

Fertilizing for Sustainable Onion Production Systems

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Studies evaluated straight versus combined applications of manures, fertilizers, and microbial biofertilizers with reference to onion bulb yield and soil nutrient balances. Given the good supply of quality manures, observations favored the combined application of inorganic fertilizers and manures over sole application of either nutrient source. Application of 50 to 75% of the fertilizer recommendation plus any microbial inoculant treatment failed to achieve a viable alternative.

Onion (*Allium cepa* L) is a highly nutrient-responsive crop. Conventional methods of fertilization have undoubtedly helped in improving both bulb yield and quality. But lately, routine management practices in India appear to be incapable of maintaining yields over the long-term. The steady depletion of native soil fertility and the occurrence of multiple nutrient deficiencies in onion fields has led to the identification of nutrient management as a key factor limiting sustainable onion production (Sharma et al., 2003). Integrated nutrient management (INM) offers an effective strategy (Dimri and Singh, 2005; Santhi et al., 2005).

Although the use of manures as nutrient sources for vegetables is common, their effectiveness is potentially limited by nutrient release patterns that are often out of synchrony with crop demand, large variability in source quality and field distribution, and food safety. All of these issues have contributed to experimentation with alternative options. A gradual shift from using purely organic sources to introducing some proportion of inorganic fertilization is gaining acceptance. This shift has formed the basis for INM, which could involve three nutrient sources: microbial inoculants or biofertilizers including azotobacter (Az), azospirillum (Azr), and phosphate solubilizing bacteria (PSB), inorganic fertilizers, and manures. However, INM further prescribes that selected nutrient inputs be used judiciously to ensure optimum supply of all essential nutrients for sustained crop production. Most INM studies conducted with onion have lacked the experimental components required to link soil nutrient budgeting with bulb yield response.

This field experiment was carried out with two major objectives: 1) determine the magnitude and economic value of responses of onion to INM-based treatments, and 2) assess the nutrient uptake pattern to determine net changes in the soil nutrient balance sheet.

The experiment was conducted during the kharif (monsoon) seasons between 2007-09 at the experimental farm (25°45'43" N latitude - 93°53'04" E longitude) of the School of Agricultural Sciences and Rural Development (SASRD), Nagaland University, Medziphema, Nagaland to study fertilization strategies for sustainable onion (var. Agrifound Dark Red) production. The experimental soil was classified as Typic Rhodustalf with a loam texture (58% sand, 20% silt, and 21% clay), pH 5.2 (1:2), high organic carbon (21.8 g/kg by Walkley

Abbreviations: N = nitrogen; P = phosphorus; K = potassium; SSP = single superphosphate; KCl = potassium chloride; RDF = recommended dose of fertilization; FYM = farmyard manure; PiM = pig manure; PM = poultry manure; Vm = vermicompost; CD = critical difference, equivalent to Least Significant Difference. INR = Indian rupee. Note: USD 1 = approximately INR 44.1.



Combined application of inorganic fertilizers with organic manures offers better results in onion production in India.

Table 1. Response of different INM-based treatments on the onion bulb yield (fresh weight basis).

Treatments	----- Bulb yield, t/ha -----		
	2007-08	2008-09	Mean
T ₁ = Control	2.80	2.60	2.70
T ₂ = Current recommendation (RDF)	3.32	3.80	3.56
T ₃ = FYM	3.10	2.94	3.02
T ₄ = Pig manure (PiM)	3.18	3.04	3.11
T ₅ = Poultry manure (PM)	3.10	3.50	3.30
T ₆ = Vermicompost (Vm)	3.60	3.46	3.53
T ₇ = 50% RDF + 50% FYM	3.70	3.98	3.84
T ₈ = 50% RDF + 50% PiM	3.50	3.80	3.65
T ₉ = 50% RDF + 50% PM	3.40	3.96	3.68
T ₁₀ = 50% RDF + 50% Vm	3.91	4.19	4.00
T ₁₁ = 50% RDF + Az	2.81	3.01	2.91
T ₁₂ = 50% RDF + Azr	2.92	2.76	2.84
T ₁₃ = 50% RDF + PSB	2.72	2.92	2.82
T ₁₄ = 75% RDF + Az	2.98	3.04	3.01
T ₁₅ = 75% RDF + Azr	3.00	3.16	3.08
T ₁₆ = 75% RDF + PSB	3.18	3.06	3.12
CD (p = 0.05)	0.12	0.18	0.15

and Black method), low available N (248 kg/ha by alkaline permanganate distillation method), low available P (11 kg P₂O₅/ha by Bray's method), and low available K (178 kg K₂O/ha, ammonium acetate extractable) (Sparks, 1996).

Table 1 outlines 16 treatments that were replicated three

Table 2. Balance sheet for nutrient input and output for onion in response to INM treatments (mean of two seasons).

Treatments	Nutrient addition, kg/ha			Nutrient removal, kg/ha			Net balance, kg/ha		
	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
T ₁ = Control	-	-	-	45 (1.68) ¹	25.2 (0.40)	32.4 (0.98)	-45	-25	-32
T ₂ = Current recommendation (RDF)	100	60	60	79 (2.22)	45.8 (0.57)	52.8 (1.24)	21	14	7
T ₃ = FYM	104	23	162	56 (1.86)	29.8 (0.44)	37.2 (1.02)	48	-7	125
T ₄ = Pig manure (PiM)	109	18	95	61 (1.96)	36.6 (0.50)	44.4 (1.20)	48	-19	51
T ₅ = Poultry manure (PM)	107	25	91	63 (1.90)	34.3 (0.44)	49.2 (1.12)	44	-9	42
T ₆ = Vermicompost (Vm)	102	18	74	75 (2.12)	41.2 (0.50)	48.0 (1.14)	27	-23	26
T ₇ = 50% RDF + 50% FYM	106	72	141	74 (1.92)	41.2 (0.46)	50.4 (1.10)	32	31	91
T ₈ = 50% RDF + 50% PiM	105	70	108	74 (2.02)	43.5 (0.51)	54.0 (1.24)	31	26	54
T ₉ = 50% RDF + 50% PM	104	69	97	73 (1.98)	41.2 (0.48)	51.6 (1.16)	31	27	46
T ₁₀ = 50% RDF + 50% Vm	101	73	106	96 (2.40)	52.7 (0.58)	64.8 (1.34)	5	20	41
T ₁₁ = 50% RDF + Az	70	69	36	51 (1.76)	29.8 (0.44)	36.0 (1.02)	19	39	0
T ₁₂ = 50% RDF + Azr	75	69	36	49 (1.72)	27.5 (0.43)	50.4 (1.88)	26	42	-14
T ₁₃ = 50% RDF + PSB	50	114	36	50 (1.78)	29.8 (0.46)	37.2 (1.11)	0	84	-1
T ₁₄ = 75% RDF + Az	95	69	36	55 (1.82)	32.1 (0.46)	40.8 (1.14)	40	37	-5
T ₁₅ = 75% RDF + Azr	100	69	36	56 (1.83)	34.3 (0.48)	43.2 (1.18)	44	35	-7
T ₁₆ = 75% RDF + PSB	75	114	36	57 (1.84)	34.3 (0.49)	67.2 (0.18)	18	80	-31
CD (p = 0.05)	-	-	-	5.4 (0.12)	2.5 (0.03)	4.6 (0.16)	-	-	-

¹Figures in parentheses represent nutrient concentration in % (expressed on elemental basis).

times and tested in a randomized complete block design. Full rates for the FYM (0.8% N, 0.08% P, 1.04% K), PiM (1.82% N, 0.14% P, 1.32% K), PM (2.14% N, 0.22% P, 1.52% K), and Vm (2.04% N, 0.15% P, 1.24% K) were designed to supply approximately the same N (100 kg N/ha) provided by the RDF treatment and were calculated to be 13 t, 6 t, 5 t, and 5 t/ha, respectively. The combined manure + fertilizer treatments were also designed to supply approximately 100 kg N/ha. Inorganic fertilizers sources were urea, single superphosphate (SSP), and potassium chloride (KCl). The anticipated nutrient to be added through the Az, Azr, and PSB biofertilizers was credited to the different treatments as 20 kg N, 25 kg N, and 20 kg P₂O₅/ha, respectively.

Each treatment received its entire dose (rate) of manure each year at the time of land preparation. The full dose of P, K, and half dose of N were applied each year at the time of planting and the remaining half dose of N was applied 30 days after planting. For the biofertilizers, the bulblets were dipped in treatment slurries at the rate of 10 g/kg bulblets and then dried under shade before planting. Experimental plots were treated with *Trichoderma* to minimize the incidence of damping-off disease. The bulblets were planted on raised beds during the first week of September and harvested in first week of January in both the seasons.

The bulbs were harvested after more than 50% of leaves dropped down, and bulb fresh weight was measured. The bulbs were dried in shade, then chopped off and dried at 63 °C ± 2 °C, finely ground, and samples were digested in a 3:1 di-acid mixture of H₂SO₄ and HClO₄. In these acid extracts, nutrients were determined as per standard procedures including N by steam distillation using the micro-Kjeldahl method, P by colorimeter using the vanadomolybdophosphoric acid yellow

color method, and K by flame photometer (Page et al., 1982). Nutrient budgets were calculated on the basis of nutrient inputs minus nutrient removal by onion bulbs.

Treatments supplying inorganic fertilizers and organic manures, either alone or in combination, generated a significant bulb yield response in both seasons over the control (**Table**



Scene at the National Research Center for Onion and Garlic in Pune, India.

1). Bulb yields were significantly correlated with bulb uptake of N ($r = 0.732$, $p = 0.01$), P ($r = 0.612$, $p = 0.01$), and K ($r = 0.405$, $p = 0.05$). Data averaged over the two seasons revealed VM to be the only manure source able to produce, by itself, bulb yields that were equivalent to those under the RDF. The best bulb yield responses were achieved with 50% RDF+Vm followed by 50% RDF+FYM. On the contrary, biofertilizers were unable to compensate for reduced application rates of inorganic fertilizer. The use of biofertilizers along with 50% or 75% RDF resulted in bulb yield averages that were at best equivalent to the poorer performing manure sources and in some cases were indistinguishable from the control. The positive performance of the reduced rate of inorganic fertilization plus either Vm or FYM does highlight the value of good manure sources as a supplement to inorganic fertilizers. Mineralization of manures aids in soil nutrient buildup that in turn leads to improved nutrient availability to growing crop (Singh et al., 2001).

Nutrient removal under the RDF treatment was hard to distinguish from that measured under any manure treatment (Table 2). A comparison of the effect of combining inorganic fertilizers with manures versus their co-application with selected biofertilizers found significantly higher nutrient uptake with the former compared to the latter. As little as 25% of the RDF could not be replaced through biofertilizer supplementation, but up to 50% of the RDF could be effectively replaced with selected manures. The treatment with 50% RDF+Vm observed the highest average nutrient removal of 96-53-65 kg N-P₂O₅-K₂O/ha.

Considering the net nutrient balances presented, the current inorganic fertilization recommendation maintained a surplus stock of nutrients over 2 years of study (Table 2). All manure treatments developed P deficits, while the treatments with 50 to 75% RDF treatments used in combination with biofertilizers generated small to moderate K deficits. Treatments providing inorganic fertilizers and manure resulted in no deficit for any of the three primary nutrients.

Economic analysis highlighted that sole reliance on manures is not a cost-cutting measure, but favorable changes in soil quality likely compensate for additional costs per hectare through improved long-term nutrient turnover due to the organic amendments. However, net returns per treatment further substantiated the superiority of any combined fertilizer/manure application compared to a fertilizer or manure application at the rates examined (Table 3).

Onion growers in this region often prefer organic manuring over inorganic fertilization. As is indicated above, this preference is suggested to be a major cause of concern for the spread of multiple nutrient imbalances. Given the good supply of quality manures, our observations favored the combined application of inorganic fertilizers and manures over sole application of either nutrient source. This is a strategy capable

Table 3. Economics of different INM-based treatments for Kharif onion production (In order of highest net return).

Treatments	¹ Cost, 000' INR/ha	² Benefit, 000' INR/ha	Net return, 000' INR/ha
T ₁₀ = 50% RDF + 50% Vm	15.94	80.00	64.86
T ₉ = 50% RDF + 50% PM	10.64	73.60	62.96
T ₇ = 50% RDF + 50% FYM	15.14	76.80	61.66
T ₂ = Current recommendation (RDF)	10.28	71.20	60.92
T ₆ = Vermicompost (Vm)	11.00	70.60	59.60
T ₈ = 50% RDF + 50% PiM	17.64	73.00	55.36
T ₁₆ = 75% RDF + PSB	9.96	62.40	52.44
T ₁₅ = 75% RDF + Azr	9.46	61.60	52.14
T ₁ = Control	2.50	54.00	51.50
T ₁₄ = 75% RDF + Az	9.46	60.02	50.56
T ₁₁ = 50% RDF + Az	8.14	58.20	50.06
T ₁₂ = 50% RDF + Azr	8.14	56.80	48.66
T ₁₃ = 50% RDF + PSB	8.64	56.40	47.76
T ₅ = Poultry manure (PM)	20.00	66.00	46.00
T ₃ = FYM	20.00	60.40	40.40
T ₄ = Pig manure (PiM)	25.00	62.20	37.20

¹Cost of treatments based on price of urea at INR 5/kg, SSP at INR 8/kg, KCl at INR 40/kg, PiM, PM and Vm at INR 2/kg, FYM at INR 1/kg, Azr and Azo at INR 50/kg, and PSB cultures at INR 100/kg. It also includes operational charges covering labor charges for land preparation and two weedings at INR 5,000/ha (USD 1 ≈ INR 44.41).

²Benefit based on minimum farm rate of onion at INR 20/kg.

of considering the sustainability of onion productivity as well as the preference to maintain a strong dependence on regional sources like FYM. 

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