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Studies on influence of biofertilizers and NPK on nutrient uptake and production economics of carrot

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Abstract
The investigation was carried at Horticultural Research Station, Dr. Y. S. R. Horticultural University, Andhra Pradesh during *Rabi* 2017-18 to study the effect of different levels of biofertilizers and NPK on nutrient uptake and production economics of carrot. Two factors were taken, the first factor being the chemical fertilizers at three levels (100%, 75%, 50% of RDF) and the second factor was the different combinations of five biofertilizers (PSB, KSB, *Azospirillum*, *Azotobacter*, VAM). Factorial RBD with 12 treatment combinations was adopted. The results revealed that, treatment with chemical fertilizers at level 100% RDF (75:60:50 kg/ha) recorded the highest uptake of nitrogen (121.71 kg/ha), phosphorous (14.06 kg/ha) and potassium (223.56 kg/ha) by the plant. Treatment with biofertilizers PSB+ KSB+ *Azospirillum*+ *Azotobacter*+ VAM recorded highest uptake of nitrogen (120.64 kg/ha), potassium (226.74 kg/ha) uptake and plants applied with PSB+ KSB+VAM recorded the highest phosphorous uptake (14.17 kg/ha). The combined application of 100% RDF+PSB+ KSB+ *Azospirillum*+ *Azotobacter*+ VAM recorded highest nitrogen (133.21 kg/ha), potassium (239.28 kg/ha) uptake and highest phosphorous uptake (15.35 kg/ha) with the application of 50% RDF +PSB+ KSB+VAM. Economics plays a crucial role in deciding the adoption of any treatment, the highest cost to benefit ratio of 3.04 was obtained with the application of 100% RDF+ PSB+ KSB+ *Azospirillum*+ *Azotobacter*+ VAM followed by the treatment of 100% RDF+ PSB+ KSB+ *Azotobacter* with 2.87.

Keywords: Carrot, biofertilizers, economics, inorganics

Introduction
It is very important to check the soil nutrients status as well as the plant’s nutrients status to know the effect of the nutrients supplied to the crop. Any treatment that is economically viable and that produces higher yields is the one that can be considered to be recommended to farmers. The inputs provided and the relevant outputs obtained form the basis of production economics. A brief yet a clear picture of the nutrient status and the production economics would help us to know the practically viable treatment combination that can be recommended for commercial adoption. The application of chemical fertilizers aid in running a better internal physiological processes that intern improve the yields on one hand and on the other hand the biofertilizers can be considered as one of the best alternatives for eco friendly, effective crop yields.

The potential growth of any crop is best expressed with the adequate nutrient availability. Among various nutrients, the macronutrients namely N, P, K are the most essential. Each of these macronutrients have a specific function as of the nitrogen plays a key role in the overall vegetative growth of the plant, phosphorous is essential for the energy storage and bonding and the potassium acts as a regulator, carrier of various elements and helps for quality regulation in the yields. Fertilizers are the exogenously applied sources of nutrition, which are to be given extra importance, as they are the ones that help plants at their different stages of growth and act as a supplementing source of energy. The different doses of fertilisers play an appropriately proportionate role in the development of the crop.

The biofertilizers are the best alternate option for a sustainable agriculture. A biofertilizer is referred as a substance that contains the biological means (living organisms) that synthesises the atmospheric plant nutrient in the soil or in the plant body and yield economically interesting results in an eco friendly manner (Youssef and Eissa, 2014) [12].

The majorly utilised biofertilizers being, the *Azotobacter spp.* that helps in nutrient uptake, seed germination and root growth thereby improves the plant growth criteria (Gahukar, 2006) [2]. The *Azospirillum spp.* are associative symbiotic bacteria that occur in the roots of the plants and produce growth promoters (IAA, gibberellins, cytokinins) and enhance root development of plant nutrients. The VAM fungus enhances the absorption of nutrients especially phosphorous and water from the substrate by the attached network of external hyphae (Schubert, 1990) [10].

Some bacterial species are also capable of mobilizing the P and K into a usable form to the plants, which are known as P solubilizing bacteria and K solubilizing bacteria. They can be applied to all the crops in association with other biofertilizers without any antagonistic effect. There has been a positive response observed in a wide range of field trials (Ghosh, 2004) [3].

The biofertilizers are effective in increasing the potential of soil over a long span of time and hence, a viable combination of chemical fertilisers with that of the biofertilizers would yield effective and efficient results, from the initial stages of application of these nutrient sources. The nutrient status analysis would act as a clear verdict for knowing the efficiency of the nutrients applied.

The increasing costs of chemical fertilizers, which are needed by the high yielding varieties (HYV's) are adding to the cost of cultivation in Indian agriculture (Panwar and Singh, 2000) [8]. Therefore, the work aims to study the effect of mineral and biofertilizers supplementation on nutrient content of the crop and knowing the economically best treatment. Hence, the work was proposed with the following objectives of;

1. To find out the effect of biofertilizers in combination with different levels of NPK on the nutrient uptake by the plant and residual soil nutrient.
2. To work out the economics of carrot production with the combined application of biofertilizers and different levels of NPK.

Material and Methods

Field experiment was conducted at Horticultural Research Station, Pandirimamidi that comes under high altitude tribal zone of Andhra Pradesh, India which is situated at an altitude of 250 m above mean sea level with 17°25' East latitude and 81°45' North longitudes. The experimental site received an annual rainfall of 1186 mm. The pH of irrigation water was recorded as 6.0 and EC was 1.66dSm^{-1}. The land used under the experiment was fairly uniform with pH of 6.5. The experiment consisted of twelve treatment combinations with three levels of inorganics [100% RDF (F_1)-75:60:50 kg/ha; 75% RDF (F_2)- 56:45:37.5 kg/ha and 50% RDF (F_3)- 37.5:30:25 kg/ha] and four levels of biofertilizers [PSB+ KSB+ *Azospirillum* (B_1), PSB+ KSB+ *Azotobacter* (B_2), PSB+ KSB+ Vesicular Arbuscular Michorrhiza (B_3), PSB+ KSB+ *Azospirillum*+ *Azotobacter*+ VAM (B_4)]. The factorial randomized block design was adopted with three replications. The experimental field was thoroughly ploughed to a depth of 30 cm and harrowed twice.

The field was laid at a gross plot size of 2.2 m X 1.8 m and net plot size of 2 m X 1.5 m. The biofertilizers [PSB, KSB, *Azospirillum, Azotobacter,* VAM] were applied to soil, by adding them to well decomposed FYM as per different treatments at the rate of 5 kg/ ha. The field was irrigated and let for the beneficial microorganisms to grow. Carrot seed cv. Pusa Rudhira was sown in ridge and furrow system at a depth of 1 cm. Standard cultural and management practices were adopted. Observations were recorded at initial and after the experiment on soil nitrogen, phosphorous and potassium contents along with the uptake of the nutrients (NPK) by the plant and were expressed in kg/ha. The data collected was subjected to analysis of variance (ANOVA). The test of significance (t-test) and critical difference was calculated at 0.05% probability. The cost of each input was calculated as per the market cost (at the time of experiment) and the total cost, gross income, net income and benefit to cost ratio was calculated.

Results and Discussion

The nitrogen uptake by the plants was found to be significantly highest with the application of chemical fertilizers at level of 100% RDF (F_1) which recorded 121.71 kg/ha and with level PSB + KSB + *Azospirillum* + *Azotobacter* + VAM (B_4) of biofertilizers (120.64 kg/ha). The interaction between chemical and biofertilizers revealed that the combination of 100% RDF + PSB + KSB + *Azospirillum* + *Azotobacter* + VAM (F_1B_4) recorded the highest nitrogen uptake (133.21 kg/ha) followed by treatment combination of 100% RDF+ PSB+ KSB+ *Azotobacter* (F_1B_2) with 128.99 kg/ha while, the combination of 50% RDF +PSB+ KSB+ *Azospirillum* (F_3B_1) recorded the lowest values of nitrogen uptake (94.56 kg/ha).

Higher concentrations of chemical fertilizers (nitrogen) readily supply the nutrients to the plants and hence, improve the nitrogen uptake. Bohec and Rey (1990) [1] also reported that the total N content of the root at harvest increased linearly with the increasing rate of application of the chemical N fertilizers. The increase in nitrogen uptake by plant might be with the application of *Azospirillum*, *Azotobacter*, which are capable of fixing nitrogen and making it available to the crop throughout the crop period. The nitrogen uptake would increase due to expanded root surface area that aided in more acquisition of nitrogen. The obtained results are in conformity with Lovato *et al*. (1994) [5] in radish.

The phosphorous uptake by the plant was significant only at different levels of chemical fertilizers and recorded maximum (14.06 kg/ha) with 100% RDF (F_1) followed by 75% RDF (F_2) with 12.90 kg/ha. The application of 50% RDF (F_3) recorded the lowest phosphorous uptake (11.27 kg/ha). Whereas, the different levels of biofertilizers (Table 1) and combination of chemical and biofertilizers at various levels were found to be non significant (Table 2) for phosphorous uptake. However, higher phosphorous uptake was recorded with the combination of 50% RDF+ PSB+ KSB+ VAM (F_3B_3) as 15.35 kg/ha.

Phosphorous majorly faces the problem of fixation in the soil and hence gets rendered for the uptake by the plants. As, the chemical fertilizers are quick in action as compared to the biofertilizers hence, the plants show proportionate results in short span and might have recorded the higher phosphorous uptake by the plants. The above obtained results are in agreement with Rodriguez and Fraga (1999) [9] and Mcpharlin *et al.* (2012) [6] in carrot.

The potassium uptake by the plant was found to be non-significant with respect to different levels of chemical fertilizers, biofertilizers and also their combinations (Table 1 and 2). This can be attributed to the fact that, all the treatments in the experiment were applied with the equal rate of KSB and also the soils under which the experiment was conducted (HRS, Pandirimamidi) are very rich in potassium content and hence, no commendable difference was noticed in the K uptake. But the chemical fertilizers at 100% RDF (F1) recorded the highest potassium uptake of 223.56 kg/ha.

The residual nitrogen in the soil was recorded maximum (192.11 kg/ha) with the chemical fertilizer application at 100% RDF (F_1) as compared to other treatments of 75% RDF (F_2) with 172.36 kg/ha and 50% RDF (F_3) with 168.65 kg/ha. Both biofertilizers at different levels and the treatment combination of chemical and biofertilizers were found to be non-significant in improving the residual nitrogen (Table 1 and 2). While, the residual phosphorous and potassium contents of the soil were found to be insignificant with respect to the application of different levels of chemical fertilizer, biofertilizers and also their combinations (Table 1 and 2).

The application of different levels of chemical fertilizers might have shown significant variation with regard to residual nitrogen due to the variations in the applied dosage. There was a linear relationship observed, where the increase in chemical fertilizer dosage, increased the residual nitrogen content in the soil (Tarvydiene *et al.,* 2003) [11]

The non-significant results with regard to phosphorous at various levels of chemical fertilizers might be attributed to the fixation of phosphorous in the soil and with regard to residual potassium, it might be due to the fact that, soils under experimental conditions (HRS Pandirimamidi) are relatively very high in potassium content and hence, the external application of chemical fertilizers did not yield any significant variance.

Biofertilizers are eco friendly means of improving the yields of the crops through adequate mobilisation of the nutrients. On the other hand biofertilizers are slow in action due to the fact that, the live bacteria have to acclimatize with the soil microflora and function appropriately and hence, the residual nitrogen, phosphorous and potassium were found to be non-significant with respect to the various levels of biofertilizers in the period of experimentation.

Table 1: Effect of different levels of chemical fertilizers and biofertilizers on nutrient status of plant and soil

Treatments	Nitrogen uptake (kg/ha) by plant	Residual Nitrogen (kg/ha) in soil	Phosphorous uptake (kg/ha) by plant	Residual Phosphorous (kg/ha) in soil	Potassium uptake (kg/ha) by plant	Residual Potassium(kg/ha) in soil
Chemical fertilizers						
100% RDF (F_1)	121.71	192.11	14.06	23.85	223.56	267.90
75% RDF (F_2)	117.80	172.36	12.90	19.33	220.32	274.01
50% RDF (F_3)	99.67	168.65	11.27	21.35	204.48	274.17
C.D. at 5%	2.26	8.06	1.76	N/S	N/S	N/S
SE(m) +	0.76	2.73	0.59	-	-	-
Biofertilizers						
PSB+ KSB+ *Azospirillum* (B_1)	104.37	179.68	11.37	20.07	200.92	263.54
PSB+ KSB+ *Azotobacter* (B_2)	116.86	174.71	12.59	21.17	220.53	284.41
PSB+ KSB+ VAM (B_3)	110.38	179.17	14.17	23.62	216.29	259.57
PSB+KSB+*Azospirillum*+*Azotobacter* + VAM (B_4)	120.64	177.26	12.83	21.17	226.74	280.58
C.D. at 5%	2.61	N/S	N/S	N/S	N/S	N/S
SE(m) +	0.88	-	-	-	-	-

Note: The Nitrogen available in the soil before the experiment -192 kg/ha
Phosphorous available in the soil before the experiment – 25.9 kg/ha
Potassium available in the soil before the experiment -360 kg/ha

Table 2: Effect of different combinations of chemical fertilizers and biofertilizers on nutrient status of plant and soil

Treatment combinations	Nitrogen uptake (kg/ha) by plant	Residual Nitrogen (kg/ha) in soil	Phosphorous uptake (kg/ha) by plant	Residual Phosphorous (kg/ha) in soil	Potassium uptake (kg/ha) by plant	Residual Potassium (kg/ha) in soil
100% RDF+ PSB+ KSB+ *Azospirillum* (F_1B_1)	110.28	190.31	14.12	22.32	194.89	253.21
100% RDF+ PSB+ KSB+ *Azotobacter* (F_1B_2)	128.99	184.41	13.26	23.83	230.33	262.29
100% RDF+ PSB+ KSB+ VAM (F_1B_3)	114.37	193.49	14.23	24.21	229.74	266.19
100%RDF+PSB+KSB+*Azospirillum*+ *Azotobacter* + VAM (F_1B_4)	133.21	200.22	14.61	25.04	239.28	289.90
75% RDF+ PSB+ KSB+ *Azospirillum* (F_2B_1)	108.27	178.47	10.97	18.74	216.95	270.15
75% RDF+ PSB+ KSB+ *Azotobacter* (F_2B_2)	120.26	172.41	13.36	21.15	219.71	299.31
75% RDF+ PSB+ KSB+ VAM (F_2B_3)	118.37	174.32	12.91	20.57	217.65	256.33
75%RDF+PSB+KSB+*Azospirillum*+ *Azotobacter* + VAM (F_2B_4)	124.31	164.25	14.36	16.86	226.97	270.24
50% RDF+ PSB+ KSB+ *Azospirillum* (F_3B_1)	94.56	170.26	9.02	19.15	190.92	267.25
50% RDF+ PSB+ KSB+ *Azotobacte* (F_3B_2)	101.34	167.31	11.16	18.53	211.54	291.64
50% RDF+ PSB+ KSB+ VAM (F_3B_3)	98.40	169.70	15.35	26.08	201.50	256.19
50%RDF+PSB+KSB+*Azospirillum*+ *Azotobacter* + VAM (F_3 B_4)	104.40	167.32	9.53	21.63	213.96	281.61
C.D. at 5%	4.52	N/S	N/S	N/S	N/S	N/S
SE(m) +	1.53	-	-	-	-	-

Economics

The different treatment combinations showed varying gross returns with respect to their input cost. The highest benefit cost ratio (3.04: 1) was obtained in the treatment combination of 100% RDF + PSB + KSB + *Azospirillum* + *Azotobacter* + VAM (F_1B_4) which recorded a gross return of Rs/ha 3,88,000 Followed by the combination of 100% RDF+ PSB+ KSB+ *Azotobacter* (F_1B_2) with 2.87:1 which recorded a gross return of Rs/ha 3,64,888. The lowest benefit cost ratio (1.66:1) was recorded with the application of 75% RDF + PSB + KSB + VAM (F_2B_3) which yielded a gross return of Rs/ha 2,09,66 (Table 3).

The obtained results are a clear verdict showing that the higher doses of nutrients provide higher crop yields and improve the benefit to cost ratio. The use of 100% RDF (F_1) of chemical fertilizers might have added to the cost of cultivation, but on the other hand it could provide relatively higher yields with the increase in overall growth of the plant along with the increase in the yield characters *viz.*, root length, diameter and ultimately the root yield of the crop on comparison with the above treatment combinations. The above results are in accordance with Meena *et al.* (2007) [7] in garden pea and Girija *et al.* (2011) in elephant foot yam.

Table 3: The production economics of crop carrot with the application of different levels of biofertilizers and NPK.

Treatments	Total costs	Gross income (Rs/ha)	Net income	B:C ratio
T_1 - F_1 B_1	1,27,357	3,22,666	1,95,309	2.53
T_2 - F_1 B_2	1,27,357	3,64,888	2,37,531	2.87
T_3 - F_1 B_3	1,27,377	3,40,000	2,12,623	2.67
T_4 - F_1 B_4	1,27,737	3,88,000	2,60,263	3.04
T_5 - F_2 B_1	1,26,182	2,74,222	1,48,040	2.17
T_6 - F_2 B_2	1,26,182	3,06,888	1,80,706	2.43
T_7 - F_2 B_3	1,26,202	2,09,666	83,464	1.66
T_8 - F_2 B_4	1,26,562	3,08,666	1,82,104	2.44
T_9 - F_3 B_1	1,25,010	2,32,666	1,07,656	1.86
T_{10} - F_3 B_2	1,25,010	2,78,222	1,53,212	2.23
T_{11} - F_3 B_3	1,25,030	2,60,000	1,34,970	2.08
T_{12} - F_3 B_4	1,25,390	3,29,111	2,03,721	2.62

Conclusion

The use of biofertilizers in combination with NPK yielded higher nutrient uptake and residual nutrient contents as compared to individual effect of biofertilizers and NPK. The residual soil nutrient content varied with different treatments and their combinations, but did not show significant effect, as chemical fertilizers have direct impact on soil whereas, biofertilizers take long duration for their effect to be significant. The treatment combination of 100% RDF + PSB + KSB + *Azospirillum* + *Azotobacter* + VAM (F_1B_4) was recognized as the best treatment as well was economically beneficial. The use of biofertilizers aid's in adding steps towards sustainable crop production, by conserving the soil health.

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