MM 2.1 : Integrated Nutrient Management for High quality Fibre and Yield

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Objective	Activity	Achievement
To study the impact of nutrient management practices on growth, yield and fibre quality (experiment 1 for third year at Hisar, Ludhiana and Abohar)	Field experiments and record growth and yield and test for fibre quality	Field experiments were conducted at 3 locations. Significant response to Zn and S was observed at Hisar. At Ludhiana balanced application of NPK was better than the existing practice followed by farmers.
To construct nutrient budgets and develop location specific modules and decision aids	Plant sampling and analysis Calculate nutrient balance sheet Field experiment on location specific INM modules	Plant samples were collected and analysed for nutrient content and uptake (except at Abohar and Ludhiana). Nutrient balance sheet was calculated. In general, K balance was negative and of more serious concern in the irrigated north zone Field experiments were conducted based on locally available manure at all 11 locations. At Surat, due to floods, on-station trials were vitiated.
To evaluate impact of nutrient management interventions	Conduct on-farm trials	94 on-farm trials were conducted across centres. At Surat, due to floods, on-farm trials were vitiated. Trials were not conducted at Ludhiana and Ganganagar.

Progress of work

Experiment – 1: Effect of nutrient management practices on growth, yield and fibre quality and Experiment – 2: To evaluate the effect of foliar application of potassium on seed cotton yield and fibre quality

Experiments -1 and -2 were conducted at three locations (Abohar, Ludhiana and Hisar) for third consecutive year to evaluate the effect of nutrient management practices on the seed cotton yield and fibre quality. At Dharwad and Bhopal, experiment 1 was conducted for the fourth consecutive year. At other locations, the trials were terminated.

The treatments details of experiment-1 are as follows:

1. Absolute control
2. Application of recommended dose of NPK
3. RDF + zinc sulphate (soil application @ 20 kg/ha)
4. RDF + $FeSO_4$ spray
5. RDF + Zn + $FeSO_4$
6. 50% nutrients through organic and 50% through inorganic
7. 25% nutrients through organic and 75% through mineral fertilizers

Treatment details of experiment-2 conducted as a randomized block design are as follows;

1. Recommended N, P (NP)
2. Recommended N, P, K (NPK)
3. Recommended N, P, K and foliar K at early boll formation (NPK + K1)
4. Recommended N, P, K and foliar K at peak boll formation (NPK + K2)
5. Recommended N, P, K and foliar K at early and peak boll formation (NPK + K3)

Experiment 3: To evaluate and develop location specific INM modules

Field experiments were conducted at 11 locations. The treatments included the most commonly available organic resources. At all locations the experiment was conducted in a randomized block design with three replications. Treatment details for each location are given in Table 1, 2 and 3 for the north, central and south zone, respectively.

Growth and yield parameters were determined on selected plants tagged at boll bursting stage. Plant samples were collected at harvest and separated into separate plant parts and dry matter recorded. At Hisar, plant samples were analyzed for nutrient content and nutrient uptake was calculated by multiplying the concentration with the plant dry matter. For the fibre quality analyses, seed cotton samples were collected and ginned and the lint samples were sent to the respective Ginning Training centres.

Data were statistically analyzed following appropriate designs and the treatment differences separated out using least significant difference at 5% probability.

On-farm trials

To evaluate the effect of the best nutrient management practice identified for the location (2003-06) in comparison with the farmers practice, trials were conducted with a large plot size of approx. 500 sq.m. on five to ten farmers fields at Hisar, Banswara, Parbhani, Surat, Khargone, Nagpur, Guntur, Dharwad, Kovilpatti and Coimbatore. Each farmer was considered as a replicate and the data was analyzed as randomized block design.

Results

Experiment – 1: Effect of nutrient management practices on growth, yield and fibre quality
Seed cotton yield and yield attributes

Seed cotton yield was significantly affected by nutrient management practices (Table 4). Seed cotton yield was the least in the control plot. With the application of recommended dose of fertilizers (RDF), seed cotton yield was significantly greater than the control plot. Seed cotton yield is primarily a function of the number of harvestable bolls. Data on the numbers of bolls per plant are presented in Table 5.

Hisar: Highest seed cotton yield was obtained in the plots fertilized with NPK and S (Table 4). No significant response was observed to the application of Zn and Fe. At this location it is necessary to apply S. Pressmud is available in the region and can be thought of recycling the organic amendment. Its application was found to be equally good to mineral fertilizers alone (NPK).
None of the fibre quality parameters determined was affected by the nutrient management practices (Tables 5 and 6). The results obtained were similar to that obtained in the previous two years.

Abohar: for the third consecutive year, differences between fertilizer treatments were not observed and the data are presented in Table 4. The data suggests that application of recommended dose of fertilizers is sufficient for this district.

Ludhiana: Differences were significant in the yield between the fertilized and control plots. All the fertilized plots were on a par.

Dharwad: Differences between fertilizer treatments were not significant, but yielded significantly more than the control.

Table 1 Treatment details for the north zone

S. No.	Tr. details	PAU, Ludhiana	HAU, Hisar	RAU, Sri ganganagar	MPUAT, Banswara
1	Control	Absolute control			Absolute control
2	FP	Farmers practice	Farmers practice	Farmers practice	Farmers practice
3	RDF	Recommended dose of fert.	RDF	RDF	RDF
4	Rec. INM	Recommended INM	Rec. INM	Recommended INM	Recommended INM (75% RDF + 10t FYM + Azotobactor + PSB)
5	INM1	2t FYM + 2t crop residue + 100%N	Pressmud alone	25% N through wheat straw and FYM, 50% through urea	75% RDF + 5t FYM + green manuring
6	INM2	2t FYM + 2t crop residue + 75% N	RDF + 25-kg S (3 bags gypsum)	25% N through wheat straw and FYM, 100% through urea	75% RDF + 2t FYM
7	INM3	2t FYM + 100% RDF	RDF + 50-kg S	-	100% N + 2t FYM + 2t vermicompost (VC)
8	INM4	2t FYM + 2t crop residue + 100% RDF	-	-	75% N + 2t FYM + 2t VC
9	INM5	-	-	-	50% N + 2t FYM + 2t VC
10	>RDF	-	1.25 times RDF	1.25 times RDF	50% N + 2-t VC
11	Limiting nutrient	-	RDF + S	-	-

Table 2. Treatment details for the central zone

S. No.	Tr. details	MAU, Parbhani	NAU, Surat	IISS, Bhopal	CICR, Nagpur
1	Control	Absolute control	Absolute control	Absolute control	Absolute control
2	FP	Farmers practice	Farmers practice	Farmers practice	Farmers practice
3	RDF	Recommended dose of fert.	RDF (240-0-0)	RDF	RDF
4	Rec. INM	Recommended INM (5t FYM + 50% RDF)	Rec. INM (25% N thro' castor cake + 50% thro' fertilizer) (240 kg basis)	Recommended INM	Recommended INM (100% RDF + 5t FYM)
5	INM1	2t FYM + 100% RDF	T4-INM on 150 kg N basis	2.5t FYM + 2.5 t Phosphocompost + 75% N	2t FYM + 100% RDF
6	INM2	2t FYM + 2t Gliricidia + 50% RDF	2.5t vermicompost + 75% N (240 kg basis)	5t FYM + 2.5t Phosphocompost + 50% N	2t FYM + 100% N
7	INM3	5t Pressmud cake alone	2.5 t vermicompost + 75% N (150 kg basis)	2.5 t Phosphocompost + 100% N	2t FYM + 2t crop residue compost + RDF
8	INM4	2.5 t PMC + 50% N	2.5 t vermicompost + 50% N (150 kg N basis)	2.5t FYM + 2.5 t Poultry manure + 75% N	2t FYM + 2t CRC + 100% N
9	INM5	2.5 t PMC + 2.5 t Vermicompost (VC)	Castor cake + vermicompost + 50% N (150 kg N basis)	5t FYM + 2.5t Poultry manure + 50% N	2t FYM + 2t CRC + 75% N
10	INM6	2.5 t VC + 50% N	150-60-60 (NPK)	2.5 t Poultry manure + 75% N	2t vermicompost
11	INM 7	-	-	-	2t vermicompost + 75% N
12	INM 8	-	-	-	2t vermicompost + 50% N

Table 3: Treatment details in the south zone

S. No.	Tr. details	ANGRAU, LAM (Guntur)	UAS (Dharwad)	TNAU (Coimbatore)
1	Control	Absolute control	Absolute control	Absolute control
2	FP	Farmers practice (100 kg DAP, 50 Kg urea, 25 kg MOP)	Farmers practice	Farmers practice (105-35-92 +FYM 16-t/ha + neemcake 40 kg/ha)
3	RDF	Recommended dose of fert. (90-45-45)	RDF	RDF (120-26-48)
4	Rec. INM	Recommended INM (25% N thro' FYM + 100% N thro' fertilizers + PK adjusted)	Rec. INM	Recommended INM (RDF + 12.5-t FYM)
5	INM1	2t FYM + 2t vermicompost	RDF + 3 t FYM + 1.7 t crop residue + 0.8 t Vermicompost	RDF + 5-t FYM
6	INM2	2t FYM + 2t vermicompsot + 50% N	RDF + 5t FYM + 2.5 t crop residue	RDF + 5-t Composted coir pith (CCP)
7	INM3	2t vermicompost + 50% N	RDF + 10 t FYM + 2% DAP	RDF + 2.5-t FYM & CCP
8	INM4	T3 + 2% DAP spray (90, 105 DAS)	1.25 times RDF	75% RDF + 2.5-t FYM, CCP
9	INM5	T4 + 2% DAP	50% N + components of 5	75% N + 2.5-t FYM, CCP
10	INM6	T6 + 2% DAP	50% N + components of 7	
11	>RDF			1.5 times RDF (180-38-74)
12	Limiting nutrient			RDF + $ZnSO_4$ (25 kg/ha)

Table 4 Effect of nutrient management practices on seed cotton yield (3rd season)

	Abohar	Ludhiana	Hisar	Dharwad	Bhopal
Control	3934	676	1128	883	1145
RDF	4256	903	1707	1722	2008
RDF + $ZnSO_4$	4138	893	1646	1784	2343
RDF + $FeSO_4$ (0.1%)	4291	936	1686	1766*	2295
RDF + $ZnSO_4$ + $FeSO_4$	4394	902	1607	1819	2467
50% N through organics + 50% N through fertilizer	-	836	1738	1808	2605
25% N through organics + 75% N through fertilizer	-	958	1707	1705	2503
1.25 RDF/STCR				1753	1811
CD (0.05)	NS	NS	36	188	208

- $MgSO_4$ (1% foliar spray)

Table 5: Effect of nutrient management practices on number of harvestable bolls per plant

	Abohar	Ludhiana	Hisar	Dharwad
Control	37.2	14.6	17.6	11.8
RDF	48.7	17.4	24.0	16.7
RDF + $ZnSO_4$	42.5	19.9	23.8	16.5
RDF + $FeSO_4$ (0.1%)	43.8	22.0	24.2	16.5*
RDF + $ZnSO_4$ + $FeSO_4$	46.5	20.6	23.7	16.9
50% N through organics + 50% N through fertilizer	-	18.0	24.4	17.3
25% N through organics + 75% N through fertilizer	-	20.9	24.7	16.4
CD (0.05)	NS	NS	0.8	2.5

***** $MgSO_4$ (1% foliar spray)

Rotational crop yield and residual effects of nutrients

No significant differences were observed with regard to soybean and chickpea yield due to residual effect of INM treatments imposed on cotton during the previous year at Dharwad. However, soybean grain and brinjal fruit yields were significantly greater with the application of organics in combination with fertilizers at Bhopal and Coimbatore, respectively. At Dharwad, recommended dose of fertilizer 25-35-325 and 25-50-0 kg NPK/ha was applied to soybean and chickpea, respectively.

Available nutrient content

Soil samples analyzed at the end of the study indicated significant improvement in the SOC and nutrient (N, P, K) in the plots supplied with nutrients and manure (Table 6). DTPA extractable Zn content was greater in the plots receiving $ZnSO_4$.

Table 6 : Effect of nutrient management practices on soil fertility

	Bhopal		Coimbatore			
	SOC (%)	Zn (mg/kg)	Av. N (kg/ha)	P (kg/ha)	K (kg/ha)	Zn (mg/kg)
Control (T1)	0.40	0.36	81	5.6	974	0.68
RDF (T2)	0.46	0.40	297	8.0	1054	0.70
RDF + Zn (T3)	0.48	0.63	292	10.2	1055	0.74
RDF + $MgSO_4$ (T4)	0.46	0.37	295	11.0	1060	0.70
RDF + Zn + $MgSO_4$ (T5)	0.49	0.59	298	107	1056	0.75
50% organic and 50% inorganic (T6)	0.57	0.47	319	22.7	1086	0.74
25% + 75% org.: inorganic (T7)	0.52	0.44	309	23.6	1078	0.72
STCR/SSNM	0.46	0.41	292	8.9	1002	0.70
LSD (5%)	0.05	0.05	11	0.5	41	0.03

Experiment-2: Effect of K application on seed cotton yield and quality

Response to foliar application of potassium at either early or peak boll formation stages was not significant at all the three locations (Abohar, Ludhiana, Hisar). Fibre quality parameters were also not affected at Hisar.

Experiment-3: To evaluate and develop location specific INM modules

Field studies to evaluate location specific INM modules were conducted across location at eleven centers. Details of the INM interventions were specific to the location. Data on seed cotton yield are presented in Tables 7-9 for the three zones. In general, interventions were found to result in a saving of fertilizer-N and or of P by supplementing nutrients through organic sources. A substantial amount of N can be reduced.

Importantly, existing INM recommendations rely on use of farmyard manure. The amount recommended (5-10 t/ha) is not feasible since the good quality manure are not readily available because of the competing uses. Our

results at various centres using the locally available resources (wheat straw, pressmud, legume residues, green manures, crop composts) resulted in seed cotton yields that were equivalent to the existing

INM recommendations.

Fibre quality data received from some of the centres, indicated no significant differences due to nutrient management interventions except at Guntur (Table 10). At Guntur, nutrient management interventions resulted in significantly greater fibre length, strength and uniformity ratio than the control.

Table 7: Seed cotton yield (kg/ha) as influenced by the INM interventions in north zone

		Ludhiana	Hisar	Sriganganagar	Banswara
T1	Control	1121			1780
T2	Farmers' Practice	1276	1585	1364	2218
T3	RDF	1549	1753	1677	2512
T4	Rec. INM	1494	2058	1833	2798
T5	INM1	1482	1524	1597	2729
T6	INM2	1287	2089	1903	2485
T7	INM3	1373	2119		2450
T8	INM4	1576			2584
T9	INM5				2552
T10	INM6				2510
T10	>RDF		1814	1750	
	LSD (0.05)	NS	89	288	205

Table 8: Seed cotton yield (kg/ha) as influenced by INM interventions in central zone

		Bhopal	Parbhani	Nagpur
Control	T1	1170	695	388
Farmers' Practice	T2	1836	1398	1145
RDF	T3	2152	1670	1335
Rec. INM	T4	2728	1568	1664
INM1	T5	2652	1835	1432
INM2	T6	2833	1488	1346
INM3	T7	2600	1105	1366
INM4	T8	2512	1176	1494
INM5	T9	2666	1157	1091
INM6	T10	2432	1234	559
INM7	T11			1239
INM8	T12			1091
LSD (0.05)		209	139	222

Table 9: Seed cotton yield (kg/ha) as influenced by INM interventions in south zone

		Guntur	Dharwad	Coimbatore
Control	T1	1293	835	1714
Farmers' Practice	T2	1641	1246	2484
RDF	T3	1649	1842	1975
Rec. INM	T4	1658	2035	2348
INM1	T5	1538	1923	2074
INM2	T6	1606	1865	2088
INM3	T7	1608	2072	2078
INM4	T8	1768	1441	1988
INM5	T9	1878	1503	1990
INM6	T10	1597		2052
INM7	T11			
INM8	T12			
> RDF			1919	2410
LSD (0.05)		233	391	109

Table 10: Fibre quality as influenced by INM interventions in south zone

	Guntur				Dharwad			
	2.5% span length (mm)	Bundle strength (g/tex)	Micro naire	UR	2.5% span length (mm)	Bundle strength (g/tex)	Micro naire	UR
T1	25.4	19.1	4.6	44	30.5	22.3	3.9	47
T2	30.4	20.9	4.7	49	29.8	23.1	4.0	47
T3	30.5	21.0	4.7	50	30.3	22.2	3.8	47
T4	30.6	21.2	4.8	51	29.0	22.5	3.8	47
T5	29.3	19.8	4.7	47	29.9	22.7	4.0	47
T6	29.9	20.3	4.7	48	29.6	21.8	4.1	47
T7	30.3	20.3	4.7	48	30.6	22.7	3.8	48
T8	30.7	21.6	4.8	51	29.9	22.3	3.8	47
T9	30.8	21.7	5.0	51	30.4	22.2	3.9	48
T10	29.5	19.9	4.7	47				
T11								
T12					30.3	21.8	4.0	47
LSD	1.9	1.1	NS	3	NS	NS	NS	NS

Plant Nutrient uptake

Data on the uptake of N, P and K are presented in tables 11-13 for the north, central and south zones. Nutrient uptake was greater in the recommended INM plots followed by balanced fertilizer plots and the least in the farmers practice plots. Nutrient uptake is a function of the yield levels (seed cotton, grain and stalks). The nutrient uptake since it was very closely related to the yield level, the pattern followed was similar to the yield trend at all the locations.

Table 11: Nutrient uptake (kg/ha) as affected by nutrient management practices at Hisar

	N	P	K
Farmers' Practice (FP)	73.6	15.7	97.4
RDF	90.2	17.9	106.8
Rec. INM	108.7	19.8	120.4
INM1	70.9	14.5	100.4
INM2	112.3	21.3	127.5
INM3	113.2	21.1	131.3
>RDF	100.0	19.5	118.2
LSD (0.05)	2.1	0.6	7.6

Table 12: Nutrient uptake (kg/ha) as affected by nutrient management practices in central zone

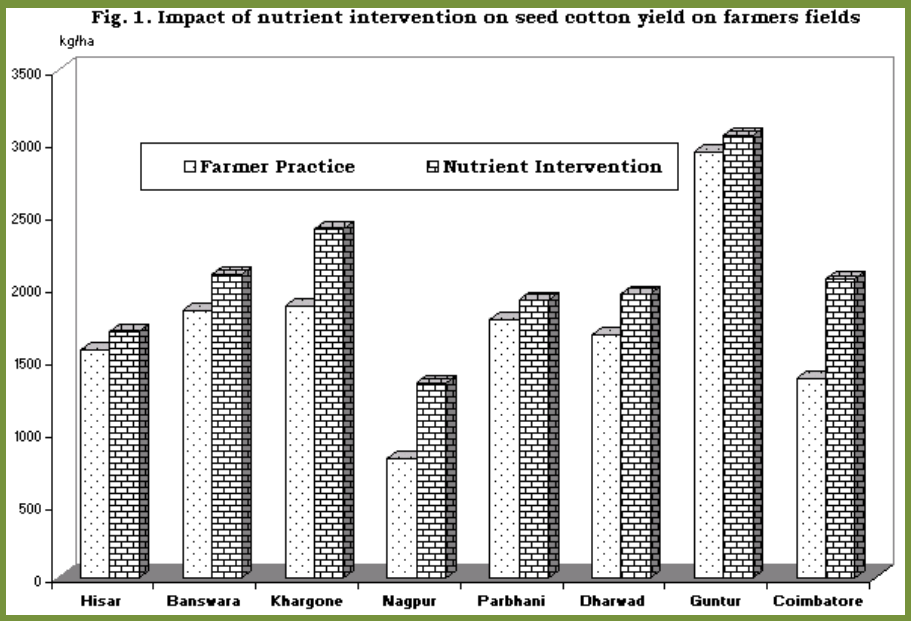
	BANSWARA			BHOPAL			NAGPUR			PARBHANI		
	N	P	K	N	P	K	N	P	K	N	P	K
Control	47.7	16.9	91.1	54.0	3.4	56.5	21.8	2.0	29.1	34.8	9.8	41.4
FP	89.2	34.2	143.4	78.6	5.7	78.4	71.0	7.3	89.2	58.3	15.8	65.1
RDF	115.3	47.0	173.8	93.4	7.3	91.3	98.9	9.7	121.2	64.4	16.6	68.3
Rec. INM	110.5	41.8	166.5	115.4	10.3	116.4	109.0	10.1	109.9	62.6	16.3	67.0
INM1	91.5	32.3	137.9	115.1	9.9	110.5	76.4	6.6	84.4	68.9	17.0	70.0
INM2	88.5	31.6	131.1	120.2	10.8	118.9	89.4	7.4	103.1	60.2	16.4	65.9
INM3	91.7	40.1	154.5	110.9	10.0	104.2	96.4	8.7	121.8	43.6	12.5	47.6
INM4	96.5	37.8	145.7	107.0	8.9	102.7	94.5	7.8	98.9	56.6	12.3	53.4
INM5	95.9	34.6	133.0	115.1	10.0	114.2	74.5	7.3	94.4	54.2	12.4	50.8
INM6	62.5	27.9	116.5	102.9	8.2	96.9	32.5	3.7	42.2	61.3	13.1	55.3
							74.4	7.5	91.6			
							68.0	6.1	78.6			
LSD	18.2	5.3	24.1	10.2	0.9	11.8	21.8	2.7	35.9	4.0	1.0	13.6

Table 13: Nutrient uptake (kg/ha) as affected by nutrient management practices in south zone

	Coimbatore		
	N	P	K
Control	68.9	9.6	41.4
Farmers' Practice	94.3	13.7	60.6
RDF	84.2	12.0	52.3
Rec. INM	93.4	13.5	59.1
INM1	86.1	12.3	53.5
INM2	87.1	12.5	54.6
INM3	86.8	12.4	54.6
INM4	84.2	11.9	52.4
INM5	83.8	11.9	52.1
INM6	85.4	12.1	53.5
>RDF	98.1	14.1	61.0
LSD (0.05)	4.5	0.6	2.8

On-farm trials: Impact of nutrient management interventions

Results of on-farm trials conducted on 94 farmers' fields across locations (8 centres) indicated significant yield improvements over the farmers practice. At most of the locations, Zn is a major limiting nutrient (Bhopal, Banswara, Parbhani, Nagpur, Coimbatore and Guntur) and the application of $ZnSO_4$ resulted in yield increases of about 13-62%. Application of just the recommended NPK alone resulted in 17% yield increases at Dharwad. The results of the on-farm trials conducted across locations, indicates the positive influence of nutrient management practices and the importance of adopting balanced fertilizer schedules, if the present yield gaps need to be brought down.



Soil fertility

Soil organic C and nutrient status was estimated at Bhopal and the data indicates a significant improvement in soil organic C content with the application of manure (Table 14). Similarly, nutrient (available N, P and exchangeable K) status also improved with the manure amended plots over the plots receiving fertilizers alone.

Table 14: Effect of nutrient management interventions on soil fertility at Bhopal

	OC (%)	Av. N	Av. P	Ex. K
Absolute control	0.47	163	8.9	503
Farmers practice	0.50	174	12.0	489
RDF	0.51	188	15.2	519
Recommended INM	0.57	212	21.0	602
2.5t FYM + 2.5 t Phosphocompost + 75% N	0.60	200	18.7	582
5t FYM + 2.5t Phosphocompost + 50% N	0.63	237	23.5	614
2.5 t Phosphocompost + 100% N	0.56	202	17.8	563
2.5t FYM + 2.5 t Poultry manure + 75% N	0.57	197	19.8	554
5t FYM + 2.5t Poultry manure + 50% N	0.60	210	21.7	602
2.5 t Poultry manure + 75% N	0.54	203	16.5	553
LSD (0.05)	0.06	15	2.1	53

The carbon labile pools were estimated at Bhopal. The data presented in Table 15 suggest that with the use of poultry manure there is a likelihood of the labile C pools decreasing which may not be desirable if applied on a long-term basis. Furthermore, CMI values were determined and a similar observation was observed.

Table 15: Effect of nutrient management interventions on C fractions at Bhopal

	Total OC	Labile OC	Non labile OC	Lability
Absolute control	6251	257	5994	0.043
Farmers practice	6694	288	6406	0.045
RDF	6827	312	6515	0.048
Recommended INM	7537	393	7144	0.055
2.5t FYM + 2.5 t Phosphocompost + 75% N	8024	429	7596	0.056
5t FYM + 2.5t Phosphocompost + 50% N	8379	452	7927	0.057
2.5 t Phosphocompost + 100% N	7448	402	7046	0.057
2.5t FYM + 2.5 t Poultry manure + 75% N	7537	348	7188	0.048
5t FYM + 2.5t Poultry manure + 50% N	7936	389	7547	0.051
2.5 t Poultry manure + 75% N	7226	333	6893	0.048
LSD (0.05)	-	27	-	-

Table 16: Carbon Management index for different nutrient management interventions

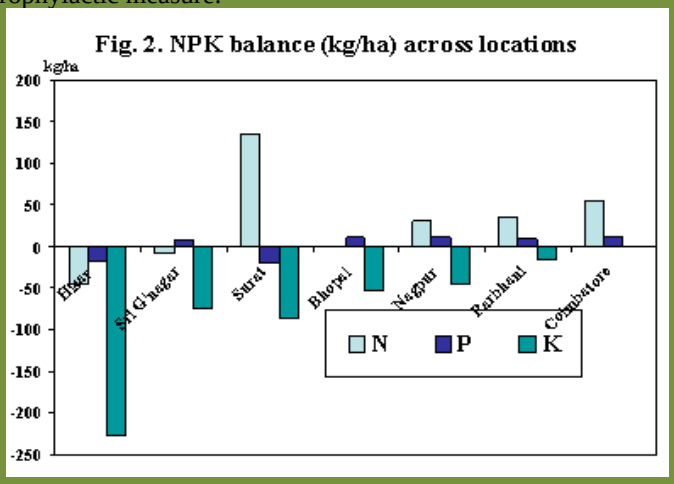
	CPI	CLI	CMI
Absolute control	1.00	1.00	1.00
Farmers practice	1.07	1.05	1.13
RDF	1.09	1.12	1.22
Recommended INM	1.21	1.28	1.55
2.5t FYM + 2.5 t Phosphocompost + 75% N	1.28	1.32	1.69
5t FYM + 2.5t Phosphocompost + 50% N	1.34	1.33	1.78
2.5 t Phosphocompost + 100% N	1.19	1.33	1.59
2.5t FYM + 2.5 t Poultry manure + 75% N	1.21	1.13	1.36
5t FYM + 2.5t Poultry manure + 50% N	1.27	1.20	1.53
2.5 t Poultry manure + 75% N	1.16	1.13	1.30

INM interventions with phosphocompost resulted in relatively higher CMI values compared to that with poultry manure.

Nutrient balances

Across locations, the nutrient balance is positive for P whereas it is negative for K (Fig. 2). N balance was either positive or negative depending on the intensity of the cropping. The magnitude of negativity was higher in the north whereas it was smaller in the rainfed cropping systems. Although the P balance was positive, a tendency to enriching the soil, there is need to apply P in recommended amounts because most of the cotton growing soils have high P fixing capacity (Vertisols). Although the soil K status is high, applying K in recommended doses should be adopted as a prophylactic measure.

Fig. 2. NPK balance (kg/ha) across locations



Project Impact:

- Location specific nutrient modules (INM) were evaluated at 11 locations. At all locations, there was a potential to **save on fertilizer-N and P** with the revised INM practices.
- Use of location specific organic resources would make the INM practices readily acceptable and **reduce dependency on farmyard manure**, a resource that is available in limited supply.
- At all locations, a **positive response to nutrient management interventions was observed on the farmers' fields**.
- **A positive externality** is the **improvement in soil health** (higher fertility and productivity).