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Effect of bioinoculant (Vam) and bioformulations on growth, yield and quality of onion (*Allium cepa* L.) Var. Arka Kalyan

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Abstract
Field experiment on the effect of bioinoculant (VAM) and bioformulations on growth, yield and quality was carried out during *Kharif* 2015 and *Kharif* 2016 at Kittur Rani Channamma College of Horticulture, Arabhavi, Karnataka. The experiment was laid out in randomized block design with nine treatments, replicated thrice. Among the nine treatments, maximum plant height (51.07, 52.60 and 51.83 cm), number of leaves per plant (8.00, 10.13 and 9.07), leaf area (82.76, 114.68 and 98.72 cm^2), leaf area index (0.55, 0.76 and 0.66), neck thickness (3.95, 5.02 and 4.48 mm) at 90 days after transplanting (DAT) and also higher bulb yield (23.82, 26.08 and 24.95 t ha^{-1}) and quality parameters like TSS (14.05, 13.92 and 13.99 °Brix) and sulphur content (0.381, 0.407 and 0.394 %) were also found higher in T_9 which received RDF + *Azospirillum brasilense* + *Azotobacter chrococcum* + VAM (1 kg m^{-2} of nursery bed) + PSB (*Pseudomonas striata*) + *Trichoderma harzianum* (2.5%) during 2015, 2016 and in pooled data.

Keywords: Onion, sulphur levels, zinc levels, interaction effect, bulb yield

Introduction
Onion (*Allium cepa* L.) is one of the important spice and vegetable crops having enormous use in daily diet. It is believed to possess stimulant, diuretic and expectorant properties and is considered useful in flatulence and dysentery. India is the world's second largest producer of onion after China. The indiscriminate use of chemicals resulted in degradation of soil health, erosion, and loss of organic matter, nitrate pollution and also health hazard for human beings. For sustainable production and productivity as well as quality, organic farming may be the alternative means (Ghanti and Sharangi, 2009) [6]. In India, onion occupies an area of 12.70 lakh hectare producing 215.64 lakh MT with an average productivity of 17.00 tonnes per hectare. In Karnataka, it is having an area of 1.20 lakh hectares with an annual production of 32.54 lakh tonnes and the average productivity is 14.16 tonnes per hectare (Anon., 2017) [1].
Microbial bio-inoculants and bio-fertilizers are the products containing living cells of different microorganisms which have an ability to mobilize nutritionally important elements from non-usable to usable form through biological processes which may help either directly or indirectly in the enrichment of soil fertility.
Application of bioformulations *viz.*, panchagavya, amritpani, biodigester, jeevamrut and vermiwash resulted in significantly higher bulb yield of onion apart from production of residue free wholesome produce. In addition to the basal application, foliar feeding has also assumed greater importance in recent years (Latha and Sharanappa, 2014) [1]. Biofertilizers or microbial inoculants are the products containing living cells of different microorganisms which have an ability to mobilize nutritionally important elements from non usable to usable form through biological processes which may help either directly or indirectly in the enrichment of soil fertility. Onion roots from organic fields had higher fractional colonization levels than those from conventional fields. Onion yields in conventional farming were positively correlated with microbial colonization level (Galvan *et al.*, 2009) [5].
Vesicular-arbuscular mycorrhizal (VAM) fungi are beneficial plant symbionts that form a mutualistic relationship with the roots of most crop plants. VAM fungi enhance the uptake of nutrients of low mobility in the soil solution such as P, Zn and Cu, but they have many other impacts on crop productivity (Bethlenfalvay, 1992) [3].

The cost of chemical fertilizers has been increasing to an extent that they are out of reach of the poor and small farmers. The use of bio-inoculants (VAM) and bio-fertilizers like *Azospirillum*, *Azotobacter*, *Trichoderma* and PSB are not only cost effective but also residue free. In recent past, use of bio-fertilizers in crops like onion has been realized by several research workers to produce vigorous plants with higher yields.

In order to meet the growing demand, concerted efforts are needed to produce sufficient quantity having high quality traits in onion. On the other hand, as there are no scopes for expansion in area under vegetable cultivation, future growth has to come from *per se* increase in output by enhanced productivity of onion through suitable agro-technologies. One of the options is by using balanced nutrition and the supply of macro as well as micronutrients through the combination of both organic and inorganic sources.

Keeping in view the above facts, the present investigation was undertaken with the objective to study the effect of microbial bioinoculant (VAM) and bioformulations on growth, yield and quality of onion.

Material and Methods

The field experiment was carried out at Kittur Rani Channamma College of Horticulture, Arabhavi (Northern dry zone of Karnataka state at 16°15' N latitude, 74°45' E longitude at an altitude of 612.03 meters above the mean sea level), Karnataka during *Kharif* 2015 and *Kharif* 2016. The details of the materials used and the techniques adopted during the investigations are presented here under.

The experiment was laid out in randomized block design with nine treatments *viz*., T_1- RDF (125:75:125 kg NPK/ha and 30 t/ha FYM), T_2- 75 % RDF + FYM (30 t/ha) + VAM (1 kg m^{-2} of nursery bed), T_3- 50 % RDF + FYM (30 t/ha) + VAM (1 kg m^{-2} of nursery bed), T_4- 25 % RDF + FYM (30 t/ha) + VAM (1 kg m^{-2} of nursery bed), T_5- VAM (1 kg m^{-2} of nursery bed) + FYM (30 t/ha), T_6- T_1 + VAM (1 kg m^{-2} of nursery bed), T_7- T_1 + VAM (1 kg m^{-2} of nursery bed) + Mulch (Sugarcane trash), T_8- FYM @ 100 % of N requirement + panchagavya (3%) + amritpani (3%) + VAM (1 kg m^{-2} of nursery bed) and T_9- T_1 + *Azospirillum brasilense* + *Azotobacter chrococcum* + VAM (1 kg m^{-2} of nursery bed) + PSB (*Pseudomonas striata*) + *Trichoderma harzianum* (2.5%). Note: VAM (*Acaulospora laevis* was applied @ 1 kg m^{-2} at the time of sowing of seeds in nursery. Panchagavya (3%), Amritpani (3%) and *Trichoderma harzianum* (2.5%) were applied as soil drench at 30, 60 and 90 days after transplanting. Root dipping at the rate of 1 kg per 10 litres of water for 30 minutes [*Azospirillum brasilense*, *Azotobacter chrococcum* and Phosphate Solubilizing Bacteria (*Pseudomonas striata*)].

A spacing of 15 cm between rows and 10 cm between the plants (ridge and furrow method) was followed. FYM (30 t/ha) was applied 15 days before transplanting and the recommended dose of fertilizers for onion *i.e.*, 125:75:125 kg half dose of N, full dose of P_2O_5 and K_2O per ha was applied at the time of transplanting (As per package of practice, UHS, Bagalkot). The remaining N was applied as top dressing at 45 days after transplanting. Further, the crop was grown with necessary cultural operations as per the recommendations of the university.

Five representative plants were selected randomly from each plot and the average from these five plants was worked out for the statistical computation. The data recorded for various observations were subjected to statistical analysis using the Fischer's method of analysis of variance as described by Panse and Sukhatme, (1985) [11].

Results and Discussion

Growth attributes

The data pertaining to the different growth attributes such as plant height, number of leaves, leaf area and neck thickness at 90 days after transplanting of crop growth as influenced by bioinoculant (VAM) and bioformulations during 2015, 2016 and pooled data are presented in Table 1a and 1b.

Table 1a: Effect of bioinoculant (VAM) and bioformulations on growth attributes in onion (90 days after transplanting)

Treatments	90 DAT								
	Plant height (cm)			Number of leaves oer plant			Leaf area (cm2)		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	37.40	39.07	38.23	5.73	7.67	6.70	56.82	69.62	63.22
T_2	37.73	38.57	38.15	5.53	7.53	6.53	48.64	65.05	56.84
T_3	38.00	38.40	38.20	5.67	7.73	6.70	47.59	60.44	54.01
T_4	38.13	37.87	38.00	5.47	7.67	6.57	50.72	61.77	56.24
T_5	37.57	37.10	37.33	5.33	7.60	6.47	47.34	60.68	54.01
T_6	41.33	45.47	43.40	6.47	8.13	7.30	62.79	94.52	78.66
T_7	44.87	45.87	45.37	6.60	8.60	7.60	64.13	93.00	78.56
T_8	40.77	42.67	41.72	7.33	8.67	8.00	72.62	71.30	71.96
T_9	51.07	52.6	51.83	8.00	10.13	9.07	82.76	114.68	98.72
SEm±	2.11	2.11	1.77	0.29	0.30	0.24	2.90	4.57	3.02
CD at 5%	6.34	6.33	5.31	0.87	0.91	0.71	8.70	13.70	9.07
CV (%)	8.99	8.71	7.41	8.08	6.41	5.67	8.48	10.31	7.70

RDF- 125:75:125 kg NPK/ha+30 t/ha FYM, NS- Non significant

Treatments

T_1: RDF (125:75:125 kg NPK/ha and 30 t/ha FYM)

T_2: 75 % RDF + FYM (30 t/ha) + VAM (1 kg m^{-2} of nursery bed)

T_3: 50 % RDF + FYM (30 t/ha) + VAM (1 kg m^{-2} of nursery bed)

T_4: 25 % RDF + FYM (30 t/ha) + VAM (1 kg m^{-2} of nursery bed)

T_5: VAM (1 kg m^{-2} of nursery bed) + FYM (30 t/ha)

T_6: T_1 + VAM (1 kg m^{-2} of nursery bed)

T_7: T_1 + VAM (1 kg m^{-2} of nursery bed) + Mulch (Sugarcane trash)

T_8: FYM @ 100 % of N requirement + panchagavya (3%) + amritpani (3%) + VAM (1 kg m^{-2} of nursery bed)

T_9: T_1 + *Azospirillum brasilense* + *Azotobacter chrococcum* + VAM (1 kg m^{-2} of nursery bed) + PSB (*Pseudomonas striata*) + *Trichoderma harzianum* (2.5%)

Table 1b: Effect of bioinoculant (VAM) and bioformulations on growth attributes in onion (90 days after transplanting)

Treatments	90 DAT					
	Leaf area index			Neck thickness (mm)		
	2015	2016	Pooled	2015	2016	Pooled
T_1	0.38	0.46	0.42	2.91	3.75	3.33
T_2	0.32	0.43	0.38	3.10	3.95	3.52
T_3	0.32	0.40	0.36	3.14	4.03	3.59
T_4	0.34	0.41	0.37	3.16	4.04	3.60
T_5	0.32	0.40	0.36	3.17	4.17	3.67
T_6	0.42	0.63	0.52	3.19	4.23	3.71
T_7	0.43	0.62	0.52	3.27	4.40	3.83
T_8	0.48	0.48	0.48	3.77	4.94	4.35
T_9	0.55	0.76	0.66	3.95	5.02	4.48
SEm±	0.02	0.03	0.02	0.13	0.14	0.09
CD at 5%	0.06	0.09	0.06	0.38	0.41	0.28
CV (%)	8.48	10.31	7.70	6.73	5.57	4.29

RDF- 125:75:125 kg NPK/ha+30 t/ha FYM, NS- Non significant
Treatments
T_1: RDF (125:75:125 kg NPK/ha and 30 t/ha FYM)
T_2: 75 % RDF + FYM (30 t/ha) + VAM (1 kg m^{-2} of nursery bed)
T_3: 50 % RDF + FYM (30 t/ha) + VAM (1 kg m^{-2} of nursery bed)
T_4: 25 % RDF + FYM (30 t/ha) + VAM (1 kg m^{-2} of nursery bed)
T_5: VAM (1 kg m^{-2} of nursery bed) + FYM (30 t/ha)
T_6: T_1 + VAM (1 kg m^{-2} of nursery bed)
T_7: T_1 + VAM (1 kg m^{-2} of nursery bed) + Mulch (Sugarcane trash)
T_8: FYM @ 100 % of N requirement + panchagavya (3%) + amritpani (3%) + VAM (1 kg m^{-2} of nursery bed)
T_9: T_1 + *Azospirillum brasilense* + *Azotobacter chrococcum* + VAM (1 kg m^{-2} of nursery bed) + PSB (*Pseudomonas striata*) + *Trichoderma harzianum* (2.5%)

Effect of bio-inoculant (VAM) and bioformulations showed significant differences for growth parameters during both the years of experimentation as well as in pooled data. The treatment T_9 (T_1 + *Azospirillum brasilense* + *Azotobacter chrococcum* + VAM (1 kg m^{-2} of nursery bed) + PSB (*Pseudomonas striata*) + *Trichoderma harzianum* @ 2.5%) recorded significantly higher growth parameters such as plant height (51.07, 52.60 and 51.83 cm), number of leaves per plant (8.00, 10.13 and 9.07), leaf area (82.76, 114.68 and 98.72 cm^2), leaf area index (0.55, 0.76 and 0.66) and neck thickness (3.95, 5.02 and 4.48 mm) compared to the other treatments. Increase in plant growth parameters was attributed to application of both the bioinoculant and bioformulations (combination) which might be due to the provision of nitrogen and growth promoting substances like IAA and GA by VAM fungi along with PSB.
This may be due to the fact that microbial inoculants (VAM) and biofertilizers *viz.*, *Azotobacter*, *Azospirillum*, PSB and *Trichoderma harzianum* have ability to produce growth promoting substances and change in the metabolic activities which might have led to enhanced cell division and cell elongation leading to increased uptake of water and nutrients further resulting in maximum plant height, number of leaves per plant, leaf length and leaf area. The growth attributes were lowest when onion was fed with only organic manures *viz.*, VAM (1 kg m^{-2} of nursery bed) + FYM 30 t/ha (T_5). This may be due to lack of plant nutrients and the plant suffered with solubilization effect of nutrients. Due to decreased content of nitrogen, the chief constituent of protein, essential for the formation of protoplasm which led to reduced plant height, number of leaves, leaf length and leaf area. Similar reports have been reported by Praveenkumar (2010) [12] in onion.

Yield attributes
The treatment receiving nutrition as in T_9 recorded significantly higher bulb yield parameters [Bulb weight (63.40, 71.13 and 67.27 g), bulb yield per plot (21.44, 23.47 and 22.45 kg) and bulb yield per hectare (23.82, 26.08 and 24.95 t)] as shown in Table 2. Increased bulb yield is attributed to better growth of plants in terms of plant height and number of leaves which had positive and significant correlation with yield. Increase in yield may also be attributed to the fact that azotobacter inoculation helped in increasing nitrogen availibility by acrophillic nitrogen fixation. These bacteria induce the plant root to secrete a mucilage which create low oxygen involvement and help to fix atmospheric nitrogen resulted in higher yield attributes. Phosphate solubilizing bacteria would have caused more mobilization and solubilization in solute phosphorus in the soil and improved the availability of phosphorous which lead to increased uptake of phosphorous by plants. Biological nitrogen fixation depends appreciably on the availible form of phosphorous. Hence the combined inoculation of nitrogen fixer and PSB may benefit the plant better than the group of organism in alone. Similar beneficial synergistic effect has also been reported by several workers (Yadav *et al.,* 2004; Galvan *et al.,* 2009; Mahanthesh *et al.,* 2009 and Yeptho *et al.,* 2009) [13, 5, 10, 14] in onion.

Table 2: Bulb yield parameters in onion as influenced by sulphur and zinc

Treatments	Bulb weight (g)			Bulb yield (kg/plot)			Bulb yield/ ha (t)		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	42.93	53.21	48.07	16.11	17.23	16.67	17.90	19.15	18.52
T_2	44.11	53.07	48.59	16.85	17.34	17.10	18.73	19.27	19.00
T_3	42.83	52.41	47.62	16.70	17.33	17.02	18.55	19.26	18.91
T_4	45.17	51.74	48.45	16.73	17.68	17.20	18.59	19.64	19.11
T_5	41.47	51.42	46.45	14.90	15.91	15.40	16.56	17.67	17.11
T_6	52.77	65.13	58.95	17.46	20.88	19.17	19.40	23.20	21.30
T_7	52.55	64.80	58.68	17.49	21.68	19.58	19.43	24.09	21.76
T_8	44.13	62.80	53.47	17.01	17.17	17.09	18.90	19.08	18.99
T_9	63.40	71.13	67.27	21.44	23.47	22.45	23.82	26.08	24.95
SEm±	2.13	1.71	1.34	0.69	0.75	0.57	0.77	0.83	0.63
CD at 5%	6.40	5.13	4.01	2.07	2.24	1.70	2.30	2.49	1.89
CV (%)	7.75	5.07	4.36	6.97	6.91	5.47	6.97	6.91	5.47

RDF- 125:75:125 kg NPK/ha+30 t/ha FYM, NS- Non significant

Treatments

T_1: RDF (125:75:125 kg NPK/ha and 30 t/ha FYM)

T_2: 75 % RDF + FYM (30 t/ha) + VAM (1 kg m^{-2} of nursery bed)

T_3: 50 % RDF + FYM (30 t/ha) + VAM (1 kg m^{-2} of nursery bed)

T_4: 25 % RDF + FYM (30 t/ha) + VAM (1 kg m^{-2} of nursery bed)

T_5: VAM (1 kg m^{-2} of nursery bed) + FYM (30 t/ha)

T_6: T_1 + VAM (1 kg m^{-2} of nursery bed)

T_7: T_1 + VAM (1 kg m^{-2} of nursery bed) + Mulch (Sugarcane trash)

T_8: FYM @ 100 % of N requirement + panchagavya (3%) + amritpani (3%) + VAM (1 kg m^{-2} of nursery bed)

T_9: T_1 + *Azospirillum brasilense* + *Azotobacter chrococcum* + VAM (1 kg m^{-2} of nursery bed) + PSB (*Pseudomonas striata*) + *Trichoderma harzianum* (2.5%)

It is also attributed to the effect of VAM in restrictive control on stomatal opening and closure, improvement of root water uptake characters and probably better nutrition status specially phosphorus and improved the ability of roots to absorb soil moisture, thus maintaining opened stomata in leaves and enhancing dry matter production. Enhanced water conductivity has been attributed to increased area for water uptake provided by hyphae in soil, due to VAM and biofertilizers symbiosis have led to higher yield (Bolandnazar and Hakiminia 2013) [4]. This conclusion corroborates the finding of Auge *et al.*, (2004) [2]. It is also reported that mycorrhizal plants under both well watered and deficit conditions had higher stomatal conductance and leaf growth rate compared to non-mycorrhizal ones. Mycorrhiza helps plants with such a shallow sparse root system to increase phosphorus uptake.

Quality attributes

Significantly higher TSS (14.05, 13.92 and 13.99 °Brix) and sulphur content (0.381, 0.407 and 0.394 %) were recorded by T_9 during 2015, 2016 and in pooled data respectively (Table 3). It might be due to adequate supply of nutrients through RDF and plant growth regulatory substances through VAM, *Azospirillum brasilense*, *Azotobacter chroococcum*, PSB (*Pseudomonas striata*) and *Trichoderma harzianum* which might have improved the quality of onion bulbs. The improvement in quality of onion with application of organic along with recommended dose of chemical fertilizers may be attributed to the enhanced metabolic activities synthesizing higher amounts of acids that contribute to synthesis of TSS, acidity and ascorbic acid in vegetables (Yogita and Ram, 2012) [15]. Krishnamurthy and Sharanappa (2005) also reported improved quality parameters of rose onion bulbs through different source of organic nutrient application. Gopakalli and Sharanappa (2014) [7] reported that, application of enriched biodigested liquid manure (EBDLM) at 75 kg N equivalent per ha recorded the maximum values for yield and quality parameters in onion.

Table 3: Effect of bioinoculant (VAM) and bioformulations on quality attributes in onion

Treatments	TSS (°Brix)			Sulphur content (%)		
	2015	2016	Pooled	2015	2016	Pooled
T_1	11.60	10.37	10.98	0.335	0.354	0.344
T_2	11.93	10.47	11.20	0.336	0.365	0.351
T_3	12.02	11.36	11.69	0.341	0.378	0.360
T_4	12.81	11.95	12.38	0.358	0.382	0.370
T_5	13.15	13.17	13.16	0.373	0.395	0.384
T_6	13.20	13.02	13.11	0.377	0.391	0.384
T_7	13.41	13.52	13.46	0.378	0.384	0.381
T_8	13.69	13.67	13.68	0.379	0.396	0.388
T_9	14.05	13.92	13.99	0.381	0.407	0.394
SEm±	0.41	0.13	0.23	0.01	0.01	0.01
CD at 5%	1.22	0.39	0.69	0.04	0.04	0.03
CV (%)	5.47	1.81	3.17	7.07	5.42	4.25

Treatments

T_1: RDF (125:75:125 kg NPK/ha and 30 t/ha FYM)

T_2: 75 % RDF + FYM (30 t/ha) + VAM (1 kg m^{-2} of nursery bed)

T_3: 50 % RDF + FYM (30 t/ha) + VAM (1 kg m^{-2} of nursery bed)
T_4: 25 % RDF + FYM (30 t/ha) + VAM (1 kg m^{-2} of nursery bed)
T_5: VAM (1 kg m^{-2} of nursery bed) + FYM (30 t/ha)
T_6: T_1 + VAM (1 kg m^{-2} of nursery bed)
T_7: T_1 + VAM (1 kg m^{-2} of nursery bed) + Mulch (Sugarcane trash)
T_8: FYM @ 100 % of N requirement + panchagavya (3%) + amritpani (3%) + VAM (1 kg m^{-2} of nursery bed)
T_9: T_1 + *Azospirillum brasilense* + *Azotobacter chrococcum* + VAM (1 kg m^{-2} of nursery bed) + PSB (*Pseudomonas striata*) + *Trichoderma harzianum* (2.5%)

Conclusion

Thus from the foregoing discussion, it is clear that the integration of bioinoculant and bioformulations along with RDF had a marked effect in increasing yield of onion and substituting nutrient requirement effectively by biofertilizers which can provide the better yield with improved quality attributes.

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