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Improving Productivity and Soil Properties in Rice Based Cropping Systems Through Pre-*kharif* Green Manuring

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ABSTRACT

In a long-term field experiment during 2002-03 to 2006-07 on a black clayey Vertisol at the Directorate of Rice Research Farm, Hyderabd , the effect of pre-*kharif* green manures (greengram , cowpea, dhaincha and sunhemp) on grain yield of *kharif* rice and *rabi* non rice crops (groundnut, sunflower, safflower and chickpea) and soil health parameters was studied. The grain legumes (green gram and cowpea) provided additional advantage through grain yield (4.5 -5.7 q ha^{-1}) in addition to providing nutrients and improving soil properties. Whereas, sole green manures with high phyotomass (dhaincha and sunhemp) improved the soil properties to a great extent. Grain yield of *Kharif* rice was significantly higher (22-74 %) in green manure applied plots over fallow plots. The *rabi* crops also recorded higher yield (by 17-76 % in different crops over 5 years) in green manured plots over fallow plots showing residual effects of regular application of green manures on non-rice *rabi* crops through improved soil health indicators.

Key words : Green manures, Productivity, Rice, Soil properties, Vertisols.

Rice and rice based cropping systems are of prime importance in global food production especially in South East Asia (Huke and Huke, 1997). India is the third largest consumer of fertilizers in the world, having currently fertilizer consumption more than 26 million tons. Intensive agriculture, involving exhaustive high yielding varieties of rice and other crops, has led to heavy withdrawal of nutrients from the soil. Imbalanced and discriminate use of chemical fertilizers has resulted in deterioration of soil health (John *et al*., 2001). This problem can be partly solved by changing from continuous rice production systems to growing rice-legume cropping systems. Green manures constitute an important component of integrated nutrient management (INM) and continuous recycling of the green manures with organic amendments enhances the organic matter content and also supplements the nutrient pool of the soil (Balwinder Kumar *et al*., 2008). Legumes such as groundnut, mungbean (*Vigna radita* L.), soyabean (*Glycine max* L.) and cowpea (*Vigna unguiculata* L.) are well suited for rice based cropping systems in peninsular India (Gowda *et al*., 2001). Summer green manuring with sesbania has been recommended to save fertilizer N in the rice-wheat cropping system in India (Meelu *et al*., 1992). Longterm addition of organic materials to soil results in increased crop productivity and improved soil properties also. Thus, considering the advantages from *in-situ* green manuring, the present field studies were conducted at the Directorate of Rice Research for five years during 2002-03 to 2006-07 to study the influence of pre-*kharif* green manures on *kharif* rice, *rabi* non-rice crops and soil properties under rice based cropping systems.

MATERIAL AND METHODS

A field experiment was conducted during pre-*kharif*, *kharif* and *rabi* for five years (2002-03 to 2006-07) at the Directorate of Rice Research farm, Hyderabad (17° 19′ N latitude, 78° 23′ E longitude, 542 m altitude, with a mean annual precipitation of 750 mm), Andhra Pradesh, India. The experimental soil was deep black clayey soil (Typic Pellustert) with 28% sand, 24% silt and 48% clay. The experimental soil characteristics were: slightly alkaline (pH 8.2), non-saline [electrical conductivity (EC) 0.51 dS m^{-1}], calcareous [free calcium carbonate ($CaCO_3$) 5.01%], with cation exchange capacity (CEC) 44.1 cmol(p+)kg^{-1} soil and medium in soil organic carbon (0.64 %). Available nitrogen was low (228 kg ha^{-1}); available phosphorus was medium (34.74 kg P_2O_5 ha^{-1}); available potassium was high (476 kg K_2O ha^{-1}) and available zinc (Zn) was also high (12.5 ppm). During *pre-kharif* season, one fallow and four *in-situ* grown legume green manure treatments *viz*., dhaincha, sunhemp, green gram and cow pea were imposed. Green manures crops were sown @ 50 kg ha^{-1}seed with the onset of pre-monsoon showers in the month of May, grown up to 60 days and were incorporated in to the soil before flowering.

Table 1. Phytomass/grain production and nutrient contributions by pre-*kharif* green manures (Mean of 5 years data (2002-03 to 2006-07).

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Treatments	Phytomass (t ha^{-1})		Grain yield (kg ha^{-1})		Lignin content (%)		L/N ratio	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Greengram	12.50-30.50	20.41	470-570	510	8.50-8.65	8.58	4.12-4.20	4.16
Cowpea	18.5-45.82	39.5	450-480	463	6.50-6.90	6.70	3.30-3.70	3.50
Sunhemp	43.00-95.89	65.54	-	-	4.00-5.20	4.60	1.43-2.60	2.02
Dhaincha	40.00-92.49	60.18	-	-	4.50-4.80	4.65	1.92-2.30	2.11
Nutrient Contribution								
Treatments	N (kg ha^{-1})		P (kg ha^{-1})		K (kg ha^{-1})		C/N ratio	
	Range	Mean	Range	Mean	Range	Mean		
Greengram	29-36	33	3.1-4.0	3.6	20-22	22	19.5	
Cowpea	38-50	42	3.5-3.8	3.7	29-35	31	19.0	
Sunhemp	89-103	94	8.5-9.0	8.7	77-82	77	14.0	
Dhaincha	85-91	89	5.2-7.4	6.7	56-58	57	13.0	

During *kharif,* rice variety, Phalguna was grown following the incorporation of green manures. NPK @ 100-60-40 kg ha^{-1}was applied for all the treatments uniformly and in *rabi,* four rice based crops *viz.*, groundnut, sunflower, safflower and chickpea were raised with recommended fertilizer schedule. The phytomass by green manure crops was recorded on fresh weight basis before incorporation in to soil. In case of green gram and cowpea, grain yield was also recorded. Their nutrient contribution was calculated by estimating the NPK content in them before incorporation. Grain yields of rice and *rabi* non rice crops were recorded.

At the end of *rabi* 2002-03 and 2006-07, composite soil samples were collected from 0-15 cm depth for each replicate plot by compiling five soil cores. The samples were air dried, processed using a 2-mm sieve, and used for measuring soil fertility (soil organic carbon, available nitrogen, phosphorous and potassium) physical parameters (bulk density, mechanical impedence and aggregate stability) and biological parameters like soil enzymes (glucosidase, phosphatase and protease) using standard procedures. Statistical analysis was done following RBD technique (Gomez and Gomez 1984) for all the parameters studied.

RESULTS AND DISCUSSION

Pre-*kharif* green manures

Phytomass /grain production

Of the four green manures grown during June-July months availing pre-monsoon rains, green gram recorded 4.7-5.7 with a mean of 5.1 q ha^{-1}grain in addition to 12.5-30.5 with a mean of 20.4 t ha^{-1}phytomass during the pre-*kharif* seasons over 5 years (Table 1). Cowpea, another dual purpose grain legume, recorded on an average 4.5-4.8 with a mean of 4.63 q ha^{-1}grain and 18.5-45.8 with a mean of 39.5 t ha^{-1}of fresh phytomass. In terms of fresh biomass for incorporation, the other sole green manures *viz.*, tall and fast growing dhaincha and sunhemp recorded comparatively higher phytomass of 60 and 65 t ha^{-1}, respectively. Lignin content, which determines release rate of nutrients from green manures was more in green gram (8.8 %) followed by cow pea (6.7 %) at maturity as compared to sole green manures crops, Sunhemp and Dhaincha (4.6 %).

Nutrient contribution

Nutrient (NPK) contribution from the four green manure crops was found varying. With regard to nitrogen, the contribution was maximum from the fast growing sole green manure crops, sunhemp (89-103 kg ha^{-1}) and dhaincha (85-91 kg ha^{-1}). Further, grain legumes, green gram (29-36 kg ha^{-1}) and cow pea (38-50 kg ha^{-1}) obviously contributed less nitrogen due to their less biomass production. Similarly, P and K contributions were more from dhaincha and sunhemp than from the other two grain legumes. However, source of these P and K nutrients is only soil, where green manures recycle them from the deeper layers of the soil. Whereas, in case of N, the contributions include N through biological nitrogen fixation (BNF) as well as soil (NO_3-N formed during aerobic phase). Thus, green manures trap the NO_3-

N formed during aerobic phase, protect it from leaching and preserve it for the next crop. Similar results were also reported by Buresh and De Datta (1991) and Yadvinder singh *et al.,* (1994). Higher NPK contribution from Dhaincha was also reported by Prasad *et al*., (2002) and Ashraff *et al*., (2004).

Kharif rice grain yield

Direct effects of sole and grain legume green manures on *kharif* rice productivity were significant. Grain yield (Table 2) from the plots added with green manures ranged from 5.5-7.8 with a mean range of 6.30 to 6.40 t ha^{-1}as compared to fallow plot (4.3-5.0 t ha^{-1} with a mean of 4.7 t ha^{-1}). The yield advantage due to pre-*kharif* green manuring in *kharif* rice ranged from 22-74% with a mean of 36% over fallow plots. Grain legumes were at par with sole green manures despite recording much lower phytomass and lower quantities of NPK contribution to succeeding rice than sole green manures. This highlights the slow and gradual release of N in grain legumes. Due to relatively higher lignin content (6.7-8.6 %) and L/N ratios (3.5 to 4.2) in grain legumes, they acted as slow release N sources and N release was more synchronous with rice N uptake and it was less prone to loss than that from quick N releasing sole green manure crops like Dhaincha and Sunhemp with less lignin (4.6%) present at flowering stage.

The explanation for the observed superior performance of green gram residue at harvest *vis a vis* sole green manures of same age at flowering is that mature green gram residue at harvest stage has relatively higher lignin and fibre contents and thus exhibits comparatively wider C:N ratio , which in turn modify the residue decomposition rate .

The wider C: N ratio, moderate lignin and fibre contents together help the release of N from residue for crop uptake so as to synchronise N release with crop demand in order to cover the vigorous growth phases of rice plant. (Watanabe1984 and Fox *et al*., 1990). Further, it is well known that combined application of green manures and inorganic fertilizers improve the efficiency of applied nutrients as compared to the sole application of either green manures or chemical fertilizers. Substantial addition of N through BNF in low land rice cropping systems by growing fast growing green manures in the short period prior to planting of rice was also reported by Ladha *et al*., (1992). Higher rice yields with green manure application compared to chemical fertilizers alone was reported by Gouranga Kar *et al.,* (2011). The grain yield response as measured by agronomic efficiency (A.E) was very high in case of green gram (36-58 kg grain /kg N) followed by cowpea (26-40 kg grain/ kg N). Sole green manures gave moderate A.E (10-20 kg grain/kg N).

Grain yield of _rabi_ crops

After harvesting of rice, with residual soil fertility, and recommended fertilizer doses, four non–rice crops (Groundnut, Sunflower, Safflower and Chick pea) were sown consecutively for five years during the *rabi* /dry (winter season) on the same land to explore the possibilities of growing these crops after rice. The effects of combined sources of nutrients applied to rice on the grain yield of succeeding *rabi* crops are presented in Table 3. It was shown that in all the years, all the *rabi* grown crops except Chick pea for the last two years were significantly superior in green manured plots over

Table 2. *Kharif* rice yields (t ha^{-1}) (2002-03 to 2006-07) as influenced by pre-*kharif* green manures.

Treatments (Green manures)	*Kharif* 2002	A.E of N 2002	*Kharif* 2003	A.E of N 2003	*Kharif* 2004	A.E of N 2004	*Kharif* 2005	A.E of N 2005	*Kharif* 2006	A.E of N 2006	Grain yield (Mean of 5 years)	A.E of N (Mean of 5 years)
Green gram	5.81	36.9	6.01	36.0	6.18	47.0	7.81	58.31	6.15	37.2	6.39	43.08
Cow pea	5.90	30.9	6.10	29.6	6.09	33.9	7.51	39.95	6.12	26.2	6.34	32.11
Dhaincha	5.53	9.60	6.15	12.1	6.24	16.2	7.23	15.78	6.34	15.6	6.30	13.70
Sunhemp	5.57	10.6	6.20	13.4	6.38	18.6	7.31	16.22	6.52	20.1	6.40	15.78
Fallow	4.63	-	4.98	-	4.75	-	4.31	-	4.81	0.51	4.70	-
C.D(0.05)	0.657		0.246	-	0.496	-						

A.E-Agronomic efficiency (kg grain/kg N added through green manures)

Table 3. Residual effect of pre-*kharif* green manures on rice based rabi crops.

Green manure crop	Grain yield (q ha^{-1})											
	rabi 2002-03				*rabi* 2003-04				*rabi* 2004-05			
	Ground nut	Sun flower	Safflower	Chickpea	Ground nut	Sun flower	Safflower	Chickpea	Ground nut	Sun flower	Safflower	Chickpea
Green gram	12.8	8.2	15.9	15.3	12.8	13.52	14.44	13.15	15.71	14.56	15.21	13.84
Cow pea	13.1	8.4	13.4	14.4	13.1	14.59	13.78	13.84	16.20	15.00	14.26	12.94
Dhaincha	15.1	9.2	15.0	14.1	14.0	13.96	14.47	13.73	15.90	14.13	14.50	13.60
Sunhemp	14.6	9.2	15.8	15.5	14.4	14.30	14.32	13.28	16.15	13.95	13.20	12.54
Fallow	9.10	6.2	8.50	9.70	9.69	10.44	10.72	9.41	11.58	9.21	9.71	9.91
C.D(0.05)	1.27	1.71	3.78	3.31	2.25	1.152	1.914	1.868	3.08	1.51	1.81	2.11

Green manure crop	Grain yield (q ha^{-1})											
	rabi 2005-06				*rabi* 2006-07				Mean data			
	Ground nut	Sun flower	Safflower	Chickpea	Ground nut	Sun flower	Safflower	Chickpea	Ground nut	Sun flower	Safflower	Chickpea
Green gram	20.21	15.42	13.27	13.55	21.14	14.31	12.51	13.12	16.53	13.20	14.26	13.79
Cow pea	22.16	16.28	13.57	14.12	21.54	15.22	12.12	14.50	17.22	13.89	13.42	13.96
Dhaincha	24.20	15.21	13.12	14.40	24.50	14.21	12.91	14.80	18.74	13.34	14.00	14.12
Sunhemp	22.67	15.64	13.60	13.27	24.67	15.43	13.10	13.79	18.49	13.70	14.00	13.67
Fallow	17.13	13.04	10.24	11.57	17.50	12.20	9.90	12.10	13.00	10.21	9.814	10.53
C.D(0.05)	2.08	1.73	1.23	NS	2.5	1.81	2.11	NS				

Table 4. Influence of pre-*kharif* green manures on soil health indicators.

Treatments	At the end of *rabi* 2002-03							At the end of *rabi* 2006-07						
	Fertility indicators				Physical indicators			Fertility indicators				Physical indicators		
Green manure crops	O.C (g kg^{-1})	Av.N (kg ha^{-1})	Av. P_2O_5 (kg ha^{-1})	Av. K_2O (kg ha^{-1})	B.D (Mg m^{-3})	Aggregate stability (% > 2.5mm)	Mechanical impedence (kg/cm^2)	O.C (g kg^{-1})	Av.N (kg ha^{-1})	Av. P_2O_5 (kg ha^{-1})	Av. K_2O (kg ha^{-1})	B.D (Mg m^{-3})	Aggregate stability (% > 2.5mm)	Mechanical impedence (kg/cm^2)
Green gram	5.7	209	43.4	475	1.22	61.2	4.52	0.62	205	48.2	490	1.20	62.1	4.41
Cowpea	5.9	206	44.2	496	1.21	61.4	5.06	0.68	238	43.1	500	1.18	61.7	4.80
Dhaincha	7.4	223	47.8	520	1.10	66.1	3.72	0.86	260	49.4	540	1.08	67.0	3.50
Sunhemp	7.1	214	45.4	509	1.12	64.5	3.98	0.82	282	51.0	550	1.10	65.0	3.78
Fallow	4.8	181	39.4	408	1.32	54.6	6.86	0.46	155	32.0	300	1.34	53.9	7.10
C.D(0.05)	1.0	21.8	NS	46.7	0.12	4.83	1.53	0.12	110	9.6	190	0.13	5.31	1.51

Biological indicators (unit: µg-p-nitro phenol $hr^{-1}g^{-1}$soil)

Treatments	At the end of *rabi* 2002-03			At the end of *rabi* 2006-07	
Green manure crops	Glucosidase	Phosphatase	Protease	Glucosidase	Phosphatase
Green gram	36.50	430	63.5	37.93	311.48
Cowpea	43.98	448	55.4	43.97	313.46
Dhaincha	42.63	442	71.2	38.68	283.81
Sunhemp	37.63	425	55.9	33.65	267.81
Fallow	40.72	420	60.0	36.46	289.34
Mean	40.29	433	61.2	38.14	293.15
C.D(0.05)	5.25	NS	NS	4.55	7.17

fallow. The yield advantage with a pre-*kharif* green manuring on *rabi* grain yields varied from 33-44, 19-58, 30-76 and 17-55% over fallow plots in case of groundnut, sunflower, safflower and chickpea, respectively. This clearly indicated the residual effect of pre-*kharif* green manures on the grain yield of *rabi* crops also. Groundnut gave significantly higher pod yields (14-24 q ha^{-1}) in sole green manured treated plots in three out of five years as compared to grain legumes which recorded 13-20 q ha^{-1}.

The higher yields of ground nut with high phytomass producing sole green manures (sunhemp and dhaincha) as compared to grain legumes (green gram and cow pea) can be attributed to the improved soil structure through reduced soil crusting allowing the penetrating pegs the smooth passage for successful development in to pods. In case of other crops also, the increase in grain yield can be attributed to the better root growth and consequent nodulation due to improved soil structure and biological health. Integrating organic sources in a cropping system to benefit both preceeding and succeeding crops, there by to increase the system productivity was emphasized by Singh *et al*., (1995). Increased pod yields of groundnut with pre-*kharif* green manures applied to rice in rice-groundnut system were also reported by Prasad *et al.,* (2002).

Soil properties

Long term effects of pre-*kharif* green manure crops on a few important soil health parameters (fertility, physical and biological parameters) were evaluated at the end of *rabi* 2002-03, and *rabi* 2006-07 (Table 4). At the end of 2002-03, soil fertility indices (except available P_2O_5) were improved significantly in the green manure treatments .However, after five years of study (2006-07), the increase was still higher in all the green manured plots than fallow plots. The important fertility indicators, organic carbon content decreased in the fallow plots after 5 years as compared to first year. The improvement in SOC was more in case of sole green manure crops than grain legumes. The physical parameter, bulk density decreased significantly in case of grain legume green manured plots only compared to the fallow plots in the initial year and after 5 years, all the green manures decreased the bulk density significantly over fallow. Similarly, soil aggregate stability also improved significantly with green manuring at the end of both years. Among the green manures, high phytomass yielding dhaincha and sunhemp showed more improvement in physical parameters than grain legume received plots. Mechanical impedence, another key soil physical attribute that influences germination and root growth was also significantly lower in green manure applied plots. Mac Rae and Mehuys, (1985) reported that repeated green manuring over time alone brought about improvement in soil physical properties. Further, sole green manures that provide more biomass recorded significantly lower soil resistance than grain legumes plots. Kumar *et al*., (2001) reported improved soil properties with *sesbania* application in rice-pulse system.

Certain aspects of biological health parameters like alkaline phosphatase, B-glucosidase and protease were studied at the end of 2002-03 and in 2006-07, showed that glucosidase activity was significantly more in cow pea and dhaincha applied plots when compared to green gram and sunhemp applied plots and the increased activity could be attributed to readily available substrates in those green manures. Phosphatase activity did not differ among the treatments at the end of first year while it was significantly higher in plots with grain legumes at the end of fifth year. Marginally higher enzyme activities recorded in fallow plots could be due to incorporation of weeds in the same plots, thus providing substrate for microbial enzyme activities.

Thus to conclude, in the long term study on the effects of pre-*kharif* green manures on the yields of *kharif* rice and non-rice *rabi* crops, the addition of green manures improved the grain yield of rice and *rabi* crops also proving that regular green manuring not only has direct effects on immediate rice crop but also show residual effects in terms of improved soil properties and biological health and thus benefiting non-rice *rabi* crops also.

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