Madras Agric. J., 2019; doi:10.29321/MAJ 2019.000322

RESEARCH ARTICLE

Balanced Fertilizer Prescription for Big Onion through Inductive Cum Targeted Yield Model on an Alfisol

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Received : 26th June, 2019
Revised : 10th July, 2019
Revised : 25th September, 2019
Accepted : 24th October, 2019

ABSTRACT

Field experiments were conducted on Typic Ustropept (Irugur soil series) soil of Southern Zone of Tamil Nadu by adopting the inductive cum targeted yield model, and fertilizer requirements were quantified for big onion based on soil test and yield target. The basic parameters *viz*., the nutrient requirement (NR) and contribution of nutrients from the soil (C_s), fertilizer (C_f), and farmyard manure (C_{fym}) were computed from the field experimental data. The fertilizer prescription equations were developed based on the basis of an integrated plant nutrition system (IPNS), and nomograms for the desired yield target of big onion for a range of soil test values. The extent of saving of inorganic fertilizer for big onion was computed using the fertilizer prescription equations under IPNS. The estimates showed that for the application of FYM @ 12.5 t ha^{-1} with 28 per cent moisture and 0.528, 0.286 and 0.520 per cent of N, P and K respectively when applied along with the N, P and K fertilizers as per soil test and desired yield target, the saving was 40, 20 and 33 kg of fertilizer N, P_2O_5 and K_2O respectively

Keywords: *Alfisol, big onion, prescription, STCR-IPNS.*

INTRODUCTION

In the modern era, precision agriculture technologies have a great role in sustaining soil fertility and enhancing crop productivity and profitability. Soil test based precise prescription found to be essential for maintaining crop productivity besides maintaining soil health. Though there is an increasing trend in the consumption among the Indian famers, there is no tremendous improvement in the achievement of use efficiency. Sustainable crop production can be possible only by efficient utilization of the resources including fertilzers. Major causes for the imbalanced fertilization among the farmers are an escalation in cost, non-uniform distribution, non-availability of fertilizers at times etc. which led to stagnated productivity and a steep reduction in soil health. Erratic rainfall, change in the cropping pattern, low productivity of indigenous milk animals, the introduction of exotic breeds for milking etc. in the semi-arid tropics like India, lead to the poor contribution of Farm Yard Manure. Depending solely on either inorganic fertilizers or organic sources is not practically possible. However, nutrient removal by crops far exceeds nutrient additions through fertilizers. An annual net negative balance of about 8-10 million tons of nutrients is reported in India (Tandon, 2007). Deterioration in soil health due to indiscriminate and imbalanced use of fertilizers, can be corrected and sustenance of soil health is possible only when fertilizers are prescribed based not only on soil testing but also with integrated use of possible organic sources with inorganic fertilizers.

Big onion *(Allium cepa var.cepa)* is one of the most important commercial vegetable crops cultivated extensively in India and the world. Onion is preferred for its flavour and pungency, which is due to the presence of a volatile sulphur compound allyl propyl disulfide and it is a rich source of minerals like phosphorus, calcium and carbohydrates, protein, vitamin C and quercetin a powerful antioxidant. It contains several anti-cancer agents which have shown to prevent cancer in animals (Yadav *et al.,* 2015).

India is the second-largest producer of onion in the world, next to China, accounting for 11.40 per cent of the area and 10.40 per cent of the world production and 16 per cent of productivity (Yadav *et al*., 2015). In the world, onion occupies an area of 3.64 m ha, with the production of 68.45 million tonnes and the average productivity being 18.82 t ha^{-1}. Onion crop removes about 90-95 kg ha^{-1} N, 30-35 kg ha^{-1} P_2O_5 and 50-55 kg

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ha^{-1} K_2O to produce 40 t ha^{-1} of the bulb (http://www.dogr.res.in). Wide variations are noticed in fertilizer prescription for onion. In Tamil Nadu, commonly, 100 kg N, 150 kg P_2O_5 and 75 K_2O kg ha^{-1} along with FYM @ 25 t ha^{-1} was followed as blanket recommendation.. Directorate of Onion and Garlic Research Centre recommends, 110, 40 and 60 kg ha^{-1} of N, P_2O_5 and K_2O respectively along with FYM @ 15 t ha^{-1} (equivalent to 75 kg ha^{-1}) for late Kharif and Rabi cultivation (http://www.dogr.res.in). In the conventional method, blanket recommendation is prescribed without considering the contribution from soil. The targeted yield approach (Ramamoorthy *et al*.1967) provides the scientific basis for balanced fertilization which in turn gives a real balance between applied nutrients and the available nutrients already present in the soil. Fertilizer prescription equations have been developed for cabbage (Smitha John,2004) carrot (Umadevi, 2005), radish (Vijayalakshmi, 2008), potato (Gayathri et al., 2009), ashwagandha (Santhi et al., 2010) and beetroot (Santhi et al., 2011) under IPNS based on this concept. In the present context, enhancing the productivity of vegetables like big onion, it is essential to develop fertilizer prescription equations for getting maximum yield and sustaining soil fertility.

MATERIAL AND METHODS

A field experiment was conducted with big onion during 2015–2016 on the Irugur soil series (Typic Ustropept) at (farmers' holding) Vellianvalsu in Dindigul District, Tamil Nadu, India. The surface soil (0–15 cm) of the experimental field is red non-calcareous, sandy loam in texture with pH 6.7 and electrical conductivity (EC) 0.06 dS m^{-1}. The initial soil available nutrients viz., alkaline $KMnO_4$-N, Olsen-P, and NH_4OAc-K were 156 kg ha^{-1}, 13.9 kg ha^{-1} and 221 kg ha^{-1}, respectively. The P and K fixing capacities of the soil were 100 and 120 kg ha^{-1}, respectively. The DTPA iron, manganese and copper were found to be in the sufficient range and DTPA-zinc found to be deficient.

Variation in soil fertility was created by adopting the inductive methodology developed by Ramamoorthy *et al*., (1967) as adopted in the All India Coordinated Research Project for investigation on Soil Test Crop Response Correlation (AICRP-STCR). The experimental field was divided into three equal strips and fertilized with three levels of N, P and K viz., $N_0P_0K_0$, $N_1P_1K_1$, and $N_2P_2K_2$ levels and a gradient crop of fodder sorghum (var. Co 30) were grown. By applying graded levels of fertilizers and by growing a gradient crop, the operational range of fertility levels in the three strips was created deliberately. Twenty four samples were collected from each strip before and after the harvest of the gradient crop and analyzed for alkaline $KMnO_4$-N, Olsen-P and NH_4OAc-K. After confirming the establishment of fertility gradients in the experimental field, in the second phase of the field experiment, each strip was divided into 24 plots and pre-sowing soil samples were collected from each plot and analyzed for alkaline $KMnO_4$-N (Subbiah and Asija, 1956), Olsen-P (Olsen *et al*., 1954) and NH_4OAc-K (Stanford and English, 1949). The experiment was laid out in a fractional factorial design comprising twenty four treatments with four levels of N (0, 50,100 and 150 kg ha^{-1}), four levels of P_2O_5 (0, 60, 120 and 180 kg ha^{-1}), four levels of K_2O (0, 40, 80 and 120 kg ha^{-1}) and three levels of FYM (0, 6.25 and 12.5 t ha^{-1}). The treatments of Integrated Plant Nutrition System (IPNS) *viz.,* NPK plus FYM @ 6.25 t ha^{-1} and NPK plus FYM @ 12.5 t ha^{-1} and the NPK alone treatments were superimposed across the strips. The 21 fertilizer treatments and three controls were randomized in such a way that all the 24 treatments were present in all the three strips in either direction. The treatment structure is given in Table 1. The full dose of FYM, half of N and a full dose of P_2O_5 and K_2O were applied basally and the seedlings were planted during September 2015. The remaining half of N was applied after 30 days of planting. The crop was grown to maturity and harvested during February 2016 and the fresh bulb yield was recorded plot-wise. From each plot, bulb and straw samples were collected, processed, and analyzed for N (Humphries, 1956), P, and K contents (Jackson, 1973), and the N, P and K uptake by big onion was computed using the total dry matter.

Calculation of basic parameters

Making use of the data on nutrient uptake, fresh bulb yield, pre-sowing soil available N, P and K, and applied fertilizer doses, the basic parameters viz., nutrient requirement (NR), contribution of nutrients from soil (C_s) and fertilizer s (C_f) were calculated as outlined by Ramamoorthy *et al*., (1967) and those from FYM (C_{fym}) were estimated as described by Santhi *et al*. (1999).

Nutrient requirement (NR) kg q^{-1}

$$\text{Kg N / } P_2O_5 \text{ / } K_2O \text{ required per quintal} = \frac{\text{Total uptake of N / } P_2O_5 \text{ / } K_2O \text{ (kg ha}^{-1})}{\text{Fresh bulb yield (q ha}^{-1})}$$

Per cent nutrient contribution from soil to total nutrient uptake (C_s)

$$\text{Per cent contribution of N / } P_2O_5 \text{ / } K_2O \text{ from soil} = \frac{\text{Total uptake of N / } P_2O_5 \text{ / } K_2O \text{ in control plot (kg ha}^{-1})}{\text{Soil test value for available N/ } P_2O_5 \text{ / } K_2O \text{ in control plot (kg ha}^{-1})} \times 100$$

Per cent nutrient contribution from to total uptake (C_f)

$$\text{Per cent contribution of N / } P_2O_5 \text{ / } K_2O \text{ from} = \frac{\text{Total uptake of N / } P_2O_5 \text{ / } K_2O \text{ in treated plot (kg ha}^{-1}) - \text{Soil test value for available N/ } P_2O_5 \text{ / } K_2O \text{ x Average Cs in treated plot (kg ha}^{-1})}{\text{N / } P_2O_5 \text{ / } K_2O \text{ applied(kg ha}^{-1})} \times 100$$

Percent contribution from organic manure (OM) (C_{fym})

$$\text{Per cent contribution from FYM} = \frac{\text{Total uptake of N / P/ K in FYM treated plot (kg ha}^{-1}\text{)} - \text{Soil test value for available N/ P/ K in FYM treated plot (kg ha}^{-1}\text{)}}{\text{Amount of N / P / K added through FYM (kg ha}^{-1}\text{)}} \times \text{Average CS} \times 100$$

Targeted yield equations under IPNS

Making use of these parameters, the prescription equations under IPNS are developed for various crops as furnished below.

i) Nitrogen (FN)

$$FN = \frac{NR}{C_f/100} \times T - \frac{C_s}{C_f} \times SN - \frac{C_{fym}}{C_f} \times ON$$

ii) Phosphorus (FP_2O_5)

$$FP_2O_5 = \frac{NR}{C_f/100} \times T - \frac{C_s}{C_f} \times 2.29 \times SP - \frac{C_{fym}}{C_f} \times 2.29 \times OP$$

iii) Potassium (FK_2O)

$$FK_2O = \frac{NR}{C_f/100} \times T - \frac{C_s}{C_f} \times 1.21 \times SK - \frac{C_{fym}}{C_f} \times 1.21 \times OK$$

where FN is N (kg ha^{-1}), FP_2O_5 is P_2O_5 (kg ha^{-1}), FK_2O is K_2O (kg ha^{-1}), NR is nutrient requirement of N or P_2O_5 or K_2O (kg q^{-1}), C_s is percentage contribution from fertilizer soil, C_f is percentage contribution from , SN is soil test value for available N (kg ha^{-1}), SP is soil test value for available P (kg ha^{-1}), SK is soil test value for available K (kg ha^{-1}), C_{fym} is percentage contribution from FYM, ON is quantity of N applied through FYM (kg ha^{-1}), OP is quantity of P applied through FYM(kg ha^{-1}), and OK is quantity of K applied through FYM(kg ha^{-1}).

These equations serve as a basis for predicting doses for specific yield targets (T) of big onion for a range of soil available nutrient levels.

RESULTS AND DISCUSSION

Bulb yield, uptake and soil available nutrient status

The bulb yield in strip I ranged from 10.5 to 29.07 t ha^{-1} with a mean of 23.96 t ha^{-1}, from 12.60 to 30.72 t ha^{-1} with a mean of 25.56 t ha^{-1} in strip II and from 13.4 to 31.65 t ha^{-1} with a mean of 26.63 t ha^{-1} in strip III (Table 2.). Strip II recorded a yield increase of 6.7 per cent over strip I and strip III recorded a yield increase of 11.1 and 4.18 per cent over strip I and strip II, respectively.

The data on nutrient uptake showed that the N uptake ranged from 36.0 to 99.9 kg ha^{-1} with a mean of 78.2 kg ha^{-1} in strip I, from 41.7 to 105.1 with a mean of 81.4 kg ha^{-1} in strip II and from 47.8 to 111.3 kg ha^{-1} with a mean of 84.4 kg ha^{-1} in strip III (Table 2). The per cent increase in mean N uptake of strip II over strip I was 4.1 and strip III over strip I and strip II was 7.9 and 3.7, respectively.

Table 1. Treatment structure of test crop experiment on big onion

Sl. No	Treatment combinations			Levels of nutrients (kg ha^{-1})		
	N	P	K	N	P_2O_5	K_2O
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	2	2	0	120	80
5	1	1	1	50	60	40
6	1	1	2	50	60	80
7	1	2	1	50	120	40
8	1	2	2	50	120	80
9	2	2	0	100	120	0
10	2	1	1	100	60	40
11	2	2	1	100	120	40
12	2	1	2	100	60	80
13	2	2	2	100	120	80
14	2	0	2	100	0	80
15	2	2	3	100	120	120
16	2	3	2	100	180	80
17	2	3	3	100	180	120
18	3	1	1	150	60	40
19	3	2	2	150	120	80
20	3	2	1	150	120	80
21	3	2	3	150	120	120
22	3	3	1	150	180	40
23	3	3	2	150	180	80
24	3	3	3	150	180	120

The P uptake ranged from 3.6 to 26.6 kg ha^{-1} with a mean of 20.5 kg ha^{-1} in the strip I, from 4.9 to 28.6 with a mean of 21.9 kg ha^{-1} in strip II and from 5.7 to 30.4 kg ha^{-1} with a mean of 23.7 kg ha^{-1} in strip III (Table 2.). The per cent increase in mean P uptake of strip II over strip I was 6.8 and strip III over strip I and strip II were 15.5 and 8.2 respectively.

Table 2. Range and mean values of available nutrients in the pre-sowing surface soil samples, bulb yield and nutrient uptake by big onion

Parameters (kg ha^{-1})	Strip I			Strip II			Strip III		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
$KMnO_4$-N	147	157	151	178	186	182	192	201	196
Olsen-P	11.0	14.8	12.8	15.6	20.2	18.3	22.0	27.4	24.5
NH_4OAC–K	226	238	233	260	274	268	279	291	287
Bulb yield (t ha^{-1})	10.50	29.07	23.96	12.60	30.72	25.56	13.40	31.65	26.63
N uptake	36.0	99.9	78.2	41.7	105.1	81.4	47.8	111.3	84.4
P uptake	3.6	26.6	20.5	4.9	28.6	21.9	5.7	30.4	23.7
K uptake	33.8	89.1	67.9	45.9	106.0	84.1	48.2	115.5	94.1

The K uptake ranged from 33.8 to 89.1 kg ha^{-1} with a mean of 67.9 kg ha^{-1} in strip I, from 45.9 to 106.0 with a mean of 84.1 kg ha^{-1} in strip II and from 48.2 to 115.5 kg ha^{-1} with a mean of 94.1 kg ha^{-1} in strip III (Table 2.).. As in N and P, the increase in mean K uptake was computed and the per cent increase of strip II over strip I was recorded to be 23.9 and strip III over strip I and strip II were 38.6 and 11.9 respectively.

Basic Parameters

Making use of the data on bulb yield of big onion, uptake of N, P and K, initial soil test values, and the doses of N, P_2O_5, and K_2O applied, the basic parameters were computed. The basic parameters for developing prescription equations for big onion are (i) nutrient requirement in kg per quintal of fresh bulb (NR), (ii) percentage contribution from soil available nutrients (C_s), (iii) percentage contribution from nutrients (C_f) and (iv) percentage contribution from FYM (C_{fym}).

Nutrient Requirement (NR)

The results emanated from the present investigation revealed that big onion requires 0.33 kg of N, 0.20 kg of P_2O_5 and 0.39 kg of K_2O for producing one quintal of fresh bulb (Fig. 1). The data revealed that the order of NR was K_2O>N>P_2O_5. Similar findings were reported by Santhi *et al.,* (2011).

Table 3. Estimates of soil test based fertilizer doses (kg ha^{-1}) for desired yield targets of Big onion

Parameter	NPK alone (kg ha^{-1})	NPK+ FYM @ 12.5 t ha^{-1} (kg ha^{-1})	Reduction over NPK alone (%)	NPK alone (kg ha^{-1})	NPK+ FYM @ 12.5 t ha^{-1} (kg ha^{-1})	Reduction over NPK alone (%)
	Bulb yield target-30.0 t ha^{-1}			Bulb yield target-32.0 t ha^{-1}		
$KMnO_4$-N (kg ha^{-1})						
150	149	109	26.9	165	125	24.3
180	131	91	30.6	147	107	27.2
200	119	79	33.6	135	95	29.7
220	107	67	37.4	123	83	32.5
240	95	55	42.1	111	71	36.1
260	83	43	48.1	99	59	40.4
Olsen-P (kg ha^{-1})						
10	155	135	12.7	166	147	11.8
14	146	127	13.4	158	138	12.4
18	138	118	14.2	149	130	13.1
20	134	114	14.7	145	126	13.5
22	129	110	15.1	141	121	13.9
24	125	106	15.6	137	117	14.3
NH_4OAc-K (kg ha^{-1})						
200	117	84	28.1	129	96	25.5
220	111	78	29.8	123	90	26.9
240	104	71	31.7	116	83	28.4
260	97	64	33.8	110	77	30.1
280	91	58	36.3	103	70	32.0
300	84	51	39.1	97	64	34.2

Per cent contribution from soil (C_s), s (C_f) and FYM (C_{fym})

The per cent contribution towards the uptake of N, P and K from soil was 24.69, 32.05 and 17.50 per cent respectively (Fig. 2). Among the three nutrients, the contribution of soil towards P_2O_5 is high, followed by N and K_2O. The per cent contribution of N, P and K from was 41.20, 34.99 and 64.12 per cent respectively. The order of contribution towards N, P and K was K_2O>N>P_2O_5. The per cent contribution of N, P_2O_5 and K_2O from FYM (Cfym) were 40.13, 19.58 and 32.98, respectively. Among the three nutrients, FYM contribution was more towards N than P_2O_5 and K_2O. Similar trend of results for Cs, Cf, and Cfym for N, P_2O_5, and K_2O were reported by Vijayalakshmi (2008) and Santhi *et al*., (2010).

Fertilizer prescription equations and optimization of doses for big onion

Making use of the basic parameters (NR, Cs and Cfym), the prescription equations under NPK alone for big onion were developed and are furnished below:

Fertilizer prescription equations for big onion under NPK alone and under IPNS

	STRC-NPK alone	STCR-IPNS
FN =	0.80 T - 0.60 SN	FN = 0.80 T - 0.60 SN - 0.84 ON
FP_2O_5 =	0.58 T - 2.10 SP	FP_2O_5 = 0.58 T - 2.10 SP -0.87 OP
FK_2O =	0.61 T - 0.33 SK	FK_2O = 0.61 T - 0.33 SK - 0.70 OK

where, FN, FP_2O_5 and FK_2O are N, P_2O_5 and K_2O in kg ha^{-1}, respectively; T is the fresh bulb yield target in q ha^{-1} ; SN, SP and SK respectively are alkaline $KMnO_4$-N, Olsen-P and NH_4OAc-K in kg ha^{-1} and ON, OP and OK are the quantities of N, P and K in kg ha^{-1} supplied through FYM.

Fertilizer requirements for big onion under IPNS

A ready reference table was prepared based on the above equations for a range of soil test values and the fresh bulb yield target of 30 and 32 t ha^{-1} under NPK alone and NPK+ FYM @ 12.5 t ha^{-1} (Table 4). The data evidently indicated that the N, P_2O_5, and K_2O requirements decreased with increase in soil test values of N, P and K. For the soil test values of 180:20:280 kg ha^{-1} of $KMnO_4$-N, Olsen P, and NH_4OAc-K, the quantity of N, P_2O_5, and K_2O doses required for a yield target of 30 and 32 t ha^{-1} were 131, 134, and 91 kg ha^{-1} and 147, 145, and 103 kg ha^{-1}, respectively. At the same time, when FYM (28 per cent moisture and 0.528, 0.286 and 0.520 per cent of N, P and K) at 12.5 t ha^{-1} was applied along with NPK, the required fertilizer N, P_2O_5, and K_2O doses were 91, 114, and 58 kg ha^{-1} and 107, 126, and 70 kg ha^{-1}, respectively.

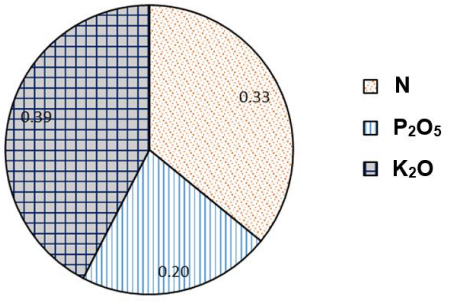

Figure 1. Nutrient requirement for big onion

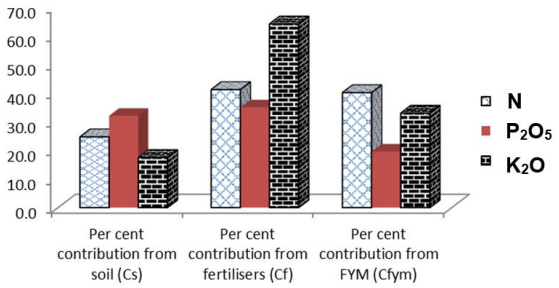

Figure 2. Contribution of nutrients from soil, and FYM for big onion

The extent of saving of inorganic fertilizers for big onion was computed using the fertilizer prescription equations under IPNS. Under STCR-IPNS, the 40, 20 and 33 kg of fertilizer N, P_2O_5 and K_2O respectively for NPK plus FYM at 12.5 t ha^{-1} can be reduced from the recommended doses of fertilizers for a particular soil test value and yield target. Balanced supply of nutrients from fertilizer, efficient utilization of applied fertilizer nutrients in the presence of organic sources and the synergistic effect of the conjoint addition of various sources of nutrients using targeted yield concept were reported by Sellamuthu *et al*., (2013) in radish and Muralidharudu *et al.,* (2011) and Dey and Das (2014) in various crops. Bhaduri and Gautam (2012) and Sellamuthu *et al.,* (2015) demonstrated the balanced use of fertilizers and FYM to enhance nutrient recovery and productivity of wheat.

CONCLUSION

In the present study, soil test based fertilizer prescriptions for big onion has been developed on the Irugur soil series (Typic Ustropept) of Tamil Nadu, India. Considering the nutrient requirement and contribution of NPK from soil, fertilizer and FYM which forms a balanced supply of nutrients through IPNS to enhance the yield of big onion and to sustain soil health. By adopting STCR-IPNS based fertilizer prescription for big onion in red non calcareous soils of Tamil Nadu (Irugur series), 40, 20 and 33 kg of fertilizer N, P_2O_5 and K_2O respectively can be reduced from the recommended doses of fertilizers for a particular soil test value and yield target.

ACKNOWLEDGEMENT

The authors express sincere thanks to the Indian Council of Agricultural Research, New Delhi and Tamil Nadu Agricultural University, Coimbatore for funding AICRP-STCR.

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