RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

The findings of the study "**Exploring the recycling potentialities of cotton waste for production of innovative sustainable products**" are discussed under the following heads.

- **4.1 Composition of willow waste**
- **4.2 Characteristics of willow waste, decomposing sources, willow waste compost and willow waste vermicompost**
- **4.3 Weight of cotton kapas from various treatments**
- **4.4 Cotton lint weight and seed weight after ginning**
- **4.5 Ginning out turn (GOT) % of the cotton obtained from different treatments**
- **4.6 Analysis of cotton fiber properties**
- **4.7 Analysis of soil composition before and after various treatments**
- **4.8 Evaluation of willow waste handmade paper**
- **4.9 Evaluation of willow waste aloe vera lemon finished wiping sheet**
- **4.10 Evaluation of willow waste composites using natural gum (TKP) and synthetic resin (PP)**
- **4.11 Evaluation of briquettes obtained using 100% willow waste (WWB) and willow waste with coir (WWCB)**

4.1. Composition of Willow waste (WW)

Table I, shows the properties of selected post industrial cotton waste, namely, willow waste (WW).

The selected willow waste had pH of 7. 08, electrical conductivity was 1.51 dS/m, moisture 12%, carbon 19.2%, total nitrogen 0. 7%, total phosphorous 0.15% and total potassium 0.25%. The C/N ratio of willow dust was found to be 27.4 respectively. The crude fiber was 47.43%, ash content was 8.5%, lignin 37.3% and cellulose 22.75%. Willow waste mainly consists of trash particles from the cotton plant that includes lignin rich particles like stem and leaf bits, along with cotton lint as a result of cleaning process. This may be the reason for higher lignin and lowered cellulose content in willow waste.

The major nutrients namely calcium, magnesium, iron, copper, zinc and manganese were 0.12%, 0.05%, 1.25 mg/kg, 3.65 mg/kg, 3.12 mg/kg and 6.1 mg/kg. The microorganisms namely bacteria, fungi and actinomycetes was reported to be 8 x 10 ^{7} CFU/ g, 6 x 10 ^{7} CFU/ g and 5 x 10 ^{7} CFU/ g respectively.

TABLE I

COMPOSITION OF WILLOW DUST

Parameters	Willow waste
pH	7.08
Electrical conductivity (dS/m)	1.51
Moisture (%)	12
Organic carbon (%)	19.2
Total Nitrogen (%)	0.7
Total Phosphorous (%)	0.15
Total potassium (%)	0.25
C/N	27.4
Crude fiber (%)	47.43
Ash content (%)	8.5
Lignin (%)	37.32
Cellulose (%)	22.75
Calcium (%)	0.12
Magnesium (%)	0.05
Iron (mg/kg)	1.25
Copper (mg/kg)	3.65
Zinc (mg/kg)	3.12
Manganese (mg/kg)	6.1
Bacteria (X 10 ^{7} CFU/ g)	8
Fungi (X 10 ^{7} CFU/ g)	6
Actinomycetes (X 10 ^{7} CFU/ g)	5

4.2. Characteristics of willow waste, decomposing sources, willow waste compost and willow waste vermicompost

The composition of raw materials in comparison to decomposing sources selected, along with composted willow dust and vermicomposted willow dust are given under Table II.

TABLE II
CHARACTERISTICS OF WILLOW WASTE, DECOMPOSING SOURCES, WILLOW WASTE COMPOST AND WILLOW WASTE VERMICOMPOST

Parameters	Raw waste	Decomposing sources		Composted willow waste		Vermicomposted willow waste	
	Willow waste	Cow dung	EM	WWCCD	WWCEM	WWVCCD	WWVCEM
pH	7.08	8.8	3 - 4	7.1	7.1	6.9	7.2
Electrical Conductivity (dS/m)	1.51	0.14	-	0.26	0.24	0.11	0.12
Moisture (%)	12	57.17	-	67.54	47.16	54.0	47.1
Carbon (%)	19.2	36.85	-	36.61	40.75	28.7	29.4
Nitrogen (%)	0.7	1.47	-	2.67	2.58	2.21	2.08
C: N RATIO	24.4	25.1	-	14.8	15.8	13.0	14.1
Phosphorous (%)	0.15	-	-	-	-	0.81	0.73
Potassium (%)	0.25	-	-	-	-	0.91	0.87

EM – Effective microorganisms, **WWCCD** – Willow waste composted with cow dung, **WWCEM –** Willow waste composted with effective microorganisms, **WWVCCD –** Willow waste vermicomposted with cow dung, **WWVCCD –** Willow waste vermicomposted with effective microorganisms

From Table II it is clear that the cow dung sample used for the study had a pH of 8.8, electrical conductivity 0.14 dS/m, moisture 57.17%, organic carbon 36.85%, total nitrogen 1.47%, and C: N as 25.1. The second decomposing source, namely effective microorganisms had a pH range of 3-4 with eighty beneficial microorganisms including photosynthetic bacteria, ray fungi, yeast and fungi (EM1 Application Manual, 1995) and (Higa and Wididana,1988).

The pH of raw material and decomposing sources used in the study, namely willow waste, cow dung and EM were 7.08, 8.8 and 3 - 4 respectively. At the end of composting the pH of WWCCD and WWCEM was 7.1, and pH of vermicomposts namely WWVCCD and WWVCEM were 6, 9 and 7.1 respectively. The pH reduced from 7.1 to 6.9 in WWVCCD which may be due to production of carbon dioxide and organic acids that are a result of microbial decomposition in the process of bioconversion of waste as narrated by Liu et al.,(2012).

Electric Conductivity of the compost should be less than 4dS/m [Abdalla, E, Ali, S, H, Saad, S, A, and Ibrahim, S, (2012)], and it is 1.51 dS/m for willow dust. EC was 0.26 dS/m and 0.24 dS/m during composting; which further reduced to 0.11 dS/m and 0.12 dS/m in vermicomposting. This helps in understanding that demerits in direct application of willow waste to farms which is the existing disposal technique. The moisture levels increased during composting and further reduced during vermicomposting. This may be due to loss of moisture in pit, porous structure and larger surface area of the manure. The heat generated during the process also reduces the moisture levels.

The total organic carbon (TOC) was 36.61% and 40.75% which decreased during vermicomposting to 28.7% and 29.4%. The reduction in carbon levels may be due to the degradation of organic matter by microorganisms. Similar results in loss of carbon content is also found to be reported by Batham, Arya, and Tiwari, (2014) and Sharma, *et.al.,* (2005), which was explained to have occurred because of denitrification, ammonia volatisation and ammonification.

Nitrogen content increased during composting to 2.67 % and 2.58 % and reduced to 2.21% and 2.08% during vermicomposting. The action of earthworms results in increase in the ash and nitrogen content, due to the breakdown of carbon and mineralisation of nitrogen. Contrastingly, composted willow waste shows increased nitrogen levels and vermicomposted willow dust shows reduced nitrogen content. This may be due to leaching of nutrients by water and volatisation of ammonia. The final nitrogen is low when compared to the initial nitrogen content and similar results were observed by Abdalla *et al.,* (2012).

Earthworms added to an organic waste aids in faster decomposition, with increase in nitrogen values and reduction in C/N ratio (Liu *et al.,* 2012). The C/N ratio of the raw willow waste (24.4) and starting materials was reduced and willow dust compost has C/N 14.8 and 15.8. It was further reduced to 13 and 14.1. During the process of composting the C/N value tends to increase due to rapid decomposition and mineralisation along with the loss of carbon as carbon-di-oxide (Singh, 1995).

Phosphorous content of the resultant manure from vermicomposting willow dust was 0.81 and 0.73 in WWVCCD and WWVCEM respectively. Potassium was 0.91 % and 0.87% in WWVCCD and WWVCEM respectively. It was found higher in vermicompost using cow dung WWVCCD, thus suggesting benefits of using cow dung for good values of P and K. The increase in potassium levels found in vermicompost may be due to presence of micro flora present in the gut of earthworms as stated by Sharma (2003).

From the results it is clear there is significant difference between carbon, nitrogen, phosphorous and potassium content of vermicompost in comparison with compost. Hence it concluded that both composted willow waste and vermin composted willow waste manures will be an effective bio-manure.

4.3. Weight of cotton kapas from various treatments

Table III and in Figure I, show the mean weight of the kapas obtained from each treatment.

Observing the mean weight of cotton kapas, it is clear that the maximum yield was 1.43 kgs as in WWEM. The least yield 0.81 kgs, was seen in CONTROL treatment. The second highest yield was 1.26kgs as in INM, followed by 1.21 kgs in WWCD. The GM and CHE gave a yield of 1.14 kgs and 1.06 kgs respectively. WWEM has the highest yield of all which is due to the presence of micro nutrients along with macronutrients. The F values prove that there is a significant difference between the cotton weight obtained from WWVCCD and WWVCEM treatments. There is no significance difference between the treatments and CONTROL samples. Thus it can be concluded that the prepared bio-manure made from up-cycling cotton dust can be used for raising the crop effectively.

TABLE III

THE WEIGHT OF THE KAPAS (in kgs) FROM VARIOUS TREATMENTS

Type of treatment	Mean (in kgs)	S.D	CV %	F Value (CONTROL VS Treatment)
WWVCCD	1.21	0.0445	3.68	0.21*
WWVCEM	1.43	0.0132	0.92	0.018
INM	1.26	0.1473	11.69	2.326
GM	1.14	0.0811	7.11	0.705
CHE	1.06	0.1158	10.93	1.438
CONTROL	0.81	0.0966	11.92	-
F VALUE (WWVCCD VS WWVCEM)	11.410*			

4.4. Cotton lint weight and seed weight after ginning

Table IV and Figure II display the mean weight of cotton fiber and seed weight after the ginning process.

TABLE IV
THE LINT WEIGHT AND SEED WEIGHT AFTER GINNING

Type of treatment		Mean Fiber weight (%)	Mean Seed weight (%)
WWVCCD	**T1**	34	53
WWVCEM	**T2**	35	56
INM	**T3**	38	58
GM	**T4**	35	55
CHE	**T5**	38	59
CONTROL	**T6**	33	60

The Table IV shows low seed weight and high fiber lint content, in samples WWCD, INM and CHE as 34% and 38 % respectively. The maximum seed weight of

59% was in CHE followed by 58% in INM. This proves the bio-manure obtained from willow waste to be an effective replacement for chemical manure. Hence it could be concluded that the CHE treatment has the maximum mean fiber weight and seed weight, but still the GM treatment also shows only a lower rate by 3% and 4% for fiber and seed weight respectively.

4.5. Ginning out turn (GOT) % of the cotton obtained from different treatments

Table V shows the ginning out turn (%) between the treatments.

TABLE V
THE GINNING OUT TURN (%) BETWEEN VARIOUS TREATMENTS

Type of treatment		Mean Fiber weight (%)	Mean Seed weight (%)	Ginning percentage (%)
WWVCCD	**T1**	34	53	18
WWVCEM	**T2**	35	56	20
INM	**T3**	38	58	22
GM	**T4**	35	55	19
CHE	**T5**	38	59	22
CONTROL	**T6**	32	52	16

The ginning out turn was found to be maximum in INM and CHE as 22%. It was 20% in WWVCEM and 18% in WWVCCD respectively. GM has 19% as ginning index. The ginning out turn percent was higher in CHE treatment by only 3% when compared to GM treatment. Hence it could be concluded that there is no significant difference in the ginning percentage between all the treatments.

4.6. Analysing the cotton fiber properties

The cotton fiber properties were tested using High Volume Index (HVI) as per ASTM D 5867 standard and compared with the standard and between the treatments as given in Table VI

TABLE VI

THE COTTON FIBER QUALITIES OF THE SELECTED COTTON VARIETY KCH 15K 39 BG II

Type of treatment		2.5% SL	UR (%)	Mic (µg/inch)	Tenacity (g/tex)	Elongation (%)	+b	Rd	True matt (%)
Standard * for KCH 15K 39 BG II		31.3 – 33	-	3.5 – 4	23.3 – 24	-	-	-	-
WWCD	**T1**	31.57	45.50	3.50	23.93	5.60	8.98	81.53	0.91
WWEM	**T2**	32.65	44.25	3.50	24.58	6.45	8.73	81.38	0.92
INM	**T3**	32.80	44.50	3.73	24.63	6.28	8.63	80.38	1.02
GM	**T4**	33.22	44.00	3.40	24.83	5.65	8.38	81.97	0.91
CHE	**T5**	32.00	44.75	3.68	23.95	6.23	8.90	81.63	0.93
CONTROL	**T6**	30.00	43.0	3.40	23.00	5.5	8.2	80.1	85
S.L – Span length, UR – Uniformity ratio, Mic- Micronairre, T – Tenacity, Rd – reflectance, +b yellowness, E – Elongation									

**** Source: ICAR, 2012***

Table VI indicates the different fiber properties of cotton obtained from the various treatments and the standard values of the selected seed variety namely KCH 15K 39 BG II. Each of the fiber properties are discussed along with their standard SD, CV and F values in the following Tables.

4.6.1. Determination of 2.5 % span length (SL)

Table VII and Figure III detail on the mean, standard deviation, coefficient Variation and F-Value cotton fibers 2.5 % Span Length (S.L) among different treatments.

TABLE VII
SPAN LENGTH (2.5%) OF COTTON FIBERS OBTAINED FROM VARIOUS TREATMENTS

Type of treatment	Mean	S.D	CV %	F Value (CONTROL VS Treatment)
WWVCCD	31.57	3.3178	10.51	1.917
WWVCEM	32.65	3.3721	10.33	1.98
INM	32.80	2.9314	8.94	1.497
GM	33.22	2.7432	8.26	1.31
CHE	32.00	3.0450	9.52	1.615
CONTROL	30.00	2.3958	7.99	-
F VALUE (WWVCCD VS WWVCEM)	0.97			

From Table VII it is clear that the GM has the highest span length of 33.22% at 2.5 %, followed by INM lint of 32.8 %, WWVCEM 32.65%, CHE 32% and WWVCCD 31.57% respectively. The span lengths of all the cotton fibers obtained from the five treatments are close to the standard value 31.3 – 33. Among the replications the coefficient of variation in length is least for CHE. The mean value shows that there is no significant difference between treatments. Thus it can be concluded that the application of selected manures has no impact on the span length of the cotton fiber.

4.6.2 Determination of uniformity ratio (UR%)

Table VIII and Figure IV indicate the uniformity of cotton fibers obtained from the various treatments.

Table VIII and Figure IV show the uniformity ratio UR (%). It is highest in WWVCCD and lowest in GM. WWVCEM has UR better than GM. It is understandable, that there is no significant difference in the uniformity ratio (%) of cotton between the treatments and CONTROL and the two types of manure. It can be concluded that the manure supplementation did not have much impact on UR (%) of cotton fiber.

TABLE VIII
UNIFORMITY RATIO (%) OF COTTON FIBERS OBTAINED FROM VARIOUS TREATMENTS

Type of treatment	Mean (%)	S.D	CV %	F Value (CONTROL VS Treatment)
WWVCCD	45.50	5.1341	11.28	2.855
WWVCEM	44.25	3.7693	8.52	1.539
INM	44.50	3.8539	8.66	1.609
GM	44.00	2.7432	6.23	0.815
CHE	44.75	4.3165	9.65	2.018
CONTROL	43.00	3.0382	7.07	-
F VALUE WWVCCD VS WWVCEM	1.86			

Table VIII and Figure IV show the uniformity ratio UR (%). It is highest in WWVCCD and lowest in GM. WWVCEM has UR better than GM. It is understandable, that there is no significant difference in the uniformity ratio (%) of cotton between the treatments and CONTROL and the two types of manure. It can be concluded that the manure supplementation did not have much impact on UR (%) of cotton fiber.

4.6.3 Determination of micronairre (µg/inch)

The micronairre values of the cotton fibers obtained from the different treatments is illustrated in Table IX and Figure V.

Micronairre was found to be higher in INM and chemical as 3.73 µg/inch and 3.68 µg/inch respectively. Manures from the research namely WWVCCD and WWVCEM were having the standard micronairre, namely 3.5. µg/inch. The least value was reported in GM which indicates fineness of cotton fibers. The CV is found to be lowest in CHE and highest in INM. From the F values it is clear that there is no significance between the different type of treatments and CONTROL and between manures. Thus it could be concluded that the micronairre values could also be increased by use of cow dung and vermicomposting.

TABLE IX
MICRONAIRRE VALUE (µg/inch) OF COTTON FIBERS OBTAINED FROM VARIOUS TREATMENTS

Type of treatment	Mean (%)	S.D	CV %	F Value (CONTROL VS Treatment)
WWVCCD	3.50	0.2201	6.29	1.468
WWVCEM	3.50	0.1485	4.24	0.668
INM	3.73	0.2698	7.23	2.205
GM	3.40	0.2065	6.07	1.292
CHE	3.68	0.2434	6.62	1.795
CONTROL	3.40	0.1817	5.34	-
F VALUE (WWVCCD VS WWVCEM)	2.20			

4.6.4 Determination of tenacity (%)

The tenacity (g/tex) of the cotton fibers obtained from the different treatments is revealed in Table X and Figure VI.

TABLE X
TENACITY (g/tex) OF COTTON FIBERS OBTAINED FROM VARIOUS TREATMENTS

Type of treatment	Mean (%)	S.D	CV %	F Value (CONTROL VS Treatment)
WWVCCD	23.93	1.1168	4.67	0.631
WWVCEM	24.58	1.0838	4.41	0.594
INM	24.63	1.6733	6.79	1.417
GM	24.83	1.6977	6.84	1.459
CHE	23.95	1.2006	5.01	0.729
CONTROL	23.00	1.4053	6.11	-
F VALUE (WWVCCD VS WWVCEM)	1.06			

The strength is found highest in GM, followed by INM, WWVCEM and CHE, lowest in WWVCCD as 24.63, 24.58, 23.95 and 23.93% respectively. The CV values show that the least was 1.26% in INM and highest was 4.94% in WWVCCD.

The fiber strength of WWVCCD and CHE treatments are similar to the standard value namely 23.3 – 24. The F-values help in understanding that there is a significant difference between treatments and CONTROL and samples obtained from WWVCCD and WWVCEM. The other three treatments show a slight increase in the strength when compared to the standard. Hence it could be concluded that the strength of the fibers was not affected by the different treatments.

4.6.5 Determination of elongation (%)

Table XI and Figure VII exemplify the elongation (%) of the cotton fibers obtained from the different treatments.

TABLE XI

ELONGATION (%) OF COTTON FIBERS OBTAINED FROM VARIOUS TREATMENTS

Type of treatment	Mean (%)	S.D	CV %	F Value CONTROL VS Treatment
WWVCCD	5.60	0.2410	4.30	0.475
WWVCEM	6.45	0.4401	6.82	1.583
INM	6.28	0.4280	6.82	1.497
GM	5.65	0.3320	5.88	0.901
CHE	6.23	0.3620	5.81	1.071
CONTROL	5.50	0.3497	6.36	-
F VALUE WWVCCD VS WWVCEM	0.299*			

As per the mean values between treatments the maximum elongation was reported to be in WWVCEM and least in WWVCCD as 6.45 and 5.60 % respectively. There is no significant difference in the elongation property of the fiber and the supplemented manures. The CV % values show the maximum in CHE with 7.48% and minimum in WWVCCD. The F-values proved significance between the two manures namely WWVCEM and WWVCCD. Hence it could be concluded that the elongation of the cotton fibers are not affected by the various treatments.

4.6.6 Estimation of yellowness (+b value) between treatments

The yellowness (+b) of the cotton fibers obtained from various treatments is depicted in Table XII and Figure VIII.

TABLE XII
YELLOWNESS (+b) OF COTTON FIBERS
OBTAINED FROM VARIOUS TREATMENTS

Type of treatment	Mean (%)	S.D	CV %	F Value (CONTROL VS Treatment)
WWVCCD	8.98	0.5960	6.64	1.121
WWVCEM	8.73	0.4455	5.10	0.626
INM	8.63	0.5877	6.81	1.09
GM	8.38	0.4981	5.94	0.783
CHE	8.90	0.5124	5.76	0.828
CONTROL	8.20	0.5628	6.86	-
F VALUE (WWVCCD VS WWVCEM)	1.79			

Lower the yellowness (+b) value higher is the acceptability of the fiber. According to this, GM with the value of 8.38% is better and WWVCCD is the least acceptable with higher yellow index of 8.98%. Since all the yellowness values are below 12 (standard value) the cotton fibers obtained from various treatments could be concluded to have good quality to reference with yellowness. However there is not much significant difference between the treatments based on the supplements.

4.6.7 Estimation of brightness index (Rd) value

Table XIII and Figure IX indicate the brightness index of the cotton fibers obtained from the different treatments.

From the Table XIII and Figure IX, it is evident, that the brightness was better in GM as 81.97% and lowest in INM 80.38% respectively. All the brightness index values range between the normal values (72-85). However the F-values show no significance difference between treatments. Therefore it can be conclude the supplement had no effect on the colour of cotton fibers.

TABLE XIII

BRIGHTNESS INDEX (Rd) OF COTTON FIBERS OBTAINED FROM VARIOUS TREATMENTS

Type of treatment	Mean (%)	S.D	CV %	F Value (CONTROL VS Treatment)
WWVCCD	81.53	4.8767	5.98	1.393
WWVCEM	81.38	6.3402	7.79	2.355
INM	80.38	4.8228	6.00	1.362
GM	81.97	4.1618	5.08	1.014
CHE	81.63	3.3547	4.11	0.659
CONTROL	80.00	4.1312	5.16	-
F VALUE (WWVCCD VS WWVCEM)	0.59			

4.6.8 Estimation of whiteness index (WI)

The whiteness index of the cotton fibers obtained from the different treatments is exposed in Table XIV

TABLE XIV

WHITENESS INDEX OF COTTON FIBERS OBTAINED FROM VARIOUS TREATMENTS

Type of Treatment	Rd	+b	WI
WWVCCD	81.53	8.98	54.74
WWVCEM	81.38	8.73	55.19
INM	80.38	8.63	54.49
GM	81.97	8.38	56.83
CHE	81.63	8.9	54.93
CONTROL	80	8.2	55.4

From Table XIV, the whiteness index is found to be 56.83% and highest in GM and 54.49%, the lowest in INM respectively. It is 54.74% in WWVCCD and 55.19% in WWVCEM respectively. The CHE has 54.93% whiteness index. In a nutshell, the WWVCCD and WWVCEM have whiteness index similar to CHE at 55%. Hence it can be concluded that the whiteness index is not affected by the kind of supplement.

4.6.9 Estimation of true mat (%)

Table XV and Figure X, illustrate the True mat (%) of cotton fibers between treatments and supplements

TABLE XV

TRUE MATT (%) OF COTTON FIBERS OBTAINED FROM VARIOUS TREATMENTS

Type of treatment	Mean (%)	S.D	CV %	F Value (CONTROL VS Treatment)
WWVCCD	0.91	0.0500	5.50	1.124
WWVCEM	0.92	0.0467	5.08	0.98
INM	1.02	0.0416	4.08	0.779
GM	0.91	0.0517	5.68	1.201
CHE	0.93	0.0666	7.17	1.996
CONTROL	0.85	0.0472	5.55	
F VALUE (WWVCCD VS WWVCEM)	1.15			

From the above Table it is clear that the INM treatment shows the maximum true matt value as 1.02. All the other treatments show values between 0.91 - 0.93. These values range between the normal values 1.26-0.87. Among replications, the variation in true mat value is more in WWVCCD compared to others and least in chemical. As per the F-values there is no significant difference between treatments and between manures. Hence it can be concluded that the true matt value is not affected by the kind of supplement.

4.7. Analysis of soil composition before and after treatment

The soil was tested for pH, electrical conductivity, organic carbon, cationic exchange capacity, nitrogen, phosphorous, potassium, sodium, potassium, calcium,

magnesium, iron, manganese, zinc and copper before and after the treatments and the values are presented in the following tables.

4.7.1 The pH of the soil before and after treatments

Table XVI and Figure XI, show the pH of the soil before and after treatments.

TABLE XVI

THE pH OF SOIL BEFORE AND AFTER VARIOUS TREATMENTS

Type of treatment	Mean	S.D	CV %	F Value (PS VS Treatment)
PS	7.20	0.4541	6.31	
WWVCCD	7.18	0.5309	7.39	0.731
WWVCEM	7.30	0.5779	7.92	0.617
INM	7.22	0.4446	6.16	1.043
GM	7.20	0.4678	6.50	0.942
CHE	7.48	0.5646	7.55	0.646
CONTROL	7.50	0.4257	5.68	1.137
F VALUE (WWVCCD VS WWVCEM)	0.84			

From Table XVI and Figure XI, it is clear that the pH of soil before the study (PS) was 7.20. The willow waste with cow dung treated soil (WWVCCD) has the least pH of 7.18. The maximum recommended pH 7.48 is found in CHE and the CONTROL has the highest pH as 7.50. WWVCEM has the second maximum pH as 7.30, which may be due to the acidic nature of the EM solution. INM and GM have a pH of 7.22 and 7.20 respectively. It is clear that there is no significant difference in pH of the soil sample between the treatments and CONTROL and between the manure. Hence, it could be concluded that the different types of supplements given to enhance the growth of the cotton plant did not affect the soil.

4.7.2 Electrical Conductivity (EC) of the soil

The Electrical Conductivity (EC) of the soil before and after treatments is presented in Table XVII and Figure XII.

From Table XVII and Figure XII, it is clear that the EC of the soil before test is 0.30 dS/m. The highest EC was in WWVCEM as 0.60 dS/m which is due to the

presence of microorganisms in the EM solution used. The EC was 0.40 dS/m in GM and 0.30 in WWVCCD, INM and CHE respectively. There is no significant difference between the treatments and CONTROL, between manures as shown in the F-value. Based on the above inferences it could be concluded that the different types of supplements had no effect on the electric conductivity of the soil.

TABLE XVII

THE ELECTRICAL CONDUCTIVITY OF SOIL BEFORE AND AFTER VARIOUS TREATMENTS

Type of treatment	Mean (%)	S.D	CV %	F Value PS VS Treatment
PS	0.30	0.0194	6.45	
WWVCCD	0.30	0.0170	5.66	0.351
WWVCEM	0.60	0.0362	6.03	0.286*
INM	0.30	0.0140	4.67	1.911
GM	0.40	0.0232	5.80	0.697
CHE	0.30	0.0142	4.74	1.852
CONTROL	0.30	0.0171	5.70	1.283
F VALUE WWVCCD VS WWVCEM	0.22			

4.7.3 Organic Carbon (%) in the soil

The Table XVIII and Figure XIII depict Organic Carbon (%) of the soil before and after treatments.

Table XVIII and Figure XIII illustrate the increase in organic carbon content in all the treatments when compared to the PS soil samples. Among the treatments INM has the highest carbon content % as 0.63.The least value was seen in CHE as 0.48. WWVCEM and WWVCCD show a carbon content of 0.61 and 0.58 % respectively. The result is closer to the commercially available municipal solid waste compost, available as GM as 0.62%. There is no significant difference between the PS and INM, CONTROL treatments. The inferences help to conclude that the carbon level was affected by the different types of treatments except INM.

TABLE XVIII

THE ORGANIC CARBON (%) OF SOIL BEFORE AND AFTER VARIOUS TREATMENTS

Type of treatment	Mean (%)	S.D	CV %	F Value PS VS Treatment
PS	0.30	0.0346	11.54	
WWVCCD	0.58	0.0694	11.96	0.248*
WWVCEM	0.61	0.0629	10.32	0.302*
INM	0.63	0.0557	8.84	0.386
GM	0.62	0.0892	14.38	0.150*
CHE	0.48	0.0656	13.66	0.278*
CONTROL	0.28	0.0283	10.10	1.498
F VALUE WWVCCD VS WWVCEM	1.22			

4.7.4 Cationic Exchange Capacity (CEC) of soil

The Table XIX and Figure XIV portray Cationic Exchange Capacity (CEC) of the soil before and after treatments

TABLE XIX

THE CATIONIC EXCHANGE CAPACITY OF SOIL BEFORE AND AFTER VARIOUS TREATMENTS

Type of treatment	Mean (meq./100 gms of soil)	S.D	CV %	F Value (PS VS Treatment)
PS	20.20	2.5305	12.53	
WWVCCD	15.75	1.7880	11.35	2
WWVCEM	14.25	1.5550	10.91	2.648
INM	19.30	2.1914	11.35	1.33
GM	15.15	1.7119	11.30	2.184
CHE	12.10	1.3206	10.91	3.671*
CONTROL	11.80	1.4130	11.97	3.207*
F VALUE (WWVCCD VS WWVCEM)	1.32			

The Table XIX and Figure XIV reveal the fact that the PS sample has 20.20% as CEC which is found to have decreased in all the types of treatments. The maximum decrease is seen in CONTROL followed by CHE as 11.80 and 12.10 % respectively. The minimum decrease is observed in INM as 19.30%. This may be due to pH level as quoted by Horneck, *et al*.,(2011).There is a significant difference between the PS and CHE, CONTROL soils and there is no significant difference between the electrical conductivity of all other treatments Therefore it could be concluded that the electrical conductivity is effected only by supplement of chemical to a great extent (Horneck, *et al.,* 2011).

4.7.5 Total Nitrogen (N) in soil

Table XX and Figure XV, illustrate the nitrogen content of the soil before and after the treatments.

TABLE XX

THE NITROGEN LEVELS OF SOIL BEFORE AND AFTER VARIOUS TREATMENTS

Type of treatment	Mean (mg/kg)	S.D	CV %	F Value PS VS Treatment
PS	98.00	10.3265	10.54	
WWVCCD	55.30	4.7962	8.67	4.635*
WWVCEM	53.00	7.3654	13.90	1.965
INM	65.00	6.4017	9.85	2.602
GM	46.30	3.5898	7.75	8.275*
CHE	53.50	5.5887	10.45	3.414*
CONTROL	44.20	5.4986	12.44	3.526*
F VALUE WWVCCD VS WWVCEM	0.42			

The nitrogen content was high in the PS sample as 98%, which has reduced after the treatments in all the soil samples. The CONTROL sample shows the maximum reduction as 44.20 % followed by GM as 46.3%. WWVCCD and WWVCEM have 55.3% and 53% of nitrogen, which is closer to nitrogen content in CHE (53.5%). The reduction in nitrogen level after all the treatments may be justified as the cause of crop removal, leaching and runoff as pointed out

in the "Nutrient cycling and maintaining soil fertility in fruit and vegetable" (www. extension.umn. edu./ nutrient-cycle).Thus, it can be suggested that WWVCCD and WWVCEM have appreciable nitrogen levels and can be a replacement for using chemical fertilisers on soil. It can also be said that the nitrogen content of manures obtained from study was higher than the commercially available GM. The F-values prove a significant difference between the treatments PS and WWVCCD, CHE and CONTROL soil samples.

4.7.6 Total phosphorous (P) in the soil

TABLE XXI
THE PHOSPHOROUS LEVELS OF SOIL BEFORE AND AFTER VARIOUS TREATMENTS

Type of treatment	Mean (mg/kg)	S.D	CV %	F Value (PS VS Treatment)
PS	4.50	0.4864	10.81	
WWVCCD	4.65	0.5830	12.54	0.695
WWVCEM	4.25	0.5786	13.61	0.706
INM	6.12	0.8542	13.96	0.324*
GM	5.50	0.5883	10.70	0.683
CHE	4.87	0.5272	10.83	0.851
CONTROL	4.10	0.3757	9.16	1.676
F VALUE (WWVCCD VS WWVCEM)	1.02			

The phosphorous content of the soil before and after treatments is compared in Table XXI and Figure XVI.

The PS soil sample has 4.5% of phosphorous. It is found to have reduced in WWVCEM to 4.25% and CONTROL sample as 4.10% respectively. In all the other treatments the phosphorous levels raised. The maximum phosphorous was in INM (6.12%). This is because of the supplementation of NPK at appropriate levels in a readily available form as fertilisers. The GM has 5.5% phosphorous. This green manure is usually made from composting municipal solid waste (MSW). MSW mostly encompasses of domestic wastes and plant remains collected from cleaning the city, which are usually rich in phosphorous.

The reason for increased phosphorous levels, in WWVCCD is due to bio-conversion of cotton dust using cow dung as a decomposing source. This is because of decomposing of selected cotton dust using a microbial consortium, which lacks in other major and micronutrients. The composition may be due to the increase in the phosphorous content of raw material and action of earthworms. The F- values prove a significant difference between the treatments PS and INM. Hence it can be concluded that the phosphorous level shows varied increase and decrease levels when compared to PS.

4.7.7 Total Potassium (%) in soil

The potassium level of PS and treatment samples is compared in Table XXII and Figure XVII.

TABLE XXII

THE POTASSIUM LEVELS OF SOIL BEFORE AND AFTER VARIOUS TREATMENTS

Type of treatment	Mean (mg/kg)	S.D	CV %	F Value PS VS Treatment
PS	0.90	0.0815	9.06	
WWVCCD	2.36	0.2824	11.97	0.083*
WWVCEM	1.73	0.1562	9.03	0.272*
INM	1.59	0.1489	9.36	0.299*
GM	1.41	0.1663	11.79	0.240*
CHE	1.53	0.1459	9.54	0.311*
CONTROL	0.75	0.0795	10.60	1.05
F VALUE WWVCCD VS WWVCEM	3.266*			

The potassium level has increased in all the treatments compared to the pre sowing sample expect in case of CONTROL soil sample. It is seen that the manures obtained from the study are very good sources of potassium. WWVCCD and WWVCEM have doubled in the potassium content. The higher values in WWCD compared to WWEM is because of the presence of cow dung as decomposing source. INM and CHE, have 1.59% and 1.53% mainly from the NPK supplements from the fertilisers supplemented to them. GM has the least K content

which is 1.41%.Hence it could be concluded that the bio-manures, obtained from the study with K content 2.36% and 1.73% are definitely better alternatives for potassium content. As for the F values obtained there is a significant difference between the PS and all other treatments expect CONTROL where no supplementation is done.

4.7.8 Sodium content of soil

Sodium content in the soil before and after cultivation is compared in Table XXIII and Figure XVIII.

TABLE XXIII

THE SODIUM LEVELS OF SOIL BEFORE AND AFTER VARIOUS TREATMENTS

Type of treatment	Mean ((meq./100 gms of soil))	S.D	CV %	F Value (PS VS Treatment)
PS	1.96	0.1825	9.31	
WWVCCD	2.15	0.2031	9.45	0.807
WWVCEM	1.41	0.1431	10.15	1.626
INM	2.26	0.3123	13.82	0.341
GM	1.74	0.1863	10.71	0.959
CHE	1.63	0.2162	13.27	0.711
CONTROL	1.03	0.1046	10.15	3.04*
F VALUE (WWVCCD VS WWVCEM)	2.01			

The sodium level was 1.96% in PS soil sample. At the end of study, the sodium content reduced in WWVCEM, CHE GM and CONTROL to 1.41%, 1.63% 1.74 and 1.03 % respectively. The sodium content increased in WWVCCD and INM by 2.15 and 2.26% respectively. From the F-values it is clear that there is a significant difference between PS and CONTROL treatments alone. Hence it could be concluded that the WWVCCD and INM treatments had an effect on the increase of sodium level in soil content.

4.7.9. Calcium content of soil

The calcium levels of soil are shown in Table XXIV and Figure XIX.

TABLE XXIV

THE CALCIUM LEVELS OF SOIL BEFORE AND AFTER VARIOUS TREATMENTS

Type of treatment	Mean (meq./100 gms of soil)	S.D	CV %	F Value (PS VS Treatment)
PS	6.50	0.7823	12.03	
WWVCCD	7.00	0.8924	12.75	0.768
WWVCEM	6.13	0.7949	12.97	0.968
INM	5.13	0.7125	13.89	1.205
GM	5.25	0.5377	10.24	2.116
CHE	5.13	0.4784	9.32	2.674
CONTROL	5.10	0.5884	11.54	1.767
F VALUE (WWVCCD VS WWVCEM)	1.26			

The soil had calcium content 6.5% before sowing (PS) which has decreased in all the soil samples expect WWVCCD which indicate an increase of 7% which can be further explained as the result of cow dung. Sample WWVCEM shows a minimum decrease of 6.13%.The calcium level has decreased in INM and CHE by 5.13% and in GM and CONTROL soil samples by 5.25 and 5.10% respectively. Hence it could be concluded that the presence of cow dung increases calcium level in soil as pointed out by Gross (2011). There is no significant difference between the treatments.

4.7.10. Magnesium content of soil

The magnesium content of the soil before and after treatments, were tested and presented in Table XXV and graphically in Figure XX.

The initial magnesium content is 8%, which increased in the soil after all the treatments expect the CONTROL sample. Among the treatments, the maximum increase was observed in CHE as 19.62%. The GM recorded the next highest level of magnesium as 13.62% and the INM sample has an increase of 12.75% respectively.

TABLE XXV

THE MAGNESIUM LEVELS OF SOIL BEFORE AND AFTER VARIOUS TREATMENTS

Type of treatment	Mean (meq./100 gms of soil)	S.D	CV %	F Value (PS VS Treatment)
PS	8.00	0.9288	11.61	
WWVCCD	8.38	1.2200	14.56	0.579
WWVCEM	9.25	1.2588	13.61	0.544
INM	12.75	1.3600	10.67	0.466
GM	13.62	1.8440	13.54	0.253*
CHE	19.62	1.7484	8.91	0.282*
CONTROL	7.80	0.7342	9.41	1.6
F VALUE (WWVCCD VS WWVCEM)	0.94			

Among the two manures obtained from the study, WWVCEM had higher level Mg of 9.25%, compared to WWVCCD with 8.38% of Mg. Hence it could be concluded that the all the supplementations increased the magnesium level in soil but however the prepared bio-manures may not be a very good alternative for supplementations to increase magnesium level in soil. The F values prove a significant difference between PS and CHE, GM treatments.

4.7.11. Iron content in the soil

Table XXVI and Figure XXI show the iron content in the soil, during PS and after sowing.

The PS soil sample has 3.24% iron, which increased in GM and WWVCCD to 3.53% and 3.42% respectively. The iron content of WWVCEM was 3.16, which was closer to INM iron content 3.2%. Iron content was least in CHE as 2.95% soil sample, since it had only NPK in its composition. Hence it could be concluded that GM and WWVCCD increased the iron level in soil and WWVCCD may be a very good alternative for supplementation of iron. The F values reveal the fact that there is no significant difference between treatments.

TABLE XXVI

THE IRON LEVELS OF SOIL BEFORE AND AFTER VARIOUS TREATMENTS

Type of treatment	Mean (mg/kg)	S.D	CV %	F Value (PS VS Treatment)
PS	3.24	0.3950	12.19	
WWVCCD	3.42	0.3488	10.20	1.282
WWVCEM	3.16	0.3546	11.22	1.241
INM	3.20	0.3717	11.62	1.129
GM	3.53	0.3483	9.87	1.286
CHE	2.95	0.3900	13.22	1.026
CONTROL	2.50	0.3152	12.61	1.57
F VALUE (WWVCCD VS WWVCEM)	0.97			

4.7.12. Manganese in the soil

The manganese content of soil before and after is given in the Table XXVII and Figure XXII.

TABLE XXVII

THE MANGANESE LEVELS OF SOIL BEFORE AND AFTER VARIOUS TREATMENTS

Type of treatment	Mean (mg/kg)	S.D	CV %	F Value PS VS Treatment
PS	2.80	0.3153	11.26	
WWVCCD	3.08	0.3122	10.14	1.019
WWVCEM	2.37	0.2207	9.31	2.041
INM	2.25	0.3174	14.11	0.987
GM	2.77	0.3294	11.89	0.916
CHE	2.38	0.2319	9.74	1.848
CONTROL	2.10	0.2517	11.99	1.569
F VALUE WWVCCD VS WWVCEM	2.00			

The WWVCCD has the highest manganese content 3.08%, which increased from 2.8% the PS sample manganese level. Except WWVCCD all other treatments

reduced from the initial value. GM has the second maximum manganese content of 2.77%. WWVCEM and CHE have similar manganese content of 2.37% and 2.38% respectively and INM had the value as 2.25%. The increase in manganese level in WWVCCD can be rightly justified as the presence of cow dung. Hence it could be concluded that WWVCCD may be used to increase manganese intensity in soil. The F values disclose the fact that there is no significant difference between treatments.

4.7.13. Zinc content in soil

Table XXVIII and Figure XXIII represent the zinc content in soil before and after the treatments.

The initial zinc content of the soil was 0.79% in PS sample; it further increased in all the treatments and decreased in CONTROL sample which shows zinc content of 0.6 %. The highest content was found in WWVCCD and WWVCEM as 1.09% and 1.03% respectively. INM and CHE have 1.02% of zinc. The GM has the lowest zinc content of 0.91%. Hence it could be concluded that all the supplementation have more or less the similar effect on soil with reference to zinc level. The F values unveil the fact that there is no significant difference between treatments.

TABLE XXVIII

THE ZINC LEVELS OF SOIL BEFORE AND AFTER VARIOUS TREATMENTS

Type of treatment	Mean (mg/kg)	S.D	CV %	F Value PS VS Treatment
PS	0.79	0.0902	11.42	-
WWVCCD	1.09	0.1522	13.96	0.351
WWVCEM	1.03	0.0984	9.55	0.839
INM	1.02	0.1176	11.53	0.588
GM	0.91	0.1085	11.92	0.691
CHE	1.02	0.1095	10.74	0.678
CONTROL	0.60	0.0777	12.95	1.346
F VALUE WWVCCD VS WWVCEM	2.39			

4.7.14. Copper content in the soil

The copper content of the soil before and after the treatments is given in Table XXIX and Figure XXIV.

TABLE XXIX

THE COPPER LEVELS OF SOIL BEFORE AND AFTER VARIOUS TREATMENTS

Type of treatment	Mean (mg/kg)	S.D	CV %	F Value PS VS Treatment
PS	1.24	0.1420	11.45	
WWVCCD	1.03	0.1145	11.12	1.538
WWVCEM	0.99	0.1303	13.16	1.189
INM	1.00	0.0893	8.93	2.532
GM	1.13	0.1651	14.61	0.74
CHE	0.96	0.0785	8.18	3.272*
CONTROL	0.84	0.0866	10.32	2.687
F VALUE WWVCCD VS WWVCEM	1.54			

Copper is highest in the PS sample as 1.24%. It reduced in all the treatments. GM has the highest copper content as 1.13% and WWVCCD and WWVCEM have 1.03% and 0.99%, where as INM and CHE have 1% and 0.96% respectively. Based on the results it is clear that all the supplementation have very less effect on soil with reference to copper level. The F values unveil the fact that there is significant difference between PS and CHE treatments.

4.8. Visual evaluation of the prepared handmade paper from willow waste

Table XXX below shows the parameters evaluated by the students on visual inspection of the prepared handmade paper from willow waste.

From the Table XXX, we can understand that the visual inspection proved that the general appearance was good as stated by 68% of the students. The thickness and colour was rated as thick and dull by 70% and 82% of the students respectively. With regard to lustre all the 100% of the students felt that the handmade paper was dull. As for smell, the paper was rated as bad by 77% of the students.

TABLE XXX

PERFORMA TO ELICIT INFORMATION REGARDING HANDMADE PAPER

S. No	Parameters	Rating (%)	
1	General Appearance	Good	68
		Bad	32
2	Thickness	Thin	0
		Medium	30
		Thick	70
3	Colour	Bright	18
		Dull	82
4	Texture	Smooth	10
		Coarse	90
5	Luster	Shine	0
		Dull	100
6	Smell	Good	0
		Moderate	23
		Bad	77

Hence the visual inspection it could be concluded that the prepared handmade paper required modification with regard to thickness, colour, texture, lustre and smell. These modifications on the whole will enhance the general appearance of the paper also.

4.8.1. Evaluation of willow waste handmade paper

The willow waste handmade paper was tested for its properties and listed as in Table XXXI.

TABLE XXXI

EVALUATION OF HANDMADE PAPER FROM WILLOW WASTE

Parameter (units)	Values

GSM (g/m^2)	410
Thickness (microns)	1166
Cobb Value	530
Elongation (%)	5.4
Tearing index ($mN.\ m^{2/}g$)	8.8
Tensile Index (Nm/ g)	10.52
Burst ($Kpa.\ m^2/g$)	0.81
Folding endurance No.	77
Water absorption(mm/ min)	4
Moisture content (%)	6.9

The Table XXXI clearly reveal the GSM of the handmade paper as 410 g/m2 and thickness 1166 microns. The cobb's value is tested to be 530. The elongation of the paper is 5.4%, tearing index is 8.8 $mN.m^2g$, tensile index is 10.52 Nm/g and burst is 0.81 $Kpa.m^2/g$ respectively. The folding endurance number or foldability is 77. The water absorption is 4 mm/min and moisture content was 6.9% respectively.

4.8.1.1. Thickness and GSM comparison with selected handmade papers

In Figure XXV, the thickness and GSM (weight) of different handmade papers are compared with the prepared papers

Studies done by Asaduzzaman *et al.,* (2010), on jute with addition of internal and external additives, fibers reinforced on surface are compared here with paper made from willow dust. GSM and thickness of willow dust paper (WW) was compared with mill made mulberry paper (MMMP), jute paper (JP), jute with internal additive (JIA), jute paper with internal additive and fiber reinforced (JIAFR) and jute paper with external additive as wax and fiber reinforced (JWRF).

The GSM was highest in willow dust paper and least in mill made mulberry paper. Willow dust paper was twice heavier than jute, which makes it an extremely advantageous to be used as carry bags, replacing polythene bags. GSM was 280-300 Gm/m^2 in all the variations made with jute. With regard to the thickness, willow waste papers, are the thickest and mill made mulberry the least. The jute with external additives and fiber reinforced had the maximum of 300μ. Papers from willow dust are four-fold higher. Thus it can be a recommendation for carrying heavy load.

4.8.1.2. Comparison of Cobb value

Cobb value for handmade paper made from 100% willow dust was 530. The value is high, which may be due to the hydrophobic surface of paper, due to absence of external additives like wax. This was compared with similar paper varieties namely, jute, mulberry, banana. From Figure XXVII, it is understandable, that 100% willow dust paper (WW) is more hydrophobic and advantageous over jute handmade paper (JP) in absorbing water. Papers made from jute with internal additives (JIA), jute with wax and fiber reinforced (JWFR) and jute with internal additives and fiber reinforced (JIAFR) absorb water at a lesser rate compared to 100% willow dust paper. Use of internal or external additives, presence of reinforcing fibers on surface will reduce the water absorbency property indicating a low Cobb value. The folding endurance number was 77 for willow dust paper. It is 10-25 for papers made from date palm leaf, 10 for papers made from jute caddies and more than 1000 for bleached jute papers with guar gum (0.5%-1%) as internal additive,

Comparing the tearing index the papers from banana plant had 12.6 mN.m$^{2/}$g, mill made mulberry paper 44, both of which is higher than tearing index of paper from willow dust (8.8 mN. m$^{2/}$g) [Goswami, et al., (2008) and Dutt, et al., (2004)]. The tensile index was 11.8 Nm/ g for paper from jute caddies (without resin). Jute with guar gum as internal resin had 22-28.5 Nm/ g and papers form banana plant had tensile strength of 57.6 Nm/ g. Papers from mill made mulberry had 37 Nm/ g which was increased by process of lamination to 79 Nm/ g. All these values are higher than paper made from willow dust. The values are low

since there were no additives added neither internally in the pulp nor externally as wax emulsion or as fibers applied on to the surface.

In Figure XXVIII, the burst strength is compared with mill made mulberry paper (MMMP), paper from jute caddies without resin (JCP), bleached jute paper with guar gum as additive (BJGG) and paper from banana (BP). The highest value was in mill made mulberry leaf paper. Handmade papers made from banana (7.5) and paper made from jute with guar gum (6.6) recorded the second and third highest values. Papers made from jute caddies (without additives) and 100% willow dust had similar bursting strength.

Thus it can be concluded that handmade paper from willow dust is a better commodity paper compared to conventional handmade papers in terms of strength. Due to the hard look, coarse texture and heavy duty it is aesthetically higher to be suggested as an alternative to carry bags/ shopping bags made from plastics or tree.

4.9. Evaluation of willow waste aloe vera lemon finished wiping sheet

The Table XXXII illustrates the results of willow waste as wiping sheets.

From the Table pH of the aqueous extract is 4.22 and in water it is 6.87. The pH values indicate that the willow waste wipe sample to slightly acidic, which may be due to the presence of lemon in the aloe vera-lemon finishing given on wipes. The top and bottom wetting time is 5.831 and 7.31 seconds respectively where as the top and bottom absorbent rates are 59.66 and 40.37 seconds (%) respectively). The top max wetted radius was 17 (mm) and the bottom max wetted radius was 17 (mm). Top spreading speed was 2.1567(mm/sec) and the bottom spreading speed was 1.8946 (mm/sec). The accumulative one-way transport index 143.6603(%) and the overall moisture management capacity (OMMC) was calculated to be 0.1623.

The finger print of moisture management properties concludes that the willow waste wiping sheet is fast absorbing and slow drying which important for a wiping cloth. The water holding capacity was 96% that confirms lesser compactness of the fabric. The overall moisture management capability (OMMC) is 0.162 and graded to be poor according to the AATCC - 195 standards. This explains the incapability of the material in managing liquid moisture and liquid transfer from one surface to another (Manshahia and Dasa, 2014).

TABLE XXXII

EVALUATION OF WILLOW WASTE WIPES FINISHED WITH ALOE VERA AND LEMON

Parameter	Results
pH of aqueous extract	4.22
pH of water used	6.87
Sinking time (sec)	3.4
Water holding capacity (%)	96
Moisture Management Test	
Wetting time top (sec)	5.831
Wetting time bottom(sec)	7.3124
Top absorption rate(%/sec)	59.6601
Bottom absorption rate(%/sec)	40.3677
Top max wetted radius (mm)	17
Bottom max wetted radius (mm)	17
Top spreading speed (mm/sec)	2.1567
Bottom spreading speed (mm/sec)	1.8946
Accumulative one-way transport index (%)	-143.6603
Overall moisture management capacity - OMMC	0.1623 (Grade: Poor)
Flushability	
1^{st} End Point (Break into 2 Pieces)	20 Cycles
2^{nd} End Point (Break into 4 Pieces)	40 Cycles
3^{rd} End Point (Break into Multiple Pieces or Disintegration)	115 Cycles (Multiple Pieces)
Overall Percentage of weight loss	8.5%
Weight Loss in Sieve	
12mm diameter	24.9%
6mm diameter	91.1%

4mm diameter	96.5%
2mm diameter	95.8%

The overall weight loss is 8.5% and weight loss in the sieve of 12mm, 6mm, 4mm and 2mm diameter was 24.9%, 91.1%, 96.5% and 95.8% respectively. The sinking time is 3.4, which is less than the sinking time of fabrics, that is normally ten seconds (Sharma and Nachane, 2010).

The flushability tests confirmed complete breakdown after 115 cycles. The overall weight loss during the test was found to be 8.5%, indicating low particle disintegration, which may be due to the absence of pre-processing in terms of size reduction to produce the wiping sheets. The maximum weight loss was in sieve of 4mm diameter, and minimum in 12mm diameter. Hence the prepared wipes may not be compactable with the existing flushable system because the result shows a breakage of two to four pieces after 20 and 40 cycles respectively. However, the test results the conducted by Tang and Jin, (2012), prove that large particle size were easy to disperse than small ones. (Appendix IV)

4.10. Evaluation of willow waste composites using natural gum (TKP) and synthetic resin (PP)

Table XXXIII explains the properties of composites made using willow waste with polypropylene (WWCPP) and willow waste with tamarind kernel powder (WWCTKP) and Figures XXIX and XXX portray the strength and elongation properties.

From Figure XXX, it is evident that, the elongation was maximum in composites made using TKP. In willow waste composites made using synthetic resin, the elongation is found to be least as 2.14% and 2.16% in 60:40 and 40:60 of WWCPP respectively. This keeps the composite board, more rigid. The elongation is found to be maximum in 50:50 at 2.49%. Flexural was maximum in 50:50 at 13.3N/q.mm and least in 60:40 with 8.4N/q.mm. 40:60 has a flexural of 11.5 N/q.mm. The strength was very low in WWCTKP at 1.86, 25 folds less. Elongation was more in WWCTKP compared to WWCPP, elongation was 1.32%, modulus was 1.32 %, flexural was also low at 1.02 N/q.mm.

The tensile strength is 27.4, 44.65 and 45.7 kg/cm^2 in 60/40, 50/50 and 40/60 of WWCPP respectively. From Figure XXIX, it is clear that the tensile strength is highest as 45.7 kg/cm^2 in 40/60 WWCPP composites, which is due to increased

TABLE XXXIII
EVALUATION OF COMPOSITES PREPARED FROM WILLOW WASTE USING SYNTHETIC RESIN (PP) AND NATURAL RESIN (TKP)

Type of resin	Variations WW: resin	Tensile strength (Kg/ cm^2)	Elongation (%)	Modulus @ 5% (Kg/ cm^2)	Flexural Stress N/ q.mm
Synthetic resin (PP)	**60:40**	27.40	2.14	2.23	8.4
	50:50	44.65	2.49	0.00	13.3
	40:60	45.70	2.16	3.40	11.5
Natural resin (TKP)	**60:40**	1.86	3.13	1.32	1.02
	50:50	-	-	-	-
	40:60	-	-	-	-

composition of polypropylene. The 60:40 WWCPP composite has the least strength. Sample WWCTKP has a very low strength as1.86 kg/cm^2. The elongation was 2.14, 2.49, and 2.16% in the 60/40, 50/50 and 40/60 ratios of WWCPP respectively. It is 3.13% in sample WWCTKP. From Figure XXX, it is evident that, the elongation was maximum in composites made using TKP. The elongation is found to be least as 2.14 and 2.16% in 60:40 and 40:60 of WWCPP respectively. This keeps the composite board, more rigid. The fiber geometry, orientation, packing arrangement and fiber volume friction are the reasons for the variations in the various percentages used in the composites (Bavan and Kumar, 2010).

The flexural is 8.4, 13.3 and 11.5 N/q.mm in 60/40, 50/50 and 40/60 ratios of WWCPP and 1.02 N/q.mm in WWCTKP sample respectively. Flexural was maximum in 50:50 WWCPP and least in 60:40 WWCPP. The modulus @ 5% was found to be 2.23 and 3.4 kg/cm^2 in 60/40 and 40/60 WWCPP samples and 1.32 kg/cm^2 in 60/40 of WWCTKP. Studies conducted by Ren, et al, (2014) on Bamboo pulp fiber reinforced polyethylene composts also show an increase in flexural and tensile strength. The results obtained for the characterizations of composites conclude that natural resins are not very effective. Research papers by Crequeira *et al.,* (2011) and Mitra (2014) also support these results.

The tensile strength among the three was found highest as 45.7 kg/cm^2 in 40/60 WW : PP composites, which is due to increased composition of polypropylene. The 60:40 WW : PP composite has the least strength of 27.4 kg/cm^2 and 50:50 WW:PP composite has strength of 44.65 kg/cm^2 closer to 40:60.

4.11 Evaluation of willow waste briquette

As per Table XXXIV, the values confirm the fuel properties of briquette made from 100% willow waste and 50:50 willow waste and coir. The Figure XXX (a) and (b) show the Thermogravimetric analysis of the prepared briquettes.

TABLE XXXIV

EVALUATION OF FUEL PROPERTIES OF WILLOW DUST BRIQUETTES

Particulars	Willow waste briquette (WWB)	Willow waste + coir briquette (WWCB)
Average length x breadth x width (inches)	8 x 4 x 4 inches	9 x 6 x 4 inches
Weight of each briquette (kgs)	0.75-1.29 kgs.	2.5-2.8 kgs
Moisture content (%)	7.81%	6.6%
Ash content (%)	13.5%	16.4%
Calorific value (Kcal/g)	3248.3 – 4767 Kcal/kg	4358 Kcal/kg
Burning rate (g/min)	11.12 g/min	12.5 g/min
Specific fuel consumption (kg/litre)	1.275 kg/litre	1.132 kg/litre
Thermogravimetric analysis	As graph	As graph
Bulk density (kg/m^3)	709.53 kg/m^3	508.34 kg/m^3

The average dimension of WWB and WWCB sample briquettes were 8x4x4 and 9x6x4 inches respectively. The average weight of each briquette was 0.75-1.29 and 2.5-2.8 kg for WWB and WWCB respectively. The calorific value was 3248.3 – 4767 Kcal/ kg for WWB and 4358 Kcal/kg for WWCB respectively. High ash signifies low calorific value. The calorific value of willow dust briquette is 3, 248.3 Cal/gms in comparison with the commonly used briquette from wood and saw dust, which has 18.1-20.8 Mj/kg, (Emerhi, 2011).

The moisture percent was 7.8% in WWB and 6.6% in WWCB which is lesser then the ideal moisture content of raw material was 10 - 12% as stated by Srivastava,(n.d.). High moisture content will lead to low heating value and thus it is expected to be a low number (Sivakumar, Sivaraman, and Mohan, 2011). The studies by Akowuah, *et al.,* (2012), on briquettes using saw dust reveal 5% moisture as ideal. With reference to the above studied, it could be concluded that both the types of briquettes made from 100% cotton and cotton and coir (50:50) are suitable as a fuel material.

The ash content from burning briquettes WWCB and WWB are 16.4% and 13.5% respectively. According to Kannan, *et al.,* (n.d.) coal releases about 30-50 % ash and fire wood 20-25% as remains after burning. The briquette in general releases 17.58-20.1 Mj/kg and 0.5-8% ash. Higher value indicates more acceptability. Lesser ash creates ease in disposal and reduces nuisance caused otherwise. Hence, it could be concluded that the prepared briquettes had lesser ash content that normally used fuel materials.

The burning rate was 12.5 and 11.12 g/min in WWCB and WWB samples respectively. The specific fuel consumption was 1.275 kg/litre for WWB and 1.132 kg/litre for WWCB samples. The research conducted by Husain, *et.al.,* (2002) using agro wastes support the obtained results..

From the above table it is clear that the bulk densities are 709.53 kg/m^3 and 508.34 kg/m^3 for WWB and WWCB briquette samples respectively. High bulk density indicates more quantity of scrap material compressed together. Coal and agro waste briquette report a density between 1100-1400 kg/m^3 (www. charcoal / briquette. com). This may be due to the fact that the willow waste comprised of particles which are not uniform in size. The fact is further justified by the WWCB value which is

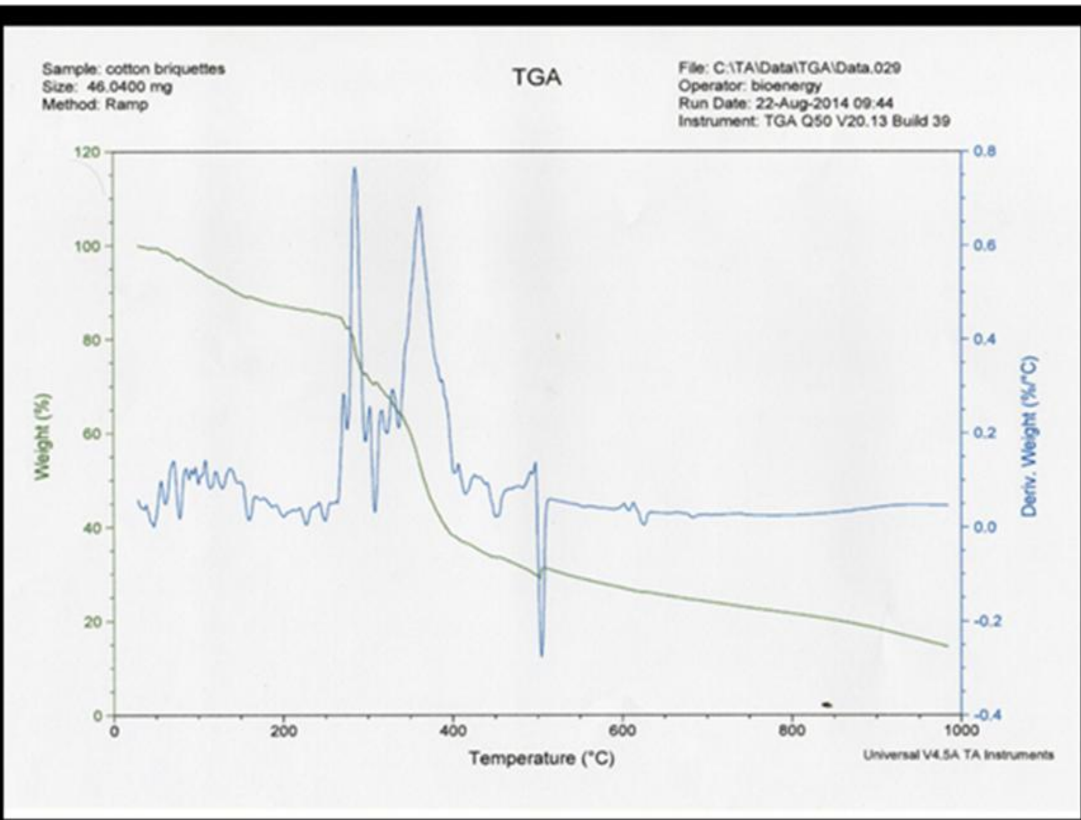

FIGURE XXX (a)

THERMOGRAVIMETRIC ANALYSIS OF 100% WILLOW WASTE BRIQUETTE (WWB)

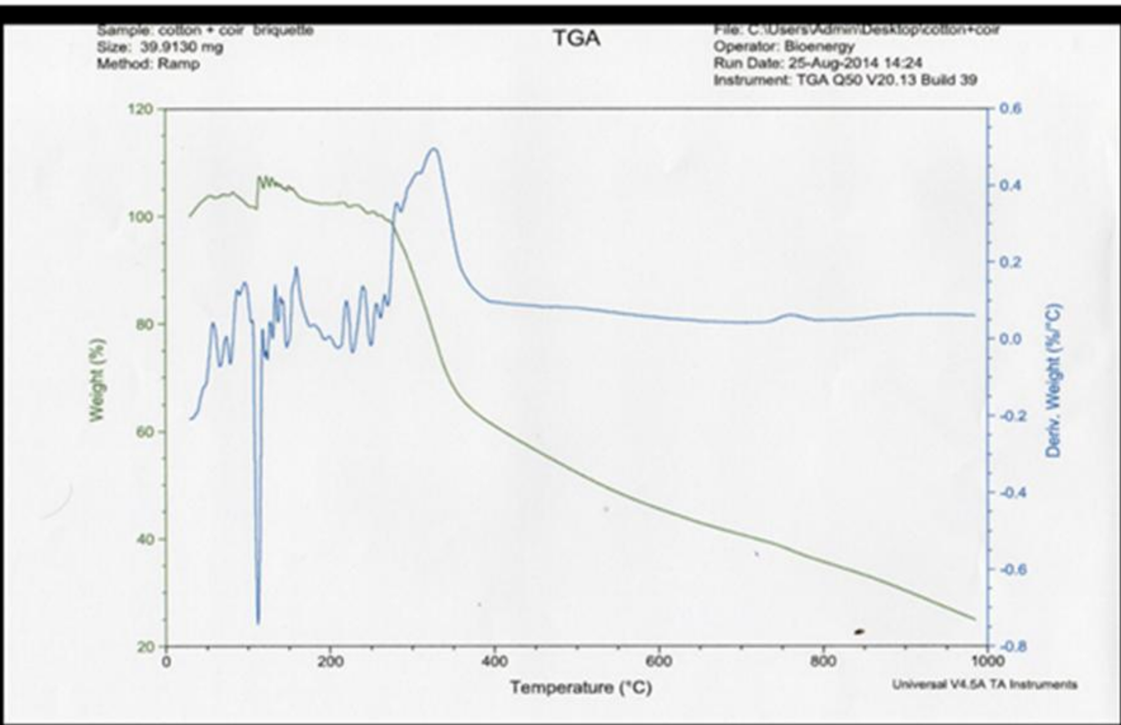

FIGURE XXX (b)

THERMOGRAVIMETRIC ANALYSIS OF WILLOW WASTE COIR BRIQUETTE (WWCB)

lesser due to the presence of coir. Therefore, it could be concluded that prepare briquette samples have a bulk density lesser than coal and other agro waste combined briquettes. In a nut shell, it could be concluded that the properties of the prepared briquettes have resistances to mechanical disintegration and can become an important renewable energy fuel source for the days to come.

The Figures XXX (a) and (b) reveal the Thermogravimetric analysis of the prepared briquettes .WWCB and WWB where the weight is compared with temperature. The weight of the WWB briquette shows a gradual reduction up to 270^0 C and then there is a steep up to 400^0 C followed by a slow reduction. In the case of the WWCB briquette the weight loss is minimum till 250^0 C proving a slow decomposition rate which may be due to the presence of coir, and then a steep reduction till 400^0 C. This reaction can be due to the presence of organic matter that show a tendency to sublime from the stage of solid to gas directly (Widmann, n.d.). From the graph it is clear that for the derivate weight the temperature reaches the maximum at 290^0 C after there is a fall at 300^0 C, later the temperature rises up 400^0 C and the weight declines to 10 g at 500^0 C the WWB sample. With reference to WWCB the weight falls at 100^0 C and then slowly raises 390^0 C. These results are similar to the study conducted by Benzler (n,d.).

4.12. Cost analysis

Table XXXV explains the comparison of costs between the products commercially available and those obtained from the research

TABLE – XXXV

COST COMPARISON OF SUSTAINABLE PRODUCTS OBTAINED FORM RESEARCH WITH THE PRODUCTS COMMERCIALLY AVAILABLE

S. No	Products	Variation	Rate per kg
1	**Bio-manure**	Compost from Municipal solid waste *	Rs. 10/kg
		Vermicompost *	Rs. 11/ kg
		Compost with 100% willow waste using cow dung **	Rs. 2.50/kg
		Compost with 100% willow waste and vermicompost using cow dung **	Rs. 40/ kg

		Compost made from EM solution **	Rs. 9.60/kg
		Vermicompost from EM solution **	Rs. 11/kg
2	**Handmade Paper**	Handmade paper made from Jute caddies *	Rs. 30-40 / sheet
		Value addition Dyed/Printed Jute *	Rs. 40-50 /sheet
		Handmade paper made from knit scrap waste *	Rs. 30-35 /sheet
		Dyed/Printed Textile waste*	Rs. 40-45 /sheet
		Willow waste **	Rs. 50 /sheet
		Willow waste Dyed/Printed **	Rs. 68 /sheet
3	**Wipes**	Kitchen wipes made from polypropylene *	Rs. 200 / 42 pieces
		Kitchen wipes made from polypropylene *(e-bay)	Rs. 169 / 5 pieces
		Degradable Wipes made from cotton*	Rs. 16 / piece
		Willow waste *Aloe-vera* Lemon finished wipes** (8 sheets)	Rs. 8-9 / piece
4	**Composites**	Polypropylene *	37 / sq.mt
		Willow waste natural resin (tamarind kernel powder) **	Rs. 5/ pc
		Willow waste synthetic resin ** (polypropylene)	Rs. 7/pc
5	**Briquettes**	Agro waste * (leaves, farmyard waste)	13 / piece
		Coal *	6 / piece
		Willow waste (100%) **	3 / piece
		Willow waste coir (50:50) **	6 / piece

(Prices does not include overhead charges and margin of profit)

* Commercially available products

** Product obtained from the research

From the above table it is clear that the cow dung compost from municipal solid waste and compost from willow waste is Rs. 10/kg and Rs. 2.50/kg. The vermicompost made using cow dung, commercially available costs Rs. 40/kg and vermicompost from 100% willow waste costs Rs. 11/kg. Bio-manure using effective microorganisms (EM) solution the compost and vermicompost prepared was calculated to be Rs. 9.60/kg and Rs. 11/kg. Handmade paper from jute caddies, printed jute, knit scrap waste and printed textile waste, per sheet cost, Rs. 30-40, Rs. 40-50, Rs. 30-35 and Rs. 40-45 respectively. Comparatively, handmade papers from willow waste cost Rs. 50 per sheet and Rs. 68 per sheet, after value addition using natural or synthetic dyes. Kitchen wipes commercially available cost Rs. 200 for 42 pieces and Rs. 169 for 5 pieces (online price). The degradable wipes made from cotton is sold at Rs. 16 per piece, whereas willow waste wipes finished with aloe vera and lemon can be sold at Rs. 8-9 per piece. Composite sheets commercially available cost Rs. 37 per square meter. Whereas willow waste composites made using natural and synthetic resin, cost Rs. 5 and Rs. 7 per piece respectively. Commercially available briquettes made using agro waste and coal are sold at Rs. 13 and 6 per piece respectively. However briquettes made using 100% willow waste can be sold at Rs. 3 per piece and along with coir at Rs. 6 per piece. Hence, it can be concluded that the willow waste which is not utilised for any products before can be recycled into five products that can be economical and sustainable.