.3
T_5 ($N_{½}$ $P_{½}$ K + VAM-SI/4)	17.6
T_6 ($N_{½}$ $P_{½}$ K + VAM-SII/5)	17.3
T_7 ($N_{½}$ $P_{½}$ K+ VAM-SIII/3)	17.4
CD (P=0.05)	0.96
CV	5.56

Grain Yield

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Grain yield presented in Table 5 revealed that affected by fertilizer dose and different isolates of VAM fungi was increased significantly and varies from 9.6 g/pot in absolute control to 15.6 g/ pot in the treatment T_5 ($N_{½}$ $P_{½}$ K + VAM-SI/4) which received half does of N, P and full dose of K with fungal isolate VAM-SI/4. Further the increase in N and P fertilizer dose from 50% to 75% and 100% increased the grain yield per pot significantly over absolute control. Full dose of fertilizer caused 41.66% increase in grain yield over the absolute control. Fungal isolates tested at 50% N, P and 100% of K increased significantly in grain yield. The highest increase grain yield (20.0%) increase in grain yield over without isolate.

Table 5. Effect of VAM fungi on grain yield of rice

Treatment	Grain yield
T_1($N_0P_0K_0$) (control)	9.6
T_2 (N P K)	13.6
T_3 ($N_{¾}$ $P_{¾}$ K)	13.3
T_4 ($N_{½}$ $P_{½}$ K)	13
T_5 ($N_{½}$ $P_{½}$ K + VAM-SI/4)	15.6
T_6 ($N_{½}$ $P_{½}$ K + VAM-SII/5)	14
T_7 ($N_{½}$ $P_{½}$ K+ VAM-SIII/3)	14.6
CD (P=0.05)	0.83
CV	5.91

Straw Yield

Straw yield per pot presented in Table 6 revealed that affected by fertilizer dose and different isolates of VAM fungi was increased significantly and varies from 21.3 g/pot in absolute control to 26.8 g/pot in the treatment T_7 ($N_{½}$ $P_{½}$ K + VAM-SIII/3) which received half dose of N, P and full dose of K with fungal inoculant VAM-SIII/3. Further the increase in N and P fertilizer dose from 50% to 75% and 100% increased the straw yield per pot significantly over absolute control. Full dose of fertilizer caused 10.79% increase in straw yield over the absolute control. Fungal isolates tested at 50% N, P and 100% of K increased significantly in straw yield. The highest increase in straw yield (17.03%) was recorded with VAM-SIII/3 increase in straw yield over without isolate.

Test Weight

Test weight per pot presented in Table 7 revealed that affected by fertilizer dose and different isolates of VAM fungi was increased significantly and varies from 13.6 g in absolute control to 16.4 g in the treatment T_7 ($N_{½}$ $P_{½}$ K + VAM-SIII/3) which received half dose of N, P and full dose of K with fungal isolates VAM-III/3. Further the increase in N and P fertilizer dose from 50% to 75% and 100% increased the test weight significantly over absolute control. Full dose of fertilizer caused 7.35% increase in test weight over the absolute control. Fungal isolates tested at 50% N, P and 100% of K increased significantly in test weight. The highest increase in test weight (20.58%) was recorded with inoculant VAM-SIII/3) increases in test weight over without isolate.

Table 6. Effect of VAM fungi on straw yield of rice

Treatment	Straw yield
T_1($N_0P_0K_0$) (control)	21.3
T_2 (N P K)	23.6
T_3 ($N_{¾}$ $P_{¾}$ K)	23.9
T_4 ($N_{½}$ $P_{½}$ K)	22.9
T_5 ($N_{½}$ $P_{½}$ K + VAM-SI/4)	25.6
T_6 ($N_{½}$ $P_{½}$ K + VAM-SII/5)	23
T_7 ($N_{½}$ $P_{½}$ K+ VAM-SIII/3)	26.8
CD (P=0.05)	1.03
CV	4.11

Table 7. Effect of VAM fungi on test weight of rice

Treatment	Test weight
T_1($N_0P_0K_0$) (control)	13.6
T_2 (N P K)	14.9
T_3 ($N_{¾}$ $P_{¾}$ K)	14
T_4 ($N_{½}$ $P_{½}$ K)	13.6
T_5 ($N_{½}$ $P_{½}$ K + VAM-SI/4)	16.2
T_6 ($N_{½}$ $P_{½}$ K + VAM-SII/5)	16
T_7 ($N_{½}$ $P_{½}$ K+ VAM-SIII/3)	16.4
CD (P=0.05)	0.73
CV	4.70

Effect of VAM on Nutrient Content in Grain and Straw of Rice

Nitrogen content (per cent) in grain and straw

Nitrogen content in rice grain and straw presented in Table 8 revealed a great impact of fertilizer dose and fungal inoculants. They increased significantly the nitrogen content in grain as well as straw. Due to different treatment nitrogen content varies from 1.01 to 1.14 and 0.45 to 0.52 per cent in grain and straw respectively. Increasing dose of fertilizers tended to increase nitrogen content in grain and straw. The treatment having full dose of nitrogen and phosphorous

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found to be significantly superior over half dose of fertilizer.

Table 8. Nitrogen content (per cent) in grain and straw

Treatment	Nitrog n (%)	
	Grain	Straw
T_1($N_0P_0K_0$) (control)	1.01	0.45
T_2 (N P K)	1.19	0.52
T_3 ($N_{¾}$ $P_{¾}$ K)	1.16	0.48
T_4 ($N_{½}$ $P_{½}$ K)	1.12	0.45
T_5 ($N_{½}$ $P_{½}$ K + VAM-SI/4)	1.14	0.46
T_6 ($N_{½}$ $P_{½}$ K + VAM-SII/5)	1.14	0.47
T_7 ($N_{½}$ $P_{½}$ K+ VAM-SIII/3)	1.14	0.46
CD (P=0.05)	0.09	0.04
CV	8.10	8.39

Phosphorous content (per cent) in grain and straw

Phosphorous content in rice grain and straw presented in Table 9 revealed a great impact of fertilizer dose and fungal inoculants. They significantly influenced the phosphorous content in grain as well as straw. Due to different treatments on phosphorous content varies from 0.27 to 0.35 and 0.11 to 0.14 per cent in grain and straw respectively. Increase dose of fertilizers from 0 to 1/2, 1/2 to 3/4th and 3/4th to full dose of fertilizer tended to increase the phosphorous content in grain and straw. The treatment having full dose of nitrogen and phosphorous found to be significantly superior over half, 3/4th dose of fertilizer and control. The increase in grain and straw may be due to the fact that the experimental soil was deficient in phosphorous content hence showed better response of applied phosphorous. Application of half dose of N, P and full dose of K and inoculation of selected VAM isolates showed higher phosphorous content in grain and straw than the treatment having half dose of N, P and full dose of K alone.

***Potassium* content (per cent) in grain and straw**

Potassium content (per cent) of rice grain and straw presented in Table 10 clearly indicates that the effect of different fertilizer dose and inoculation of selected VAM isolates at 1/2 doses of N and P was insignificant and they varies from 0.26 to 0.35 and 1.38 to 1.42 in control and full dose of NPK fertilizer respectively.

Table 9. Phosphorous content (per cent) in grain and straw

Treatment	Phosphorous (%)	
	Grain	Straw
T_1($N_0P_0K_0$) (control)	0.27	0.11
T_2 (N P K)	0.35	0.14
T_3 ($N_{¾}$ $P_{¾}$ K)	0.33	0.13
T_4 ($N_{½}$ $P_{½}$ K)	0.29	0.11
T_5 ($N_{½}$ $P_{½}$ K + VAM-SI/4)	0.3	0.12
T_6 ($N_{½}$ $P_{½}$ K + VAM-SII/5)	0.3	0.12
T_7 ($N_{½}$ $P_{½}$ K+ VAM-SIII/3)	0.31	0.12
CD (P=0.05)	0.02	0.01
CV	6.47	11.22

Table 10. Potassium content (per cent) in grain and straw

Treatment	Potassium (%)	
	Grain	Straw
T_1($N_0P_0K_0$) (control)	0.26	1.38
T_2 (N P K)	0.35	1.42
T_3 ($N_{¾}$ $P_{¾}$ K)	0.32	1.41
T_4 ($N_{½}$ $P_{½}$ K)	0.3	1.4
T_5 ($N_{½}$ $P_{½}$ K + VAM-SI/4)	0.32	1.41
T_6 ($N_{½}$ $P_{½}$ K + VAM-SII/5)	0.31	1.41
T_7 ($N_{½}$ $P_{½}$ K+ VAM-SIII/3)	0.32	1.41
CD (P=0.05)	NS	NS
CV		

Effect of VAM on Nitrogen, Phosphorus and Potassium (mg pot^{-1}) Uptake in Grain and Straw

Uptake of nitrogen

Nitrogen uptake (mg/pot) by grain, straw and total presented in Table 11 revealed that fungal inoculant of VAM significantly increased grain, straw and total uptake of nitrogen. Nitrogen uptake in grain varies from 0.108 mg/pot in control to 0.178 mg/pot in treatment (T_5) with VAM-SI/4 inoculant. Increasing dose of fertilizer has significantly increased the uptake of N in grain.

The effect of different fertilizer dose and VAM inoculant on nitrogen uptake by straw was significant and they vary from 0.096 mg/pot in control to 0.123 mg/pot in full dose of fertilizer as well as T_7 ($N_{½}$ $P_{½}$ K+VAM-SIII/3).

Total uptake of nitrogen by different dose of fertilizers and fungal inoculants was significant and they vary from 0.203 mg/pot in control to

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0.295 mg/pot in VAM treatment T_5 ($N_{½}$ $P_{½}$ K + VAM-SI/4) with inoculant VAM-SI/4. The increasing dose of fertilizers significantly increased the total N uptake by 3/4th and full dose of fertilizer over control.

Uptake of phosphorous

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Phosphorous uptake (mg/pot) by grain, straw and total presented in Table 12, revealed that fungal inoculant of VAM significantly increased the uptake in grain, straw and total uptake. Phosphorous uptake in grain varies from 0.026 mg/pot in control to 0.047 mg/pot in full dose of fertilizer. Increasing dose of fertilizer has significantly increased the uptake of P in grain. The effect of VAM treatment in increasing P uptake by grain was much more and significant as compared to without inoculant. The highest P uptake by grain was recorded 0.047 mg/pot in VAM treatment (T_5) ($N_{½}$ $P_{½}$ K + VAM-SI/4) with inoculant VAM-SI/4.

The effect of different fertilizer dose with VAM inoculant on Phosphorous uptake by straw was significant and they varies from 0.024 mg/pot in control to 0.033 mg/pot in full dose of fertilizer. Increasing dose of fertilizer has significantly increased the uptake of P in straw. The effect of VAM treatment increasing P uptake by straw was much more and significant as compared to without inoculant.

Table 11. Nitrogen uptake (mg pot^{-1}) in grain and straw

Treatment	Nitrogen		
	Grain	Straw	Total
T_1($N_0P_0K_0$) (control)	0.108	0.096	0.203
T_2 (N P K)	0.163	0.123	0.286
T_3 ($N_{¾}$ $P_{¾}$ K)	0.156	0.115	0.271
T_4 ($N_{½}$ $P_{½}$ K)	0.147	0.103	0.250
T_5 ($N_{½}$ $P_{½}$ K + VAM-SI/4)	0.178	0.118	0.295
T_6 ($N_{½}$ $P_{½}$ K + VAM-SII/5)	0.160	0.108	0.268
T_7 ($N_{½}$ $P_{½}$ K+ VAM-SIII/3)	0.166	0.123	0.290
CD (P=0.05)	0.03	0.01	0.03
CV	18.70	9.60	10.85

Table 12. Phosphorous uptake (mg pot^{-1}) in grain and straw

Treatment	Phosphorous		
	Grain	Straw	Total
T_1($N_0P_0K_0$) (control)	0.026	0.024	0.049
T_2 (N P K)	0.047	0.033	0.081
T_3 ($N_{¾}$ $P_{¾}$ K)	0.044	0.031	0.075
T_4 ($N_{½}$ $P_{½}$ K)	0.038	0.025	0.063
T_5 ($N_{½}$ $P_{½}$ K + VAM-SI/4)	0.047	0.030	0.078
T_6 ($N_{½}$ $P_{½}$ K + VAM-SII/5)	0.042	0.028	0.070
T_7 ($N_{½}$ $P_{½}$ K+ VAM-SIII/3)	0.045	0.032	0.077
CD (P=0.05)	0.006	0.004	0.007
CV	14.337	14.085	9.804

Table 13. Potassium uptake (mg pot^{-1}) in grain and straw

Treatment	Potassium		
	Grain	Straw	Total
T_1($N_0P_0K_0$) (control)	0.025	0.294	0.319
T_2 (N P K)	0.048	0.335	0.383
T_3 ($N_{¾}$ $P_{¾}$ K)	0.043	0.337	0.379
T_4 ($N_{½}$ $P_{½}$ K)	0.039	0.321	0.360
T_5 ($N_{½}$ $P_{½}$ K + VAM-SI/4)	0.050	0.361	0.411
T_6 ($N_{½}$ $P_{½}$ K + VAM-SII/5)	0.044	0.325	0.368
T_7 ($N_{½}$ $P_{½}$ K+ VAM-SIII/3)	0.047	0.378	0.425
CD (P=0.05)	0.005	0.020	0.024
CV	12.836	5.713	6.098

Total uptake of Phosphorous by different dose of fertilizers and fungal inoculant was significant and they vary from 0.049 mg/pot in control to 0.081 mg/pot in full dose of fertilizer.

Uptake of potassium

Potassium uptake (mg/pot) by grain, straw and total presented in Table 13, revealed that microbial inoculant of VAM significantly increased the uptake in grain, straw, and total uptake. Potassium uptake in grain varies 0.319 mg/pot in control to 0.025 mg/pot VAM treatment T_5 ($N_{½}$ $P_{½}$ K + VAM-SI/4) with inoculant VAM-SI/4. Increasing dose of fertilizer has significantly increased the uptake of potassium in grain.

The effect of different fertilizer dose with VAM inoculant on Potassium uptake by straw was significant and they vary from 0.294 mg/pot in control to 0.378 mg/pot in VAM treatment T_7 ($N_{½}$ $P_{½}$ K + VAM-SIII/3) with inoculant VAM-SIII/3. Increasing dose of fertilizer has significantly increased the uptake of potassium in straw. The effect of VAM treatment in increasing potassium uptake by straw was much more and significant as compare to without VAM inoculant.

Total uptake of potassium by different dose of fertilizers and fungal inoculants was significant and they vary from 0.425 mg/pot in control to 0.503 mg/pot in VAM treatment T_7($N_{½}$ $P_{½}$ K + VAM-SIII/3) with inoculants VAM-SIII/3. The increasing dose of fertilizers has significantly increased the total potassium uptake by $3/4^{th}$ and full dose of fertilizer over control.

CONCLUSION

Vesicular arbuscular mycorrhizal fungi" increase the physiologically activity root system of plants and help in uptake of N, P, K nutrients and water. They have efficient enzyme system which breaks down complex organic substances into similar forms which are then absorbed by root system of VAM- infected plants. Conclusively our findings suggested that the use of VAM may be a boon for the farmers which are destined to grow cereal.

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