Attribute based coding, review and gap analysis of cotton harvesting processes and machines

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Abstract: Mechanical cotton harvesters, i.e. strippers and pickers are commercially available, but these cannot be used for cotton harvesting from varieties presently grown in India due to design constraints and agronomic practices. Higher initial cost and field capacity make cotton harvesters unsuitable and unaffordable for small and medium farms. Hence, a comprehensive review of cotton harvesting mechanisms developed till date was carried out. Under the study, different types of crop and machine attributes were identified and expressed in matrix form which could be utilized by researcher For the development and refinement of mechanical cotton harvesters for small and medium farms. The matrix depicts on academic work of each paper and each attribute and coding/grading of attributes was done as per their importance in the research publications. Summation of coded attributes was done publication-wise as well as category-wise so that the value of each attribute and each publication gets identified for the development of a need based mechanical cotton harvester. Attribute coding was assigned in two category i.e. publication wise and category wise. A total of 19 publications with 21 attributes were reviewed and related with the mechanical cotton harvesters and assigned a score 105. Under the category-wise attribute coding, attributes such as crop variety, yield, row spacing, plant height and plant population were considered and assigned grade more than 20 as most of the authors discussed these attributes in their studies. Other parameters like limb length, plant canopy (spread width) along and across the rows, height of lower and upper boll were accorded less importance as their grade was less than 10 out of a total 95 score. Defoliant attributes were discussed in 14 out of 19 papers reviewed and had 28 grade points as compared to desiccant, which was discussed in only 2 papers and assigned a grade of 5 only. Under the machine parameters, type of mechanism was assigned a grade point 66 as mechanical harvester performance was mainly dependent on this attribute.

Keywords: Cotton harvester, crop parameters, machine parameters, attributes coding

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1 Introduction

Cotton is cultivated in tropical and subtropical countries, namely China, USA, India, Pakistan, Uzbekistan, Turkey, Brazil, Greece, Egypt and Argentina. These countries with temperatures ranging between 11℃ and 40℃ contribute about 80% of the global cotton production (Anonymous, 2010). Major crop production operations for cotton include field preparation, planting, weed control, spraying, picking and stalk uprooting. Amongst all cotton picking is the most difficult, tiresome and tedious job. The labour requirement for cotton picking is reported to be about 500 man h/ha. It was not only tedious but also ten times costlier than irrigation and about twice more costlier than the weeding operation (Prasad and Majumdar, 1999). A grown up person can pick about 15-20 kg/day of seed cotton, compared to an average pick of 870-2180 kg/day by a single row spindle type picker (Sandhar, 1999).

Cotton is mostly picked manually in most of the developing countries. In advanced countries like USA, Australia, Brazil and Russia, cotton picking is carried out mechanically by cotton pickers (the most commonly used machines) or cotton strippers. In India too, harvesting of cotton is done manually and cost of cotton harvested by hand is quite high and increasing further each year.

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Hence, there is an urgent need to develop a suitable cotton harvester for small and marginal farmers in India. Hence an exhaustive review of available cotton harvesting machines and equipment was carried out.

The objective of this paper is to code the important attributes of crop and machine performance and to help the researchers, engineers and manufacturers in the development of a suitable mechanical cotton harvester. The crop and machine performance attributes of mechanical cotton harvesters developed with different mechanisms have been reviewed in this paper. Coding of different attributes of crop and machine performance showed the values of attributes range as well as the importance in the research publications.

2 Material and methods

2.1 Identification of attributes

Different attributes were identified under three categories viz. 1) crop attribute which includes row spacing, plant height, plant protection, crop yield; 2) specific requirement of harvesting aid like defoliant and desiccant spray; 3) Machine and performance attributes like picking efficiency, trash content, gin turnout, field capacity, losses etc. as shown in Table 1. These attributes are discussed briefly in the paragraphs as follow.

Table 1 Identification of different attributes

S. No.	Attributes		
	Crop	**Specific aid requirement**	**Machine and performance**
1	Row spacing	Defoliant spray	Picking efficiency
2	Plant height	Desiccant spray	Trash content
3	Plant population	-	Gin/Lint turnout
4	Crop yield	-	Field capacity
5		-	Losses (pre-harvest, ground, stalk etc.)

2.1.1 Attributes of cotton crop and agronomic practices

Crop attributes which affect the performance of a harvesting machine include row spacing, plant height, plant population and crop yield. These attributes are discussed in this section and coding of these attributes is done as per importance in their respective research study.

2.1.2 Attributes of specific requirement of harvesting aid

These include defoliant, desiccants and other chemicals used in crop production to accelerate the preparation of crops for mechanical harvesting. Farmers use chemicals to enhance harvesting efficiency, minimize lodging, trash and lint staining and control insect population which is desirable by crop variety.

2.1.3 Attributes of machine and its performance

Machine and its performance include attributes related to cotton harvesting machines i.e. harvesting mechanism, picking efficiency, field capacity, different types of Losses, gin or lint turnout and trash content. The coding or grading of attributes is done as per their importance and used by the authors during their study on mechanical cotton harvesters. The coding/grading of crop and machine parameters established from the publication may be used into the design and development of the local mechanical cotton harvester for Indian conditions.

There were three main causes such as crop, specific requirement of harvesting aid and machine & performance attributes which contributed in effect to the mechanical cotton harvester. Under the crop attributes, crop variety, row spacing, plant population and crop yield put the major impact on the cotton harvesters rather than the other crop parameters like plant height, plant canopy spread along and across the row and limb length have been discussed further in results and discussion. Specific requirement of harvesting aid was another cause covered the defoliant and desiccant as its attributes which affect the picking efficiency of cotton harvester. Machine attributes such as harvesting mechanism, picking efficiency and trash content were the important attributes which influenced the performance and development of cotton harvester. The other attributes such as field

capacity, field losses and gin/lint turnout influenced the mechanical performance of cotton harvester.

2.2 Matrix identification

A matrix is identified to express the importance of each attribute in the reviewed paper is given in Table 2. Summation of codes/grades has been done category-wise as well as publication-wise so that the importance of each attribute and every publication can be identified for the development of mechanical cotton harvester. The attribute grading/coding was generated in terms of numerical values from 1 to 5 and the attribute having code/grade close to 5 considered as the important attribute for further studies and development of mechanical cotton harvester. The grading /coding of each parameter is given as per the importance given and discussed in each paper reviewed. In this attribute coding based review study, total 19 papers are reviewed and all attributes are divided in three main categories i.e. crop parameters, specific requirement of harvesting aid and machine mechanism and its performance parameters.

Table 2 Matrix for different attributes of crop and machine

Attribute Based Coding of Crop and Harvesting Machines							
Attributes (Category A)	**Research Publication**						
	P1	**P2**	**P3**	**.....**	**P18**	**P19**	**ΣA**
A1	a1	a2	a3	.....	a18	a19	ΣA1
A2	a1	a2	a3	.....	a18	a19	ΣA2
A3	a1	a2	a3	.....	a18	a19	ΣA3
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
A9	a1	a2	a	.....	a18	a19	ΣA9
A10	a1	a2	a3	.....	a18	a19	ΣA10
(Category B)							
B1	b1	b2	b3	.....	b18	b19	ΣB1
B2	b1	b2	b3	.....	b18	b19	ΣB2
(Category C)							
C1	c1	c2	c3	.....	c18	c19	ΣC1
C2	c1	c2	c3	.....	c18	c19	ΣC2
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
C6	c1	c2	c3	.....	c18	c19	ΣC6
ΣP	**ΣP1**	**ΣP2**	**ΣP3**	**.....**	**ΣP18**	**ΣP19**	ΣP = **ΣA**

2.3Rank distribution of attribute coding

Coding of attributes had been done as per their importance in the research work. The highest numeric grade points i.e. 5 points were decided to observe the importance of attribute and distribution of rank to the attribute was observed by the degree of closeness to that highest grade points in the research work conducted by researchers. The more the degree of closeness of attribute to the highest grade points the more rank was awarded to that attribute. Table 3 shows the rank distribution of attribute coding as per their importance in the conducted research work.

Table 3 Rank distribution of attribute coding

Sr. No.	Attribute coding	Rank
1	5	Excellent
2	4	Very good
3	3	Good
4	2	Average
5	1	Poor

The attribute awarded with 5 grade points was ranked excellent because the attribute was discussed thoroughly in the study with the help of graph, table and text discussion and also explained its effect on the performance of cotton harvester. Attribute carried 4 points was ranked under very good category. The reason for awarding 4 grade points to the attribute was that that the author had discussed different aspects such as text

description, data measurement and explanation with the help of table formation, observations of data and effect of that attribute on machine and other attributes in the research work. Attribute having 3 grade points represented the good rank. Under this category, the author had discussed the attribute in textual form as well as the data for that attribute was also measured but effect of the attribute was not discussed in the conducted study. Attribute coding 2 discussed and explained in the textual form but no physical data was recorded regarding this hence this attribute was come under the average rank category. Under the poor rank carried 1 grade point only, author had mentioned only the name of the attribute without explaining its function and effect on the machine and other attributes.

3 Results and discussion

3.1 Category-wise attribute coding

Different attributes relating to harvesting machine as well as the resultant performance are discussed in detail as below;

3.1.1 Crop attributes

Among all the attributes discussed under this category, crop variety, yield, row spacing, plant height and plant population received grades more than 20. But crop variety was discussed and given importance by all the papers reviewed and total grade points for this attribute was highest i.e. 59 among all the attributes due to its importance in the development of mechanical harvester. It has been observed from the review that the mechanical harvester need particular varieties that should be semi dwarf, determinant and single mono-poded. Second most important attribute was crop yield which again dependent on crop variety. It indicated that when researchers studied the effect of variety on the performance of mechanical harvester, then yield is also equally important for that particular variety. As far as agronomic parameters like row spacing, plant population and plant height are concerned; some of the authors have given importance to these attributes but some of the authors have not considered these parameters in their studies. As row spacing and plant population are again correlated with each other, hence in many of research papers, in which crop spacing was discussed, the plant population was not considered a parameter. Plant height is also an important parameter for the performance of a mechanical harvester as this parameter was discussed in 11 papers out of 19 papers and it's having attribute coding 27.

Other parameters like limb length, plant canopy width along and across the row, height of lower and upper boll were given lesser importance as their grade was less than 10 out of total grade 95. These attributes were considered by only 2 or 3 papers for discussion to see their effect on the performance of mechanical cotton harvesters. Although these attributes also affect the performance of a mechanical harvester but not as above discussed attributes.

3.1.2 Specific requirement of harvesting aid

Under this category, defoliant and desiccant were considered to discuss their effect on the performance of cotton harvester. Defoliant used for removing of green leaves at the plants, is useful to increase the performance of harvesters by increasing its cleaning efficiency as a result of reducing the trash content in seed cotton. Defoliant attribute was discussed in 14 papers out of total 19 papers reviewed and is having 28 grade points as compared to desiccant, which was discussed in only 2 papers and having grade of 5 only. Desiccant is chemical used to dry leaves rapidly, but the leaves remain attached to the plants as they do not shed off the plants.

3.1.3 Machine and its performance attributes

Two type of mechanisms were discussed either mechanical type i.e. picker or stripper and pneumatic type. Total of 16 researchers discussed about mechanical type comprising of 10 discussed about spindle type and 6 about stripper type among the total 19 papers reviewed under the study. This attribute obtained maximum grade points i.e. 66 as mechanical harvester performance mainly depends on the type of mechanism. As far as

performance of harvester is concerned, various parameters like picking efficiency, trash content, lint turnout and losses were discussed in different studies. Among these attributes picking efficiency and trash content are equally important parameters to judge the performance of a mechanical harvester, as both attributes are having grade points 58, which is also comparable importance with lint turnout attribute having grade point of 49. Seed cotton losses are considered in the form of pre-harvest, ground, stalk or total losses during the harvesting of cotton by using mechanical harvesters. This is also an important parameter to judge the performance of a mechanical harvester. Pre-harvest loss, which is the loss before the operation of harvester is mainly dependent on the crop variety suitable for the mechanical harvester. Ground and stalk losses are the losses after the operation of harvesters are dependent on the variety selected as well as the working of a harvester.

3.2 Publication-wise attribute coding

Total numbers of selected dependent and independent attributes were 21, which are important for a mechanical harvester. Total 19 numbers of publications were reviewed related with the mechanical picker shown in the columns of Table 4. Any publication in which all the 21 selected attributes would be discussed in detail would get 105 grades.

Among the different researches reviewed under the study, publication P5 received maximum grade points i.e. 49. The author has discussed crop parameters, specific requirement of harvesting aid and machine mechanism and performance parameters in details. In this paper, spindle type harvesting mechanism was evaluated for the LH 1556, CNH 120 MB, CNH (123, 155, 911, 2713 & 4736) and GSH 2 sown in India(Prasad et al., 2007).Study (P1) received second highest grade points i.e. 46 points comprising of crop parameters with 20 grade points, harvesting aid having 2 points and mechanism and its performance parameters with 24 grade points(Corley and stokes, 1964).Publications P9, P14, P16 and P17 received equal grade points i.e. 40 (Kapner et al., 1979, Faulkner et al., 2011, Tupper, 1966 and Khalilian et al., 1999), but Kapner et al., 1979 and Faulkner et al., 2011 have emphasized on the crop parameters and on the other hand, P16 and P17 have discussed mainly mechanism and performance parameters of a mechanical harvester(Tupper, 1966 and Khalilian et al., 1999).(P8) received minimum grade points i.e. 18 as the author has mainly discussed mechanism and performance parameters of Pneumatic suction harvesters for a particular variety without discussing its agronomic practices(Rangaswamy et al., 2006).

3.3 Grading/Coding of attributes

The attribute coding is done to find the importance of each attribute for further applications. Table 4 shows the grading/coding of attributes among and within the research publications.

Table 4 Paper wise coding for different attributes of crop and machines

Attribute Based Coding, Literature Review and gap Analysis of Cotton Harvesting Processes and Machines																					
Category A:	**Attributes**	**Research Publications**																			
Crop Parameters		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	**ΣC**
A1	Crop variety	4	3	2	4	4	4	3	3	4	4	2	1	2	4	3	4	2	2	4	**59**
A2	Crop yield	4	2	3	4	3	1	3	1	3	1	3	1	4	4	1	4	4	0	3	**49**
A3	Row spacing	1	3	3	0	2	4	3	0	4	1	3	0	4	3	1	1	2	3	1	**39**
A4	Plant height	4	0	0	3	3	4	3	0	3	0	0	0	1	3	1	0	0	1	1	**27**
A5	Plant population	4	1	2	2	1	1	1	0	3	0	0	0	4	1	0	0	0	0	1	**21**
A6	Limb length	3	0	0	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**8**
A7	Plant canopy width along row	0	0	0	0	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	**7**
A8	Height of lower boll	0	0	0	0	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	**7**
A9	Height of upper boll	0	0	0	0	2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	**6**
A10	Plant canopy width across row	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	**4**
	ΣP_x	**20**	**9**	**10**	**17**	**21**	**31**	**13**	**4**	**17**	**6**	**8**	**2**	**15**	**15**	**6**	**9**	**8**	**6**	**10**	**ΣC_x = 227**
Category B: Specific requirement of harvesting aid																					
B1	Defoliant Spray	2	1	1	1	2	0	3	0	2	0	3	0	3	2	0	2	2	1	3	**28**
B2	Desiccant Spray	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	3	**5**
	ΣP_y	2	1	1	1	2	0	3	0	2	0	3	0	3	2	0	4	2	1	6	**ΣC_y= 33**
Category C: Machine mechanism and its performance parameters																					
C1	Harvesting mechanism	5	4	5	4	4	0	0	2	3	2	4	3	4	5	2	5	5	5	4	**66**
C2	Picking efficiency (%)	5	5	1	5	5	0	1	4	0	1	2	4	4	1	4	5	2	4	5	**58**
C3	Trash content (%)	5	4	3	4	0	1	2	3	4	4	3	4	2	5	5	1	4	0	4	**58**
C4	Gin or Lint turnout (%)	5	4	4	4	0	1	2	1	4	4	3	0	3	5	0	1	4	4	0	**49**
C5	Field capacity	0	0	0	0	4	0	0	4	0	3	0	3	1	2	4	1	0	0	0	**22**
C6	Losses (%)																				
	Total loss	0	0	1	0	3	0	0	0	3	0	0	1	0	4	1	3	5	0	0	**21**
	Pre-harvest	4	4	0	4	4	1	0	0	4	0	0	1	1	0	0	4	0	0	4	**31**
	Ground	0	0	0	0	3	0	0	0	0	0	0	3	0	1	0	4	5	0	4	**20**
	Stalk	0	0	0	0	3	0	0	0	3	0	0	0	3	0	0	3	5	0	0	**17**
	ΣP_z	**24**	**21**	**14**	**21**	**26**	**3**	**5**	**14**	**21**	**14**	**12**	**19**	**18**	**23**	**16**	**27**	**30**	**13**	**21**	**ΣC_z = 342**
$\Sigma P = \Sigma P_x + \Sigma P_y + \Sigma P_z$ $\Sigma C = \Sigma C_x + \Sigma C_y + \Sigma C_z$		46	31	25	39	49	34	21	18	40	20	23	21	36	40	22	40	40	20	37	**$\Sigma C = \Sigma P$ = 602**

In Table 4, notations P1, P2, P3----------P18 represent the research publications and can be mentioned as

P1	-	Corley and Stokes (1964)	P11	-	Sandhar N S (1999)
P2	-	Oz and Karayol (2007)	P12	-	Asota C N (1996)
P3	-	Faircloth et al. (2004)	P13	-	Tupper G R (1966)a
P4	-	Corley T E (1970)	P14	-	Faulkner et. al. (2011)
P5	-	Prasad et al. (2007)	P15	-	Ankit (2008)
P6	-	Goyal et. al. (2009)	P16	-	Tupper G R (1966)b
P7	-	Sandhar N S (1999)	P17	-	Khalilian et. al. (1999)
P8	-	Rangaswamy et. al. (2006)	P18	-	Perish and Shelby (1974)
P9	-	Kapner et al. (1979)	P19	-	Mathews and Tupper (1965)
P10	-	Tajuddin A (2008)			

3.4 Benefits of attribute coding

Different stake-holders like researchers/scientists, designers/developers and manufacturers can take benefits from attribute coding as per their applications.

3.4.1 For researchers/scientists

As this format consists of research publications having different attributes of crop and machine parameters, so the coding/grading of these attributes is done to select the important attributes as per their requirement. Researchers do not require to do exercise for selection of design and operational parameters. It

also helps in selection of the parameters for field evaluation of cotton harvesting machines. Cotton breeders/Agronomist can obtain data regarding the varieties, row spacing, height, canopy and plant population suitable for cotton harvester.

3.4.2 For designers/engineers

Attribute coding provides opportunity to designer/engineer to identify the important parameters for designing a new machine or modify an existing design. For developing a mechanical harvester, machine parameters like picking mechanism, picking efficiency, trash content and gin turn out are the important parameters which can be considered by the designer/engineers. Different machine parameters like trash content and losses are needed to focus on by designer/engineer to modify the existing machines. Cleanliness of picked cotton is a main issue for the mechanical cotton harvesters due to foreign materials like leaves, shell, burs, sticks and dust particles. Hence, designer/engineer needs to work on the design ofon-board pre-cleaner and improvement of existing technologies. So that trash content can be reduced to improve the quality of seed-cotton.

3.4.3 For manufacturers

Both established and inexperienced manufacturers can take benefits from attribute coding for production of cotton harvesters. Type of harvesters and their mechanisms mentioned in the reviewed paper can be a part of manufacturers' interest. It helps them to understand the kind of harvesters used for cotton picking in different countries as per their field conditions.

4 Conclusions

From the review of research publications, different attributes, expressed with the help of matrix were identified under three categories such as crop attributes, harvesting aid and machine& performance attributes as per their effect on the performance and development of a mechanical cotton harvester. Coding/grading of these attributes was done as per their importance in the research publications and summation of coded attributes was done publication-wise as well as category-wise so that the importance of each attribute and each publication could be identified for the development of a mechanical cotton harvester. Attribute coding helps Researcher/Scientist in the selection of parameters for field evaluation of cotton harvesting machines. Cotton breeders/Agronomist can obtain data regarding the varieties, row spacing, height, canopy and plant population suitable for cotton harvester. Attribute coding provides opportunity to designer/engineer to identify the important parameters for designing a new machine or modify an existing design. Different machine parameters like trash content and losses are needed to focus on by designer/engineer to modify the existing machines. Cleanliness of picked cotton is a main issue for the mechanical cotton harvesters due to foreign materials like leaves, shell, burs, sticks and dust particles. Hence, designer/engineer needs to work on the design of on-board pre-cleaner and improvement of existing technologies. So that trash content can be reduced to improve the quality of seed-cotton. As the study suggested that the cotton harvester with best mechanical performance was cotton stripper with finger type of mechanism. Cotton stripper was having picking efficiency more than 90% and was easy to design due to its less components and moving parts (Tupper, 1966a). Hence, small holder cotton cultivation and manufacturers can be focused on to select, design and development of mechanical cotton stripper with finger type of mechanism. Attribute coding also helps the manufacturers to understand the kind of harvesters used for cotton picking in different countries as per the field conditions.

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