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RESEARCH ARTICLE

Development of Soil Test Based Fertilizer Prescription Equations for Chrysanthemum on Alfisol

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ABSTRACT

Field experiments were conducted during 2017 – 2018 to develop fertiliser prescriptions equations (FPEs) through IPNS for the desired yield targets of Chrysanthemum on Udic Haplustalf . The fertilisers prescription equations (FPEs) were developed under NPK alone and under IPNS for the desired yield target of Chrysanthemum by using the basic parameters. The variation observed in the achievement of targets was within the range of ± 10 per cent (90 – 110%) proving the validity of FPEs. Hence, the Inductive cum Targeted yield approach applied to develop fertiliser equations provides a strong basis for maintenance of soil fertility with high productivity and efficient nutrient management in "Precision Farming" for sustainable and enduring Agriculture.

Keywords: *Chrysanthemum; Alfisol; STCR-IPNS; Fertiliser prescription equations;Yield target*

INTRODUCTION

Horticulture has emerged as an indispensable part of agriculture, offering a wide range of choices to the farmers for crop diversification. It also provides ample opportunities for sustaining large number of agro-industries which generate substantial employment. The horticulture sector contributes about 24.5% of the GDP from 8% of the area. India has a reputation throughout the world as a soft power and now 'flower power' is blooming, as the country emerges as the second largest producer of flowers around the world, next to China. Floriculture is an age old farming activity in India having immense potential for generating self-employment among small and marginal farmers. In the recent years it has emerged as a profitable agri-business in India and worldwide. The annual domestic demand for the flowers is growing at a rate of over 25%.

Chrysanthemum is one of the important flower crops commercially grown in different parts of the world. In India, commercial cultivation of this flower has good demand. Chrysanthemum flowers are mainly used for garland making, religious offering and as cut flowers for party arrangements. The species of Chrysanthemum have shallow root system with herbaceous perennial nature growing about 50 – 150 cm with deeply lobed leaves and large flower heads, yellow, pink or white. Basically, the Chrysanthemum is short day plant, in other words, it requires long days for vegetative growth and short days for flowering. The best suitable soil for Chrysanthemum cultivation is well drained sandy loam good textured soils. Having good amount of organic matter will result in excellent yield. Avoid soils where too much of water stagnation is possible. The optimum soil pH range for its growth is 6.5 – 7.5.

Over-exploitation of soils over many decades has resulted in the exhaustion of the agricultural production systems and steadily declining crop and soil productivity in long term experiments (Bhandari *et al.,* 2002; Ladha *et al.,* 2003; Manna *et al.,* 2005). The decision on fertiliser use requires knowledge of the expected crop yield response to nutrient application, which is a function of crop nutrient needs, supply of nutrients from indigenous sources, and the fate of fertilizer applied (Dobermann *et al.,* 2003).

The concept of 'Soil test based fertiliser recommendation' emphasize the much needed approaches namely, 'Fertilizing the soil' versus 'Fertilizing the crop' confirming for real balance (not apparent balance) between the applied fertilizer nutrients among themselves and with the soil available nutrients, in the era of precision agriculture. Truog (1960) illustrated the possibility of 'Prescription method' of fertilizer use for obtaining high yield of corn using empirical values of nutrient availability from soil and fertilizer. However, Ramamoorthy and his associates developed the theortical basis and field experimental proof and validation for the fact that Liebig's Law of Minimum of Plant nutrition during 1965-67 (Liebig, 1855) works equally well for N, P and K for the high yielding varieties of wheat, rice and pearl millet, although

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it is generally found that this law is valid for N and not for P and K which were supposed to follow the percentage sufficiency concept of Mitscherlich and Baule and Mitscherlich and Bray. Among the various methods of computing fertilizer recommendations, the one based on yield targeting is unique in the sense that this approach not only indicates soil test based fertilizer dose but also the level of yield the farmer can hope to achieve, if good cultivation package is adopted (Velayutham, 1979).

In the "Inductive Approach" of STCR field experimentation, all the needed variation in soil fertility level obtained not by selecting soils at various locations as in previous agronomic trials, but by deliberately creating it in one and the same field experiment in order to reduce heterogeneity in the soil population (types and units) studied, management practices adopted and climatic conditions. Ramamoorthy and Velayutham (1971, 1972 & 1974) have explained this Inductive approach and the STCR field design, which is also quoted by Black (1993). The experimental data can be used for calculating fertilizer recommendation for maximum yield and profit and for desired yield targets of crops. Field specific balanced amounts of N, P and K were prescribed based on crop based estimates of indigenous supply of N, P and K and by modelling the expected yield response as a function of nutrient interaction (Dobermann and White 1998; Witt *et al.,* 1999). Sakarvadia *et al.* (2012) found yield targeting approach was effective in soil fertility built up. Khosa *et al*. (2012) also reported the superiority of target yield concept over other practices for different crops as it gave higher yields and optimal economic returns. The specific yield equation based on soil health simultaneously ensuring sustainable crop production also steers the farmers towards economic use of costly fertiliser inputs depending on their financial condition and prevailing market price of the crop under consideration (Bera *et al*., 2006).

Using this model, the developed fertiliser prescription equations can be applied to Inceptisols of all tropical regions by substituting the soil nutrient status of the particular field. Moreover, the adopted methodology in the present investigation can very well be used to derive fertilizer prescription equations for any field or horticultural crop (except perennial crops) on any soil series. With this background, the present investigation was carried out in Chrysanthemum on Alfisol so as to elucidate the significant relationship between soil test values and crop response to fertilizers, to develop fertiliser prescription equations under STCR and STCR-IPNS for desired yield target of chrysanthemum and to test verify the validity of fertiliser prescription equations developed for chrysanthemum.

MATERIALS AND METHODS

Studies were conducted by adopting the Inductive cum Targeted yield model so as to develop Soil Test Crop Response based Integrated Plant Nutrition System (STCR – IPNS) equations on a Udic Haplustalf of Tamil Nadu. The field experiments were carried out in three phases *viz.,* Phase I with fertility gradient experiment with fodder *sorghum var.* CO 30, Phase II with test crop experiment with chrysanthemum hybrid poornima and Phase III with validation experiments with chrysanthemum hybrid poornima. The details about field experiments, methods of soil and plant analysis and the methodology adopted for development of prescription equation are presented below.

Basic concept

The prescription procedure outlined by Trough (1960) and modified by Ramamoorthy *et al.* (1967) as "Inductive cum Targeted yield model" was adopted in this study. This provides a scientific basis for balanced fertilization and balance between applied nutrients and soil available nutrients. Operational range of variation in soil fertility was created deliberately to generate data covering appropriate range of values for each controllable variable (fertilizer dose) at different levels of uncontrollable variable (soil fertility) which could not be expected to occur at one place normally. Hence, a gradient experiment was conducted prior to the test crop experiment in order to create fertility variation in the same field and also to reduce the heterogeneity in the soil population studied, management practices adopted and climate conditions prevailing.

Materials

Both gradient and test crop trails were conducted at Kadayampatti, Kadayampatti Block, Salem Dt on Alfisol (Udic Haplustalf). This field is situated in the Northwestern zone of Tamil Nadu with north latitude of 11º52'0.12" and east longitude of 78º07'0.12" and an altitude of 282 m above MSL. The season during which gradient crop experiment conducted was June to August 2017 (Kharif) and test verification experiment during September to October 2017 (Rabi). The soil series of the experimental field is Somayanur with taxonomical expression as Udic Haplustalf. The type, texture, reaction and salinity of soil was coarse, sandy clay loam, neutral (pH 7.45) and non – saline (EC 0.76 dS m^{-1}) respectively. Further, the soil is isohyperthermic in thermal regimes and calcareous in lime status. The soil fertility status was low in available N (174 kg ha^{-1}), high in available P (30.4 kg ha^{-1}) and medium in available K (316.0 kg ha^{-1}). The sufficient range of available Zn, Cu AND Mn (8.76, 2.35 and 6.88 mg kg^{-1} respectively) and deficient range of available Fe

(0.43 mg kg^{-1}). The P and K fixing capacities of the soil were 100 and 80 kg ha^{-1}.

Experimental Design

The approved treatment structure and lay out design ie "Inductive cum Targeted yield model" Ramamoorthy *et al.* (1967) as followed in the All India Coordinated Research Project for Investigations on Soil Test Crop Response Correlation (AICRP-STCR) was adopted in the present investigation.

Gradient experiment and soil and plant analysis

Operational range of variation in soil fertility was created deliberately in the gradient experiment. The experimental field was divided into three equal strips, the first strip received no fertilizer ($N_0 P_0 K_0$), the second and third strips received one ($N_1 P_1 K_1$) and two ($N_2 P_2 K_2$) times the standard dose of N, P_2O_5 and K_2O respectively in order to create operational range of variation and a gradient crop of fodder sorghum (*var.* CO 30) was grown. Pre-sowing and post-harvest soil samples were collected from eight spots of each fertility strip and subjected to analysis for alkaline $KMnO_4$-N (Subbiah and Asija, 1956), Olsen-P (Olsen *et al.,* 1954) and NH_4OAc-K (Stanford and English, 1949). Plant samples were collected at harvest, processed and analyzed for N (Humphries, 1956), P and K contents (Jackson, 1973) and NPK uptakes were computed.

Test crop experiment and soil and plant analysis

After confirming the establishment of fertility gradients in the experimental field, each strip was divided into 24 plots. Initial soil samples were collected from each plot and subjected to analysis for alkaline $KMnO_4$-N, Olsen-P and NH_4OAc-K. The design of the experiment was fractional factorial comprising twenty four treatments. The test crop experiment with chrysanthemum was conducted with four levels each of N (0, 80, 160 and 240 kg ha^{-1}), P_2O_5 (0, 50, 100 and 150 kg ha^{-1}) and K_2O (0, 25, 50 and 75 kg ha^{-1}) and three levels of FYM (0, 6.25 and 12.5 t ha^{-1}). The experiment was conducted as per the approved guidelines and norms prescribed by AICRP-STCR and fertilizer recommendations were developed.

The treatments *viz.,* NPK alone, NPK+FYM @ 6.25 t ha^{-1} and NPK+FYM @ 12.5 t ha^{-1} were superimposed across the strip. There were 21 fertilizer treatments along with three controls which were randomized in each strip in such a way that all the treatments occurred in both the directions. The treatment structure and lay out are given in Fig. 1. The fertilisers viz., urea, single super phosphate and muriate of potash were used as sources of NPK nutrients. The crop was grown to maturity, harvested and plot wise flower yield was recorded. The flower and plant samples of chrysanthemum and soil samples after the harvest of crops were collected from each plot. As done in gradient crop, the soil and plant samples were processed and analyzed for NPK and NPK uptake by chrysanthemum was computed using the dry matter yield.

Basic parameters for fertilizer prescription equations

The data on flower yield of chrysanthemum, total uptake of N, P and K, initial soil test values for available N, P and K and doses of fertilizer N, P_2O_5 and K_2O were used to compute the basic parameters *viz.,* nutrient requirement (NR), contribution of nutrients from soil (Cs), fertilizer (Cf) and farm yard manure (Cfym) as outlined by Ramamoorthy *et al.* (1967).

Nutrient Requirement (NR):

kg of N/P_2O_5/K_2O required per quintal (100 kg) of chrysanthemum flower production, expressed in (kg q^{-1}).

NR=(Total uptake of N or P_2O_5 or K_2O in control plot (kg ha^{-1})) Chrysanthemum flower yield (q ha^{1}) ----- (1)

Per cent contribution of nutrients from soil to total nutrient uptake (Cs):

Cs = [(Total uptake of N or P_2O_5 or K_2O in control plot (kg ha^{-1})] / (Soil test value for available N or P_2O_5 or K_2O in control plot (kg ha^{-1}))*100 ------ (2)

2.4.3. Per cent contribution of nutrients from fertilizer to total nutrient uptake (Cf):

Cf = {[(Total uptake of N or P_2O_5 or K_2O in treated plot (kg ha^{-1})) - (Soil test value for available N or P_2O_5 or K_2O in control plot (kg ha^{-1}) * Average Cs)]/Fertilizer N or P_2O_5 or K_2O applied (kg ha^{-1})}* 100 ------ (3)

Per cent contribution of nutrients from organics to total nutrient uptake (Co):

Per cent contribution from FYM (Cfym):

Cfym = {[(Total uptake of N or P_2O_5 or K_2O in treated plot (kg ha^{-1})) – (Soil test value for available N or P_2O_5 or K_2O in FYM treated plot (kg ha^{-1}) * Average Cs)]/Nutrient added through FYM (kg ha^{-1})}*100 ----- (4)

By making use of these basic parameters, prescription equations were developed for deriving fertilizers doses. Hence, the soil test based fertilizer recommendations were prescribed in the form of a ready table for desired yield target of chrysanthemum under NPK alone as well as under IPNS.

Fertilizer prescription equations

Making use of these parameters, the fertilizer prescription equations (FPEs) were developed for chrysanthemum below.

1. Fertilizer nitrogen (FN):

FN = {[(NR / (Cf/100))*T] – [(Cs/Cf)*SN]}

FN = {[(NR / (Cf/100))*T] – [(Cs/Cf)*SN] – [(Cfym/Cf)*ON]}

2. Fertilizer phosphorus (FP_2O_5)

FP_2O_5 = {[(NR / (Cf/100))*T] – [(Cs/Cf)*2.29SP]}

FP_2O_5 = {[(NR / (Cf/100))*T] – [(Cs/Cf)*2.29SP] – [(Cfym/Cf)*2.29SP]}

3. Fertilizer potassium (FK_2O)

FK_2O = {[(NR / (Cf/100))*T] – [(Cs/Cf)*1.21SK]}

FK_2O = {[(NR / (Cf/100))*T] – [(Cs/Cf)*1.21SK] – [(Cfym/Cf)*1.21SK]}

where, FN, FP_2O_5 and FK_2O are fertiliser N, P_2O_5 and K_2O in kg ha^{-1}, respectively; NR is nutrient requirement (N or P_2O_5 or and K_2O) in kg q^{-1}, Cs is per cent contribution of nutrients from soil, Cf is per cent contribution of nutrients from fertilizer, Cfym is per cent contribution of nutrients from FYM, T is the grain 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 in kg ha^{-1}.

These equations serve as a basis for predicting fertilizer doses for specific yield targets (T) of chrysanthemum for varied soil available nutrient levels.

RESULTS AND DISCUSSION

Chrysanthemum flower yield and Uptake (Figure 3 and 4)

The range and mean values of the chrysanthemum flower yield are furnished in Table 1. The chrysanthemum flower yield ranged from 11.16 t ha^{-1} in absolute control of strip I to 21.01 t ha^{-1} in $N_{240}P_{150}K_{75}$+FYM @ 12.5 t ha^{-1} of strip III. The mean flower yield of 15.83, 17.78 and 18.77 respectively in strip I, II and III. The N, P and K uptake by chrysanthemum varied from 71.09 to 194.1, 14.93 to 48.89 and 130.3 to 217.5 kg ha^{-1} respectively in strip I, II and III.

Table 1 Pre-sowing soil available NPK, chrysanthemum flower yield and NPK uptake by chrysanthemum (kg ha^{-1})

Parameters (kg ha^{-1})	Strip I		Strip II		Strip III	
	Range	Mean	Range	Mean	Range	Mean
KMnO4-N	159 – 166	163	174 – 186	181	193 – 205	199
Olsen-P	26.0 – 27.9	26.8	35.1 – 39.0	37.3	43.8 – 50.4	47.0
NH4OAc-K	283 – 295	288	324 – 337	329	344 – 356	350
Flower yield (t ha^{-1})	11.16 – 17.86	15.83	12.13 – 20.34	17.78	13.32 – 21.01	18.77
N uptake	71.09 – 165.90	131.6	86.57 – 188.9	147.0	94.40 – 194.1	156.4
P uptake	14.93 – 43.10	34.22	19.10 – 46.05	38.14	20.21 – 48.89	41.7
K uptake	130.3 – 190.1	161.8	145.69 – 210.11	177.8	169.0 – 217.5	190.1

The mean $KMnO_4$-N was 163, 181 and 199 kg ha^{-1}, respectively in strip I, II and III. The mean Olsen-P values were 26.8, 37.3 and 47.0 respectively in strip I to III and the mean NH_4OAc-K values were 288, 329 and 350 in strip I, II and III respectively (Table 1 and Figure 2).

The existence of operational range of soil test values for available N, P and K status was clearly found from the initial soil available nutrient status, variations in the chrysanthemum flower yield and NPK uptake, which are prerequisite for calculating the basic parameters, computing fertilizer prescription equations and for calibrating the fertilizer doses for specific flower yield target of chrysanthemum.

Table 2 Response of chrysanthemum to different levels of fertilisers

S. No.	Nitrogen (N)			Phosphorus (P_2O_5)			Potassium (K_2O)		
	Level (kg ha^{-1})	Response (kg)	Response Ratio (kg kg^{-1})	Level (kg ha^{-1})	Response (kg)	Response Ratio (kg kg^{-1})	Level (kg ha^{-1})	Response (kg)	Response Ratio (kg kg^{-1})
1.	80	972	12.15	50	404	8.09	25	370	14.79
2.	160	2394	19.95	100	997	9.97	50	824	16.48
3.	240	3683	23.02	150	1537	11.83	75	1487	19.82

Response of chrysanthemum to fertilizer N, P_2O_5 and K_2O (Figure 5a, 5b and 5c)

The response of the crop to applied fertilizer nutrients largely determines the optimization of nutrients. The plant growth and yield are significantly influenced by the application of N, P and K. The response of chrysanthemum to different levels of fertilizer N, P_2O_5 and K_2O were calculated in terms of response ratio (RR). The response of chrysanthemum to fertilizer N, P_2O_5 and K_2O is depicted in Table 2. The progressive increase in response for N, P_2O_5 and K_2O levels was observed from N_{80} to N_{240}, P_{50} to P_{150} and K_{25} to K_{75}, respectively and the highest RR of N recorded was 23.02 at $N_{240.}$ Similar pattern of the highest RR of 11.83 and 19.82 at P_{150} and K_{75} was noticed for phosphorus and potassium, respectively.

STRIP I	STRIP II	STRIP III	
OUTS			
$N_2 P_3 K_2$	$N_0 P_0 K_0$	$N_2 P_2 K_1$	**NPK alone B I**
$N_2 P_1 K_1$	$N_2 P_2 K_3$	$N_1 P_1 K_1$	
A $N_1 P_1 K_2$	**B** $N_1 P_2 K_1$	**C** $N_2 P_3 K_3$	
$N_3 P_3 K_2$	$N_3 P_3 K_3$	$N_2 P_1 K_2$	
$N_1 P_2 K_2$	$N_2 P_2 K_2$	$N_0 P_0 K_0$	
$N_3 P_1 K_1$	$N_2 P_0 K_2$	$N_0 P_2 K_2$	
$N_2 P_2 K_0$	$N_3 P_2 K_1$	$N_3 P_3 K_1$	
$N_0 P_0 K_0$	$N_3 P_2 K_3$	$N_3 P_2 K_2$	
OUTS			
$N_0 P_0 K_0$	$N_2 P_2 K_1$	$N_2 P_3 K_2$	**NPK + FYM @ 6.25 t ha^{-1} B II**
$N_2 P_2 K_3$	$N_1 P_1 K_1$	$N_2 P_1 K_1$	
B $N_1 P_2 K_1$	**C** $N_2 P_3 K_3$	**A** $N_1 P_1 K_2$	
$N_3 P_3 K_3$	$N_2 P_1 K_2$	$N_3 P_3 K_2$	
$N_2 P_2 K_2$	$N_0 P_0 K_0$	$N_1 P_2 K_2$	
$N_2 P_0 K_2$	$N_0 P_2 K_2$	$N_3 P_1 K_1$	
$N_3 P_2 K_1$	$N_3 P_3 K_1$	$N_2 P_2 K_0$	
$N_3 P_2 K_3$	$N_3 P_2 K_2$	$N_0 P_0 K_0$	
OUTS			
$N_2 P_2 K_1$	$N_2 P_3 K_2$	$N_0 P_0 K_0$	**NPK + FYM @ 12.5 t ha^{-1} BIII**
$N_1 P_1 K_1$	$N_2 P_1 K_1$	$N_2 P_2 K_3$	
C $N_2 P_3 K_3$	**A** $N_1 P_1 K_2$	**B** $N_1 P_2 K_1$	
$N_2 P_1 K_2$	$N_3 P_3 K_2$	$N_3 P_3 K_3$	
$N_0 P_0 K_0$	$N_1 P_2 K_2$	$N_2 P_2 K_2$	
$N_0 P_2 K_2$	$N_3 P_1 K_1$	$N_2 P_0 K_2$	
$N_3 P_3 K_1$	$N_2 P_2 K_0$	$N_3 P_2 K_1$	
$N_3 P_2 K_2$	$N_0 P_0 K_0$	$N_3 P_2 K_3$	

Fig. 1. Layout plan of STCR-IPNS experiment with chrysanthemum *Basic parameters (Table 3)*

The basic parameters for developing fertilizer prescription equations for chrysanthemum in the targeted yield model are (i) nutrient requirement (NR) in kg per quintal of chrysanthemum flower yield, (ii) per cent contribution of nutrients from soil (Cs), (iii) per cent contribution of nutrients from fertilizers (Cf) and (iv) per cent contribution of nutrients from farmyard manure (Cfym).

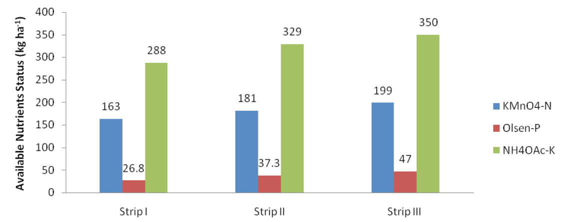


Fig. 2. Effect of operattional Range of Variations on nutreint status

The basic parameters were computed by making use of data i.e. yield of chrysanthemum, total uptake of N, P and K, initial soil test values for available N, P and K and doses of fertilizer N, P_2O_5 and K_2O applied,.

Nutrient requirement of chrysanthemum (Figure 6)

Application of adequate amount of nutrients is a pre-requisite for getting optimum yield of any crop. The N, P_2O_5 and K_2O requirement to produce one quintal (100 kg) of chrysanthemum flower yield was 0.83, 0.50 and 1.21 kg respectively. In the present study, while comparing the nutrient requirements, the requirement of K_2O was higher which is followed by N and P_2O_5. The K_2O requirement was 1.46 times higher than N and 2.42 times higher than $P_2O_{5.}$

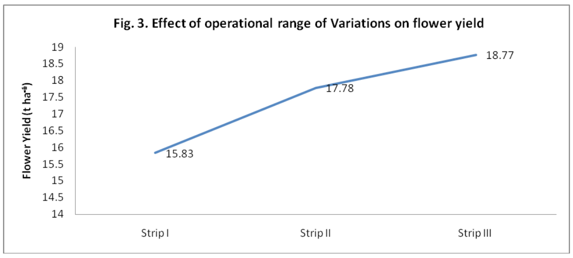


Fig. 3. Effect of operational range of Variations on flower yield

Per cent contribution of nutrients from soil (Cs) and fertilizers (Cf) to total uptake of chrysanthemum (Figure 7a and 7b)

The per cent contribution of nutrients from soil (Cs) actually depicts the capacity of the crop to extract nutrients from soil. Hence, it is calculated from the absolute control plots. The contribution of soil available N, P and K towards the total N, P and K uptake by chrysanthemum was 46.94, 52.05 and 47.08 per cent respectively (Table 3). The nutrient contribution of the soil to chrysanthemum was relatively higher for P_2O_5 as compared to that by N and K_2O.

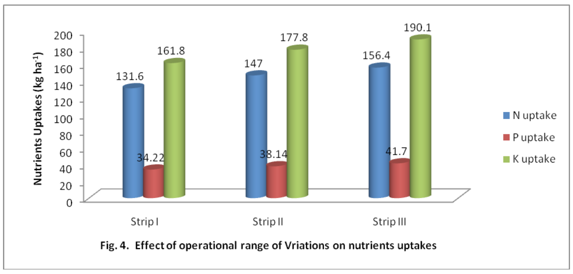


Fig. 4. Effect of operational range of Vriations on nutrients uptakes

The per cent contribution from fertilizer nutrients (Cf) towards the total uptake by chrysanthemum was 41.03, 46.53 and 76.95, respectively for N, P_2O_5 and K_2O and followed the order of $K_2O > P_2O_5 > N$ (Table 3). The magnitude of contribution by fertilizer K_2O was 1.65 times higher than P_2O_5 1.88 as that of N. The contribution from fertilizers was higher than from the soil for all the three nutrients.

Table 3. Nutrient requirement, per cent contribution from soil, fertilizer and FYM (%) for chrysanthemum

Parameters	Basic data		
	N	P_2O_5	K_2O
Nutrient requirement (kg q^{-1})	0.83	0.50	1.21
Per cent contribution from soil (Cs)	46.94	52.05	47.08
Per cent contribution from fertilizers (Cf)	41.03	46.53	76.95
Per cent contribution from FYM (Cfym)	27.39	32.10	47.71

Contribution of nutrients from FYM (Figure 7c)

The contribution of nutrients from FYM is to be quantified to envisage the extent to which the fertilizer requirements of chrysanthemum can be reduced under IPNS. Hence, the fourth basic parameters for the targeted yield model, the per cent contribution of N, P_2O_5 and K_2O from FYM was computed. The estimated contribution of N, P_2O_5 and K_2O from FYM (Cfym) were 27.39, 32.10 and 47.71 per cent respectively for chrysanthemum (Table 3) which indicated that relatively higher contribution was recorded for K_2O followed by N and P_2O_5. The present findings corroborated with the findings of (40, 20 and 30 kg of fertilise N, P_2O_5, K20 could be added through FYM) Santhi *et al.* (2002) and Saranya et al. (2012) and the response yardstick recorded was 4.66 kg kg^{-1}.

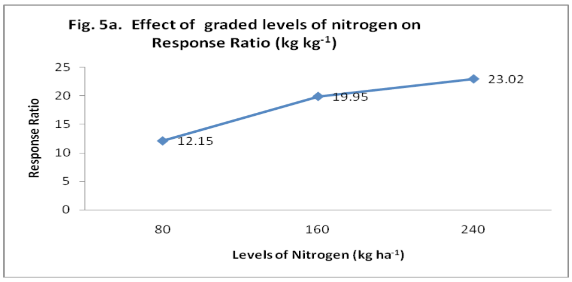


Fig. 5a. Effect of graded levels of nitrogen on Response Ratio (kg kg^{-1})

Fertilizer prescription equations for chrysanthemum

Fertilizer response is represented by the functional relationship between increase in flower yield and added fertilizers. It can be expressed graphically or algebraically by an equation. Milap Chand *et al.* (2006) stated that the superiority of the targeted yield concept over other practices for different crops as it gave higher yield, net benefit and optimal economic returns.

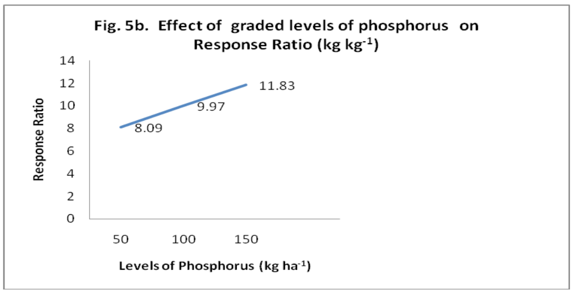


Fig. 5b. Effect of graded levels of phosphorus on Response Ratio (kg kg^{-1})

The yield targets were achieved within reasonable limits when the fertilizer was applied on soil test basis in majority of the crops thus estabilishing the utility of the prescription equations for recommending soil test based fertilizer application to the farmers. With this background, in the present investigation, soil test based fertilizer prescription equations for desired yield target of chrysanthemum was developed using the basic parameters obtained.

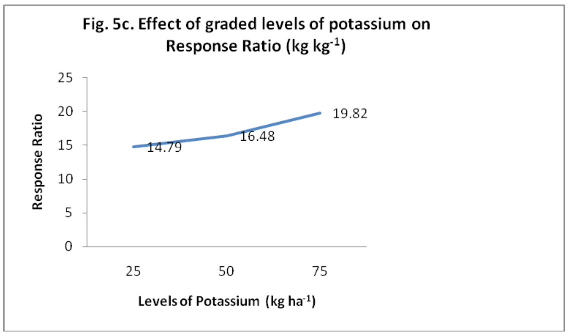
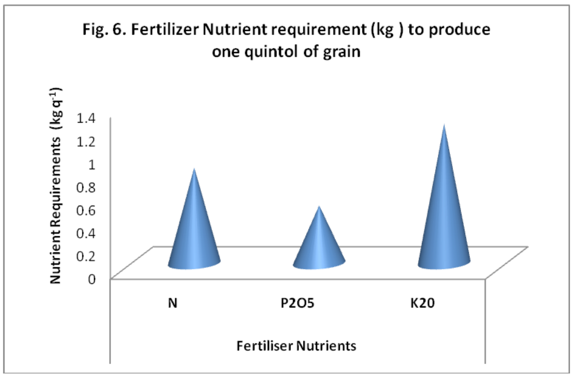
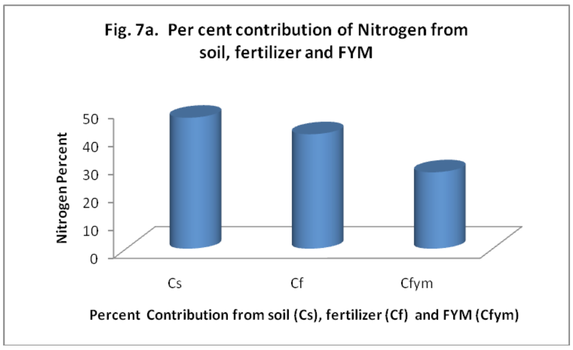


Fig. 5c. Effect of graded levels of potassium on Response Ratio (kg kg^{-1})

The data clearly revealed the fact that fertilizer N, P_2O_5 and K_2O requirements decreased with increase in soil test values and increased with increase in flower yield targets.



The development of fertiliser prescription equation on Chrysanthemum in accordance with the soil test and yield target based fertilizer prescriptions under IPNS for 25 crops comprising cereals, millets, pulses, oilseeds, sugarcane, cotton, vegetable, spices and medicinal crops on 14 soil series for Tamil Nadu by Santhi *et al.* (2012)



Soil test based fertilizer prescription equations for desired yield target of chrysanthemum were formulated using the basic parameters (Table 4a, 4b and 4c) and are furnished below:

STCR-NPK alone	STCR-IPNS (NPK + FYM)
FN = 2.01 T-1.14 SN	FN = 2.01 T- 1.14 SN –0.67 ON
FP_2O_5 = 1.08 T-2.56 SP	FP_2O_5 = 1.08 T- 2.56 SP -0.69 OP
FK_2O = 1.57 T-0.74 SK	FK_2O = 1.57 T- 0.74 SK -0.62 OK

where, FN, FP_2O_5 and FK_2O are fertiliser N, P_2O_5 and K_2O in kg ha^{-1}, respectively; T is the flower 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.

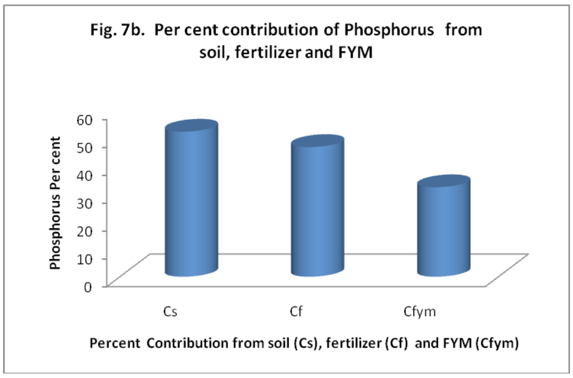
Fertilizer prescription under IPNS for desired yield target of chrysanthemum

(Table 4a, 4b and 4c)

A ready reckoned table was prepared by making use of fertiliser prescription equations for a range of soil test values and for a flower yield target of 175 q ha^{-1} for chrysanthemum. For achieving an flower yield target of 175 q ha^{-1} of chrysanthemum with a soil test value of 200, 20 and 300 kg ha^{-1} of $KMnO_4$-N, Olsen-P and NH_4OAc-K, the fertilizer N, P_2O_5 and K_2O doses required were 124, 153 and 54 kg ha^{-1}, respectively under NPK alone 86, 129 and 19 kg ha^{-1} under IPNS (NPK + FYM @ 12.5 t ha^{-1} with 22, 0.58, 0.36 and 0.57 per cent of moisture, N, P and K respectively). Similarly for the target of 200 q ha^{-1}, the respective values were 174, 180 and 94 kg ha^{-1} under NPK alone and 136, 156 and 59 under IPNS. Under IPNS, the fertilizer savings were 38, 24 and 35 kg ha^{-1} respectively when FYM was applied @ 12.5 t ha^{-1} along with NPK fertilizers.

Table 4a. Soil test ($KMnO_4$-N) based fertilizer doses (kg ha^{-1}) for desired yield targets of 150, 175 and 200 q ha^{-1} of Chrysanthemum

Soil test values (kg ha^{-1})	Fertiliser – N (kg ha^{-1})		Per cent reduction over NPK	Fertiliser – N (kg ha^{-1})		Per cent reduction over NPK	Fertiliser – N (kg ha^{-1})		Per cent reduction over NPK
	NPK alone	NPK+FYM		NPK alone	NPK+FYM		NPK alone	NPK+FYM	
$KMnO_4$-N			150 q ha^{-1}			175 q ha^{-1}			200 q ha^{-1}
160	119	81	31.9	169	131	22.5	220	182	17.3
170	108	70	35.2	158	120	24.1	208	170	18.3
180	96	63	34.4	147	109	25.9	197	159	19.3
190	85	63	25.9	135	97	28.1	185	147	20.5
200	73	63	13.7	124	86	30.6	174	136	21.8
210	63	63	0.0	112	74	33.9	163	125	23.3
220	63	63	0.0	101	63	37.6	151	113	25.2
230	63	63	0.0	89	63	29.2	140	102	27.1
240	63	63	0.0	78	63	19.2	128	90	29.7
250	63	63	0.0	66	63	4.5	117	79	32.5
260	63	63	0.0	63	63	0.0	105	67	36.2



A distinct response to the application of NPK fertilizers was noticed in the present study. The magnitude of response was higher under IPNS as compared to NPK alone. The per cent reduction in NPK, fertilizers under IPNS also increased with increasing soil fertility levels with reference to NPK and decreased with increase in flower yield targets. These could be achieved by integrated use of FYM with NPK fertilizers. The role of FYM is multidimensional ranging from building up of organic matter, maintaining favourable soil physical properties and balanced supply of nutrients. In the present investigation also, these factors might have contributed for the flower yield enhancement in chrysanthemum when NPK fertilizers coupled with FYM.

Table 4b. Soil test (Olsen-P) based fertilizer doses (kg ha^{-1}) for desired yield targets of 150, 175 and 200 q ha^{-1} of Chrysanthemum

Soil test values (kg ha^{-1})	Fertiliser – P (kg ha^{-1})		Per cent reduction over NPK	Fertiliser – P (kg ha^{-1})		Per cent reduction over NPK	Fertiliser – P (kg ha^{-1})		Per cent reduction over NPK
	NPK alone	NPK+FYM		NPK alone	NPK+FYM		NPK alone	NPK+FYM	
Olsen-P			150 q ha^{-1}			175 q ha^{-1}			200 q ha^{-1}
16	136	112	17.6	163	139	14.7	190	166	12.6
18	131	107	18.3	158	134	15.2	185	161	13.0
20	126	102	19.0	153	129	15.7	180	156	13.3
22	121	97	19.8	148	124	16.2	175	151	13.7
24	116	92	20.7	143	119	16.8	170	146	14.1
26	111	87	21.6	138	114	17.4	165	141	14.5
28	106	82	22.6	132	108	18.2	159	135	15.1
30	100	76	24.0	127	103	18.9	154	130	15.6
32	95	71	25.3	122	98	19.7	149	125	16.1
34	90	66	26.7	117	93	20.5	144	120	16.7
36	85	61	28.2	112	88	21.4	139	115	17.3

Validation Experiments

Chrysanthemum flower yield and achievement (Table 5)

The results of the validation experiments showed that the flower yield of chrysanthemum ranged from 6.40 t ha^{-1} in control to 21.94 t ha^{-1} in STCR-IPNS 20.0 t ha^{-1}. Irrespective of the yield targets, the yield recorded in the STCR-IPNS treatments were higher when compare to their corresponding STCR-NPK alone treatments. The lower flower yield of chrysanthemum under general recommendation of fertilisers and farmer's practice were recorded, when compare to the yield obtained at 15.0, 17.5 and 20.0 t ha^{-1} fixed targets. Further, the results of the validation experiments on chrysanthemum clearly revealed that the per cent achievement was within ± 10 per cent variation (90 to 110 %) at all yield target levels proving the validity of the fertiliser prescription equations. This is in accordance with the Velayutham *et al.* (1984). The highest achievement of the yield targets was recorded with STCR-IPNS target of 20.0 t ha^{-1} (109.7 %) followed by STCR-IPNS target of 17.5 t ha^{-1} (106.7 %). The yield targeting with IPNS recorded relatively higher per cent achievement than that aimed under their respective NPK alone treatments. It is also confirm from the data that lower yield targets were better achieved than the higher one. This might be due to the better use efficiency of applied NPK fertilisers at low yield target levels (Santhi *et al.*, 2002 and Bera *et al.*, 2006).

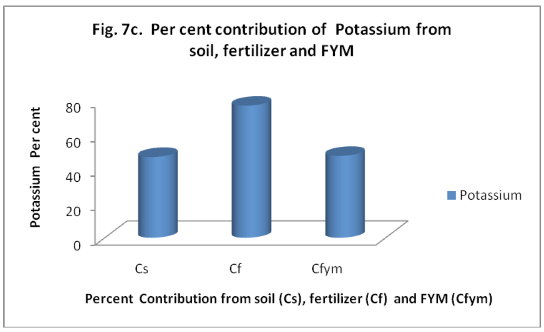


Table 4c. Soil test (NH_4OAc-K) based fertilizer doses (kg ha^{-1}) for desired yield targets of 15.0, 17.5 and 20.0 q ha^{-1} of Chrysanthemum

Soil test values (kg ha^{-1})	Fertiliser – K (kg ha^{-1})		Per cent reduction over NPK	Fertiliser – K (kg ha^{-1})		Per cent reduction over NPK	Fertiliser – K (kg ha^{-1})		Per cent reduction over NPK
	NPK alone	NPK+FYM		NPK alone	NPK+FYM		NPK alone	NPK+FYM	
NH_4OAc-K	150 q ha^{-1}			175 q ha^{-1}			200 q ha^{-1}		
280	30	13	56.7	69	34	50.7	108	73	32.4
300	15	13	13.3	54	19	64.8	94	59	37.2
320	13	13	0.0	40	13	67.5	79	44	44.3
340	13	13	0.0	25	13	48.0	64	29	54.7
360	13	13	0.0	13	13	0.0	49	14	71.4
380	13	13	0.0	13	13	0.0	35	13	62.9
400	13	13	0.0	13	13	0.0	20	13	35.0
420	13	13	0.0	13	13	0.0	13	13	0.0
440	13	13	0.0	13	13	0.0	13	13	0.0
460	13	13	0.0	13	13	0.0	13	13	0.0
480	13	13	0.0	13	13	0.0	13	13	0.0

Response Ratio (RR)

The RR recorded for various treatments ranged from 15.82 kg kg^{-1} in blanket to 39.33 kg kg^{-1} in STCR-IPNS – 20.0 t ha^{-1}. Among the STCR treatments, IPNS recorded relatively higher RR than NPK alone treatments (Table 6). Relatively higher RR recorded under STCR-IPNS treatments when compared to blanket and farmer's practice might be

Table 5. Range and mean values of results of validation experiments on Chrysanthemum

S. No.	Treatments	Fertiliser doses (kg ha^{-1})			Grain yield (kg ha^{-1})	PA (%)	RR (kg kg^{-1})	BCR
		FN	FP_2O_5	FK_2O				
1.	Blanket (RDF alone)	125	120	25	10675	---	15.82	1.74
2.	Blanket(RDF+FYM @12.5 t ha^{-1})	125	120	25	11488	---	18.83	1.87
3.	STCR- NPK alone 15.0 t ha^{-1}	83-116	60-123	13*-38	13993	94.1	35.57	2.44
4.	STCR- NPK alone 17.5 t ha^{-1}	133-166	60-150	13*-38	17230	98.3	37.31	2.73
5.	STCR - NPK alone 20.0 t ha^{-1}	183-188**	78-177	13*-38	20020	100.9	39.33	2.90
6.	STCR-IPNS- 15.0 t ha^{-1}	63-78	60-99	13*-38	15231	101.6	36.62	2.20
7.	STCR-IPNS- 17.5 t ha^{-1}	95-128	60-126	13*-38	18808	106.7	38.19	2.47
8.	STCR-IPNS- 20.0 t ha^{-1}	133-178	60-150	13*-38	21940	109.7	38.90	2.75
9.	Farmer's practice	60	60	10	12223	----	39.50	1.61
10.	Absolute Control	0	0	0	6403	----	0.00	0.80

PA : Per cent Achievement

STCR-IPNS: NPK+FYM @ 12.5 t ha^{-1}; *maintenance dose **maximum dose

Major nutrients (kg ha^{-1})

$KMnO_4$-N : 163 – 192

Olsen-P : 15 – 34

NH_4OAc-K : 183 – 632

Micronutrients (mg kg^{-1})

DTPA-Zn : 0.05 - 0.26

DTPA-Fe : 1.62 - 3.40

DTPA-Mn : 5.78 - 13.15

DTPA-Cu : 0.78 - 1.84

FN : 2.01 T - 1.14 SN - 0.67 ON

FP_2O_5 : 1.08 T - 2.56 SP - 0.69 OP

FK_2O : 1.57 T - 0.74 SK - 0.62 OK

due to 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. Similar trend of superiority of STCR-IPNS over farmer's practice was reported by Coumaravel (2012) for maize-tomato sequence.

CONCLUSION

The gradient experiment was conducted during Kharif 2017 to create operational range of soil fertility in strip I, strip II and strip III with fodder *sorghum var.* CO 30. Each strip was divided into 24 plots, then the test crop experiment with chrysanthemum was conducted with four levels each of N (0, 80, 160 and 240 kg ha^{-1}), P_2O_5 (0, 50, 100 and 150 kg ha^{-1}) and K_2O (0, 25, 50 and 75 kg ha^{-1}) and three levels of FYM (0, 6.25 and 12.5 t ha^{-1}). The data on flower yield of chrysanthemum, total uptake of N, P and K, initial soil test values for available N, P and K and doses of fertilizer N, P_2O_5 and K_2O were used to compute the basic parameters *viz.,* nutrient requirement (NR), contribution of nutrients from soil (Cs), fertilizer (Cf) and farm yard manure (Cfym) were calculated. Using these basic parameters, the following fertiliser prescription equations were computed.

STCR-NPK alone		STCR-IPNS (NPK + FYM)	
FN	= 2.01 T-1.14 SN	FN	= 2.01 T- 1.14 SN –0.67 ON
FP_2O_5	= 1.08 T-2.56 SP	FP_2O_5	= 1.08 T- 2.56 SP -0.69 OP
FK_2O	= 1.57 T-0.74 SK	FK_2O	= 1.57 T- 0.74 SK -0.62 OK

The fertiliser prescription equations were test verified in six locations of salem Dist.

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