Value Addition to Crop Residues: An Indigenous Resource Conserving and Soil Fertility Enhancing Technology of India

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ABSTRACT. A two-year field experiment was conducted during the rainy seasons of 2004 and 2005 in the farmers' fields of Mahbubnagar district in Andhra Pradesh, India, to test the practice of cattle shed bedding with groundnut (*Arachis hypogaea* L.) shells by preparing Groundnut Shell Manure (GSM) and its application along with Farmers' practice (FP) and in comparison with five treatments namely, FP only, FP and GSM, FP and compost, regenerative (only organics) and Recommended Dose of Fertilizers (RDF), FP and RDF being the checks on rainy season rainfed groundnut and castor (*Ricinus communis* L.) crops. The results indicated that crops receiving GSM and compost performed well during the deficit rainfall year (2004) as well as during the normal rainfall year (2005) and recorded 12-16% higher yields of groundnut and 9-14% higher yields in castor over the FP. During 2004 which was a deficit rainfall year, GSM and compost application enhanced soil moisture by 14-40%, percentage of filled pods by 59-65% and 100 seed weight by 18% in groundnut while in castor 6-33% improved soil moisture enhanced capsules per plant from 45 to 57% without any significant effect on 100 seed weight. These treatments were followed by groundnut shell applied crop, RDF and regenerative (organics only) treatments. However, during 2005 the order in which higher yields achieved by treatments were GSM application, compost followed by RDF due to well-distributed rainfall. Therefore to sustain yields in rainfed groundnut and castor crops, present experimentation emphasized application of organics to improve soil fertility and drought management ability by recycling crop residues through a simple process of cattle shed bedding. This was an attempt to introduce the practice of cattle shed bedding as value addition to process other locally available crop residues to the practitioners of farming (especially parts of Africa and Latin America). doi:10.1300/J064v31n04_03

KEYWORDS. Castor, cattle shed bedding, decomposition, groundnut shell manure, indigenous practice, inorganics

INTRODUCTION

Prior to the advent of green revolution technology, indigenous crop production practices sustained agriculture for several centuries in India (Warren, 1991). Green revolution technology with its emphasis on synthetic inputs substantially increased the productivity of crops but at the same time caused deterioration in soil and environmental quality.

These negative consequences of the green revolution technology prompted a look back at indigenous practices that had faded into the background during the green revolution phase. Some indigenous practices managed to persist through the green revolution phase, mainly due to their strength and local relevance (Thrupp, 1989). One such practice is the preparation and application of groundnut shell manure (GSM) using groundnut (*Arachis hypogaea* L.) shell, a crop residue that the groundnut farmers of Anantapur district in India have practiced for generations and continue to practice even today. In the olden days, these farmers used to cope with the nutrient requirements of crop through crop residuemanagement as significant amount of nutrients are still present in the plant residues after harvest (Fraser and Francis, 1996). This practice used to improve the water-holding capacity of the soils by enhancing the organic matter in the soil (Jenny, 1941; Perucci et al., 1997). The farmers of Anantapur believe that the practice of applying GSM has maintained the fertility of their soils and helped them to achieve reasonable yields even in years of drought.

In the neighbouring district of Mahbubnagar, Andhra Pradesh, India, that bears many similarities to Anantapur district, this practice is unknown. We studied the indigenous practice in Anantapur and attempted to introduce the practice in Mahbubnagar district with a hypothesis that value addition to crop residues and its application improves crop yields by improving soil characteristics. Therefore the present study was carried out to test the practice of cattle shed bedding as value addition to various crop residues prevalent in different regions with an example of GSM application for introduction in the groundnut-growing region alongside other existing and recommended soil fertility management and crop nutrition practices

MATERIALS AND METHODS

Study of the Practice in Anantapur District

Anantapur district has an arid climate with an average annual rainfall of 560 mm, most of which is received in the monsoon season from June to October. The soils are mostly shallow red sandy loams with low water-holding capacity. Low and ill-distributed rainfall coupled with low water-holding capacity of the soils predisposes the crops to water stress during the growing period. The district experiences drought in 3 out of every 5 years. Groundnut (*Arachis hypogaea* L.) is the predominant crop and is grown in 70% of the district's cultivated area.

The practice of shell manure preparation and application was identified during a survey of indigenous soil fertility management practices followed by farmers of Anantapur. An in-depth study was made in Bukkarayasamudram, Tadipathri and Battalapalli blocks (a subdivision of district) to understand the practice. Whole village meetings, focus group meetings and individual farmer interactions were employed to gather information about the practice.

Shells constitute 30-40% by weight of harvested groundnut pods. While the weight of shells obtained from a single crop in a hectare of land is not much (typically 400 kg), the volume of shells is large. The farmers of Anantapur spread the groundnut shells to a height of 2 inches on the floor of the cattle shed where cattle are housed. The cattle urinate and defecate on the layer of shells and these wastes get mixed with the shell as the cattle trample and roll over the floor of the cattle shed. Urine and dung-laden shells are removed from the floor after 4 days and heaped outside. Another layer of shells is spread, removed and added to the heap. This process continues until all the available shells get exhausted. The material in the heap is allowed to decompose for 2-3 months after which it turns into fine organic manure. At the beginning of the monsoon season, the shell manure is spread in the field and incorporated during preparatory tillage. Typically, a farmer with 2 ha of land gets about 800 kg of shell after removing the seed. In a cattle shed of 10 m long and 3 m wide designed to house 5 adult cattle, about 200 kg shell is required for each spreading. Thus, the shell available with the farmer is exhausted in 4-5 cycles of spreading and removal spanning 20-25 days. During the rest of the year, the farmers prepare farmyard manure with the urine, dung and fodder waste from the cattle shed. After 2-3 months, 600-700 kg of shell manure (dry weight) is obtained. Since the quantity of shell manure generated is small, farmers divide their field into two parts and apply the available shell manure to each of the two plots in alternate years.

We collected 10 samples each of shells, shell manure and farm yard manure from the farmers and analyzed them for organic C, N, P and K. Shell manure had a considerably higher N content compared to FYM (Table 1).

Introduction of the Practice in Mahbubnagar District

Mahbubnagar district has a semi-arid climate with average annual rainfall of 603 mm, which occurs mainly in the monsoon season from

TABLE 1. Nutrient contents in samples collected at Anantapur and Mahbubnagar, Andhra Pradesh, India.

Material	Organic C (%)	N (%)	P_2O_5 (%)	K_2O (%)
Anantapur (Mean of 10 samples)				
Groundnut shell	33.0	1.10	0.08	0.55
Shell manure	20.7	1.75	0.18	0.62
FYM	29.0	0.54	0.19	0.41
Mahbubnagar (Mean of 8 samples)				
Cattle urine	10.1	0.70	Traces	1.25
Cattle dung	31.4	0.35	0.14	0.22
Groundnut shell	34.4	1.19	0.08	0.55
Shell manure	21.2	1.75	0.18	0.62
FYM	29.0	0.54	0.18	0.41
Compost	24.2	0.58	0.11	0.51

June to October. The soils are sandy loams with low water-holding capacity, low organic matter and nutrients. Groundnut is grown extensively (20%) in the district apart from castor (*Ricinus communis* L.) (18.8%; Statistical abstract AP-2006). Mahbubnagar district was a natural choice for introducing the practice of shell manuring, as the farmers of Mahbubnagar are not aware of the practice and the agro climatic conditions of the district and social conditions of the farmers are identical to Anantapur.

The introduction of the practice was made a part of a systematic experiment with several other treatments for comparison. The treatments were as follows:

1. Farmers' practice (FP) = 1 t FYM ha^{-1} + 17.5 N + 36.3 P_2O_5 + 17.5 K_2O every year
2. Groundnut shell (GSM) = 1 t groundnut shell ha^{-1} + FP
3. Shell manure = 1 t GSM ha^{-1} + FP
4. Compost = 1 t compost ha^{-1} + FP
5. Organics only = 1 t GSM + 1 t compost + 1 t FYM ha^{-1}
6. RDF = Recommended dose of fertilizer (20:40:20 (N:P:K) + 5 t FYM ha^{-1})

FP refers to the practice being adopted by majority of the farmers in the area. A groundnut shell treatment was included to examine how direct application of shell fares compared with shell manure. The rate of application of shell manure was increased to 1 t ha^{-1} from 600 to 700 kg as practiced in Anantapur assuming that better management would enhance the yield and make more shell available for manure preparation. The compost treatment was included as some agencies working in the area are promoting the use of compost prepared from shells and other agricultural wastes. The organics only treatment was chosen to see whether avoidance of chemical fertilizers has any beneficial effects on crop productivity and soil quality. The RDF treatment is based on the recommendations of the local agricultural research station (ANGRAU, 2003).

Two villages, Edammagadda, where groundnut (*Arachis hypogaea* L.) is the predominant crop and Tadipathri, where castor (*Ricinus communis* L.) is the major crop were chosen for introducing the GSM practice. Village meetings were conducted in both the villages and the practice of shell manuring, and the benefits of applying shell manure were explained to the farmers. Subsequently, four farmers from each village, who evinced keen interest in the practice, were selected for on-farm experiments. Farmers of Edammagadda took the experiments with groundnut while farmers of Tadipathri took up experiments with castor. The objective of testing GSM on castor was to encourage the farmers to prepare and use castor shell manure in the same way as GSM. The area of land allocated for the experiment in each of the 8 farmers' fields was around 0.60 ha.

In both 2004 and 2005, each of the 8 farmers was given 800 kg of groundnut shell and they were taught the method of preparation of shell manure. Subsequently, they were guided in the preparation of shell manure in exactly the same manner as it is done in Anantapur. The shell had to be supplied to the farmers as they usually sell away the groundnut pods to merchants in town. Samples of cattle urine, dung and groundnut shell used for preparing shell manure and shell manure prepared by them were collected and analysed for organic carbon, N, P and K. The results of the analysis (Table 1) showed close agreement with the analysis of samples from Anantapur, indicating a successful reproduction of the method. Samples of FYM and compost prepared by the farmers were also analysed. FYM, compost and shell manure were spread in the field at the onset of monsoon and incorporated through preparatory cultivation.

Cultivation of groundnut and castor: Groundnut (cv. 'TMV-2') and castor (cv. 'Kranthi') were sown in the last week of June in both years and harvested after 110 and 180 days, respectively. Basal and top dress chemical fertilizers were applied as per treatments. Interculture, pest and disease control measures were taken up as required uniformly across treatments.

Soil samples were collected from three spots in each plot at initial and final stages of the crop to the depth 15 cm. The collected soil samples were air-dried and crushed to pass through 2 mm sieve before chemical analysis. Analysis was carried out for organic carbon (Walkley and Black, 1934) after passing the soil through 0.5 mm sieve; available nitrogen (Subbaiah and Asija, 1956), available phosphorus (Olsen et al., 1954) and available potassium (Hanway and Heidel, 1952). Plant samples were collected from 0.5 m^2 areas at different stages of crop growth and dried and powdered to estimate nutrients. Plant samples were analysed for nitrogen using Micro-Kjeldhal method (Humphries, 1956). Phosphorus and potassium in triacid digests were estimated using spectrophotometer and flame photometer, respectively (Jackson, 1973). Pod and haulm yields at harvest were determined from 900 m^2 net plots for each treatment. Soil moisture was measured gravimetrically at critical stages. N sufficiency index was determined in groundnut and castor using chlorophyll meter at critical stages (Peterson et al., 1993). A value of 95% of the N index with RDF treatment was taken as threshold sufficiency level below which N deficiency was inferred.

The experiments were laid out in a randomized block design with 6 treatments. The four farmers in each of the two villages served as replicates. Experiments with groundnut were separate and independent of experiments with castor. Experimental results for each crop were analysed using ANOVA for RBD (Gomez and Gomez, 1984). Statistical significance of treatments was determined using F test and treatments were compared using LSD at 5% probability. Pooled analysis of results of 2004 and 2005 was not undertaken as the two years were markedly different in terms of rainfall. 2004 was a drought year with only 265 mm rainfall during groundnut-growing period (131 days) and castor (180 days) while 2005 was a normal rainfall year with 503 mm rainfall during crop growth period of groundnut (110 days) and castor (180 days), respectively.

RESULTS AND DISCUSSION: 2004 AND 2005

Drymatter Accumulation (Leaf + Stem)

At harvest, higher total drymatter accumulation by the groundnut crop was observed with GSM (3210 kg ha^{-1}) and compost (3161 kg ha^{-1})

applied treatments followed by RDF (2886 kg ha^{-1}) plot, groundnut shell (2766 kg ha^{-1}) applied treatment and organics only treatment (2749 kg ha^{-1}). Unlike 2004, the sequence observed during 2005 was in the descending order of GSM applied plots (7819 kg ha^{-1}), RDF (7392 kg ha^{-1}) followed by compost applied field (6663 kg ha^{-1}) and other treatments. This might be due to the difference in the amount of rainfall received and its distribution during 2005. During 2004, deficit rainfall of 265 mm reduced the expression of inorganic fertilizers while good rainfall quantity and distribution (503 mm) helped in the expression of inorganic fertilizers. However, in both the years significant effect of GSM and compost application was observed on groundnut drymatter production (Table 2).

No significant difference was observed in the effect of GSM/compost on drymatter accumulation in castor in both the years since it was a long duration crop (Subba Reddy et al., 1996). However, GSM application resulted in 2784 kg drymatter ha^{-1} during 2004 while 5041 kg drymatter ha^{-1} was recorded in the year 2005 due to the receipt of almost double the quantity of rainfall of 2004, and also because of good distribution without any dryspell unlike 2004 in which two dryspells occurred. Regenerative treatment (only organics) did not show any significant effect (Table 2).

Soil Moisture

Soil moisture, measured at critical stages, fluctuated widely during groundnut crop-growing season, at times reaching extremely low levels (<2% gravimetric) during prolonged rainless periods. GSM and compost applied plots recorded 14-40% and 15-34% more soil moisture, respectively over FP during 2004 while 6-10% increased soil moisture retention was observed during 2005. The improved presence of soil moisture in these treatments might be due to the application of more organics over FP in the form of GSM (Unger, 1986; Dormaar and Carefoot, 1996). However, as per Hill et al. (1985) and Nuttall et al. (1986), this difference in holding soil moisture becomes insignificant because of the extended dry periods. This was confirmed by Peterson et al. (1996), Moitra et al. (1996) and Bissett and O'Leary (1996). Substantial quantity of rainfall received and better distribution during 2005 reduced the difference in holding soil moisture among the treatments over FP (Table 3). RDF in groundnut recorded either lowest or equivalent to FP in most of the stages due to the insignificant role of inorganics in holding soil moisture (Patter et al., 1999; Subba Reddy et al., 2004).

TABLE 2. Effect of application of different treatments on drymatter accumulation (kg ha^{-1}) in groundnut and castor during 2004 and 2005.

Treatments	Groundnut at harvest (130 DAS)						Castor at harvest (152 DAS)					
	2004			2005			2004			2005		
	Leaf	Stem	Total	Leaf	Stem	Total	Leaf	Stem	Total	Leaf	Stem	Total
FP	948	1,746	2,694	2,805	3,056	5,861	541	1,934	2,475	2,268	2,511	4,779
FP + Groundnut shell	1,092	1,674	2,766	3,125	3,338	6,463	595	2,038	2,633	2,389	2,560	4,949
FP + GSM	1,188	2,022	3,210	3,787	4,032	7,819	656	2,130	2,784	2,436	2,605	5,041
FP+ Compost	1,133	2,028	3,161	3,275	3,388	6,663	612	2,039	2,651	2,444	2,585	5,029
Regenerative (only organics)	996	1,853	2,849	3,119	3,344	6,463	560	1,711	2,271	2,329	2,500	4,829
RDF	1,074	1,812	2,886	3,472	3,920	7,392	585	1,906	2,491	2,425	2,539	4,964
LSD (P = 0.05)	NS	NS	275	159	119	217	48	153	168	45	30	54

NS: Not Significant.

TABLE 3. Soil moisture (% w/w) recorded for different periods during 2004 and 2005 for groundnut and castor.

Treatments	Groundnut						Castor					
	2004			2005			2004			2005		
	Flowering (20 DAS)	Pegging and pod formation (40 DAS)	Pod filling (70 DAS)	Flowering (20 DAS)	Pegging and pod formation (40 DAS)	Pod filling (70 DAS)	Vegetative (30 DAS)	Flowering (60 DAS)	Capsule filling (105 DAS)	Vegetative (30 DAS)	Flowering (60 DAS)	Capsule filling (105 DAS)
FP	2.14	6.45	4.61	9.96	9.89	8.47	1.42	7.02	6.67	13.1	13.0	2.89
FP + Groundnut shell	2.41	6.91	5.57	10.5	10.2	8.68	1.49	7.19	7.22	13.7	13.5	3.30
FP + GSM	3.03	7.38	5.70	11.0	10.9	8.97	1.89	7.82	7.55	15.1	14.0	3.63
FP + Compost	2.87	7.48	5.30	11.0	10.9	9.07	1.58	7.46	7.28	15.7	14.3	4.13
Regenerative (only organics)	2.55	6.90	5.30	10.4	10.6	8.72	1.72	7.38	6.83	13.6	14.2	3.75
RDF	2.56	6.63	4.62	10.7	9.60	8.53	1.55	7.24	7.20	13.7	13.5	3.22

FP: Farmers' Practice.

The soil moisture content recorded at flowering, capsule formation and flowering of secondaries and capsule filling and development of primaries in castor in GSM and compost applied plots was 6-33% higher than FP during 2004. However, inconsistent trend was observed during 2005 (Table 3). Castor unlike the groundnut crop, being a non-legume non-edible oilseed crop with deep root system (Subba Reddy et al., 1999), might have tapped soil moisture from deeper layers.

Nitrogen Sufficiency

Nitrogen sufficiency measurements with 95% RDF as threshold showed N insufficiency only in FP and shell treatments at some intervals during groundnut crop growth. Nitrogen deficiency was observed at only one stage (at pod formation stage) in FP during 2004 while no deficiency was observed during 2005. The rest of the treatments showed sufficiency at all stages in both the years, indicating that the crop did not face nitrogen deficiency under these treatments (Table 4). This expression of nitrogen insufficiency in FP might have occurred due to the insufficient soil moisture conditions during 2004 as Thomsen (1993) observed, that very dry conditions limit the availability of soil moisture and in-turn the nutrients. However, treatments other than FP did not experience N insufficiency due to the enhanced soil moisture retention due to growing season precipitation.

Nitrogen sufficiency was observed in all the treatments of castor except in FP at capsule filling stage of primaries, which was the manifestation of non-availability of soil moisture besides being the treatment of less organics reducing the availability of nitrogen (Table 4).

Nutrient Uptake

Total uptake of N, P and K by aboveground plant parts was highest with shell manure barring a few exceptions in which the highest uptake was associated with the compost treatment.

Nutrient uptake by the groundnut crop was high during 2005 compared to 2004 due to the receipt of normal quantity of rainfall and distribution. This confirms the observation of Doel et al. (1990) that nutrient uptake was reduced at low soil water contents and increased with good soil moisture conditions, however, during 2004, nitrogen uptake was increased by 23%. During 2005, nitrogen uptake by groundnut increased on an average by 40% in GSM plots over FP plots. This is because when leguminous crop residues are returned to the soil, they can be a significant

TABLE 4. N sufficiency Index (%) for two years of application of different treatments for groundnut and castor.

Treatments	DAS, 2004				DAS, 2005			
	30	80	105	125	30	80	105	125
Groundnut								
FP	98.6	94.5	98.5	93.5	97.4	96.5	97.1	96.4
FP + Groundnut shell	100.5	96.9	99.1	94.5	98.3	97.2	98.4	97.2
FP + GSM	100.7	99.0	100.2	99.9	98.7	97.9	99.4	98.6
FP + Compost	100.6	96.6	99.5	98	99.4	98.6	99.5	98.7
Regenerative (only organics)	100.3	95.8	97.0	97.1	97.7	98.5	98.8	98.3
RDF	–	–	–	–	–	–	–	–
Castor								
FP	96.4	94.7	96	96	96.8	99.2	97.5	97.2
FP + Groundnut shell	96.6	95.8	96.9	96.9	97.8	99.9	98.3	97.4
FP + GSM	97	98.8	97.4	99	98.8	100.2	98.9	98.6
FP + Compost	96.9	95.9	97.4	99.5	99.3	100.8	99.3	99.1
Regenerative (only organics)	95	95	96.3	98.3	98.6	99.6	98.5	98.7
RDF	–	–	–	–	–	–	–	–

Values are calculated based on the 95% of RDF chlorophyll meter values.

source of nutrients since decomposition is faster for plant uptake (Mosier and Krowze, 1998) as it can have a substantial impact on soil water (Radke and Honeycutt, 1994). During 2005, RDF was third best after GSM and compost plots in uptake of total nutrients by groundnut since the rainfall was sufficient to extract nutrients from inorganic sources. As per Singh and Das (1995), when the soil moisture availability is high, expected response from the added nutrients is also high and this was confirmed by Randhawa and Singh (1983) (Table 5).

GSM and compost application increased the uptake of N, P and K over RDF in castor crop, since application of leguminous crop residues in a decomposed state to the soil improved the soil moisture availability and in turn uptake of nutrients. As per Thomas (1986), higher soil moisture may result in increased plant uptake of nutrients indirectly, which move primarily by diffusion (Table 5). Further, Randhawa and Singh (1983) stressed that soil moisture is a prerequisite for nutrient cycling (Cassman and Munns, 1980; Sommers et al., 1981; Doel et al., 1990).

Yield Attributes

Improved soil moisture resulted in concomitant increase in yield attributes of groundnut namely, percent filled pods per plant and 100 seed weight through enhanced nutrient uptake (Table 6). In both the years, FP showed lowest percentage of filled pods per plant. Percentage of filled pods per plant realized was 59-67% during a deficit rainfall year (2004) while it rose to 87-93% during 2005. Dry spells at flowering and pod-filling stages affected both the percentage of filled pods per plant and 100 seed weight (Subba Reddy et al., 1999) in groundnut. GSM, compost followed by groundnut shell applied crop realized higher percentage of filled pods per plant and 100 seed weight. Most influenced yield attribute during 2005 was percentage of filled pods per plant rather than the 100 seed weight due to the well-distributed growing season precipitation (Table 6).

Capsules per plant and 100 seed weight are the attributes for yield in castor. Recorded capsules per plant during 2004 ranged from 45 to 57%, which rose to 60-69% during 2005 (Table 6). Interestingly significant effect of treatments was observed on capsules per plant during a deficit rainfall year rather than on 100 seed weight unlike groundnut crop. This might be due to the dry spell that occurred during capsule formation stage of the castor crop as was observed by Subba Reddy et al. (1996). However, both capsules per plant and 100 seed weight were influenced during 2005 in achieving high yields. During 2005, GSM (69),

TABLE 5. Total uptake of nutrients (kg ha^{-1}) during 2 years of experimentation.

Treatments	Groundnut (harvest) (kg ha^{-1})						Castor (harvest)(kg ha^{-1})					
	N		P		K		N		P		K	
	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
FP	35	89	4.0	10.3	4.3	7.5	19.4	105	7.9	24.4	7.5	19.8
FP + Groundnut shell	37	100	4.6	11.6	4.8	8.7	20.8	119	8.7	27.2	7.4	22.8
FP + GSM	43	125	5.4	14.5	5.8	10.3	28.3	125	12.0	29.2	8.0	24.4
FP + Compost	42	108	5.4	12.5	5.9	8.7	25.4	133	10.9	30.2	8.1	24.6
Regenerative (only organics)	38	102	4.6	11.4	4.8	8.1	24.1	118	10.1	26.6	6.1	19.2
RDF	38	115	4.8	14.0	4.9	10.3	19.9	129	8.6	25.8	7.3	20.4

TABLE 6.. Effect of different treatments on yield attributes of groundnut and castor during 2004 and 2005.

Treatments	Groundnut				Castor			
	Filled pods (%)		100 seed weight (g)		Capsules per plant (No.)		100 seed weight (g)	
	2004	2005	2004	2005	2004	2005	2004	2005
FP	59	88	26.7	37.3	47	60	22.2	37.9
FP + Groundnut shell	63	92	31.0	38.1	50	65	22.5	40.0
FP + GSM	65	93	31.4	38.4	57	69	23.2	40.7
FP + Compost	67	87	30.3	38.5	54	69	23.0	40.1
Regenerative (only organics)	59	93	29.1	37.7	45	66	22.2	38.5
RDF	65	87	30.7	38.6	50	68	22.2	38.8
LSD (P = 0.05%)	–	–	1.4	NS	1.8	1.1	NS	1.6

compost (69) and RDF (66) applied plots have recorded higher number of capsules per plant followed by organics only treatment (66) and groundnut shell application treatment (65).

Yields

The groundnut crop suffered from dryspells of 24 days and 30 days duration at flowering and pod-filling stages during 2004. This deficit rainfall (265 mm) reduced soil moisture availability at critical stages, which affected the nutrient uptake resulting in low percentage of filled pods per plant (59 to 67%). Hence the low groundnut yields during 2004 and the yields ranged from 459 to 546 kg ha^{-1} only (Table 7). However, the receipt of 503 mm rainfall during 2005 resulted in yields to the tune of 1817 kg ha^{-1} to 2102 kg ha^{-1}. This emphasized the importance of soil moisture availability to the crop in drylands (Das et al., 1993). Equivalent yields were recorded by GSM and compost applied crop during 2004 and 2005, while groundnut shell applied crop (500 kg ha^{-1}) recorded similar yields that of compost (515 kg ha^{-1}) during 2004. Expression of low yields by groundnut shell could be due to high content of which is known to be a recalcitrant substance highly resistant to decomposition (Giller and Cadisch, 1997). Further, the repeated drying and wetting during 2004 affected the decomposition of N compounds in the shell (Franzluebbers et al., 1994). Regenerative treatment comprising of only organics yielded lowest during 2004 (469 kg ha^{-1}), which was on par with FP as the build up of nutrients may take some more time to show the effect. Till that time, the effect may not be obvious as was observed by Aggarwal et al. (1997) that the short-term addition may show only a slight or no increase in soil organic matter. However, all the treatments except FP had recorded yields on par with each other during 2005. This emphasized the importance of application of more organics in improving soil moisture conditions and maintaining soil health in drylands.

Haulm yield of groundnut in 2004 did not differ with treatments. Highest groundnut haulm yield in 2005 was obtained with shell manure treatment (3055 kg ha^{-1}); however, no significant difference was observed among different treatments except that of treatments over FP.

High and equivalent yields were recorded by the castor crop in GSM (508 kg ha^{-1}) and compost (477 kg ha^{-1}) applied plots during 2004. Similar trend was observed during 2005 also. During the year of drought (2004), RDF applied plots yielded equivalent to groundnut shell applied plots (455 and 458 kg ha^{-1}, respectively) while during a good rainfall

TABLE 7. Effect of different treatments on yields of groundnut and castor during 2004 and 2005.

Treatments	Groundnut				Castor			
	Pod yield (kg ha^{-1})		Haulm yield (kg ha^{-1})		Seed yield (kg ha^{-1})		Stalk yield (kg ha^{-1})	
	2004	2005	2004	2005	2004	2005	2004	2005
FP	459	1,817	818	2,687	435	838	2,136	3,840
FP + Groundnut shell	500	2,012	847	2,882	458	876	2,380	4,051
FP + GSM	546	2,102	902	3,055	508	923	2,500	4,122
FP + Compost	515	1,952	942	3,054	477	902	2,440	4,089
Regenerative (only organics)	469	1,974	877	3,004	404	835	2,040	3,894
RDF	465	1,981	821	2,934	455	899	2,172	4,127
LSD (P=0.05%)	35	157	NS	192	40	47	128	131

year (2005), RDF fared equivalent to GSM and compost applied plots since application of inorganics ensures instantaneous availability of nutrients provided there is no scarcity of soil moisture. This condition was fulfilled during 2005. Hence the better yields from the castor crop with RDF was observed (Table 7). Application of groundnut shells as such did not have immediate impact on yield of castor during 2004 as found by Haider and Martin (1981) that drying and re-wetting produce no effect on N mineralization (Vanlauwe et al., 1996; Hammel, 1997) while the haulm yields recorded by the crop in groundnut shell treated plot was equivalent to the crop in GSM and compost applied plots. Low partitioning efficiency in castor with more of vegetative growth due to application of groundnut shell was observed. Application of only organics has shown no significant impact on grain yields or on stalk yields in both the years, This treatment of only organics initially showed low response as the shift to entirely organics does not result in concomitant improvement in the soil environment.

There were gains in organic C, N, P and K in soil with two years of treatments over levels before start of experiment in both the crops. However, organic C, N, P and K after 2 years did not differ significantly with treatments. Percent change observed was more in case of nitrogen with GSM and compost applied plots while no particular trend was observed with regard to phosphorus and potassium (Table 8).

CONCLUSION

The present study indicated that preparation and application of GSM as well as compost to the crops of rainy season groundnut and castor sustained the yields both during a deficit rainfall year (265 mm during 2004) as well as during a normal rainfall year (503 mm during 2005) unlike RDF which fared well only during a good rainfall year. GSM and compost applied fields yielded high through enhanced soil moisture (14-40%), increased nitrogen uptake by 22-31% and an improvement in soil available nitrogen at the rate of 16-21 kg ha^{-1}. Application of groundnut shell as such demands more water for the decomposition and short-term application of organics cannot show remarkable improvement in soil health. However, Mcdonagh et al. (2001) highlighted the importance of inputs as high-quality residues (legumes) for nutrient supply in the short term in contrast to the inputs of poor quality residues of cereals in building soil organic matter in the longer term. Keeping all

TABLE 8. Nutrient status of soils after 2 years of application of treatments and experimentation.

Treatments	Nitrogen (kg ha^{-1})			Phosphorus (kg ha^{-1})			Potassium (kg ha^{-1})			Organic Carbon (%)		
	Initial	Final	Change (±)	Initial	Final	Change (±)	Initial	Final	Change (±)	Initial	Final	Change (±)
Groundnut												
FP	176	192.8	16.8	5.9	7.3	1.4	218.6	225.1	6.5	0.28	0.31	0.03
FP + Groundnut shell		194.5	18.5		8.1	2.2		228.8	10.2		0.35	0.07
FP + GSM		195.8	19.5		8.6	2.7		232.0	13.4		0.38	0.07
FP + Compost		197.2	21.2		7.9	2.0		235.0	16.4		0.30	0.02
Regenerative (only organics)		194.3	18.3		8.1	2.2		229.4	10.8		0.33	0.05
RDF		196	20.0		8.1	2.2		230.0	11.4		0.35	0.07
Castor												
FP	217.1	230.0	12.9	6.6	7.6	0.1	197.6	204.4	6.8	0.41	0.45	0.04
FP + Groundnut shell		233.3	16.2		7.8	1.20		213.2	15.6		0.51	0.10
FP + GSM		235.7	18.6		8.0	1.40		216.8	19.2		0.51	0.10
FP + Compost		235.2	18.1		7.9	1.30		210.2	12.4		0.48	0.07
Regenerative (only organics)		233.0	15.9		7.6	1.0		206.2	8.6		0.45	0.04
RDF		235.0	17.9		7.12	0.52		215.0	17.4		0.48	0.07

the above points in view, the practice of cattle shed bedding to prepare GSM as a simple technique may be adopted to process other crop residues available locally for sustainable agriculture.

To make the above practice universal over time and space, the crop resources like groundnut shell as studied in the present experiment can be replaced with the crop residues pertinent to any given region and time for making this practice sustainable. Inclusion of animal component besides the crop residues as in a farming system made it a better sustainable method for even small and marginal farmers.

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