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Effect of integrated use of chemical fertilizers, FYM and bio-fertilizers on crop productivity and soil fertility under onion (*Allium cepa* L.)

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Abstract
A field experiment was conducted during 2016-17 to evaluate the influence of integrated use of chemical fertilizers, FYM and bio-fertilizers on crop productivity and soil fertility under onion. The treatments were control (T_1), 50% NPK (T_2), 50% NPK + FYM (10 tons ha^{-1}) +VAM (10 kg ha^{-1}) (T_3), 100% NPK (T_4), 100% NPK + FYM (10 tons ha^{-1}) + VAM (10 kg ha^{-1}) (T_5), 150% NPK (T_6), 150% NPK + FYM (10 tons ha^{-1}) + VAM (10 kg ha^{-1}) (T_7) and FYM (10 tons ha^{-1}) + VAM (10 kg ha^{-1}) + PSB + Azotobacter (T_8). Application of 100% NPK along with FYM (10 tons ha^{-1}) and VAM (10 kg ha^{-1}) i.e. T_5 significantly increased the growth and yield as well as soil fertility status as compared to chemical fertilizers alone. Significantly higher plant height, number of leaves per plant, bulb diameter and bulb yield of onion and soil properties in terms of organic carbon, available NPK and S were obtained with application of 100% NPK + FYM (10 tons ha^{-1}) + VAM (10 kg ha^{-1}) (T_5) in comparison to other treatments. Significantly higher NPKS uptake was also observed with T_5. This experiment indicated the superiority of integration between chemical fertilizers; FYM and bio-fertilizer (VAM) over chemical fertilizer alone at all level of fertility.

Keywords: NPKS, Onion, bio-fertilizers, VAM, soil properties, nutrient uptake, growth, yield

Introduction
Onion (*Allium cepa* L.) is one of the most important commercial vegetable crops cultivated extensively in India. It belongs to family Alliaceae. It is an indispensable item in every kitchen as vegetable and condiment. Onion is liked for its flavour and pungency which is due to the presence of a volatile oil ‘allyl propyl disulphide’- an organic compound rich in sulphur. Onion bulb is a rich source of minerals like phosphorus, calcium and carbohydrates. It also contains protein and vitamin C. India is the second largest producer of onion in the world, next to China, accounting for 26.38% of the world area and 24.8% of the world production. In India in the year of 2015 - 16 onion is being grown in an area of 1.22 million hectares with production of 20.991 million tons and the productivity is 15.1 tons per hectare (FAOSTAT, 2016) [4]. Maharashtra is the leading onion growing state and other important states are Karnataka, Gujarat, Bihar, Madhya Pradesh, Andhra Pradesh, Rajasthan, Haryana, Uttar Pradesh and Tamil Nadu. There is a wide gap between yields obtained in India and other developed countries, reflecting the huge scope to increase yield and productivity of onion. Optimum fertilizers application for onion and cultivation of suitable cultivars under reclaimed calcareous soils are necessary for obtaining good yield with high quality of bulbs. The essential nutrients particularly, the primary macro nutrients e.g. nitrogen, phosphorus and potassium (NPK) are necessary for plant growth, maturity, bulb yield and quality. Experience and literature have shown that NPK mineral nutrition each alone or in combinations had a pronounced effect (positive or negative) on the growth, maturity, productivity and quality of onion crop (Razzak, 2007) [15]. The basic concept underlying the principals of integrated nutrient management (INM) is the maintenance and possible improvement in soil fertility for sustained crop productivity on long term basis. INM holds great promise in meeting the growing nutrient demands of intensive agriculture and maintaining the crop productivity at higher levels with overall improvement in the quality of resource base (Rai *et al.* 2014) [14]. Limited availability of additional land for crop production along with declining yield of major food crops have put a question mark against our ability to feed the ever increasing population

of our country. Therefore Future strategies for increasing agricultural productivity will have to focus on using available nutrient resources more efficiently and sustainably than in the past. Achieving balance between the nutrient requirements of plants and the nutrient reserves in soil is essential for maintaining high yields and soil fertility, preventing environmental contamination and degradation, and sustaining agricultural production over the long term. Vesicular Arbuscular mycorrhizal (VAM) fungi, one of the diverse soil micro biota, are ubiquitous and common in natural and agricultural ecosystems (Naik, 2014) [12]. This association contributes to plant growth by enhancing the mineral acquisition by host plants particularly plant uptake of poorly mobile soil nutrients such as phosphorus. Besides the facilitation of phosphorus uptake (Rai *et al.* 2014) [14], VAM fungi also increase the zone of absorption in soil. The VAM symbiosis is being recognized to influence soil development as much as plant development. Hence, this investigation was planned to evaluate the effect of integrated use of chemical fertilizers, FYM and bio-fertilizers on crop productivity and soil fertility under onion.

Materials and Methods

A field experiment was conducted in Rabi season (2016-2017) at agricultural form of Udai Pratap Autonomous College, Varanasi developed on alluvium deposited. The soil of experimental site was sandy loam in texture, slightly saline and non-alkaline in reaction. The initial physico-chemical properties of experimental soil were bulk density 1.46 g cm^{-3}, particle density 2.65 g cm^{-3}, pH (1:2.5) 7.70, EC 2.46 dSm^{-1}, organic carbon 0.62%, available nitrogen 270.65 kg ha^{-1}, available phosphorus 9.50 kg ha^{-1}, available potassium 275.80 kg ha^{-1} and available sulphur 8.0 kg ha^{-1}. The various treatments applied to onion were control (T_1), 50% NPK (T_2), 50% NPK + FYM (10 tons ha^{-1}) +VAM (10 kg ha^{-1}) (T_3), 100% NPK (T_4), 100% NPK + FYM (10 tons ha^{-1}) + VAM (10 kg ha^{-1}) (T_5), 150% NPK (T_6), 150% NPK + FYM (10 tons ha^{-1}) + VAM (10 kg ha^{-1}) (T_7) and FYM (10 tons ha^{-1}) + VAM (10 kg ha^{-1}) + PSB + Azotobacter (T_8). The treatments were triplicated in randomized block design (RBD). Nitrogen, phosphorus, potash and sulphur were applied by chemical fertilizers (Urea, SSP & MOP) as per treatments. Half dose of nitrogen (50 kg ha^{-1}) and full dose of phosphorus, potassium and sulphur were applied as basal application at the time of sowing. Remaining half dose of nitrogen applied as topdressing at 30 and 60 DAT (Days after transplanting) respectively. PSB and Azotobacter applied as seed treatments at time of transplanting. Soil samples from 0-15 cm depth were collected in plastic bag from individual plots at 30, 60 DAT and after harvest of the crop. Soil sample of each plot was air- dried, processed to pass through 2 mm round hole sieve and analyzed for oxidizable organic carbon (1*N* $K_2Cr_2O_7$), available N (0.32% alkaline $KMnO_4$ oxidizable), P(0.5 M $NaHCO_3$ extractable), K (1 *N* neutral ammonium acetate extractable) and S (0.15% $CaCl_2$) following the methods described by Walkley and Black method (1934) [19], Subbiah and Asija (1956) [18], Olsen's *et al.* (1954) [13], Hanway and Heidel (1952) [6] and Williams and Steinbergs (1959) [20], respectively. Soil pH was determined in 2:1 soil: water suspension with the help of glass electrode in digital pH meter and electrical conductivity of soil was measured in the supernatant liquid of soil water suspension (1:2) by conductivity bridge (Jackson, 1973) [7]. Bulk density in undisturbed samples collected with metal cores of 4.2 cm diameter and 5.8 cm height was measured (Blake, 1965). Five plants were marked randomly in each replicated plot and height was measured from base of plant to the tip of the upper most latest leaf for calculating mean plant height at 30 and 90 days after transplanting. Number of leaves of selected plant for height was counted and average was obtained per plant. After harvesting and threshing the weight of bulb was recorded. The diameter of onion bulb was determined by dividing the circumference of onion bulb by the factor (3.14 cm). The data collected from field and laboratory were analyzed statistically using standard procedure of randomized block design (Cochran and Cox, 1957) [3]. Critical difference (C.D.) and standard error of mean (SEM) were calculated to determine the significance among treatment means.

Results and Discussion

Effect of integrated use of chemical fertilizer, FYM and bio-fertilizers on growth and yield of onion crop.

Plant height

The plant height of onion crop increased continuously with advancement in growth stages up to the harvest under all the treatments and was found in the order of $T_5>T_7>T_3>T_4>T_6>T_2>T_8>T_1$ (Table No-1). The mean plant height under integrated use of chemical fertilizer, FYM and bio-fertilizers applied plots was significantly higher as compared to other combinations. 100% NPK + FYM @10 tons ha^{-1} + VAM @10 kg ha^{-1} (T_5) application was observed more significantly superior than other treatments. The maximum average plant height under T_5 was recorded as 25.03, 34.88 and 56.56cm respectively at 30, 60 DAT and at harvest, where as lowest average plant height under T_1 were recorded as 17.57, 28.66 and 33.67 cm respectively at 30, 60 DAT and at harvest. Similar results were observed by Mohanty *et al.* (2015) [11], where application of organic inputs in combination with chemical fertilizer was observed as better option than alone application of organic manures and chemical fertilizer. Significantly higher plant growth under integrated use of organic manure, chemical fertilizer and bio-fertilizers over the sole use of chemical fertilizers was also observed by Jayathilake *et al.* (2003) [9].

Number of leaf plant $^{-1}$

Number of leaf $plant^{-1}$ increased continuously with advancement of crop age. Application of VAM and FYM along with NPK significantly improved the number of leaf $plant^{-1}$ at all growth stages. 100% NPK + FYM @10 tons ha^{-1} + VAM @ 10 kg ha-1 (T_5) application was observed more significantly superior than other treatments (Table No^{-1}). The maximum leaf number was recorded with the application of treatment T_5 and the minimum was recorded with T_1 (Control). Order of number of leaf $plant^{-1}$ among various treatment at all the growth stages was found as $T_5>T_7>T_3>T_4T_6>T_2>T_8>T_1$. The average number of leaf $plant^{-1}$ under T_5 was recorded as 5.17, 10.00 and 10.53 respectively at 30, 60 DAT and at harvest, where as lowest number of leaf $plant^{-1}$ under T_1 were recorded as 2.83, 6.92 and 7.07 respectively at 30, 60 DAT and at harvest. The availability of higher quantity of nutrients might be responsible for improvement in the physical and chemical properties of soil along with increased activity of microbes might have helped in increasing number of leaf in onion. This result was in conformity with Naik (2014) [12] and Mohanty *et al.* (2015) [11], where significantly higher number of leaf $plant^{-1}$ was observed with organic manures and bio-fertilizers.

Bulb diameter

Significantly higher bulb diameter was observed with T_5 (100% NPK + FYM @10 tons ha^{-1} + VAM @10 kg ha^{-1}) in comparison to other treatment (Table No-1). The order of bulb diameter of onion among various treatment was observed as $T_5>T_7>T_3>T4>T6>T_2>T_8>T_1$. The bulb diameter under treatments T_1, T_2, T_3, T_4, T_5, T_6, T_7, and T_8 were observed as 2.67, 4.56, 5.47, 5.32, 6.39, 4.70, 5.67, and 4.43 cm respectively. Similar findings were observed by Mohanty *et al.* (2015) [11] and Srivastav *et al*. (2012) [17], where integrated use of organic and inorganic fertilizer significantly increased the bulb diameter in onion due to better physical condition of soil influenced by reduction in bulk density and increase in porosity.

Bulb Yield

Significantly higher yield was observed with T_5 (100% NPK + FYM @10 tons ha^{-1} + VAM @10 kg ha^{-1} +) in comparison to other treatments (Table No-1). The order of yield of onion crop was observed as $T_5>T_7>T_3>T4>T6>T_2>T_8>T_1$. Yield under treatments T_1 to T_8 was were observed as 105.90, 133.94, 164.99, 154.99, 173.98, 139.00, 169.98, and 127.95 q ha^{-1} respectively. Application of inorganic fertilizers, FYM and bio-fertilizers in combination significantly increased the yield of onion at all level of nutrients might be due to improved physical, chemical and biological properties of soil. Incorporation of FYM and bio-fertilizers provide favorable soil environment for onion. The higher yield of crops might be due to higher availability of nutrients due to decomposition and mineralization of applied manures (Jawadagi *et al*. 2012) [8]. The beneficial effect of organic manures on yield might be due to the additional supply of plant nutrients as well as improvement in overall soil's physico-chemical and biological properties (Naik, 2004) [12]. These findings are in conformity of Ghanti & Sharangi (2009) [5] and Khang *et al*. (2011) [10], where improvement in yield of onion was observed due to integrated use of VAM with chemical fertilizer.

Table 1: Effect of integrated use of chemical fertilizer, FYM and bio-fertilizers on plant growth and yield attributes of onion

Treatments	Plant height (cm)			Number of leaves $plant^{-1}$			Bulb diameter (cm)	Bulb yield (q ha^{-1})
	30 DAT	60 DAT	At harvest	30 DAT	60 DAT	At harvest		
T_1	17.57	28.66	33.67	2.83	6.92	7.07	2.67	105.90
T_2	21.31	30.63	41.73	3.97	8.75	8.88	4.56	133.94
T_3	24.03	33.25	52.50	4.37	9.67	9.82	5.47	164.99
T_4	23.40	32.17	51.78	4.25	9.33	9.55	5.32	154.99
T_5	25.03	34.88	56.56	5.17	10.00	10.53	6.39	173.98
T_6	21.95	31.50	50.58	4.17	9.00	9.03	4.70	139.00
T_7	24.74	34.33	55.50	4.97	9.75	9.98	5.67	169.98
T_8	20.85	29.63	40.42	3.50	8.50	8.67	4.43	127.95
SEm(±)	0.291	0.250	0.314	0.161	0.203	0.226	0.202	3.392
CD (P=0.05)	0.665	0.760	0.954	0.489	0.615	0.805	0.612	10.29

DAT = Days after transplanting

Effect of integrated use of chemical fertilizer, FYM and bio-fertilizers on uptake of nutrients by onion

The data related to nutrient uptake by onion crop under integrated use of chemical fertilizer, FYM and bio-fertilizersapplication has been presented in Table no-2. Significantly higher nutrients uptake was observed in T_5 (100% NPK + FYM @10 tons ha^{-1} + VAM @10 kg ha^{-1}) in comparison to other treatment. Lowest nutrients uptake was observed in T_1 (control). The order of nutrients uptake among various treatment was observed as $T_5>T_7>T_3>T4>T6>T_2>T_8>T_1$. Nitrogen uptake in treatments from T_1 to T_8 was observed as 82.31, 126.39, 145.42, 139.81, 158.75, 135.38, 154.62 and 121.38 kg ha^{-1} respectively. Phosphorous uptake among various treatments from T_1 to T_8 was observed as 13.21, 17.15, 22.45, 20.16, 26.45, 19.08, 25.00, and 16.72 kg ha^{-1} respectively. Potassium uptake among various treatments from T_1 to T_8 was observed as 62.45, 82.41, 110.75, 103.56, 123.45, 99.63, 116.09 and 79.50 kg ha $^{-1.}$ Sulphur uptake among various treatments from T_1 to T_8 was observed as 13.16, 17.81, 25.45, 22.63, 31.56, 20.06, 29.63 and 16.00 kg ha $^{-1}$ respectively among different treatments. Higher uptake of nutrients along with 100% NPK + FYM @ 10 tons ha^{-1} + VAM @ 10 kg h^{-1} application might be due to more availability of nutrients due to application of higher dose of fertilizers along with more mobilization and solubilization of nutrients under the influence of chemical fertilizer, FYM and bio-fertilizers application. These results were in conformity of Rai *et al*. (2014) [14].

Effect of integrated use of chemical fertilizers, FYM and bio-fertilizers on soil organic carbon and available NPKS in post–harvest soil under onion.

The data of soil organic carbon content and available NPKS content of post-harvest soil under various levels of NPK, FYM and VAM under onion crop has been presented in Table no-2.

Table 2: Effect of integrated use of chemical fertilizer, FYM and bio-fertilizers on soil organic carbon, available N.P.K.S and nutrients uptake pattern of onion in post harvest soil

Treatments	Nutrients uptake (kg ha^{-1})				Organic Carbon (%)	Nutrient availability (kg ha^{-1})			
	N	P	K	S		N	P	K	S
T_1	82.31	13.21	62.45	13.16	0.39	278.65	10.31	186.6	8.5
T_2	126.39	17.15	82.41	17.81	0.41	300.76	12.15	204.4	10
T_3	145.42	22.45	110.75	25.45	0.49	319.79	17	225.25	14.36
T_4	139.81	20.16	103.56	22.63	0.47	315.38	15.26	221.41	13
T_5	158.75	26.45	123.45	31.56	0.55	330.46	20.31	238.76	16.69
T_6	135.38	19.08	99.63	20.06	0.44	309.69	13.61	214.39	11.58
T_7	154.62	25.00	116.09	29.63	0.54	326.82	19	233.69	16
T_8	121.38	16.72	79.50	16.00	0.40	294.5	11.59	200.71	9.75
SEm(±)	0.209	0.301	0.245	0.177	0.026	0.243	0.112	0.072	0.186
CD (P=0.05)	0.879	0.913	0.743	0.535	0.079	0.738	0.341	0.217	0.565

Soil Organic Carbon
100% NPK + FYM @ 10 tons ha^{-1} + VAM @ 10 kg ha^{-1} (T_5) application was observed more significantly superior than other treatments in respect to soil organic carbon content in post-harvest soil. The highest organic carbon status was recorded with the application of T_5 followed by other treatments in decreasing order as T_5>T_7>T_3>T_4>T_6>T_2>T_8>T_1. Among various treatments organic carbon content varied from 0.55, 0.54, 0.49, 0.47, 0.44, 0.41, and 0.40 to 0.39% respectively. Fertilizer and VAM application helped in increasing the organic carbon content, which is due to increased contribution from the biomass and contribution from root stubble could also be expected reason for higher organic carbon content. The subsequent decomposition of these materials might have resulted in enhanced organic carbon of soil. These results also corroborates with the findings of Sharma *et al*. (2009) [16]. Khang *et al*. (2011) [10] also observed the increase in organic carbon content in soil due to higher contribution of biomass due to use of inorganic fertilizers**.**

Available Nitrogen
Increasing levels of NPK were associated with improvement in the nitrogen availability in soil. Available nitrogen content of soil continuously decreased with advancement in crop growth stage under all treatments. 100% NPK + FYM @ 10 tons ha^{-1} + VAM @ 10 kg ha^{-1} (T_5) application was observed more significantly superior than other treatments in respect to nitrogen availability in post-harvest soil. The highest available nitrogen was recorded with the application of T_5 followed by other treatments in decreasing order as T_5>T_7>T_3>T_4>T_6>T_2>T_8>T_1. Available nitrogen content ranged from 330.46, 326.82, 319.79, 315.38, 309.69, 300.76, and 294.50 to 278.65 kg ha^{-1} after under various treatments respectively. Decline in nitrogen content with increasing growing time could be attributed to higher nitrogen requirement for crop with age (Khang *et al.* 2011) [10]. Increase in available nitrogen with VAM application might be attributed to the addition of nitrogen to the available pool of soil through VAM after mineralization (Azamal *et al.* 2013) [1]. Decline in nitrogen content with increasing growing time could be attributed to higher N requirement. The soil availability of nitrogen Increased significantly with the application of various organic sources of nutrients in combination with fertilizers over the fertilizers alone (Rai *et al.* 2014) [14].

Available Phosphorus
In general, available phosphorus content of soil gradually decreased with age of crop. The combined application of 100% NPK + FYM @ 10 tons ha^{-1} + VAM 10 @ tons ha^{-1} (T_5) registered the highest available phosphorus content at all growth stages. The highest available phosphorus was recorded with the application of T_5 followed by other treatments in decreasing order as T_5>T_7>T_3>T_4>T_6> T_2>T_8>T_1. Soil phosphorus after harvesting varied from 20.31, 19.00, 17.07, 15.26, 13.61, 12.15, and 11.59, to 10.31 kg ha^{-1}, respectively under various treatments. These findings are in accordance with Khang *et al.* (2011) [10], where they observed higher availability of phosphorus in treatments applied with VAM might be due more mobilization of phosphorus by VAM. Significant reduction in available phosphorus content under unfertilized treatment due to removal of phosphorus by the crop in the absence of phosphorus supplementation through external source. The buildup P_2 O_5 might also be due to the release and increased solubility of native phosphorus (Sharma *et al.* 2009) [16].

Available Potassium
The data revealed that available potassium status of soil of onion decreased continuously with advancement of crop age. The combined application of 100% NPK + FYM @ 10 tons ha^{-1} + VAM @ 10 kg ha^{-1} (T_5) registered the highest available potassium content at all growth stages. The highest available potassium was recorded with the application of T_5 followed by other treatments in decreasing order as T_5>T_7>T_3>T_4>T_6>T_2>T_8>T_1. Available potassium values in post harvest soil sample were varied from 238.76, 233.69, 225.25, 221.41, 214.39, 204.40, and 200.71 to 186.60 kg ha^{-1}, respectively among various treatments. Similar result was found by Rai *et al.* (2014) [14]. Application of 100% NPK + VAM 10 kg ha^{-1} (T_5) proved its superiority in increasing the potassium availability might be due to the direct addition of potassium to the available pool of the besides the reduction of potassium fixation and releases of potassium due to the interaction of organic matter with clay. Khang *et al.* (2011) [10] also observed that the soil available K content increased significantly with the application of various organic sources of nutrients in combination with fertilizers over the fertilizer alone.

Available Sulphur
Application of inorganic fertilizers and organic manure had significant influence on the sulphur content of soil. Among the various NPK levels, application of 100% NPK + FYM @ 10 tons ha^{-1} + VAM @ 10 kg ha^{-1} (T_5) registered the highest sulphur content. The highest available sulphur was recorded with the application of T_5 followed by other treatments in decreasing order as T_5>T_7>T_3>T_4>T_6>T_2>T_8>T_1. The available sulphur content was varied from 16.69, 16.00, 14.36, 13.00, 11.58, 10.00, and 9.75 to 8.50 kg ha^{-1}. Decline in sulphur content of soil with advancement of crop age might be attributed to rise in sulphur requirement for onion with growing period. Similar result was found by Khang *et al.* (2011) [10], where conjunctive use of organic manure and fertilizers along with bio-fertilizers gave highest availability of sulphur under onion crop in compared to other treatments.

Conclusion
It is concluded from the present study that the application of 100% NPK + FYM @ 10 tons ha^{-1} + VAM @ 10 kg ha^{-1} not only produced the higher yield of onion but also improved the soil fertility as compared to application major nutrients alone. Thus, optimum mineral nutrition in conjunction with bio-fertilizers can play a vital role in exploiting high yield potential of onion through the favourable effect on nutrient supply and soil properties.

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