Applicability of targeted yield equation

- The equations should be used within the soil-agro-climatic region from they were developed.
- In case the yield targeting equations are to be extended to similar soils of other zone or dissimilar soils of the same zone, it is better to lay demonstration with three to four yield targets in the farmers' field and select the best one for recommendation.
- Yield targets chosen should be neither too low nor too high. It should be within yields range of the main experiment obtained. The maximum target should not be exceeded 75-80% of the highest yield achievable for that crop in the area
- Adjustment equations must be used within the experimental range of soil test values and cannot be extrapolated.
- In soils of low or very low fertility, the fertilizer requirement based on yield target equations may be too high, which results in abnormal rise in input cost and lowers the benefit cost ratio. In such cases, the upper limit of fertilizers recommendation may be limited to 150% of general recommendation.
- In case of high fertile soils, fertilizer requirement based on soil test value may reach zero level. In such cases the lower limit of fertilizer recommendations may be fixed at 50% of general recommendation as a maintenance dose so as to preserve soil fertility for the coming years.
- Upper and lower limit rules are not applicable at the time of conducting demonstrations in the farmers' fields for verification of yield targeting equations.
- It is better to get soil analyzed for every two years in case of intensively cultivated soils and three years for dry land soils.
- Appropriate recommended agronomic practices need to be followed while raising the crop.
- Other micro and secondary nutrients should not be yield limiting.

How to use targeted yield equations

1. Standard procedure must be followed for the collection and preparation of representative soil samples.
2. Farmers should select the variety of crop that they are willing to grow.
3. Resources (money) must be available for purchasing of fertilizers to get fixed target yield of respective crop variety.
4. Depending upon the variety of crop and resources available, yield target should be fixed.
5. Chemical analysis of soil sample should be carried out by a technical person only and should be very accurate.
6. The soil analysis values should be present in N, P and K kg/ha instead of P_2O_5 and K_2O.
7. Use these values of N, P and K in kg/ha in the targeted yield equations in place of SN, SP and SK., respectively.

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Agresearch with a human touch

READY RECKONER FOR SOIL TEST AND TARGETED YIELD BASED NUTRIENT MANAGEMENT IN RICE

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Published by :
Prof. B. S. Mahapatra, Director

February : 2013

CENTRAL RESEARCH INSTITUTE FOR JUTE & ALLIED FIBRES
(Indian Council of Agricultural Research)
BARRACKPORE, KOLKATA- 700 120

Rice is one of the staple food crops cultivated in India, it ranks first in both area and production of food grains. Despite, the productivity of rice is relatively low as compared to other countries perhaps due tothe ignorance of farmers about the appropriate nutrient management practices of the crop. West Bengal ranks first in area and production in the country.

About 78% of total area under rice in the state is concentrated under high and medium productivity groups, which accounts for nearly 84% of total production of rice in this state. Area under high yielding varieties is nearly 85%.

Chemical fertilizers is the most precious and costly input applied for the production of different crops including rice. Increasing pressure of food security for future generation is the biggest challenge to meet out the increasing demand of food. Simultaneously to fulfill our demand, we are gradually increasing doses of chemical fertilizers for obtaining higher yield of rice which causes serious environmental impact on surface as well as ground water. Hence, judicious use of chemical fertilizers is the only way to sort out the increasing demand of grain production without causing environmental impact. Current general recommendations of chemical fertilizers adopted by most of the farmers are sub-optimal based on medium soil fertility status. The variations in fertility status of soil are not taken into consideration in such recommendation. Infact, soils of these regions very greatly in plant-available nutrients especially available N, P and K due to imbalance fertilizer application. Under low or high soil fertility conditions, the applied nutrients often prove a wasteful expenditure or insufficient. Soil testing is an important tool for assessing their inherent capacity of nutrient supply, predicting profitable response of fertilizers and recommending of fertilizers for various crops. However, it would be more useful if fertilizer is recommended on the basis of site-specific soil-crop-variety-fertilizers-climate-management interaction.A workable integrated plant nutrient supply system (IPNSS) based fertilizer prescription equations or targeted yield equation (TYE) for different varieties of rice have been developed under All India Coordinating Research Project (AICRP) on Soil Test and Crop Response (STCR) at CRIJAF, Barrackpore, West Bengal. Under Targeted yield equations, four basic parameters, viz. nutrient requirement of crop/variety, efficiency of nutrients available in soil and nutrients from added fertilizers and organic sources are considered.

Component of Soil testing and targeted yield equation:

Soil testing is a chemical method for estimating the inherent nutrient supply ability of the soil. The primary advantage of soil testing is its ability to determine the nutrient status of soil before the crop is planted but does not measure the exact quantity of a nutrient taken up by a crop. The objectives of soil testing are:

1. To provide an index of nutrient supply power of a given soil sample.
2. To predict the probability of obtaining a profitable response of fertilizers.
3. To provide a basis for recommendation on amount of available fertilizers
4. To evaluate the fertility status of a soil in a respective area

i. *Collection of representative soil samples*

The most important aspect of soil testing is to obtain a soil sample that is representative of the field. Soils are normally heterogeneous and wide variability may occur even in a uniform field. Intensive soil sampling is the most efficient way to evaluate variability. Therefore, accurate measurement of available nutrient in a particular soil depends upon the way of soil sample collection because sampling error in a field is greater than the error in laboratory analysis. The soil sampling should be taken at least from 15-20 locations over the fields for each composite sample.

ii. *Sampling time:*

Soil sample should be taken before sowing of each crop. For agricultural crops, the best time of sampling is when the fields are free from the crops. As a general rule a couple of weeks prior to seed bed preparation is the best time for soil sampling.

iii. *Sampling equipment*

1. Probe auger or soil sampling tube auger or spade or a *khurpi* can be used for moist soils. All the sampling tools and storage bags should be perfectly cleaned.
2. Polythene bucket for collection and mixing of soil samples
3. Cloth bags (25 cm × 15 cm size)
4. Scale (12 inches) or measuring tape
5. Ball point pen or lead pencil
6. Polythene sheet (2ft×3 ft size) for making representative soil samples
7. A sheet of thicker paper

iv. *Sampling area and number of samples*

If all the conditions are uniform then the sample area should not exceed two hectare. Sample should be prepared by collecting soil from 6-8 sites per acre or 15-20 sites per hectare with following precaution. Soil should not be collected from place close to irrigation channels, manure pits, bunds and below trees.

v. *Sampling unit*

Divide the area into sampling units based on visual observations on crop growth, appearance of the soil colour, topography, previous crop history like manuring, fertilization and cropping pattern, etc. Collect one composite soil sample from each block or unit as explained in following steps:

Step 1: Remove the litter from the surface by scrapping it away at each spot selected for soil sampling.

Step 2: If probe auger or specially designed soil sampling tubes are available, then take about 15-20 surface soil samples (0-15 cm) from each block of half acre area in a random zigzag manner. Avoid sampling near houses, roads, bunds, channels, marshy spots, trees, recently fertilized area, compost pits, any other abnormal spots and other non representative locations. Collect these in a clean dry container or cloth bag.

Step 3: If a khurpi or a spade is used, first dig a 'V' shaped hole (15-20 cm) and take out the soil-slice (like bread-slice) of ½inch thickness from one of the exposed surface(Fig.1)

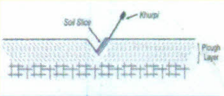

Fig. 1. Soil Sampling with the help of *khurpi*

Step 4: Mix the soil sample collected in step 2 or 3 thoroughly on a clean piece of cloth or polythene sheet (Fig.2).

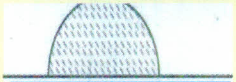

Fig. 2. Mixing of soil sample (put sub samples on clean piece of cloth or polythene sheet

Step 5: Level and divide into four quarters with the help of finger or wooden stick (Fig. 3). Discard the soil in the opposite quarters (Fig. 4).

Step 6: Mix rest of the soil and continue quartering till about ½ kg of representative soil is obtained. Dry the sample in shade and fill in the cloth or polythene bag. Label the sample with important relevant information viz. field number, name of cultivars and identification, marks, slope, drainage, irrigation, previous cropping history, fertilizers used, etc. The soil sample is now ready for submitting/sending to the nearest soil testing laboratory for its analysis.

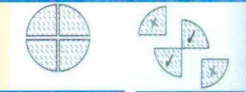

Fig. 3. Levelling & dividing the soil sample into soil approx. four equal parts (quarters)

Fig. 4. Selecting two quarters marked as ✓ for further quartering

b. Targeted yield equation or fertilizer prescription equation

Following three basic parameters are worked out for the specific crop and area for the development of targeted yield equation.

1. Nutrient requirement (N, P, K) in kg to produce one quintal of grain of specific crops under particular type of soil and climatic conditions.

$$NR\ (kg/q) = \frac{\text{Total uptake of nutrient (kg)}}{\text{Grain yield (q)}}$$

2. Efficiency of soil available nutrients (N, P, K) in percent in particular type of soil and climatic conditions.

$$CS\ (\%) = \frac{\text{Uptake in control plots (kg/ha)}}{\text{STV in control plots (kg/ha)}} \times 100$$

3. Efficiency of nutrients (N, P, K) in percent applied through fertilizers in particular type of soil and climatic conditions.

$$CF\ (\%) = \frac{\text{Total uptake of nutrient in fertilizer plots (STV in fertilizer plot)} \times CS}{\text{Nutrient applied through fertilizer (kg/ha)}} \times 100$$

1. Development of fertilizer adjustment equations

$$FN\ (kg/ha) = XT - Y\ SN$$
$$FP_2O_5\ (kg/ha) = XT - Y\ SP,$$
$$FK_2O\ (kg/ha) = XT - Y\ SK$$

i. Without IPNSS

$$\text{Fertilizer nutrient dose} = \frac{NR}{CF/100} \times T - \frac{\%CS}{\%CF} \times STV$$

After calculating these three basic parameters from the yield and uptake data from the well conducted test crop experiment, these basic parameters in turn are transformed into simple workable fertilizer adjustment equations as mention below:

$$FN\ (kg/ha) = XT - Y\ SN - Z\ ON,$$
$$FP_2O_5\ (kg/ha) = XT - Y\ SP - Z\ OP,$$
$$FK_2O\ (kg/ha) = XT - Y\ SK - Z\ OK$$

i. With IPNSS

$$\text{Fertilizer nutrient dose} = \frac{NR}{CF/100} \times T - \frac{\%CS}{\%CF} \times STV - \frac{\%CO}{\%CF} \times ON$$

Where:

T = Yield target (q/ha), X, Y, Z = constant

FN, FP_2O_5 and FK_2O are fertilizer N, P_2O_5 and K_2O dose (kg/ha)

SN, SP and SK are available soil test values (kg/ha)

NR = Nutrient requirement in kg/q of grain production

CS% = Per cent contribution from soil available nutrient

CF% = Per cent contribution from fertilizer nutrient without FYM

CO% = Percent contribution of nutrients from FYM or any other organic resources

STV = Soil test values

Thus, prescription based fertilizer recommendations avoid wide variations in soil rating limits as it substitute the exact values for soil available N, P and K as SN, SP and SK, respectively in the said fertilizer adjustment equations. Moreover, as the nutrient requirement of the crops and the efficiency of soil available nutrients as well as those applied through fertilizers are being taken into account. Prescription based fertilizer recommendation ensures the balance nutrition of crops besides maintaining the soil fertility.

This approach is better than others because

(a) It ensures the achievement of desired yield target within ±10% deviation under optimum management conditions,

(b) Efficient use of fertilizers according to soil fertility and crop requirement ensures high profit and response to applied fertilizers,

(c) It ensures maintenance of soil fertility at appropriate levels in cropping system for sustainable crop production,

(d) It offers wide choice of fixing appropriate yield target according to the availability of resources and soil fertility,

(e) Suitable crop rotations can be adopted from the point of view of relative ability of crops and crop varieties to utilize soil and fertilizer nutrient.

IPNSS fertilizers prescription or targeted equations of different varieties of rice as derived from the field experiment are as follows:

IPNSS Targeted yield equations developed by STCR, CRIJAF

Variety - Khitish FN = 5.29 T- 0.39 SN- 0.12 ON FP = 1.03 T- 0.24 SP- 0.11 OP FK = 1.98 T- 0.20 SK- 0.07 OK Variety.- MTU 1010 FN = 4.26 T- 0.37 SN- 0.11ON FP = 1.03 T- 0.27 SP - 0.14 OP FK = 2.14 T- 0.42 SK- 0.11OK	Variety- Satabdi FN = 7.55 T- 0.66 SN - 0.19 ON FP = 2.07 T - 0.58 SP- 0.14 OP FK = 3.37 T -0.46 SK - 0.10 OK Variety- NDR 97 FN = 5.64 T- 0.56 SN - 0.23 ON FP = 1.28 T - 0.40 SP- 0.66 OP FK= 2.18 T- 0.38 SK - 0.26 OK

How to calculate fertilizers dose ?

The following procedure should be followed while calculating fertilizer doses for a specific yield target of a particular crop. To make it clearer, let us take an example:

1. Agro climatic zone : Hot sub-humid to humid (New Alluvium)
2. Crop : rice
3. Yield target fixed : 50 q/ha
4. Fertilizers adjustment equations (Without IPNSS)
   FN = 5.29 T - 0.39 SN , FP = 1.03 T - 0.0.24 SP, FK = 1.98 T- 0.20 SK
5. Soil test values:
   Available N = 250 kg/ha, Available P = 35 kg/ha , Available K = 250 kg/ha
6. Fertilizers calculation :

i) Without IPNSS

FN (kg/ha)	F P_2O_5 (kg/ha)	F K_2O(kg/ha)
= 5.29 × 50 -0.39 = 264.5-97.5 = 167 kg N/ha	= 1.03 × 50 - 0.24 × 35 = 51.5-8.4 = 43.1 kg P_2O_5/ha	= 1.98 × 50 - 0.20 × 250 = 99-50 = 49 kg K_2O/ha

ii) With IPNSS

FN =5.29 T - 0.39 SN - 0.12 ON, FP = 1.03 T - 0.24 SP - 0.11 OP , FK = 1.98 T- 0.20 SK - 0.07 OK

FN (kg/ha)
= 5.29 × 50- 0.39 × 250-0.12 × 25
= 264.5-97.5 -3.0
= 164 kg N/ha

F P_2O_5 (kg/ha)
= 1.03 × 50-0.24× 35-0.11×15
= 51.5-8.4-1.65
= 41.4 or say 41 kg P_2O_5/ha

F K_2O (kg/ha)
= 1.98 × 50- 0.20 × 250- 0.07 × 35
= 99-50-2.45
= 46.6 or say 47 kg K_2O/ha

Suppose a farmer added FYM @ 5 t/ha which contains 0.5%N, 0.3%P and 0.7% K on dry weight basis. It means, 5 toneFYM added about 25 kg N, 15 kg P and 35 kg K/ha into the soil which will multiply with the factor of organic N, P and K will show actual N, P and K contribution by the FYM (e.g. 0.12 is the factor for organic N and 25 kg N supplied by 5 t/FYM = 0.12 × 25= 3.0 kg N supplied by FYM added in to the soil) and subtract it from the total nutrient required.

For getting 50 q/ha fixed yield target of rice in above zone, we need to apply 164, 47 and 46 kg N, P_2O_5 and K_2O, respectively. Depending upon the availability of fertilizer sources with the farmers, these N, P_2O_5 and K_2O doses should be converted to their fertilizer equivalents. For example, suppose a farmer has urea, single super phosphate (SSP) and muriate of potash (MOP) as fertilizer source for N, P_2O_5 and K_2O, respectively. Since urea contains 46% N, single super phosphate contains 16% P_2O_5 and muriate of potash contains 60% K_2O, we can easily convert N, P_2O_5 and K_2O in to their fertilizer eauivalents as under.

a) Nitrogen (164 kg/ha) = $\frac{100}{46} \times 164 = 2.17 \times 164 = 355$ kg urea/ha

b) Phosphorus (41 kg/ha) = $\frac{100}{16} \times 41 = 6.25 \times 41 = 256$ kg SSP/ha

c) Potash (46 kg/ha) = $\frac{100}{60} \times 46 = 1.68 \times 46 = 78$ kg MOP/ha

How to use the ready reckoner?

A ready reckoner for different yield targets of various high yielding varieties of rice has been developed for judicious use of fertilizers (Table-1). For example, if a farmer wishes to produce 50 q/ha grain yield of rice (Khitish) and if the soil test values for nitrogen, phosphorus and potassium are 250, 35 and 250 kg/ha. The requirement of Urea, SSP and MOP may be derived from directly from the table 2 as 355, 259 and 78 kg/ha, respectively. Same pattern may also be followed for obtaining dose of urea, SSP and MOP at definite target of grain yield of paddy for high yielding variety like MTU 1010 (Table 3), Satabdi (Table 4) and NDR 97 (Table 5). One third quantity of nitrogen through urea applied as basal dose at the time of sowing and remaining two third doses of nitrogen applied in two equal split doses. One third applied as top dressing when the crop is 30-35 days old and the remaining one third when the crop is about 50-55 days old as per ready reckoner of respective varieties.

Farmers can easily decide the yield target of paddy grain as per the resources available and yield potential of variety and accordingly they can apply the fertilizers on the basis of their soil test values by using this ready reckoner table. Thus, this ready reckoner may serve as a useful guide to the resource-poor farmers of the country by facilitating themto judicious application of chemical fertilizers.

Table 1. Ready reckoner for nutrients requirement to achieve the targeted yield of rice var. Khitish in alluvial soils of West Bengal

Soil test values (kg/ha)			Targeted paddy grain yield (q/ha)								
			40			50			60		
			kg/ha								
N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
100	5	100	169	38	57	222	49	77	275	59	96
125	10	125	159	37	52	212	48	71	265	58	91
150	15	150	149	36	47	202	46	67	255	56	86
175	20	175	140	35	42	193	45	61	246	55	82
200	25	200	130	34	37	183	44	57	236	54	76
225	30	225	120	32	32	173	43	52	226	53	71
250	**35**	**250**	111	31	27	164	41	46	216	52	66
275	40	275	101	30	22	153	40	42	206	51	61
300	45	300	91	29	17	144	39	36	197	49	57
325	50	325	81	28	12	134	38	32	187	48	51
350	55	350	71	26	7	124	37	27	177	47	46
375	60	375	62	25	2	115	36	21	168	46	41
400	65	400	52	24		105	34	17	158	44	36

Table 2. Ready reckoner for fertilizer requirement to achieve the targeted yield of rice var. Khitish in alluvial soils of West Bengal

Soil test values (kg/ha)			Targeted paddy grain yield (q/ha)								
			40			50			60		
			kg/ha								
N	P	K	Urea	SSP	MOP	Urea	SSP	MOP	Urea	SSP	MOP
100	5	100	367	240	95	482	304	129	596	368	162
125	10	125	346	232	87	460	297	120	575	361	153
150	15	150	324	225	79	439	289	112	554	353	145
175	20	175	303	217	70	418	282	103	533	346	137
200	25	200	282	210	62	397	274	95	512	338	128
225	30	225	261	202	53	376	267	87	491	331	120
250	**35**	**250**	240	195	45	**355**	**259**	**78**	469	323	111
275	40	275	219	187	37	333	252	70	448	316	103
300	45	300	197	180	28	312	244	61	427	308	95
325	50	325	176	172	20	291	237	53	406	301	86
350	55	350	155	165	11	270	229	45	385	293	78
375	60	375	134	157	3	249	222	36	364	286	69
400	65	400	113	150	-	228	214	28	342	278	61

Table 3. Ready reckoner for nutrients requirement to achieve the targeted yield of rice var. (MTU 1010 in alluvial soils of West Bengal

Soil test values (kg/ha)			Targeted paddy grain yield (q/ha)								
			40			50			60		
			kg/ha								
N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
100	5	100	130	38	40	173	48	61	215	58	83
125	10	125	121	36	29	164	47	51	206	57	72
150	15	150	112	35	19	154	45	40	197	56	61
175	20	175	102	34	8	145	44	30	188	54	51
200	25	200	93	32	0	135	43	19	178	53	40
225	30	225	84	31	0	126	41	9	169	52	30
250	35	250	75	30	0	117	40	0	160	50	20
275	40	275	65	28	0	108	39	0	151	49	9
300	45	300	56	27	0	99	37	0	141	48	0
325	50	325	47	26	0	89	36	0	132	46	0
350	55	350	38	24	0	80	35	0	123	45	0
375	60	375	29	23	0	71	33	0	113	44	0
400	65	400	19	22		62	32	0	104	42	0

Table 4. Ready reckoner for nutrients requirement to achieve the targeted yield of rice var. Satabdi (super fine short duration) in alluvial soils of West Bengal.

Soil test values (kg/ha)			Targeted paddy grain yield (q/ha)								
			30			40			50		
			kg ha^{-1}								
N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
100	5	100	230	78	85	268	88	102	306	99	119
125	10	125	214	75	74	252	85	90	289	96	108
150	15	150	197	72	63	235	82	79	273	93	96
175	20	175	181	69	51	218	80	68	256	90	85
200	25	200	165	66	39	202	76	56	240	87	73
225	30	225	148	63	28	186	74	45	224	84	61
250	35	250	131	60	16	169	71	33	207	81	50
275	40	275	115	57	5	153	68	21	190	78	39
300	45	300	98	55	0	136	65	10	174	75	27
325	50	325	82	52	0	119	62	0	157	72	15
350	55	350	65	49	0	103	59	0	141	69	4
375	60	375	49	46	0	87	56	0	124	67	0
400	65	400	32	43		70	53	0	108	64	0

Table 5. Ready reckoner for nutrients requirement to achieve the targeted yield of rice var. NDR 97 in alluvial soils of Best Bengal

Soil test values (kg/ha)			Targeted paddy grain yield (q/ha)								
			40			50			60		
			kg/ha								
N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
100	5	100	163	39	40	219	52	61	276	65	83
125	10	125	149	37	30	205	50	52	261	63	74
150	15	150	135	35	21	191	48	43	247	61	64
175	20	175	121	33	11	177	46	33	234	59	55
200	25	200	107	31	2	163	44	24	219	57	45
225	30	225	93	29	0	149	42	14	206	55	36
250	35	250	79	27	0	135	40	5	192	53	27
275	40	275	65	25	0	121	38	0	177	51	17
300	45	300	51	23	0	107	36	0	164	49	8
325	50	325	37	21	0	93	34	0	149	47	0
350	55	350	23	19	0	79	32	0	135	45	0
375	60	375	9	17	0	65	30	0	122	43	0
400	65	400	0	15	0	51	28	0	107	41	0