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AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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FARM MACHINERY INDUSTRIAL RESEARCH CORP.

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EDITORIAL

AMA's Maiden Issue Now and Then

Twenty-eight years have passed when the maiden issue of AMA was published with the name "Agricultural Mechanization in Southeast Asia". I vividly recall that even in that year, population increase and food shortages was already a critical issue. That issue is still very much alive these days even as the importance of agricultural mechanization was, and still is, AMA's rallying point. The economic gap between developed and developing countries then, as now, prompted the AMA to come into view.

Then as now, AMA's main concern is what we can do for the farmers in developing countries in terms of reducing the gap between them and those in developing countries or those living in urban centers. And in order to find solutions to the problem, AMA has since been linking agriculture and agricultural engineers world-wide. Most of them, if not all, have been very cooperative indeed in sharing their expertise and thoughts via AMA in matters of promoting agricultural mechanization. As a net result, not a few farmers have constantly made efforts to influence other farmers to improve their living conditions through the blessings of farm mechanization.

One wonders aloud how much longer it will be before the vast majority of farmers in developing countries can enjoy good, hot meals and otherwise live a life of ease. Having attended to the publication of AMA for 28 years now, in my capacity as its publisher and chief editor, this question has since bothered me.

In less than a year from now, Y2K will be upon us — what with all the ugly rumors going around that computer failure will create havoc in everyone's lives.

As agricultural mechanization has become more dependent on electronics, and have made some headway, it is unthinkable that large numbers of farmers still depend on animals for farm power.

As this overdue Spring Issue of AMA goes to the press [and we apologize for its delay due to circumstances beyond our control], the 2-week old aerial bombing by NATO forces in Yugoslavia has unexpectedly made miserable the lives of some 600 000 refugees fleeing from Kosovo to neighboring countries — a scenario that will set back food production in those parts of Europe.

The AMA joins many others in wishing that the troubles in Yugoslavia will end soonest.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
April, 1999

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Tractor Industry in India

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Summary

Tractor manufacturing in India started in 1961. The tractor industry has grown at a phenomenal pace in the last 5 decades to achieve a record production of over 255 000 units by 1997. It has emerged as one of the leading producers of wheel type tractors in the world. This achievement reflects the dynamism of the tractor manufacturers, as also the pragmatic policies adopted by the Government of India to enable it to meet the growing demand of tractors by the Indian farmers. By the end of 1997, there were about two million tractors and 66 000 power tillers in use on Indian farms. The highest concentration of tractors is in northern India having good irrigation infrastructure. Punjab has reached a saturation level with 82 tractors per 1 000 ha followed by two neighboring states, Haryana with 63 tractors per 1 000 ha and Uttar Pradesh with 24 tractors per 1 000 ha. The sale of tractors continues to be high in the northern and western states (Uttar Pradesh, Punjab, Madhya Pradesh, Haryana, Rajasthan, Gujarat and Maharashtra) using dry land preparation and growing mainly wheat. The annual sale of power tillers has been only about 10 000 units. Most of the power tillers have been sold in rice growing states, namely; West Bengal, Tamil Nadu, Karnataka, Assam, Kerala and Andhra Pradesh. Easy availability of agricultural credit has contributed significantly towards the growth of the tractor industry.

Introduction

Agricultural mechanization made a small beginning with the introduction of imported tractors and by acquiring war surplus tractors and bulldozers for undertaking, basically, land reclamation and to some extent mechanical cultivation. In 1947, the Central tractor organization and a few State tractor organizations were set up, which, during 1947-1959, reclaimed about one million ha of land. This in turn created demand for tractors to undertake follow up cultivation in the reclaimed areas. The number of tractors in use (estimated by Jain, 1971) was 8 500 in 1951, 20 000 in 1955 and 37 000 in 1960. Up to 1960, the annual demand for tractors was met entirely through imports.

When planned economic development of the country was launched in 1951, the tractor industry was included in the 'Core Sector' which indicated its strategic importance. Its growth and development policies were, therefore, reviewed on Plan to Plan basis. As in the case of all other industries, the farm equipment industry had to follow the legislation enacted under Industrial Development and Regulation Act, 1951, the main features of which were:

1. Reservation of certain sectors of core and heavy industry for the Government i.e., steel, machine-tools, aircraft, etc.;
2. Reservation of certain class of items exclusively for the defined small scale sector;
3. Necessity of obtaining an industrial license from the Government of India for manufacturing any new article when capital investment in land and building exceeds Rs. 1.0 million;
4. Phased local manufacturing program;
5. Imported plant and machine; and
6. Technical experts from collaborators and training of Indian counterparts.

A policy of protection of domestic industry was introduced, wherein; imports were totally prohibited if local manufacturing capabilities were adequate for meeting demand. Import tariffs were levied in other cases where local manufacturing, though set up, was inadequate, necessitating imports. As industrialization progressed, exemptions from licensing were liberalized first to Rs. 10.0 million, then to Rs. 30.0 million, and further to Rs. 50.0 million. During 1992-96, licensing was further liberalized and most of the industries were de-licensed. Development Councils for various sectors of industry were also set up at the national level to advise the Government on the steps to promote and foster the industry. The growth of the farm equipment industry in India has to be viewed in the backdrop of this national scenario.

Tractor Industry: 1961-70

The development of the tractor industry in the 60s was dictated by the anxiety to promote mechanization of agriculture by encouraging local manufacturing of tractors and at the same time, protecting the interest of farmers by making tractors available at reasonable prices. Tractor manufacturing in India started in 1961. The names of the units, their collaborators and the year of commencement of local manufacture are given in **Table 1**. First four entrepreneurs were representing trading houses as dealer or sub-dealer of tractors, the fifth, Mahindra & Mahindra, was a major player in the automobile sector. These units were licensed in 1960-61 with aggregate capacity to manufacture 11 000 tractors. Though all these units went into production subsequently, it was noted that the pace of installation of production capacity was slow. On the other hand, the demand for tractors was increasing at a steep rate and expected to grow further in the ensuing years. Besides considering industrial licenses to add the additional production capacity, import of tractors continued to meet the demand of farmers. As the prices of tractors imported from the East European countries were lower than locally manufactured tractors, the duties on imported component were raised to 40%. Simultaneously, to protect the interest of farmers in the situation of acute shortage of tractors the Government imposed statutory control on the selling prices of indigenously manufactured tractors in 1967. However, this control was withdrawn in October 1974 when the supply position was eased. To meet the growing demand, the Government decided to invite additional entrepreneurs into tractor manufacture in 1968. As given by Mehta (1989), the production of tractor started in 1961 with 880 units which

Table 1. List of Tractor Manufacturers, their Collaborators and Year of Commencement of Production

Manufacturer	Collaborator	Year
Eicher Tractors Ltd.	Gebr, Eicher Tractorenfabrik, West Germany	1961
Gujarat Tractors Ltd./Tractors and Bulldozers Ltd.	Motokov-Praha, Czechoslovakia	1963
Tractor and Farm Equipment Ltd.	Messey Ferguson, UK	1961
Escorts Ltd.	Moloimport Warazawa Zaklady Mechaniczne Ursus, Poland	1964
Mahindra & Mahindra Ltd./ International Tractor Co. of India Ltd.	International Harvesters, UK	1965
+Escorts Tractor Ltd./Escorts Ltd. (Farmtrac Division)	Ford, UK	1971
Hindustan Machine Tools Ltd. (Central Sector PSU)	Motokov-Praha, Czechoslovakia	1971
*Kirloskar Tractors Ltd.	Klochner-Humboldt Deutz, Germany	1974
Punjab Tractors Ltd. (State Sector)	CMERI, India	1974
*Pittie Tractors Ltd.	Own know-how	1974
*Harsha Tractors Ltd.	Motoimport, Russia	1975
*Auto Tractors Ltd.	British Leyland, UK	1981
**Haryana Tractors Ltd./Pratap Steel Rolling Mills Ltd.	Own know-how	1983
VST Tillers & Tractors Ltd.	Mitsubishi, Japan	1983
*United Auto Tractors Ltd.	Uzina Tractorul, Romania	1986
*Asian Tractors Ltd.	Own know-how	1989
Bajaj Tempo Ltd.	Own know-how	1997
International Tractors (Sonalika) Ltd.	Own know-how	1998
New Holland Tractor (India) Pvt.	New Holland Tractors, Italy	++
Larsen & Tubro Ltd.	John Deere, USA	++
Greaves Ltd.	Same Deutz-Fahr, Italy	++

*Currently not in production **Have been producing small quantities on "On & Off" basis
+Now producing Farmtrac tractors ++Product under test and evaluation

Table 2. Model, Power Range and Indicative Price of Tractors in 1997

Model	Engine		Max. PTO power (kW)	SFC at max. power (g/kWh)	Weight / PTO power (kg/kW)	*Price (Sep. 30, 98) (Rs)
	No. of Cylinders	Capacity (cm^3)				
Mahindra 225 DI	2	1 261	12.0	271	142.92	176 950
Mahindra 265 DI	3	1 788	22.8	249	76.10	200 395
Mahindra B-275 DI	3	1 892	23.3	256	74.68	215 383
Mahindra 365 DI	3	1 810	21.9	255	78.54	208 797
Mahindra 475 DI	4	2 384	29.0	238	61.38	235 730
Mahindra 575 DI	4	2 523	31.2	233	59.94	264 308
Swaraj 724 FE	2	1 728	16.0	259	107.81	170 500
Swaraj 735 FE	3	2 592	25.1	250	73.11	211 000
Swaraj 855	3	3 308	33.9	257	57.27	263 000
Escorts 325 M	2	1 795	16.6	288	100.00	174 700
Escorts 335 M	2	1 960	20.9	250	83.97	200 500
Escorts 340 M	3	3 120	33.2	339	54.97	228 000
Escorts 355 M	3	2 727	29.6	245	62.67	247 000
Farmtrac 50	3	2 868	31.0	297	59.35	269 000
Farmtrac 60	3	3 147	33.3	253	59.31	298 000
TAFE 25 DI	2	1 670	17.7	269	90.41	176 340
TAFE 30 DI	3	1 788	25.1	258	65.74	213 273
TAFE 1035 DI	3	2 365	24.9	243	65.66	218 738
MF 245	3	2 500	30.5	256	58.20	256 475
Eicher 241 NC	1	1 557	15.1	262	109.93	162 075
Eicher 242 NC	1	1 558	14.1	267	114.54	165 620
Eicher 312	2	1 790	20.3	259	85.47	184 745
Eicher 364 NC	2	1 963	22.9	272	76.20	204 035
HMT 2522 Edi	2	1 560	16.1	266	102.48	180 950
HMT 3511	3	2 340	22.5	254	84.44	211 214
HMT 4511	3	2 698	30.5	274	69.67	249 381
HMT 5911	4	3 456	37.2	264	63.71	312 391
Hindustan G 312	2	1798	18.7	271	91.18	133 184
Hindustan G 453 DI	3	2697	32.3	290	61.61	242 903
Hindustan Super G 614	4	4160	39.2	285	68.88	277 902
Hindustan G 614	4	4667	48.9	277	55.52	307 066

*US$1 = 42 Indian Rupees (Rs)

Table 3. Production, Sale and Population of Tractors

Year	Production	Import	Export	Sale	Population*
Upto 1946	0	4 500	0	4 500	4 500
1947-51	0	4 000	0	4 000	8 500
1952-56	0	12 500	0	12 500	21 000
1957-60	0	16 000	0	16 000	37 000
1961	880	2 998	0	3 877	39 000
1962	1 414	2 616	0	4 030	41 000
1963	1 983	2 346	0	4 329	43 000
1964	4 323	2 323	0	6 646	47 000
1965	5 673	1 989	0	7 662	52 000
1966	8 816	2 591	0	11 407	62 000
1967	11 394	4 038	0	15 432	76 000
1968	15 466	4 726	0	20 192	93 000
1969	18 093	10 478	0	28 571	118 000
1970	20 099	13 300	0	33 399	146 000
1971	18 100	19 739	0	37 839	176 000
1972	20 802	1 000	0	21 802	210 000
1973	24 425	1 000	0	25 425	228 000
1974	31 088	793	0	31 881	256 000
1975	33 252	1 100	0	34 352	287 000
1976	33 146	2 920	0	36 066	319 000
1977	40 946	0	0	40 946	356 000
1978	54 322	0	0	54 322	406 000
1979	62 275	0	0	62 275	462 000
1980	71 024	0	0	72 012	526 000
1981	84 137	0	0	79 467	594 000
1982	63 155	0	0	65 776	644 000
1983	75 872	0	0	76 545	701 000
1984	84 876	0	0	82 390	754 000
1985	75 550	0	0	76 817	798 000
1986	80 369	0	0	80 670	841 000
1987	92 092	0	0	92 092	911 000
1988	109 987	0	0	109 987	996 000
1989	121 624	0	0	121 624	1 085 000
1990	139 831	0	458	139 373	1 190 000
1991	150 556	0	583	149 973	1 304 000
1992	144 350	0	1 174	143 601	1 407 000
1993	138 770	0	1 498	138 057	1 491 000
1994	164 841	0	3 038	164 309	1 593 000
1995	191 329	0	3 454	191 196	1 712 000
1996	221 689	0	3 719	220 941	1 853 000
1997	255 327	0	7 000	250 378	2 038 000

*Based on estimated life of 15 years

rose to over 5 000 units in 1965 and crossed 20 000 units in 1970 (**Table 3**). There were about 52 000 tractors in use in 1965, which increased to 146 000 units in 1970.

Tractor Industry: 1971-80

The Government decision to invite new entrepreneurs to manufacture tractors in 1968 and the sudden upsurge in demand due to the Green Revolution led to a flood of requests for new collaborations. Of these only 6 units established the manufacturing facilities (Number 6 to 11 in **Table 1**). Escorts established the Escort Tractors Limited and started manufacturing Ford tractors in 1971 in collaboration with Ford, UK. Three of these units, namely; Kirloskar Tractors, Harsha Tractors and Pittie Tractors could not survive and closed down their plants. During this period, the emphasis was on indigenous production of tractors and the Government extended full support to old and new entrepreneurs to establish local manufacture. The credit facilities to the farmers for the purchase of tractors were increased and liberalized to enlarge the market. The import of tractors, both fully built and in CKD form to new entrepreneurs was continued. Because of the oil crisis in 1973, and the resultant economic crisis, the import of fully built tractors was banned in 1973 except under specific World Bank Projects and CKD import to new entrepreneurs in the process of establishing local production facilities. With more manufacturers entering the field in a stagnant demand situation, the market became intensely competitive from 1973 onward. The Statutory Price Control on tractors was lifted in October 1974. As a result of Government directive to the commercial banks to increase their proportion for rural lending, the commercial banks opened branches in rural areas. This action was supported by the availability of refinance facilities to commercial banks for agricultural development from National Bank for Agriculture and Rural Development. Credit available to farmers increased significantly and the tractor market expanded rapidly from the beginning of 1977. The production of tractors more than doubled during a five-year period. It was 33 000 units in 1975 and increased to over 71 000 units in 1980 (**Table 3**). The number of tractors in use also crossed the 500 000 units mark.

Tractor Industry: 1981-90

The expansion in the tractor market during the late seventies led to the setting up five more units for the manufacture of tractors. One of these was in the public sector in collaboration with an U.K. firm and the rest were in the private sector. Only one firm in private sector had collaboration with an outside (Romanian) firm and others used indigenous know-how. These units are listed in **Table 1** at serial numbers 12 to 16.

After having attained complete indigenous production by most of the already established tractor units, the post-1980 period was marked by increased production from all units. However, except VST Tillers & Tractors, other four newly established units during the eighties could not sustain the market competition and closed their plants. In order to make available tractors to the farmers with small holding of land, the Government exempted production tax (excise duty) for tractors of 12 and lower drawbar horsepower. This exemption was extended to the tractors fitted with engine not exceeding 1 800 cubic centimeters, subsequently. This phase of the industry was comprised of consolidation and upgrading of technology to improve the quality of products. The Working Group in the Ministry of Industry and later on a Group in the Ministry of Agriculture, recommended to improve fuel efficiency of tractors by fixing norms of specific fuel consumption at power take-off shaft. They also recommended improving the parameters of noise and vibration levels, emission levels, ergonomics and safety aspects. The industry grew slowly in the early eighties and produced about 75 000 tractors in 1985 (**Table 3**). In the later half of eighties the industry grew very fast and produced almost 140 000 tractors in 1990 (**Table 3**). The number of tractors in use in India reached one million units mark in 1989 and in 1990 the population of tractors was estimated to be 1.2 million units. Export of tractors mainly to the African countries, also started in the eighties. Thus, India, a net importer up to mid-seventies became an exporter during the eighties.

Tractor Industry: 1991-98

The Indian industry has seen a remarkable change from a complete protection in early days to a competition in the international market during nineties. Government approval and obtaining industrial license for manufacture of tractor was dispensed with in 1992. The foreign companies can also take up tractor production in India, after following prescribed procedure or obtaining approval from the Government. However, the import of fully built tractor has been restricted presently and the same can be imported against import license or public notices issued in this behalf. Credit facilities to the farmers for the purchase of tractors have been continued. The collaboration of Escorts with Ford came to an end in 1994 and Escorts started to produce Farmtrac tractor in place of Ford tractor. Haryana Tractors (S. No. 13, **Table 1**) has been producing tractors on a very irregular basis. Bajaj Tempo started manufacturing in 1997 and International Tractors (Sonalika) started production in 1998. The production of tractors from all units during 1997 was over 255 000 units (**Table 3**). The number of tractors in use in India at the end of 1997 was estimated to be over two million units.

Present Status and Future Plans of the Tractor Industry

The tractor manufacturing industry is now well established in India. Of the 16 units who took up manufacturing before 1990, six units, namely, Eicher, Escorts, HMT, Mahindra & Mahindra, PTL and TAFE are major manufacturers (**Table 6**). Of the six units, five were set up with foreign collaborations and one with indigenous know-how (Punjab Tractors). Therefore, it may be said that the establishment and present status of the tractor industry in India owe a great deal to the foreign collaborators who supported the Indian entrepreneurs during the initial phase of manufacture. All these six units are now on their own and having mastered the manufacturing technology of tractor, have developed capabilities to expand their base further. Ancillaries have also been well established and the industry is no longer dependent on import of components or systems. Mahindra & Mahindra has emerged as the largest manufacturer with about 68 000 tractors produced in 1997. TAFE and Escorts with about 49 000 and 48 000 units each follow it, respectively. The Punjab Tractors produced over 40 000 units.

Three manufacturers who are likely to start production in near future are listed at serial numbers 19 to 21 in **Table 1**. New Holland Tractor (India) launched 70 hp Ford tractors with matching equipment in April 1998. The company is making US$75 million initial investment in a state of the art plant in Greater NOIDA, Uttar Pradesh with an initial capacity to produce 35 000 tractors annually. The Larsen & Toubro (L&T) is establishing a joint venture with John Deere of the USA. This joint venture will manufacture 35-65 hp tractors in a plant in Pune, Maharashtra. SAME Deutz-Fahr, Italy is developing a joint venture with Greeves Limited to produce SAME brand of tractors. Case and M&M are developing a joint venture for producing tractors in the range of 60-200 hp for the export to South America. With the entry of new European tractor manufacturers into India, technology and sophistication is expected to improve further in the near future. The production is expected to rise to an estimated level of about 300 000 tractors by the year 2000.

The growth of physical output of tractors is accompanied by a significant increase in the number of models produced with different horsepower ranges to meet the diverse needs of the farmers. For instance, during initial years, when the production of tractors began in the country only a few models were produced and the same have now increased to over 40 numbers, in the power range of 11 kW to 50 kW at power take-off shaft. A few technical details of the tractor models produced in India are given in **Table 2**. The increase in the power range is a reflection of the preference of the tractor purchasers, which is composed of large, medium and small farmers as well as entrepreneurs who provide custom hire services.

Power Tiller Industry

The import of power tillers

started in 1961 and continued till 1974. A total of 12 211 power tillers were imported from Japan during this period (**Table 5**). Initially, six manufacturers were given license to make 40 000 power tillers annually (**Table 4**). Krishi Engines limited; Hyderabad was the first manufacturer to start the production of Krishi power tillers in 1965. In 1970, three manufacturers, namely; VST Tillers & Tractors Limited (Mitsubishi), Maharashtra Co-operative Engineering Society (Yanmar) and Kerala Agro-Machinery Corporation (Kubota) started production of power tillers. The production of Yanmar power tillers was discontinued in 1977. In 1971 Indequip Engineering Limited started production of Iseki power tillers and discontinued production in 1977. The J K Satoh Agricultural Machines Limited started production of Satoh power tillers in 1973 and discontinued production in 1985. Production of Krishi power tiller was discontinued in 1986. The Bihar Agro-Industries started producing Kubota power tillers in 1975 but discontinued production in 1989. The National Engineering Company started producing National power tiller in 1984 and closed production in 1989. The Dogar Tools Private Limited started production of Universal power tiller in 1984 and stopped production in 1994. Details on manufacturers are given in **Table 4**. At present there are only two well established manufacturers, namely; VST Tillers & Tractors Limited, Banglore and Kerala Agro-Machinery Corporation, Ernakulam producing about 10 000 power tiller units per year.

Table 4. Power Tiller Manufacturers

Manufacturer	Make	Size (hp)	Continuing	
			Started	Closed
Krishi Engines Ltd., Hyderabad	Krishi	5-8	1965	1986
VST Tillers & Tractors Ltd., Banglore	Mitsubishi	8-10	1970	Continuing
Maharashtra Co-op. Engg. Society, Kolhapur	Yanmar	8-12	1970	1977
Kerala Agro Machinery Corp., Ltd., Ernakulam	Kubota	8-12	1970	Continuing
Indequip Engineering Ltd., Ahmedabad	Iseki	5-7	1971	1977
J K Satoh Agricultural Machines Ltd., Kanpur	Satoh	7-9	1973	1985
Bihar Agro-Industries Corp. Ltd., Patna	Kubota	8-12	1975	1989
National Engineering Company, Chennai	National	6.5	1984	1989
Dogar Tools Private Ltd., Raipur	Universal	6.5	1984	1994
Kalinga Engineers Ltd., Bhubaneshwar	Kalinga	3	1997	Starting

Table 5. Production, Sale and Population of Power Tillers

Year	Production	Import	Export	Sale	Population*
1961	0	2	0	2	2
1962	0	22	0	22	24
1963	0	12	0	12	36
1964	0	173	0	173	209
1965	329	983	0	1 312	1 521
1966	577	1 101	0	1 678	3 199
1967	171	1 271	0	1 442	4 641
1968	286	994	0	1 280	5 919
1969	314	961	0	1 275	7 172
1970	1 387	1 030	0	2 417	9 577
1971	1 081	2 523	0	3 604	13 008
1972	1 199	1 072	0	2 271	13 967
1973	1 526	1 107	0	2 633	14 922
1974	2 142	960	0	3 102	16 582
1975	2 617	0	0	2 617	17 919
1976	1 949	0	0	1 949	18 593
1977	1 602	0	0	1 602	17 778
1978	2 297	0	0	2 297	16 471
1979	2 576	0	0	2 576	16 776
1980	2 125	0	53	2 072	16 215
1981	2 352	0	59	2 293	15 406
1982	2 248	0	140	2 108	14 897
1983	2 751	0	107	2 644	15 592
1984	4 244	0	184	4 060	18 050
1985	3 917	0	21	3 896	19 649
1986	3 527	0	0	3 527	20 600
1987	3 258	0	0	3 258	21 786
1988	4 923	0	0	4 923	24 416
1989	5 324	0	10	5 314	27 622
1990	6 194	0	11	6 183	31 161
1991	7 573	0	60	7 513	34 614
1992	8 743	0	22	8 721	39 439
1993	9 406	0	96	9 310	45 222
1994	8 315	0	294	8 021	49 985
1995	10 375	0	256	10 119	55 181
1996	10 048	0	3	10 045	59 912
1997	12 200	0	0	12 200	65 929

*Based on estimated life of seven years

Recently a new manufacturer, Kalinga Engineers Limited, Bhubaneshwar has started to produce 3-hp power tiller in small quantities. Another manufacturer, Field Worthy Equipment Pvt. Ltd., Ahmedabad, Gujrat is also planning to produce 5-hp power tillers. A number of companies in West Bengal and TamilNadu are importing power tillers from China.

Though there is encouraging trend in the production of power tillers the present production of 10 000 units per year is only 25% of the installed capacity of 40 000 units. In the recent past the sale of power tillers has increased significantly and the situation is highly favorable with the introduction of subsidy by the central government and many state governments. Development of several new matching equipment and R&D support by ICAR are contributing towards increased use of power tillers.

Population of Tractors and Power Tillers

The annual production and annual sale of tractors and power tillers are given in **Tables 3** and **5**, respectively. Data on annual sales of tractors during the last five decades clearly show that these sales more than doubled in the next decade. It is expected that by the year 2000 the

Table 6. Tractor Sales of Major Manufacuters

Company/Make	1995	1996	1997
Eicher	21 875	23 129	24 255
Escorts(+Farmtrac)	38 597	43 442	48 329
Gujrat (Hindustan)	1 807	1 354	1 115
H.M.T.	16 981	19 018	19 275
Mahindra & Mahindra	50 005	57 379	67 779
Punjab (Swaraj)	26 315	33 034	40 245
TAFE	36 370	43 585	49 160

Note: The data include sales from April of the stated year to March of next year.

Table 7. Population and Density of Tractors and Power Tillers, 1997

State	Agri. Land 1 000 ha	Tractor		Power tiller	
		Population	Density/000 ha	Population	Density/000 ha
Andhra Pradesh	14 460	100 067	6.92	3 564	0.22
Assam	3 205	6 434	2.01	6 127	1.73
Bihar	10 743	74 130	6.90	735	0.06
Goa	67	126	1.88	813	11.00
Gujrat	10 292	146 528	14.24	1 710	0.15
Haryana	3 711	233 376	62.89	21	0.01
Himachal Pradesh	1 010	2 189	2.17	12	0.01
Jammu & Kashmir	1 014	3 717	3.67	23	0.02
Karnataka	12 321	73 856	5.99	9 227	0.68
Kerala	1 796	7 708	4.29	5 121	2.59
Madhya Pradesh	22 111	195 108	8.82	407	0.02
Maharastra	20 925	110 763	5.29	3 153	0.14
Manipur	175	357	2.04	845	4.38
Orissa	5 296	12 989	2.45	1 551	0.27
Punjab	4 033	332 675	82.49	21	0.00
Rajasthan	20 971	175 288	8.36	32	0.00
Tamil Nadu	7 474	85 062	11.38	12 399	1.50
Uttar Pradesh	17 986	434 412	24.15	255	0.01
West Bengal	5 656	16 121	2.85	17 396	2.79
Other states*	2 123	77	0.04	2 237	0.96
Union Territories	140	4 568	32.63	281	1.82
Total	165 509	2 015 551	12.18	65 929	0.40

sale of tractors in India will be around 300 000 units. Assuming the life of tractors as 15 years and power tillers as seven years, based on their sales, the population of tractors and power tillers in different states was estimated. The population density of tractors and power tillers was computed by dividing their respective numbers by the agricultural land area of a state. These population densities of tractors and power tillers as units per 1 000 ha for different states are given in **Table 7**. It is clear from the **Table 7** that in 1997 Punjab had the highest density of tractors with 82 tractors per 1 000 ha. This was followed by neighboring states of Haryana (63 tractors per 1 000 ha) and Uttar Pradesh (24 tractors per 1 000 ha). Although the sale of power tillers has been rather small in India most of these have gone to rice growing states like West Bengal, Tamil Nadu, Karnataka, Assam, Kerala and Andhra Pradesh.

The easy availability of the agricultural credit has contributed significantly towards the growth of the tractor industry, as more than 90 percent tractors are sold on credit. The Reserve Bank of India has also proposed to increase the capital of the National Bank for Agriculture and Rural Development (NABARD) from Rs 5 000 million to Rs 20 000 million to help it meet the needs of the rural sector better. Punjab with over 80 tractors per 1 000 ha has reached a saturation point and will have mainly a replacement market. Haryana, with over 60 tractors per 1 000 ha, will reach a similar position in the next five years. The sale of tractors will continue to be very high in northern and western India, especially in Uttar Pradesh, Madhya Pradesh, Punjab, Haryana, Rajasthan, Gujarat and Maharashtra. The sale of tractors is expected to increase significantly in the southern states, namely; Andhra Pradesh, Karnataka and Tamilnadu.

The average size of tractor in India at present is about 35 hp which is expected to increase slowly to 45 hp in year 2020. The present population of two million tractors in India is expected to increase to about five million in 2020. The annual sale of tractors in India is expected to increase to about 320 000 units. The average size of power tiller in India at present is about 10 hp. The present population of 66 000 power tillers is expected to grow quite rapidly to 300 000 units in 2020 with annual sales reaching over 50 000 units.

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Tractor Repair and Maintenance Costs in Sudan - I:

Development of a Standard Model

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Abstract

A standard model was established for the prediction of repair and maintenance costs of the medium-size, two-wheel drive, diesel engine tractor in Sudan. The model was derived based on data collected over a ten-year period, from several locations in Sudan, and it predicts repair and maintenance costs as a power function of tractor cumulative use in hours. The model showed that the tractor cumulative use in hours was the major determinant of the tractor repair and maintenance costs. It also revealed that a number of other factors, which were not quantified in this study due to lack of information, influenced repair and maintenance costs but to a lesser degree as compared to cumulative use. Those factors include: maintenance management; operator skill and attitude; working conditions; availability of replacement parts at the appropriate time; and tractor design features. Comparison of Sudan standard prediction model with similar models established in some industrial and developing nations revealed that the estimates of repair and maintenance costs of the agricultural tractor in Sudan were significantly higher when compared with industrial countries. However, when compared with other developing countries, there was no significant difference between the estimates for Sudan and those of other developing countries.

Introduction

Agriculture plays a great role in the economy of Sudan. Agriculture in Sudan is generally characterized by predominantly government owned land with varying degree of government intervention in their management. Farming in the Sudan is largely under mechanized with almost 75% of the rain-fed area still relying on manual cultivation. However, the government conceives agricultural mechanization as a major component of any agricultural development strategy and production expansion process. The agricultural tractor represents the central component of any mechanized farming system in Sudan since it is the most frequently used piece of machinery. Repair and maintenance costs are a small but relatively important portion of the total costs of owning and operating farm machinery. Estimates of repair costs are important tools that assist in tractor replacement decisions and in developing an optimal policy in order to minimize those costs over the useful and economic life of the tractor.

The objectives of this study were:

1. To develop a standard prediction model for repair and maintenance costs of the medium-size, diesel engine, two-wheel drive tractor in Sudan;
2. To investigate the major factors which influence repair and maintenance cost; and
3. To compare the established model with similar models in industrial and developing countries.

Literature Review

Very little data concerning repair and maintenance costs of the agricultural tractors were available for developing countries with no information available at all for tillage and harvesting machinery. Most surveys conducted in developing countries involved small samples of tractor population (Beppler and Hummeida, 1985). Previous investigations and studies indicated that using American and European data in estimating repair and maintenance costs of tractors in developing countries produced unrealistic and misleading estimates (Inns, 1978; Hanna and Younis, 1987; Adekoya and Oteno, 1990 and Suhaibani and Wahby, 1995). Repair and maintenance costs of agricultural machinery were highly variable. They were expected to vary from one part of a country to another because of differences in soil, weather and production system (Hunt and Fuji, 1976). A best model structure which well suited for the prediction of repair and maintenance costs of machines was a power function of the form (ASAE, 1989):

$$Y = a X^b$$

Where "Y" was the total cumulative repair and maintenance costs in percent of the machine initial purchase price, while the independent variable "X" was the machine cumulative use in hours. The constants (a) and (b) were model parameters established for each case. The model assumed that a machine cumulative repair and maintenance cost was a function of its cumulative use in hours. The parameters of the model varied with a complex of factors such as machine maintenance management, working conditions, skill and attitude of the machine operator, machine design features, size of samples surveyed, accuracy of data keeping systems and operational systems adopted (Larson and Bowers, 1965; Bowers and Hunt, 1970; Furrow et al., 1980; Ward et al., 1985; Rotz, 1987; Morris, 1988 and Ward, 1990). The prevailing high inflation rates suggested that the model developed to predict repair and maintenance costs should include an inflation factor (Smith and Oliver, 1974; Bloome et al., 1975; Peterson and Mitligan, 1976; Schaney and Finner, 1981; Rotz et al., 1981 and Mitlal and Kaul, 1984).

Methodology

A field survey of a number of management parameters, including repair and maintenance expenditure (parts and labour) and the respective annual use in hours for a medium-size, diesel engine, two-wheel drive tractor, operated in different locations in Sudan was conducted. The locations were selected to represent the main agricultural production systems adopted in the Sudan. Selection was operations whose management had been maintaining relatively appropriate and reliable operation and management data-system.

The total number of tractor population surveyed was 250 units. The data was collected from the tractor logbook and it included: tractor make and model; date of purchase; initial purchase price, tractor registration; chasis and engine numbers; detailed repair and maintenance expenditure (parts and labour); and the annual use in hours. In addition, staff (agricultural engineers, maintenance management personnel) were interviewed. As the accumulated hours for tractors were not known in all cases, tractors of the same age were grouped together and the mean use (hours) for each group together with the mean annual repair and maintenance expenditure of that group were calculated for each year/group by summation of the total mean annual use for all years up to and including that year. The same procedure was followed in obtaining the total accumulated expenditure (Ward et al., 1985). Statistical analysis of the data was performed using the statistical processing system (SPS) computer program on IBM-586 compatible personal computer. All monitored costs in this study were accrued over a period of 10 years during which the inflation rate was remarkably high. Consequently, an average inflation rate (30%) was used to adjust those prices and costs (Bank of Sudan Annual Report, 1987-1988). Tractor accumulated use (hours) was linearly correlated with the average annual repair and maintenance costs per hour per 1 000's initial purchase price of the tractor. Simple linear and non-linear regression models were established using data transformation methods (Neter and Wasserman, 1974). Total repair and maintenance costs expressed as a percentage of the tractor initial purchase price were calculated from the established best fit model equation. The data was then set and analyized using (MSTAT) statistical computer program (Freed and Eisensmith, 1989). Analysis of variance and mean tests were performed. The prediction model was established by the integration of the best model equation.

Results and Discussions

The analysis of data showed that the logarithmic regression model was the best fit. **Table 1** shows a summary of the analysis of variance (ANOVA) of the logarithmic model data. The linear model was also tested for comparison and it yielded relatively weaker correlation (r^2 = 0.54). The retransformed logarithmic model equation was:

$$Y = (6.07 X^{1.4})10^{-6} \qquad (1)$$

Where :

Y = average repair and maintenance costs/h/1 000's tractor initial purchase price,

X = tractor cumulative use (h).

On integrating equation (1) and expressing the cumulative repair and maintenance costs in percent of tractor purchase price, it yielded the fol-

Table 1. Regression Function of the Logarithmic Model

Original equation	r^2	F	Integrated equation
$\log Y = 5.216 + 1.41 \log X$ giving $Y = (6.076X^{1.4})10^{-6}$	0.6	327.1	$Y = (2.53X^{2.4})10^{-7}$

Table 2. Comparison of Repair and Maintenance Cost Model for Sudan with Industrial Countries

Source	Equation	Average ratio between Sudan and Industrial country
Bower and Hunt (1974) USA	$Y = (3.58X^{1.6})10^{-5}$	5
ASAE (1989) USA	$Y = (1\text{-}2X^{2})10^{-6}$	6
Morris (1988) UK	$Y = (9.96X^{1.48})10^{-5}$	5
Ward et al (1981) Ireland	$Y = (4.82^{1.9})10^{-6}$	3
This study (Sudan)	$Y = (2.53X^{2.4})10^{-7}$	—

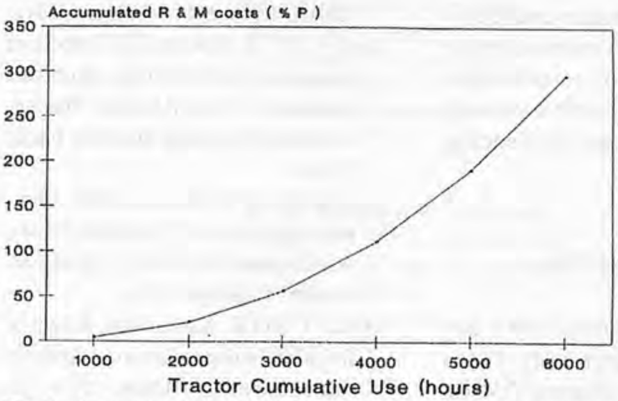

Fig. 1 Accumulated repair and maintenance cost in Sudan tractor as a function of cumulative use.

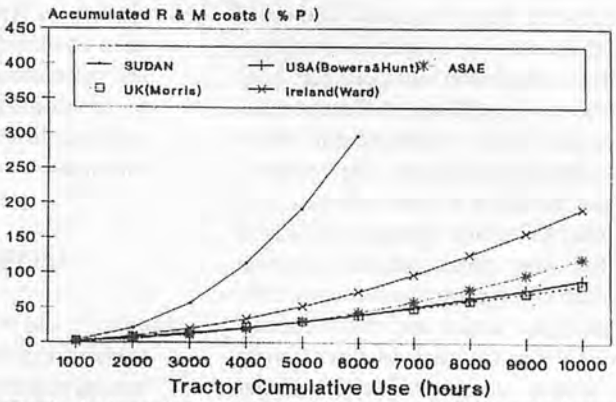

Fig. 2 A comparison of tractor repair and maintenance cost in Sudan with the cost in some industrial countries.

lowing equation which represents the prediction model for Sudan:

$$Y = (2.53\,X^{2.4})10^{-7} \quad (2)$$

where

Y = accumulated repair and maintenance costs in par cent of tractor initial purchase price.

The analysis of the data indicated that repair and maintenance costs increased proportionally with tractor cumulative use in hours. The coefficient of determination ($r^2 = 0.6$) indicated that the available data reflected that the tractor cumulative use in hours could adequately explain variation in repair and maintenance costs. However, it also suggested that repair and maintenance costs were affected by other factors which could not be quantified in this study due to lack of information. The surveys and interviews conducted revealed that these factors included, maintenance management, skill and attitude of tractor operator, working conditions, production system, availability of replacement parts at the appropriate time, and tractor design features. **Figure 1** shows the model prediction curve indicating that the repair and maintenance costs were increasing as cumulative use in hours increased. **Figure 2** compares the tractor repair and maintenance costs prediction model for the Sudan with similar models established for industrial countries. **Table 2** shows that the Sudan predicted estimate of tractor repair and maintenance costs were highly significant when compared with industrial countries' estimates.

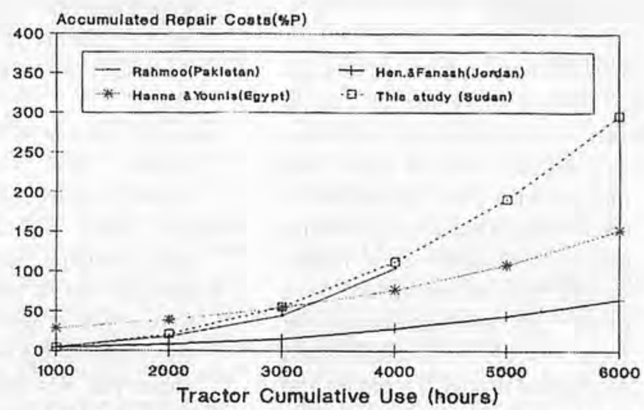

Fig. 3 A comparison of tractor repair and maintenance cost in Sudan with the cost in some developing countries.

Sudan estimate was five-fold that of USA and UK (Bowers and Hunt, 1974 and Morris, 1988, respectively) and threefold that of Ireland (Ward et al., 1981). This result was attributed to a number of reasons:

i) Sudan relied on imported replacement parts which were prohibitively expensive;
ii) Poor repair and maintenance facilities, specially preventive maintenance;
iii) Unavailability of replacement

parts at the appropriate time due to scarcity of foreign exchange and long procedure of procurement; and

iv) Poor skill of tractor operators due to inadequate training facilities and low salaries and incentives.

Figure 3 shows the comparison between Sudan estimate and similar developing countries estimates. The comparison indicated that there was no significant difference between Sudan estimate and those countries' estimates. The comparison between Sudan estimate and other countries estimates indicated that using American and European established prediction models in estimating repair and maintenance costs for tractors in developing countries would produce lower and misleading estimates.

Conclusions

Based on the analysis of data utilized in this study the following groups of conclusions can be drawn:

1. Correlation between repair and maintenance costs in percent of tractor initial purchase price and tractor cumulative use in hours, would best be described by a power function equation of the form $Y = aX^b$. The established prediction model for repair and maintenance costs for Sudan was: $Y = (2.53\ X^{2.4})\ 10^{-7}$
2. Tractor cumulative use in hours was the major determinant of repair and maintenance costs.
3. Other factors which were not quantified in this study influenced tractor repair and maintenance costs, however, their influence was not of the same weight as tractor cumulative use. These factors include: maintenance management, skill and attitude of tractor operator, working conditions, availability of parts at the appropriate time and tractor design features.
4. Sudan estimate of repair and maintenance costs was five-fold that of USA and UK and three-fold that of Ireland. However, there was no significant difference between Sudan estimate and other developing countries estimates investigated in this study. Consequently, using prediction models of American and European countries to estimate repair and maintenance costs of tractors in developing countries would produce lower and misleading estimates.

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Tractor Repair and Maintenance Costs in Sudan - II:

A Comparative Study Among Major Agricultural Schemes

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Abstract

Standard repair and maintenance cost models for the medium size diesel engine tractor were established and compared among the four agricultural schemes in Sudan. Those schemes are all government owned and are allocated for different crops following various production systems, and adopting deviant operation management. The established models were based upon data collected over a 10-year period and it included repair and maintenance expenditure (parts and labour), maintenance management parameters, training and experience of tractor operators and maintenance personnel, salary scales and incentives, infrastructure (roads and communication), tractor acquisition cost and its design features and facilities for replacement parts availability at the appropriate time. The analysis of data indicated that the correlation between tractor accumulated repair and maintenance costs and its cumulative use in hours was best described by a power function ($Y = aX^b$) for each and every scheme but with different parameters (a, b). The comparison of the established models among the four surveyed schemes indicated that tractor cumulative use in hours was the major determinant of tractor cumulative repair and maintenance costs in the case of Sudan Gezira Board (SGB) and Kinana Sugar Company (KSC) ($r^2 = 0.79$ and 0.76, respectively). However, its influence in the case of New Halfa Agricultural Corporation (NHAC) was moderate ($r^2 = 0.40$) and in the case of Sim Sim Dryland Agricultural Project (SDAP) its influence was very low ($r^2 = 0.14$). It also indicated that KSC had the lowest costs followed by SGB and NHAC. The reasons for lower costs were attributed to the relatively better maintenance facilities and availability of replacement parts at the appropriate time, availability of better training facilities for operators and maintenance personnel, better infrastructure and relatively better salary and incentives scale.

Introduction

Sudan is a country with a relatively large area (2.4 km^2) encountering sizable fertile lands. More than 35 million ha in Sudan are arable in addition to about 100 million ha that are potentially suitable for animal and forestry. Earliest adoption of an agricultural mechanization system in the Sudan was in mid-1920s when the Gezira Agricultural Board scheme, a government owned project that represented the largest irrigation scheme under one management in the world (882 000 ha), expanded after the completion of Sinar Dam on the Blue Nile river. This scheme has since maintained its operation size and production mandate (cotton, wheat and groundnuts). A new era in agricultural mechanization followed during the Second World War as a result of the government efforts to alleviate food shortage during that period. Consequently, the government established sorghum production schemes in the rainfed area of the eastern Sudan. Further major changes in Sudan agriculture occurred in the mid 1960s with the introduction of agricultural reforms, leading to dramatic shifts in land tenure systems and the consequent rapid expansion in adoption of mechanization technology and new schemes were established such as the KSC, NHAC, and SDAP with mandates for the production of sugarcane, cotton and wheat, and sorghum, repectively. Concurrently Sudan tremendously increased its tractor, harvester and other field machinery populations. However, the respective tractor per ha distribution, for example, remained low (1.5 tractor/1 000 ha - FAO, 1988), with a reliability index of less than 50 percent (Haffar and Ahmed, 1990). The low tractor reliability index was attributed in part to poor maintenance and management resulting from unavailability of skilled maintenance personnel and trained tractor operators. Also, it was partly associated with the inadequacy of foreign currency to support the purchase of replacement parts in good quantities and when needed. Further complications in mechanization management in Sudan were a result of lack of reliable statistical records pertaining to general management of operation of agricultural machinery. Since the agricultural tractor is the most frequently used piece of machinery and represents the major component of any mechanized farming system in Sudan, the main purpose and objectives of this study were :

1. To develop standard models for repair and maintenance costs for the medium-size, diesel engine, 2WD tractor in the four major agricultural schemes in Sudan. The models would be based upon the average cumulative tractor use in hours;
2. To compare the predicted repair and maintenance rates among those schemes; and
3. To investigate the influence of other factors, such as maintenance management and facilities, operators skills and attitude, availability of replacement parts and any other factors, on the repair and maintenance costs of the tractor in the surveyed schemes.

Literature Review

In most of the agricultural schemes in Sudan, machinery maintenance, especially preventive maintenance, was not given much attention. About 40% of the agricultural machinery, most of it were tractors, in Gezira scheme were out of work because of lack of maintenance and unavailability of replacement parts (Dawelbeit and Ahmed, 1987). Johnson (1979) reported that the spare parts required by the machinery were influenced by the type and size of operation and the service facilities available. Hoffman and Kucera (1987) reported that farmers could reduce their machinery repair costs by 25% by improving routine maintenance procedures. Ward (1990) presented a cost model for tractor ownership as a function of annual use in hours. His results indicated that a reduction in repair costs by careful operation and adequate maintenance could result in a significant reduction in tractor ownership costs. Adekoya and Otono (1990) investigated tractor repair models in Nigeria and attributed the higher repair costs to the high costs of imported parts, misuse of tractors, and the negligence of preventive maintenance. Ward et al., (1985) attributed the relatively high rates of repair and maintenance of tractor in Ireland, compared to that in USA and Europe, to differences in machine operation conditions, maintenance regime, operating practices and inherent machine qualities. Morris (1988) derived repair cost functions which related tractor repair and maintenance costs to tractor cumulative use in hours. He concluded that skill and attitude of tractor operator, working conditions and maintenance management, together with tractor cumulative use in hours, were recognized as important determinants of tractor repair costs. Beppler and Hummeida (1985) reviewed the literature on repair and maintenance costs in North America, Europe and developing countries. They reported that repair costs of tractors in developing countries were three to five times greater than the corresponding costs in European and American countries. Inns (1978) applying the established repair and maintenance cost models for developing countries, concluded that the estimated repair and maintenance cost of tractors in developing countries were double that in industrial countries. He attributed the result partly to negligence and lack of preventive maintenance and partly to the comparatively higher cost of replacement parts.

Methodology

Data pertainning to repair and maintenance expenditure (parts and labour) and annual tractor use in hours for the medium-size, diesel engine, two-wheel drive tractor were collected over a ten-year period from records of the four surveyed: SGB, NHAC, KSC, and SDAP. In addition, the data included maintenance management parameters (facilities and personnel), training facilities and status of tractor operators (primary and in-service training), infrastructure (roads and communication), salary and incentives scale, and replacement parts status (availability and procedure for procurement). In case when the accumulated repair and maintenance costs and the respective tractor use (hours) were not known in all cases, tractors of the same age were grouped together and their repair costs and the respective use in hours were calculated using the procedure suggested by Ward et al., (1985). Statistical analysis of the data was performed for each of the four schemes using (MSTAT) statistical computer program (Freed and Eisensmith, 1989). The accumulated repair and maintenance costs/h/1 000' tractor purchase price were correlated with tractor cumulative use in hours utilizing the least square regressions method incorporated in the Statistical Processing System (SPS) computer program. Linear, quadratic, logarithmic and power function regression were tested. The best fit function was selected based on the value of the determination factor (r^2) and its respective "F" value. The accumulated repair and maintenance cost in percent of the tractor purchase price were calculated from the transformation of the best fit equations for each scheme. The data for maintenance management (tractor operation status, and training status of maintenance personnel) and training status of tractor operators, were set and analyzed using 'MSTAT' computer program.

Results and Discussions

The Kinana Sugar Company was found to have the most adequate data recording and keeping system (computerized) of the four surveyed schemes, where a separate logbook was kept for each tractor and machine in which all tractor information was kept. The remaining schemes assigned a general file for each type of similar machines where data was kept. **Table 1** shows the analysis of variance (ANOVA) of the best fit regression models for the four schemes and it included the retransformed equations obtained by integration of the best fit original equations. The integrated equations correlated the accumulated repair and maintenance cost in percent of tractor purchase price to the tractor cumulative use in hours. The relatively higher factor of determination for SGB and KSC (0.79 and 0.76, respectively) suggested that tractor cumulative use in hours was the major determinant of tractor repair and maintenance costs. However, the low factor ($r^2 = 0.14$) in case of SDPA indicated that the influence of other factors had more and substantial effect on repair and maintenance costs. The limited data available did not help to quantify the influence of these factors. The integration of the original model equations showed that the correlation of repair and maintenance costs in percent of tractor initial purchase price was described by a power function similar in form but different in the magnitude of the model parameters $Y = aX^b$.

Figure 1 shows the curves of the established repair and maintenance cost models for SGB, NHAC, KSC and SDAP, respectively. The trend of the curves indicated that repair and maintenance costs increased progressively with increase in tractor cumulative use in hours. **Table 2** shows a summary of the result of the analysis of maintenance management parameters (tractors' condition status and training status of tractor operators and mechanics) for SGB, NHAC and KSC. Data for SDAP was not included due to limitations in the scheme recorded data. The result of the analysis indicated that KSC had relatively the highest percentage of operable tractors and trained operators and mechanics. This was attributed to the fact that KSC had privilages to utilize part of its foreign exchange earnings to import its needed replacement parts. KSC had its own training center and regularly organized training programs for its tractor operators and maintenance personnel. In addition, KSC had relatively better field roads (paved roads) better communication system and better field repair and preventive maintenance compared to the other surveyed schemes. However, the difference between KSC ad SGB in the percentage of operable tractors was insignificant and this was likely due to the fact that SGB had funds made available

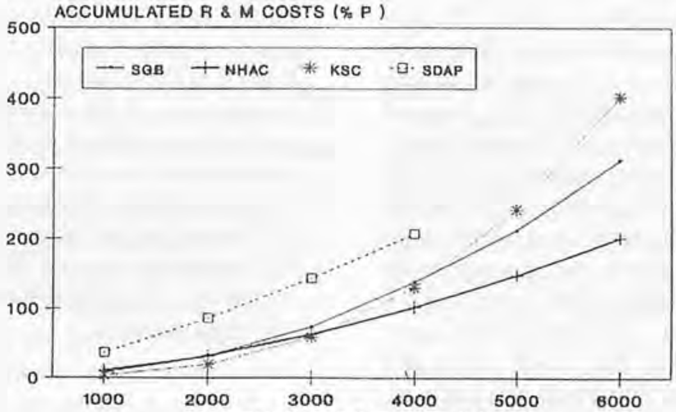

Fig. 1 Comparison of repair and maintenance cost modelsamong the surveyed schemes.

Table 1. Comparison of the Best Fit Models Among the Four Surveyed Schemes

Scheme	Model equation (original equation)	r^2	F	Integrated equation
SGB	$Y^* = (7.619X^{1.1})10^{-5}$	0.79	172.9	$Y^{**} = (3.63X^{2.1})10^{-6}$
NHAC	$Y^* = (1.3X^{0.71})10^{-3}$	0.40	25.85	$Y^{**} = (7.58X^{1.7})10^{-5}$
KSC	$Y^* = (2.96X^{1.8})10^{-3}$	0.76	323.y	$Y^{**} = (10.6X^{2.8})10^{-9}$
SDAP	$Y^* = (7.03X^{0.27})10^{-3}$	0.14	4.498	$Y^{**} = (5.54X^{1.27})10^{-3}$

Y* = Accumulated repair and maintenance cost /h/1 000 purchase price.
Y** = Accumulated repair and maintenance cost in percent of tractor initial purchase price.

Table 2. Comparison of Means of Maintenance Management and Training Status Among the Three of the Surveyed Schemes (BGB, NHAC and KSC)

Scheme*	% of operable tractors	% of trained mechanics	% of trained operators
SGB	68.2a	79.4b	45.6b
NHAC	61.4b	72.0c	47.0b
KSC	69.6a	86.8a	64.0a

* means with a common letter in a column are not significantly different using Duncan's Multiple Range Test ($\propto \leq 0.05$)

to its management, during that period, through the Gezira Rehabilitation and Modernization Program sponsored by the World Bank. Part of this funds were utilized in importing replacement parts for its existing fleet of tractors and machinery. Data points of tractor use were taken at 1 000 hours intervals which fell in average range of tractor annual use. Over the range for which data for the surveyed schemes were comparable (up to 6 000 hours), the result of the analysis indicated that up to approximately 4 000 hours of tractor cumulative use, KSC had the lowest average rates of repair and maintenance costs. This result was likely attributed to the fact that KSC had relatively the most efficient system of maintenance management, infrastructural availability of replacement parts, and better salary and incentive scale and training facilities as compared to the other surveyed schemes. Beyond 4 000 hours of tractor cumulative use the result of the analysis showed that the repair and maintenance cost rates for SGB and NHAC were relatively lower than that for KSC. The reason was attributed to the observation that tractors at this age in the case of SGB and NHAC were assigned to light work (transportation of production inputs and used as vehicles to transport labours). In the case of SDAP the repair and maintenance cost rates were the highest over the range of the available data (3 000 h of tractor cumulative use), compared to the other surveyed schemes. This result was likely attributed to the fact that tractors in SDAP experienced high rates of breakages, specially of major components (transmission and hydraulic assemblies), during the first early life of the tractors, due to rough roods, manufacturing defects and inexperienced and less trained tractor operators.

Conclusions

The following conclusions can be drawn from this comparative study:

1. Tractor cumulative use in hours was one of the major determinants of tractor repair and maintenance costs. Correlation between accumulated repair and maintenance costs in percent of tractor initial purchase price and tractor cumulative use in hours were described by a power function ($Y = aX^b$).
2. The study indicated that other factors such as maintenance management (maintenance facilities, training status of personnel, field repairs and availability of replacement), tractor operators skill and attitude (training status, salary and incentives), operational conditions (infrastructure) and tractor design features, had substantial influence on the rates of repair and maintenance costs. However, the available data could not help to qualify the influence of these factors.
3. Comparison of the established prediction models of repair and maintenance costs among the surveyed schemes indicated that the Kinana Sugar Company had the lowest rates up to 4 000 h of tractor use, compared to the other surveyed schemes.

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Determination of Efficiency of Different Plowing Patterns

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Abstract

The efficiency of three plowing patterns most commonly adopted by the farmers was investigated. The values obtained were 93.6% for headland pattern from boundaries of field, 86.5% for headland pattern from back furrow and 92.4% for headland pattern mixed mode (02 back furrowed 03 land pattern).

The time efficiencies of 03 selected patterns of plowing were also determined and the values obtained were 94.0%, 86.5% and 92.4% for headland pattern from boundaries of field, headland pattern from back furrow and headland pattern mixed mode, respectively. The headland pattern from boundaries gave the highest plowing and time efficiencies.

It was concluded that the efficiency of plowing patterns was influenced and affected by the number of back furrows, plowing speed, idle travel speed at the ends of the field and idle travel speed at the ends of headlands.

Introduction

Plowing the field is the first and foremost preliminary operation for preparing the proper seed bed. Before plowing, it is necessary to keep in mind some benefits to be derived from it such that whole plowing operation turns to be easy, economical and time efficient. Generally, the main objectives to be achieved from appropriate plowing pattern should be to:

1. Minimize field travel time;
2. Minimize the number of non-working turns and idle travel inside and at the ends of field;
3. Reduce the time of operation to make the field plowing a time efficient operation;
4. Avoid excessive dead furrows and back furrows in the field as they will be detrimental in irrigating the soil; and
5. Avoid excessive dead furrows and back furrows in the field as they will be detrimental in irrigate the soil, and to improve maneuverability of the tractor while making short turns at the ends as well as in the interior of field.

In common practice the farmers hire tractors and plows for plowing the fields and are at the mercy of the tractor operators. Usually, the unskilled operators carry out plowing in a manner such that the above mentioned objectives of plowing are not borne in mind. As a consequence, the plowing operation results as disastrous, uneconomical and time inefficient.

The primary field parameter affecting the plowing efficiency is field lay out. Before starting the plowing operation, the main field should be divided and staked out in sub-fields of uniform width. If the field is laid out with narrow spaces, numerous dead furrows will appear in the entire field and excessive time will be required to cover the dead furrows.

After dividing the main field into sub-fields, the headlands equal to twice the width of the implement should be marked off at the ends of fields which provide adequate space for high speed turns and minimize the end turning time losses.

Another parameter affecting the plowing efficiency is the pattern of plowing operation which is closely related to the size, shape of field,

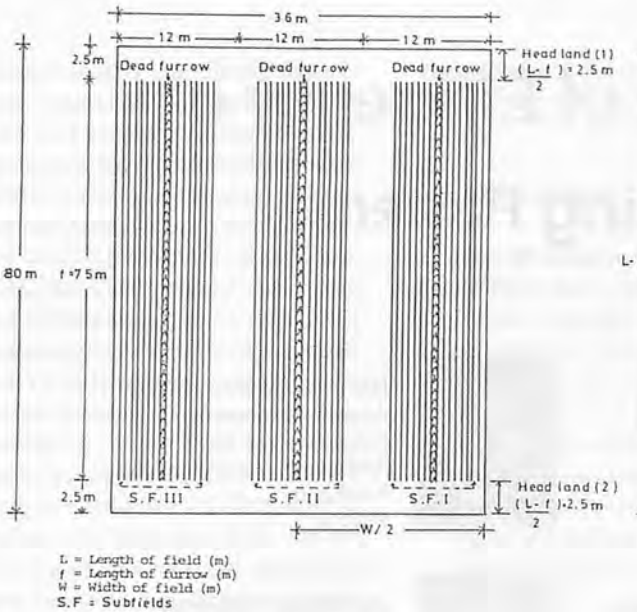

Fig. 1 Field layout of headland pattern from boundaries of the field.

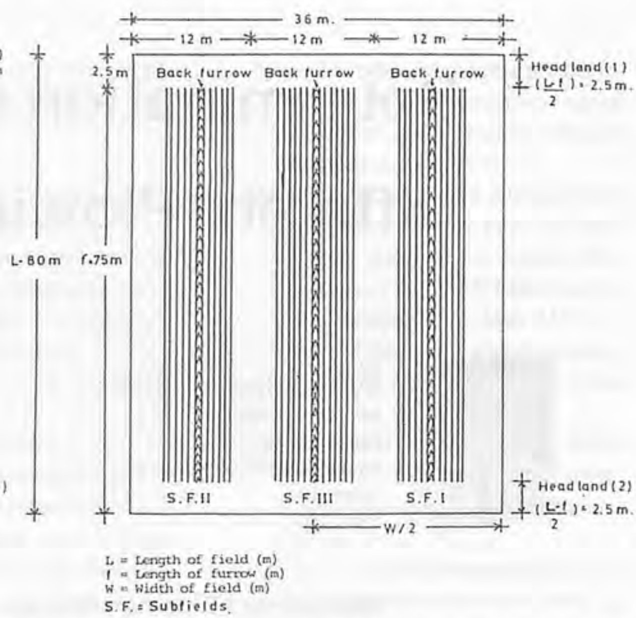

Fig. 2 Field layout of headland pattern from back furrow in the centre of field.

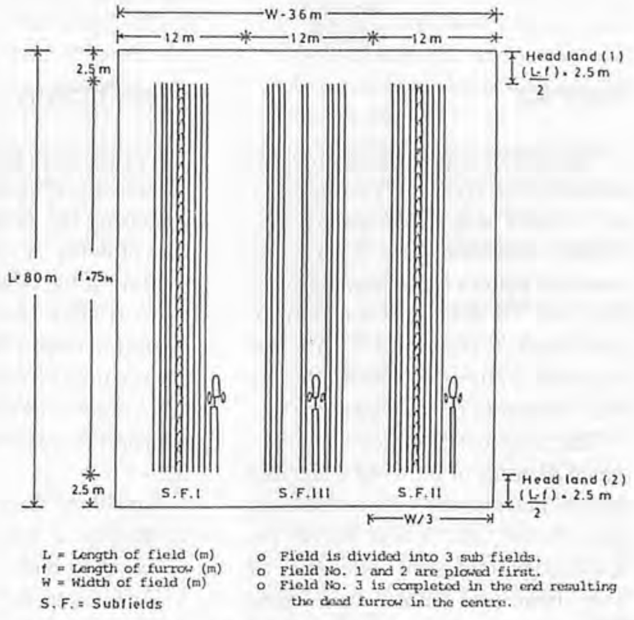

Fig. 3 Headland pattern mixed mode with 02 back furrowed 03 lands.

and the design of the plow. It is essential to identify and use proper plowing pattern matching the field shape, size, and over all configuration of the field such that the entire plowing operation turns to be successful and efficient.

Thus, the present study was conducted to examine the efficiency of three plowing patterns in order that recommendations and suggestions could be made to the farming community regarding improving the field operations. The main objectives of this study were:

1. Determine the efficiency of selected plowing patterns;
2. Determine time efficiency of selected plowing patterns; and
3. Suggest appropriate and efficient plowing patterns.

Methodology

Land Preparation and Field Lay Out

An experimental field measuring about one ha (2.5 acres), comparatively levelled and rectangular in shape and size was acquired. The dykes (bunds) were plowed to convert the whole piece of land in one levelled piece of field. The experimental land was divided into three units and each unit was further divided into three sub-fields of 12 meters wide each. The idea for dividing the field into sub-fields was to use almost the entire area of experimental land and to execute the total number of plow trips in all sub-fields. Accordingly, the whole field was divided into nine sub-fields of 12 m x 80 m each. The headlands that were equal to approximately twice the width of the plow (2.5 m) were staked at both ends of each field and fixed in accordance with the recommendations of Renoll (1969).

The dimensions of individual sub-fields and headlands were measured with steel tape. The sub-fields and headlands were laid out, demarcated by erecting poles at their extremities for guidance of the tractor operator in making turns for each plowing trip and to plow the individual sub-field and headland properly.

Selection and Choice of Plowing Patterns

The selection of plowing patterns for the present study was decided on the following grounds:

(a) The conventional patterns of plowing adopted by most of the farmers in the area were considered for investigation; and

(b) The selected patterns must match the topography, overall configuration and size of field.

Most of the farmers of the area preferred to adopt headland pattern and different modes of headland pattern. Accordingly it was decided to select the following three patterns of plowing:

1. Headland pattern from boundaries;
2. Headland pattern from back furrow; and
3. Headland pattern mixed mode with 02 back furrowed 03 land pattern.

The field lay out sketches of above mentioned patterns of plowing were prepared are shown in **Figs. 1** to 3.

Materials

A tractor mounted 3-bottom moldboard plow fitted with depth control wheel was used for plowing the fields. The size of plow was one of the variables involved in calculating the plowing pattern efficiency. Therefore, the size of plow was determined by measuring the distance from the wing of the share of the first bottom to the landside of the last bottom by holding the meter scale perpendicular to the landside. The overall size of the plow so measured was 120 cm (1.2 m) (**Table 1** and **Fig. 4**). The other materials used in the research study were: ruler; meter scale; steel tape (50 m); ranging poles; wooden pegs; and stop watch.

Table 1. Size of Three-bottom Mounted Type Moldboard Plow

Mean width of each bottom (cm)	Total width of plow (cm)	Rated width of plow (cm)	Remarks
40 40 40	120	120	No variation in the rated size quoted by manufacturer and recorded size of plow was observed because the plow was new one.

Overall length of moldboard plow with tractor = 270 cm.

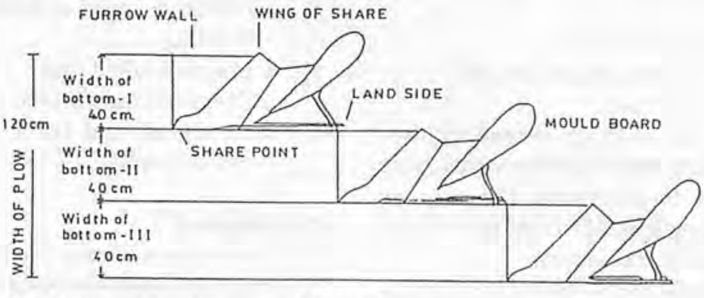

Fig. 4 Size of three bottom mouldboard plow.

Allocation and Labelling of Fields

The experimental area was divided into three fields. Each field was meant and allotted for performing and carrying out the plowing operation for the selected plowing patterns. The allocation of fields for different plowing patterns was made and labelled as follows:

Plowing pattern	Field label
Headland pattern from boundaries of the field	Field-A
Headland pattern from back furrow	Field-B
Headland pattern mixed mode (02 back furrowed 03 land pattern)	Field-C

Field Parameters

The field parameters and variables required for the calculations of pattern efficiency were identified as follows:

1. Width of fields (W) m;
2. Length of field (L) m;
3. Length of furrow (f) m;
4. Width of headland (L-f) m;
5. Number of back furrowed lands (n); and
6. Number of dead furrowed lands (n-1).

Tractor and Plow Parameters

The tractor and plow parameters affecting the calculation of pattern efficiency were also identified as follows:

1. With of plow (w) m
2. Speed of plowing (S_p) km/h
3. Effective speed (S_e) km/h
4. Tractor speed (S_t) km/h at ends of headlands.

Duration of Plowing Patterns

Various duration of plowing operation influencing the determination and calculation of the pattern efficiency and duration efficiency of the selected plowing patterns were assessed. Accordingly the following durations were considered:

1. Duration required for one plowing trip;
2. Actual duration of plowing the field;
3. Duration of plowing headlands;
4. Duration required to finish the dead furrows (if any);
5. Idle travel duration across the ends of fields; and
6. Idle travel duration across the headland ends.

Determination of Plowing Speeds

In order to determine the plowing speed (S_p), the time taken by the tractor to plow one furrow strip between ends of the field was recorded, knowing the distance or length of furrow, the speed of plowing (S_p) was calculated using the following equation:

$V = D/t$

where,
V = Speed (km/h)
D = Furrow length (m) and
t = time (sec)

Three readings of time required to plow three furrow strips were taken to determine the average plowing speed to avoid possible error in the calculation.

Similarly, S_e and S_f were calculated by recording the idle travel time at the headland while plowing the sub-fields and recording the idle time at the ends of the headland.

Equations Used

The plowing pattern efficiency and time efficiency were calculated by using the following equation:

$$P.E. = 4(2n-1)LW\,S_eS_f/[4(2n-1)LW.S_eS_f + 4(2n^2-3n+1)fw.S_e + S_f + 2W^2S_pS_f + (2n-1)(L-f)^2S_pS_e]$$

Where
n = number of back furrowed lands,
n–1 = Dead furrowed lands;
2n–1 = Total number of lands;
W = Width of field (m);
w = Width of plow (m);
S_p = Speed of plowing (km/h);
S_e = Effective speed at headland (km/h);
L = Length of field (m);
f = Length of furrow (m); and
S_f = Headland end travel idle speed (km/h).

Assumptions

1. It was assumed that back-furrowed and dead-furrowed lands were of equal dimensions;
2. One additional plowing trip across the field was required to finish the dead furrowed land; and
3. Time of finishing the dead furrow was considered equal to the time of regular plowing trips.

Results and Discussion

Determination of Pattern Efficiency (P.E.)

For calculation and determination of pattern efficiency of three selected patterns of plowing, the data of different related variables were recorded in the field. The data of variables so recorded was tabulated and the results were analyzed and calculated. For the present study the results obtained were discussed, interpreted and presented as under:

Table 2 shows the data of dead furrows and back furrows which appeared after completely plowing the main fields allotted for different plowing patterns. It was found that the number of dead furrows which resulted in the case of headland pattern from boundaries, headland pattern from back furrow and headland pattern mixed mode were 1, 0, 1, respectively. The number of back furrows observed in the case of above mentioned three selected patterns were 0, 03, 02, respectively.

Table 3 shows the values of S_p, S_e and S_f. The value of plowing speed (S_p) as calculated from the actual field plowing time data recorded for three plowing patterns. The plowing speed calculated for three selected patterns was 4.11, 4.10 and 4.13 km/h, respectively. The idle travel speeds (S_e) calculated from field time data of headland pattern from boundaries, head-

Table 2. The Number of Back Furrowed, Dead Furrowed Subfields as Resulted after Plowing with Selected Plowing Patterns

Plowing patterns	Sample field	Subfields (2n – 1)	Back furrowed subfields (n)	Dead furrowed subfields (n – 1)
Headland pattern from boundaries	Field-A	03	—	03
Headland pattern from backfurrow	Field-B	03	03	—
Headland pattern mixed mode (02 back furrowed 03 land pattern)	Field-C	03	02	01

Table 3. Plowing Speed (S_p), Idle Speed (S_e) at End of Field, Idle Speed at Headland Ends (S_f) of Three Selected Patterns

Plowing patterns	Sample field	S_p km/h	S_e km/h	S_f km/h
Headland pattern from boundaries	Field-A	4.11	6.08	4.00
Headland pattern from backfurrow	Field-B	4.10	5.81	3.74
Headland pattern mixed mode (02 back furrowed 03 land pattern)	Field-C	4.13	5.99	4.78

Table 4. Plowing Patterns Efficiency for Three Selected Plowing Patterns

Plowing patterns	Pattern efficiency (P.E)	Pattern furrowed (%)
Headland pattern from boundaries	0.9357	93.6
Headland pattern from backfurrow	0.86506	86.5
Headland pattern mixed mode (02 back furrowed 03 land pattern)	0.92416	92.4

Table 5. Time Efficiency of Three Selected Plowing Patterns

Plowing patterns	Theoretical plowing time (sec)	Actual plowing time (t) (sec)	Time efficiency (%)
Headland pattern from boundaries	1 603	1 704	94.00
Headland pattern from backfurrow	1 603	1 853	86.5
Headland pattern mixed mode (02 back furrowed 03 land pattern)	1 603	1 734	92.4

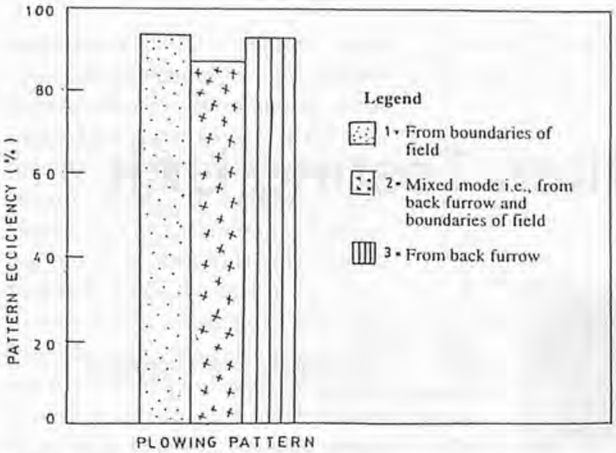

Fig. 5 The plowing pattern efficiency (P.E).

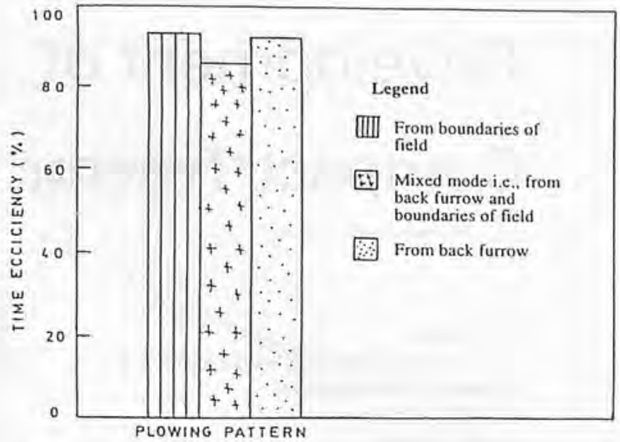

Fig. 6 Time efficiency (T.E) of selected plowing patterns.

land pattern from back furrow and headland pattern mixed mode was 6.08, 5.81 and 5.99 km/h, respectively.

The idle travel speeds (S_f) across the ends of headlands are shown in **Table 3**. The values of idle travel speeds across the ends of the sample fields of the three selected plowing patterns were 4.00, 3.74, 4.78 km/h, respectively.

After having developed and determined the data of various variables involved in the P.E. equation, this data was used and substituted in the equation and the value of efficiencies of three selected patterns of plowing was calculated. The results of efficiencies so calculated were 93.6% for the headland pattern from boundaries, 86.5% for headland pattern from back furrow and 92.4% for headland pattern mixed mode (02 back furrowed 03 land pattern) (**Table 4**).

The histograms showing the efficiency of three plowing patterns were also constructed to compare the efficiency of different selected plowing patterns (**Fig. 5**). The results of plowing pattern efficiency obtained during the present study are in close conformity and concurrence with the results of Hunt (1983).

The time efficiencies of selected plowing patterns are tabulated in **Table 5** and illustrated in **Fig. 6**. The values obtained were 94% for headland pattern from boundaries of field, 86.5% for headland pattern from back furrow, 92.4% for headland pattern mixed mode (02 back furrowed 03 land pattern), respectively. The time efficiency and plowing efficiency of headland pattern from the boundaries was higher than the other two patterns of plowing due to the fact that idle time loss accountable for this pattern of plowing was less than the other two patterns of plowing. The greater time loss in the case of headland pattern from back furrow and for the mixed mode of headland pattern affected S_c, S_f which, in turn, influenced and reduced the plowing efficiency of the remaining two patterns of plowing.

Conclusions

The present study of different plowing patterns was carried out and the following conclusions were drawn:

1. Headland pattern from boundaries of the field was the best pattern of plowing for the rectangular fields as it fetched the highest plowing efficiency;
2. Headland pattern from boundaries of the field was an easier method of plowing in terms of maneuverability of the machine and executing 90° turns at the ends of the field; and
3. It is suggested that headland pattern from boundaries be practiced and adopted which is more appropriate and efficient.

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Development of Compact Tractor Hitch Testing Unit

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Abstract

The development of a low-cost hitch testing facility that complies with relevant international standards is described.

A simulation model of the actual hitch forces encountered by a large 150 kW agricultural tractor, operating under actual field conditions, was developed. These indicated a maximum pulling force of 81.36 kN which is just above the ISO Standard value of 80 kN. It was found that, for cost effectiveness, the maximum feasible frequency of application of the testing force is 6 Hz.

The resultant unit is compact (4 m x 2 m) and applies a maximum loading of 90 kN at a maximum cycle frequency of 6 Hz and complies with international standards. Additional features were added in order to meet the more stringent Dromone Standard*. These include lifting (maximum lifting force 100 kN) and destructive (increasing load to failure – maximum 500 kN) tests.

A fatigue test was carried out on a Renault Ceres 95 pick-up hitch. Deflection of the hook was less than 10 mm and no cracking was observed. The hitch was deemed to conform with the ISO and EU Standards. It is envisaged that this unit will be integrated into a computer-based design and testing facility that will minimize the number of destructive tests required.

*Dromone Engineering, Ireland

Introduction

Tractor pick-up hitches must be designed to meet EU and ISO Standards in relation to their structural integrity. These Standards are intended to simulate field conditions and include both fatigue and static load tests. All tractor manufacturers must meet these requirements and there are only a limited number of specialized hitch testing facilities in the EU.

The objective of this study was to develop a low-cost, in-house hitch testing facility that would comply with the relevant standards and would enable testing to be carried out during the design stage of a new hitch. In addition, it is required that the test units could be used to carry out further tests in accordance with the stricter Dromone Standard.

Methodology

Fatigue failure occurs due to alternating stresses, of relatively small magnitudes, which cause fracture in a metallic structure which could otherwise carry much greater static loads (Higgens, 1983). When a material is cyclically loaded within the elastic region, stress and strain are linearly related to each other by the elastic modulus, hence it is only necessary to measure one of the two in order to know them both.

The actual forces acting on a tractor pick-up hitch in the field vary continuously with time. Alternating forces such as those caused by acceleration/deceleration, ascent of slopes, terrain roughness, steering and so forth, are a major cause of failure in pick-up hitches (Collins, 1991; Chisholm and Harral, 1989). Safety is a major concern in the design of any hitch testing rig, particularly where failure of the pick-up hook may be expected (Dier and Hobbs, 1986).

ISO Standards

ISO Standard (ISO TC23/SC2/WG1) specifies that the dynamic force application frequency shall not exceed 10 Hz and that 5.10^5 test cycles be carried out. In contrast, the EU Standard (EEC Directive 89/173/EEC) limits the application frequency to 30 Hz and the number of test cycles to 2×10^5. Both the EU and ISO Standards outline dynamic and static tests, either of which can be carried out for certification. In this study, dynamic tests were considered because fatigue failure is the main cause of failure in pick-up hitches (Collins, 1991; Chisholm and Harral, 1989). As outlined above, the EU Standard states that the dynamic test may be carried out at a frequency up to 30 Hz. Research has shown that the fatigue life in cycles depends only on the amplitude of the wave form and its mean value (Sherratt, 1994). If the test loading is applied at twice the rate, failure occurs in half the time. Hence the clear advantage of carrying out tests at high frequencies is that it enables the test to be completed much sooner. In the ISO Standard, the maximum test frequency should not exceed 10 Hz. However, due to costs involved, the maximum feasible frequency was found to be 6 Hz. Calculations showed that the maximum force required under the EU standard is 81.8 kN (Evans, 1996). This is in general agreement with the ISO Standard which sets this value at 80 kN.

Computer Simulation

A computer simulation model was developed (Evans, 1996) to determine the forces acting on a hitch for a given tractor and trailer in order to confirm that the forces calculated in the Standards were of similar magnitude to those experienced under actual field conditions. The computed forces were verified as being close approximations to forces actually experienced, using available OECD Test Results for Deutz-Fahr DX 4.70 and DX 6.30 tractors [OECD Reports (1984, a and b)].

Details of the simulation model are given elsewhere (Evans, 1996). The model outputs the maximum pulling force. The two main assumptions made were that the tractor is 2-wheel drive and that it has an infinitely variable gearbox. The latter resulted in an error at low speed (<4 km/h) as illustrated in **Fig. 1**.

The computer simulation was then run for a "worst case scenario" — using typical input values for a large "top of the range" 150 kW tractor (**Table 1**). These resulted in a calculated maximum pulling force of 81.36 kN, which is just above the maximum allowable ISO value of 80 kN. The maximum possible dynamic force that the hydraulic actuator could generate was specified as 90 kN, in order to allow for a factor of safety and for increases in the size of future tractors.

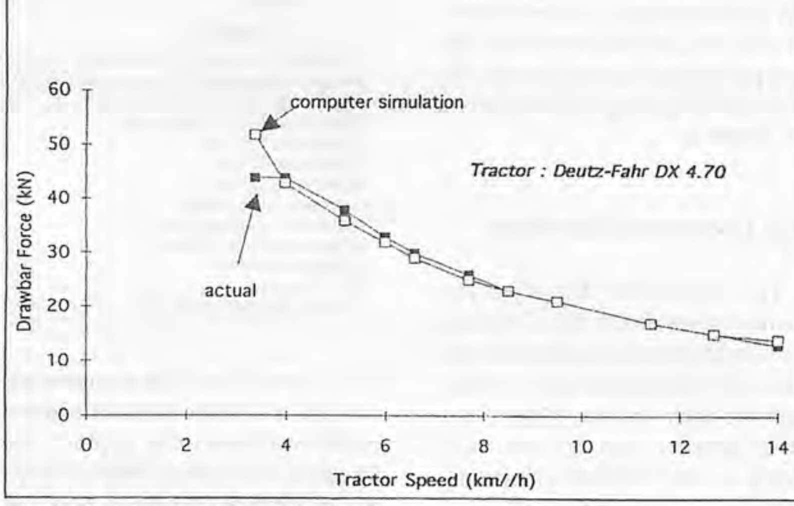

Fig. 1 Computer simulation of drawbar forces v. actual field performance.

Table 1. Tractor Simulation Model — Inputs and Outputs: Variables

Inputs	
Tractor mass	9 000 kg
Tractor height	3 m
Tractor wheelbase	3 m
Distance from Centre of Gravity of the tractor to the ground	1.1 m
Distance from Centre of Gravity of the tractor to the rear axle	1.1 m
Hitch height from the ground	0.5 m
Distance forward of hitch from rear axle	0.4 m
Moment of Inertia of wheels	0.7 kg m^2
Rear tyre rim diameter	0.95 m
Rear tyre width	0.5 m
Moment of Inertia of engine	0.06 kg m^2
Engine power at rated speed	140 kW
Maximum engine torque	730 Nm
Rated engine speed	2 200 rev/min
Tractor acceleration	0 m/s^2
Tractor velocity	5 km/h
Wheel slip	9%
Ground slope	0°
Coefficient of rolling resistance of tractor front tyres	0.03
Coefficient of rolling resistance of tractor rear tyres	0.02
Outputs	
Total gear ratio, engine: driving wheels	199.045
Engine torque at rated engine speed	607.7 Nm
Maximum pulling force	81.36 kN

Table 2. General Hydraulic Specifications for the Pick-up Hitch Fatigue Tester

Part Description	Specification
Hydraulic actuator (Double acting)	Maximum dynamic loading force of 90 k maximum oscillating frequency of 6 Hz Built in pressure transducers
High response servo valve	Force accuracy of ±2%
PSC (Programmable servo controller)	Input/Output interface with servo valve and PC. Built in Data Acquisition Card Pressure Feedback Control
Power pack	Suitable gear pump and 3 phase electric motor to generate maximum force and frequency. Heat exchanger, smoothing accumulator, reservoir, pressure relief valve, and oil filters
Linear potentiometer	Accurate measurement of actuator stroke/hook deflection

Once the maximum dynamic force and frequency had been established (viz. 90 kN and 6 Hz) the general hydraulic specifications for the hook fatigue tester were drawn up (**Table 2**).

The Dromone Standard

The Dromone Engineering planned to establish the Dromone Standard comprising additional tests that could be carried out to further improve their hitches. These tests cover aspects that are not fully tested in the official Standards. These are:

1. Lifting Test: This test simulates the lifting and lowering of trailers. During the tests, two lifting hydraulic actuators would be attached to the link-arms, and would generate a force 100 kN. A third actuator, capable of delivering a maximum force of 50 kN, would apply a constant load to the pick-up hook, thereby simulating the forces acting on the hook during hitching and unhitching; and
2. Destructive Test: Once the hitch is mounted on the rig, an actuator would apply an increasing load to the hook until failure occurs (maximum force = 500 kN).

Design and Construction

Details of the design are given elsewhere (Evans, 1996). A closed loop control system is used in order to ensure accurate control of the unit (Anon., 1972). Special long-life seals, capable of withstanding 100 million cycles, are used — each test duration is c. 2 million cycles. The tester is compact (4 m x 2 m) and designed as a single unit. The design incorporates a high response servo-valve which is essential for carrying out tests at 6 Hz. The entire rig is controlled by a 386 PC, enabling testing to be carried out with minimum supervision. The operator enters the maximum and minimum dynamic forces to be applied, the frequency of the test and the number of cycles to be carried out. The fatigue test stops automatically if the pick-up hook breaks. At the end of the test period the hook is inspected for cracks or tears.

Table 3. Input Conditions for Preliminary Fatigue Test on a Renault Ceres 95 Pick-up Hitch

Variables	Values		
Technically permissible total mass of the tractor	M_T	4 000	kg
Technically permissible total mass of the trailer	M_R	18 000	kg
Maximum static drawbar load	S	900	kg
Horizontal force component		32.1	kN
Horizontal test load	$F_h = 1.0.D$	32.1	kN
Vertical test load	$F_v = g.1.5.S$	13.2	kN
Resultant test force		34.7	kN
Direction of resultant		22.4	deg
Maximum loading force	F_{max}	34.7	kN
Minimum loading force	$F_{min} = 5\%$ of F_{max}	1.7	kN
Loading direction	α	22.4	deg
Test frequency	f	5<—>6	Hz
Total number of cycles	N	100 000	

Testing

A fatigue test was carried out on an unpainted Renault CERES 95 pick-up hitch. Sinusoidal dynamic forces were successfully applied to the hook (under PC control). Deflection of the hook, as a result of the forces applied, was observed as being well within the capabilities of the actuator stroke (maximum of 10 mm). Details of the input conditions are given in **Table 3**. The EU Standard requires that a colour penetration method be used to identify cracks. Accordingly, on completion of the test, the surface of the pick-up hitch is cleaned and dried. A penetration fluid containing a UV fluorescent dye is sprayed on the surface which is then warmed to 90°C. After penetration is complete, the excess is flushed from the surface with warm water (the surface tension of the water is too high to allow it to penetrate the narrow fissures). The surface is then dried and the cracks, containing the dye, are visible under UV light. No cracks had developed and the hitch was deemed to conform with the International Standards.

Conclusions

The aim of this project was to develop a cost effective and compact pick-up hitch testing unit that complied with current standards and that offered the option of developing the Dromone Standard. The unit developed meets these requirements.

It is envisaged that this unit will be used to assist in the on-going R&D and, consequently, further testing features will be added, thereby extending the Dromone Standard. Future development will include integrating the test unit with a computer-based finite element analysis (FEA) model. This approach would enable preliminary design and testing to be computer based with actual testing only being carried out on the final design.

Ultimately it is envisaged that both design and final testing can be computer based with statistically based sampling regimes (using actual testing) used to continuously certify the computer based models.

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Proper Selection of Submersible Turbine Pumps for Deep Wells

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Abstract

Proper selection of submersible turbine pumps is essential as their initial costs are considerable. The usual way to select the pump, the system curve method, is costly due to the installation of a pump inside the well to perform the pumping test. Moreover, its results are changed with the passage of time. This leads to unsatisfactorily selection of pump and, accordingly, the motor. A simplified procedure is developed to select properly the submersible turbine pump taking into account the aquifer and well's characteristics as well as the specification of the irrigation system used in the field. An example is provided to demonstrate the simplicity of this procedure.

Introduction

Submersible turbine pumps are used more widely in pumping water from deep wells than any other types of pumps. They are vertical centrifugal pumps of the turbine type that can be installed inside the well casing and below the water level. These pumps consist of a number of pump bowls with impellers, each set above another, which are added so as to build up the head required. The impellers are driven by a submerged electric motor directly coupled to the pump as shown in **Fig. 1**. These pumps are installed at depths of 3 to 6 m below the lowest water level during operation. Submersible turbine pumps have many advantages. They are cheaper for deeper settings and smaller discharge rates. They can be used in a crooked well where it is impossible to use a long line shaft vertical submersible pump if the line shaft is not perfectly straight. Moreover, the motor's efficiency improves due to the continuous cooling in water. However, they are more susceptible to service interruptions due to electric line voltage fluctuations.

Pump selection is the process of choosing the most suitable pump for a particular irrigation system. Because deep wells are long-term installations (about 25 years), a proper selection of pumps and motors is essential as the initial cost is considerable. Pumps must be selected to fit the physical requirements of the well, including yield, drawdown, head, casing diameter, pump depth setting, etc. Motors must be selected to provide adequate power to operate the pump at the proper rotation speed on a continuous basis. Oversizing selection of pump and motor may result in pumping sand, cause larger capital cost for the pump and motor and higher demand charges for electrical power units. On the other hand, undersizing selection of pump and motor causes lower efficiencies and usually reduces their service life because of overheating (Karassik et al., 1976). Saqib and Khan (1993) carried out an evaluation of the performance of 64 deep wells already installed in Pakistan. The study showed that the average pump efficiency was 51% which is about 64% of the maximum attainable level of about 80%. The average measured overall efficiency of pumps and motors were 39% against a maximum average attainable level of 70%. This was mainly attributed to oversize selection of pumps and motors.

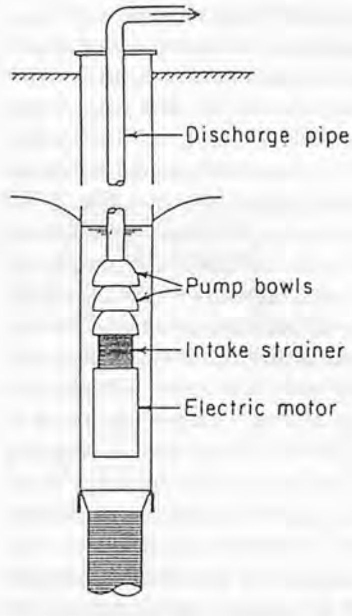

Fig. 1 Schematic presentation of the submersible turbine pump.

The usual way to select a proper pump for a deep well is called the *system head curve method* (Jensen, 1983). It is based on pumping the well with various discharge rates and measured corresponding drawdown in the water level inside the well. **Figure 2** is a sketch of a typical system head curve illustrating the parameters which contribute to the total head and how they vary as the discharge increases. The curve represents the relation between the discharge and head of the pump (TDH-Q curves) that is selected from pump manufacturer's catalogues and superimposed on the system curve. All superimposed graphs should have the same vertical and horizontal scales. The point where the TDH-Q curve and the system curve cross would be the actual operating point as shown in **Fig. 2**. The disadvantage of this procedure is that the installation of a pump to get the well drawdown curve is costly. It is difficult to measure the fluctuations of the water level in a very deep well. Moreover, with the passage of time, changes may occur to the TDH-Q curve due to clogging of the well screen openings or increasing the roughness of the pipe wall. As a result, the position of the head-capacity curve will be changed and the selected pump may not satisfy the required operating conditions. In many instances, farmers consult the pump's dealers in order to obtain a new submersible turbine pump to produce a specific discharge and to operate under an approximate value of the total head. Considering this information, the dealer selects a pump from manufacturer's catalogues that are capable of supplying the discharge and head requirements regardless of the aquifer characteristics such as permeability, storage and transmissivity coefficients. Accordingly, the pump may be overloaded and exhausted. This will reduce its service life and increase the maintenance costs. The main objective of this research is to develop a simplified procedure to select properly the submersible turbine pumps for deep wells, based on the aquifer and well characteristics as well as the irrigation system specifications.

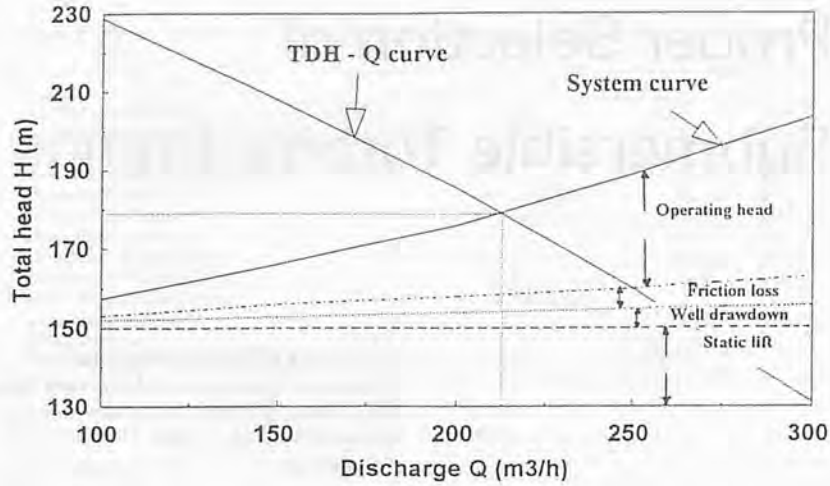

Fig. 2 Determining the pump operating point.

Theoretical Considerations

In actual practice the pumping levels in wells nearly stabilize after a few days of continuous pumping. The well drawdown s, can be computed using the non-steady state equation developed by Theis (Todd, 1980):

$$s = \frac{Q}{4\pi T}\left[-0.5772 - \ln u + u - \frac{u^2}{2.2!} + \frac{u^3}{3.3!}\right] \qquad (1)$$

where:

s = well drawdown in m.

Q = well discharge rate in m^3/d.

T = transmissivity coefficient in m^2/d.

$u = r_w^2 S/4 T t$ (2)

r_w = well radius in m

S = storage coefficient (dimensionless)

t = time in days since pumping started.

Jacob (Todd, 1980) considered that the series terms in Eq. (1) become negligible after the two terms. As a result, Eq. (1) can be expressed as follows:

$$s = \frac{Q}{4\pi T}\left(-0.5772 - \ln\frac{r_w^2 S}{4 T t}\right) \qquad (3)$$

Jensen suggested to consider the value of t equals at least one day in Eq. (2). The aquifer characteristics S and T can be obtained from previous investigations in the area or from the pumping test data when the well is drilled. Assuming a reasonable well diameter and normal pumping time t, equation (1) is reduced to:

$$s = C_1.Q \qquad (4)$$

where C_1 is a constant. Since the system is operated by electrical energy, the kilo-Watt that is used in the analysis. The input power required to drive the electric motor is calculated from the following equation (Marino and Luthin, 1982):

$$\text{Input Power (kW)} = \frac{Q.TDH}{270\ E_{overall}} \qquad (5)$$

where:

Q = pump discharge in m^3/h

TDH = total dynamic head in m.

$E_{overall}$ = overall pumping efficiency and equals:

$$E_{overall} = E_{pump} \times E_{motor} \qquad (6)$$

in which E_{pump} and E_{motor} are the pump and motor efficiencies, respectively. Jensen (1983) recommended a value of 0.65 for overall efficiency of an electric power source. The total dynamic head TDH is determined as follows:

$$TDH = h_s + h_d + s + h_f + h_p + h_v + h_{En} + h_{Ex} \quad (7)$$

where:

h_s = static lift (m)
h_d = static discharge head (m)
h_f = friction head loss (m)
h_p = operating head (m)
h_v = velocity head (m)
h_{En} = entrance head loss (m)
h_{Ex} = exit head loss (m)

The static lift h_s is the vertical distance from the center of the discharge pipe to the static water level in the well when the pump is not operating. It is independent upon Q. Static discharge head h_d is a measure of the elevation difference between the center line of the discharge pipe and the eventual point of use. It is also independent of the discharge rate. Friction head loss h_f through the discharge pipe can be determined from the Hazen-Williams formula (James, 1988):

$$h_f = 10.77\, L(Q/C_{HW})^{1.852}/d^{4.865} \quad (8)$$

where:

L = total pipe length in m.
Q = discharge rate in m^3/sec.
C_{HW} = Hazen-Williams coefficient
d = pipe diameter in m.

The total discharge pipe length L equals the sum of h_s, s, length of the discharge pipe and 3 to 6 m to keep the pump submerged all the time. Knowing the static water level, the diameter and material of the discharge pipe and substituting in Eq. (8), the friction head loss can be expressed as follows:

$$h_f = f_1(s, Q^{1.852}) \quad (9)$$

Irrigation systems, such as sprinkler and drip systems, require some operating heads h_p to continuously increase as the discharge rate increases. The relationship between the system operating head and discharge is normally established by the pressure discharge. Most pumps will not operate efficiently over wide ranges in operating heads. Therefore, it is assumed that there is a specific condition that is most prevalent. Then, the pump must be selected to operate efficiently for that set of conditions. Values of h_{En} and h_{Ex} are usually very small and the error induced by disregarding them does not exceed one meter (Power, 1981). The velocity head $h_v = v^2/2g$, where v is the velocity in the discharge pipe and g is the acceleration of gravity. For deep wells, h_v normally does not exceed 0.5-1 m (Jensen, 1983). Equation (7), then, can be simplified into the form:

$$TDH = f_2(s, Q^{1.852}) \quad (10)$$

Substituting of Eqs. (4) and (10) in Eq. (5) and assuming a reasonable overall efficiency, yields

$$\text{Input power (kW)} = f_3(Q) \quad (11)$$

Equation (10) is used to determine the power required for the motor to operate submersible pump based on the aquifer and well characteristics as well as the specifications of the irrigation system used.

Analysis and Discussions

In order to demonstrate the simplicity Eq. (11) the following example is given which it is requires to select a submersible turbine pump to deliver 250 m^3/h from a deep well of 40 cm diameter. The static water level is located at 150 m under the ground surface. The average transmissivity and storage coefficients in the site are 1.166 m^2/min and 4.59 x 10^{-3}, respectively. An irrigation system consists of 50 sprinklers is used in the farm. The system has the same elevation as the discharge pipe of the well. It is located at a distance of 100 m from the well. The relation between the operating pressure and the discharge for this system is expressed by the following form:

$$Q_s = 0.3P^{0.5} \quad (12)$$

where:

Q_s = sprinkler discharge in m^3/h
P = operating pressure for the system in kPa

The water temperature in the irrigation system is about 25°C (water specific weight $\gamma = 9\,779\ N/m^3$). The diameter of the discharge pipes is 30 cm. They are fabricated from new unlined steel ($C_{HW} = 150$).

Using Eq. (2), the value of u at t equals one day is determined

$$u = \frac{(0.20)^2 \times 4.59 \times 10^{-3}}{4 \times 1.166 \times 60 \times 24} = 2.73 \times 10^{-8}$$

Using Eq. (1), the well drawdown is calculated

$$s = \frac{250}{4\pi 1.166 \times 60}[-0.5772 - \ln u] = 4.79\ m$$

The pump is situated at 4 m under the lowest water level during pumping the well. Substituting of the value of s in Eq. (8), the friction head loss in the discharge pipe is calculated as follows:

$$h_f = 10.77(150 + 4.79 + 100 + 4) \times [250/(3\,600 \times 150)]^{1.852} \times (0.30)^{-4.865} = 0.65\ m$$

The operating pressure required for 50 sprinklers can be determined from Eq. (12) as follows:

$$P = 11.11\, Q_s^2 = 4.4 \times 10^{-3} Q^2 \quad (13)$$

in which Q is the well discharge and equals $50Q_s$.

The operating head h_p (m) = P/γ =

$$1\,000\ P/9\,779 = 0.102\ P. \quad (14)$$

Substituting of Eq. (13) in Eq. (14) yields:

$$h_p = 4.5 \times 10^{-4} Q^2 \quad (15)$$

Consequently, h_p is required to deliver 250 m^3/h = 28.12 m.
The velocity head = $(0.982)^2/(2 \times 9.81)$ = 0.05 m. The sum of h_{En} and h_{Ex} is assumed equal 1.0 m. According to Eq. (7), the total dynamic head equals:
TDH = 150 + 4.79 + 0.65 + 28.12 + 0.05 = 184.61 m
Since the required pumping head is greater than what a single stage can be develop, it is necessary to use multistage turbine pump. Manufacturer's catalogues always produce the TDH-Q curve for a single stage. The head/stage is determined at Q equals 250 m^3/h. Dividing the total dynamic head by the head produced by a single stage pump yields the required number of stages. Using Eq. (5), the motor power required to operate the pump is determined as follows:

$$\text{Input power (kW)} = \frac{250 \times 184.61}{0.65 \times 270}$$

= 263 kW

Conclusions

Oversizing the selection of submersible pumps and motors may result in pumping sand and cause higher demand charges for electricity bills. Meanwhile, undersizing selection causes lower efficiencies and reduces the service life of pumps and motors. The system curve method may lead to unsatisfactorily selection of submersible pumps. A simplified procedure has been developed to select properly the submersible turbine pumps as well as motors for deep wells based on the well and the aquifer characteristics as well as the irrigation system specifications.

Appendix I

Notation

d = pipe diameter
E = efficiency
h_d = static discharge head
h_{En} = entrance head loss
h_{Ex} = exit head loss
h_f = friction head loss
h_p = operating head
h_s = static lift
h_v = velocity head
L = pipe length
Q = well discharge
r_w = well radius
s = well drawdown
S = storage coefficient
t = time
T = transmissivity coefficient
TDH = total dynamic head

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Engineering Perspective in Saline Agriculture

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Introduction

Pakistan is an agricultural country. An appropriate combination of soil-water-plant is the basic requirement for reaping optimum crop production. An account of land and water resources in the country, by province, is given in **Table 1**.

Table 1. Land and Water Resources

Item	Pakistan	Punjab	Sind	NWFP	Baluchistan
Geographical area (m ha)*	79.61	20.63	14.09	10.17	34.72
Cultivated area (m ha)*	21.25	11.99	5.68	1.92	1.66
Canal command area (m ha)*	12.24	8.64	2.44	0.69	0.47
Salt affected area (m ha)**	5.23	2.44	2.27	0.52	—
Water allocation (MHM)***	14.48	6.90	6.02	1.08	0.48
Delta of water (mm)	1 183	799	2 467	1 565	1 021

*Agri. statistics, 1993, **Hassan, 1990 and ***Water Accord, 1991.
Delta of water: Ratio of water to irrigation land

Water is a vital resource that is essential for agriculture. Of the many benefits, a good quality water is potentially required for a sound plant growth and washing out or diluting salts in the soil. The most ideal for agriculture is the canal water. As an estimate, the irrigation demand for a piece of land that is continuously cropped is about 1 832 mm per year (PARB, 1996). Except Sind, all other provinces are deficient in this required quantity of water in canal commands.

As a result, there is no alternative except to tap tubewell water which is an unbearable load on farmers, particularly in Punjab with the highest responsibility in agricultural domain in the country. The situation has enforced the farmers to install a large number of tubewells, more than 273 000, indiscriminately without much consideration for the quality of water to be pumped. There are 4.94 MHM total resources of ground water in Pakistan (PARB, 1996). Of this quantum, 25% is underlain by fresh water. About 25% is moderately brackish and the remainder, 50%, is highly brackish. Pumping of brackish water and its supply to fields would progressively cause an increase in salt accumulation in soil and jeopardize plant's health. After sometime when salts start interfering with crop growth, farmers have no choice except to abandon the tubewells. The insufficient canal irrigation supply, the arid climatic conditions involving scanty rainfall and high evaporation during hot temperature in summer accelerate capillary action which pushes salts up to the soil surface.

Under these circumstances, salinity is one of the major problems with which agriculture in Pakistan is confronted. Various methods to reclaim salt-affected soils have been recommended and some of them are practised with variable success. The Irrigation Department runs land reclamation programme in the Government sector. Under this scheme, 1 000 to 3 000 cusec of additional canal water is allocated annually over and above the normal irrigation supplies. The reclamation so achieved is temporary in nature because on reverting to normal irrigation supply, the salinity appears again. The normal irrigation supply of canal water in Punjab is one cusec for 330 acres.

No doubt, reclamation is the proper cure for salinity problem but it is not easily possible as it is constrained by scanty canal supply and unfit tubewell water commonly coexisting in salty tracts. Farmers in such areas have no choice except to live with saline condition. This study envisages tapping of various ways and means to use the salt-affected soils to the best viable and sustainable economic pursuit under saline agriculture.

Saline agriculture is purely a management issue. The basic objective is to improve soil water availability to plant keeping in view the quality of soil and irrigation water and the water requirement of the crop. The following management practices are recommended in carrying out successful cropping under saline conditions, scanty canal supply and unfit ground water: selection of crops; land preparation; irrigation management and practices; sowing; weeding; manure and fertilizer; use of amendments; harvesting; and cultivation of economic plants.

Selection of crops

Depending upon the quantity of water available for irrigation on a known soil in a particular climatic conditions, the selection of a crop

Table 2. Crop Tolerance to Salinity

Level	Crops	Vegetables	Condiment, spices and narcotics	Fruit plants
Highly tolerant EC 10 dSm^{-1}	Barley and surgar beet.	—	—	Date palm
Tolerant EC 5-10 dSm^{-1}	Wheat, oats, pearl millet, sorghum, castor, linseed, safflower, soybean, cotton and sunhemp.	Spinach	—	Pomegranate, guava and ber.
Semi tolerant EC 3-5 dSm^{-1}	Rice, finger millet, maize, minor millets, cluster bean, pigeon pea, cowpea, groundnut, sunflower, seasame and sugarcane.	Ash gourd, bitter gourd, brinjal cabbage, pea, lady's finger, musk melon, onion, potato, sweet potato, tomato, radish, carrot, turnip and water melon.	Chillies, fenugreek, garlic and tobacco.	Custard-apple and kagzi lime.
Sensitive EC 1.5-3.0 dSm^{-1}	Gram and lentil.		Mint	Grape, mango and sweet orange

Table 3. Salt Sensitive Stages of Important Crops

Crop	Stage
Wheat	Seedling (2 leaf) and grain formation
Cotton	Seedling (2-4 leaf)
Rice	Seedling (14 days old) and initiation
Sugarcane	Bud sprouting
Maize	Seedling
Sunflower	Seedling
Raya and rapeseed	Seedling
Barley	Seedling (2 leaf stage) and grain formation
Gram, lentil, mash, soybean, groundnut, berseem, lucern and sorghum	Germination
Peas and radish	Germination
Potato, onion, garlic and carrot	Vegetative

and its variety, which can be best suited on economic considerations, is a very important aspect that deserves consideration. On the basis of tolerance with respect to irrigation water and soil salinity, the crops can be classified in four groups, namely; (a) highly tolerant; (b) tolerant; (c) semi-tolerant; and (d) sensitive. **Table 2** shows the tolerance of common crops/plants to saline conditions of variable grades (Hansen, 1979 and Agri. Hand book, 60).

Land Preparation

Precision land levelling should definitely be conducted to increase the uniformity of water application and allow shallow irrigation. Land should be prepared under good moisture (WATTAR) conditions because, due to dryness, the soil may tend to become hard to penetrate. Deep plowing with the use of chisel or sub-soiler is an invariable prerequisite for flushing down the salts with increased leaching. The subsequent seedbed preparation should be done with disc harrow instead of cultivator.

Avoid puddling and using rotavator as both these practices tend to destroy soil structure which impedes water leaching and causes salt accumulation in the upper profile. Frequent use of furrow turning plow should also be avoided as it brings leached salts on the top and increases concentration in the soil surface. Also, although there is no practical substitute at present yet consideration must be given the commonly used shallow deep plowing equipment break soil under compaction. Soil top is the weakest plane and, at the time of breakage, migration of leached salts takes place upward to varying extent. The answer to the problem is to break the soil under tension.

Irrigation Methods and Practices

Surface irrigation is a useful method under specified conditions but precision land levelling is its prerequisite. Drip irrigation also gives good results even when using relatively high salinity water. By this method, low moisture tension levels can easily be maintained throughout the growing season. After harvest, leaching is required to lower the salt contents in soil before sowing a new crop. Similarly, soluble salts tend to accumulate in the top few centimetres of the soil during fallow periods, so a heavy presowing irrigation with good quality water to free the root zone from excess salts and to improve germination of seeds is the most essential requirement.

In situations where good quality water is available but in limited quantity, high salinity waters can be used for irrigation in conjuction with the former. The prerequisite of this practice is that good quality water should remain at the disposal of the user. The soil salinity in the root zone resulting from continuous use of saline water can be prevented to increase beyond the permissible limits when two to three cycles with saline water are followed by one cycle with good quality water. Alternately, saline water can be used at tolerant growth stages and good quality water at sensitive stages of plant growth as given in **Table 3**. Germination stage, however, remains usually most sensitive. Likewise, the selection of crop rotation may be made in such a manner that sensitive crops can be raised using good quality water and tolerant crops with saline water, so that the annual salt balance remains staple. The timing and amount of substitution will vary with quality of the two waters, the cropping pattern, the climate and the irrigation system. As a rule soils and irrigation waters must be periodically analyzed to check out the future plan accordingly.

Sowing

The seed should be treated with suitable fungicide before sowing. Seed soaking in the tubewell water to be applied for irrigation or any of the chemicals; copper sulphate, calcium chloride, betaines, sodium sulphate and gebralic acid should also be done to energize and enhance

Table 4. Common Economic Trees

Local name	Botanical name	Local name	Botanical name
Apl Apl	*Leucaena leucocephala*	Arjan	*Terminalia arjuna*
Sukh chain	*Pongamia pinnata*	Parkin sonia	*Parkinsonia aculeata*
Shrin	*Albizzia* Spp.	Kikar	*Acacia nilotica*
Sufada	*Eucalyptus camaldulensis*	Beri	*Zizyphus* Spp.
Phurwan	*Frash (Tamarix aphylla)*	Jand	*Prospopis spicegera*

germination.

Obtaining a satisfactory stand by furrow irrigation is a serious problem. One alternative is to use seeds at higher rates than the normal. The other alternative consists of appropriate adjustment in planting. Procedures can be adopted to ensure that area around germinating seed is lowest in salinity. This can be done by selecting suitable planting practices, bed shapes and irrigation management, e.g., by using sloping beds with seeds placed on the sloping side and the seed row placed just above the water line.

On light textured soils where water penetration rate is high, dry sowing technique is more appropriate i.e., prepare the land, sow the seed and immediately after sowing apply irrigation. After germination, apply irrigations normally. On heavy textured soils or waterlogged soils, make raised beds, sow the seed on the beds and apply irrigation through the trenches. Here sowing should be done when soil moisture is enough for seed germination.

The saline water can be used more rationally by growing two different crops simultaneously in strips. The irrigation of the main crop helps in the unirrigated intercrop and thus both the crops play a complementary role, e.g., inter-crop of irrigated gram and raya can be raised successfully with wheat irrigated with low and high salinity water conditions, respectively.

Weeding

Manual weeding should be preferred and use of weedicide avoided as phytotoxity may damage the crop. Mechanical weeding may also be adopted where possible, e.g., wheat, barley, cotton, sunflower, maize and sugarcane.

Manure and Fertilizer

The fact is manure and fertilizer enhance the suitability of saline water for irrigation has been recognized widely. So it is recommended that the application of farm yard manure and fertilizers to various crops is beneficial under saline water irrigation up to a moderate level of salinity. Green manuring is also one of the useful practices in the management of saline water irrigated agriculture and, therefore, it should find an important place in crop rotation. The efficiency of *Sesbania aculeata* is higher than sunnhemp and cluster bean in such conditions of soils and irrigated waters. Nitrogen and potassium can be increased about 10 to 20% but phosphorous should be applied according to the recommendation on the normal soils. In such soils and irrigated water, the application of zinc at the rate of about 20 kg/ha zinc sulphate is recommended for various crops, especially for rice.

Use of Amendments

In areas where saline sodic waters are being used for irrigation, the physical properties of the soils are likely to deteriorate resulting in permeability problem. This results in decreased water supply to the crop just as a salinity problem does. The average adverse effect of high sodicity of waters is more pronounced in heavy textured soils (loam to clayey) than in light to medium textured (sandy to sandy loam) soils. So the application of gypsum improves the soil permeability. Therefore, it is recommended that 25-30 kg gypsum/acre having purity of not less than 80% should be applied to lower extra RSC 1 $meql^{-1}$ than the permissible limit, i.e., 1.25 $meql^{-1}$ for each 7 cm of irrigation.

Harvesting

Harvesting of crops should not be delayed. Having harvest, the organic residues should be plowed back into the soil up to the maximum extent. The programme to bring land for the next crop should immediately be taken up and, in no case, kept fallow.

Cultivation of Economic Plants

Recently such type of soil and waters are being utilized in some economic plants cultivation such as jojoba cultivation in desert areas. The plant is drought-tolerant and ever green shrub. It thrives under marginal conditions of soil and water. Its green foliage and nuts are used as animal feed. The seed of the plant is reported to contain 46 to 56% liquid wax. Tree and salt bush plantation, **Table 4**, can be undertaken on ultra saline soils to use them more beneficially.

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Mechanization of Paddy Cultivation in Kerala, India: An Interim Evaluation

by

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Abstract

Paddy cultivation in Kerala needs appropriate mechanization to cope with the increased cost of cultivation due to high wages and scarcity of labourers. Ploughing, puddling and spraying are almost done completely by machinery. Transplanting, harvesting and threshing machinery of various sizes, powered by tractors, tillers and diesel engines are being developed and field tested. The manual and self-propelled transplanters as well as tractor front-mounted reapers and flow through rasp bar type threshers were found suitable for Kerala conditions.

Introduction

Labour scarcity has been a major problem of farm mechanization in most rice-growing countries. It holds true in the case of Kerala, a southern coastal State of India. Paddy cultivation in Kerala is at present confronting a crisis. The total cultivated area has declined to 0.54 million ha in the last 10 years. There is a steady decrease in the area and yield of paddy as shown in **Table 1**.

This situation is due to the uneconomical cost of cultivation of paddy. The labour force in the State is mostly literate and the wages are much higher than any of the other states of the country. However the labour output is comparatively low.

Labour shortage is felt during paddy transplanting, harvesting and threshing periods. The State has a history of burning tractors by organized farm labourers almost three decades back for fear that mechanization would replace a large number of labourers from the farms leaving them jobless. The present scenario is of the other extreme — not enough farm workers to transplant or harvest the crop. Many instances of leaving the matured paddy crop unharvested in the field for want of labourers are frequently reported. The introduction of labour and time-saving machinery is about the only way out to help the paddy farmers in Kerala but there are many problems in adopting rice mechanization in the state. The distribution of operational holdings in Kerala is shown in **Table 2**.

Table 1. Area and Production of Paddy in Kerala

Year	Area ('000 ha)	Production ('000 t)
1984-85	730.78	1 255.00
1985-86	678.28	1 173.05
1986-87	663.80	1 133.78
1987-88	604.08	1 032.60
1988-89	577.56	1 012.56
1989-90	583.39	1 141.23
1990-91	559.45	1 086.58
1991-92	541.33	1 060.35
1992-93	537.61	1 084.88

Table 2. Distribution of Operational Holdings in Kerala

Size class (ha)	Percentage of holdings	Percentage of total area
Below 0.02	11.7	0.5
0.02-0.50	72.3	29.7
0.50-1.00	8.6	18.6
1.00-2.00	5.2	21.2
2.00-3.00	1.4	9.9
3.00-4.00	0.4	4.1
4.00-5.00	0.2	3.0
5.00-7.50	0.2	2.3
7.50-10.00	Negligible	1.0
10.00-20.00	Negligible	1.3
20.00 & above	Negligible	8.4
Total	100.0	100.0

Kerala has a 3 000-mm annual rainfall, starting from May-June to August-September and from October-November to December. The temperature rises to 34°C and hence most of the fields dry up. These conditions are added problems to the rice farmers that need to be resolved before a tractor designer can recommend the right type of farm machineries in Kerala.

The State occupies the southwest portion of India. It is bounded by the Western-ghats in the east and the Arabian Sea in the west. The total area is 39 000 km^2. The state lies between 8 and 13 degrees South latitude. Its location in the humid tropics offers a larger venue for the most efficient agricultural production using natural resources. Topographically, the state can be divided into three natural zones: the lowland, mid-land and the high land. The lowland is characterized by a number of lagoons and back waters. Paddy and coconut are important crops grown in the low land. The mid-lands are characterized by a number of 'Elas' (small cultivable water sheds). A number of low laterite hills in this region are interspersed with paddy fields, coconut and arecanut groves. The most reserve forests in the state are in the high land (altitudes of a few hundred meters to 2 000 m) region. The state of Kerala has a total of 2.184 million ha under cultivation, of which 0.54 million ha is planted to paddy crop. It is estimated that 0.975 million t rice is produced from an area of 0.503 million ha annually.

Cultivation Practices

As rice is cultivated in a wide spectrum of agro-climatic conditions, it also needs a variety of suitable machinery. However, the two prominent and popular methods are direct seeding in upland area and transplanting in flooded areas. The major cultivation practices of paddy includes land preparation, transplanting, harvesting and threshing. The various machineries presently adopted for these practices are briefly explained below.

Land Preparation

It is estimated that 30-35% of total energy input in rice production accounts for tillage and seeding (Mittal, 1976). Rotavators are found to be the best soil working tool for land preparation in both dry and wet land conditions. In the rotavator, the sickles-like steel blades rotating at high speed cut the weeds, mix with the well fragmented soil and make a good tilth. The performance details of the tractor-mounted rotavator is shown in **Table 3**. The cultivators are exclusively used for land preparation in the dry season.

It has been established beyond doubt that transplanting paddy has a series of advantages over direct seeding under the present soil-water-plant-climate-cultural practices combination. The land preparation for wet cultivation involves primarily puddling, after the initial tilling of the land by tractor-mounted cultivator or local ploughs for 2 or 3 times. For puddling the field, animal-drawn puddlers or tractor/tiller-mounted cage wheels are used. Puddling is widely adopted in rain-fed lowlands because it greatly reduces the weed population, increases water retention in soil and reduces percolation. Unpuddled soil has increased percolation and receives twice the water that puddled soil receives. Rice in puddled soil had 2.5 times the efficiency of water use (7.9 kg/ha/mm and 2.9 kg/ha/mm) (Datta and Karim, 1974). It also increases the availability of many nutrients like N, P, K, Ca, Si and Fe, by preventing leaching (Obenmueller, *et al*, 1974). After the preparation of the puddled field, transplanting of seedlings, already raised in the nursery, is done either manually or mechanically. The rotavator is found to be the recently accepted soil working tool for both dry and wet land cultivation in the State (**Figs. 1** and **2**).

Table 3. Details of Tractor-Operated Rotavator

Weight	300-400 kg
Size	1.2-1.5 m
Power	35-45 HP
Field capacity	2 ha per day
Depth of penetration	10-15 cm
Number of blades	26
RPM of blades	300
Cost	Rs.40 000-5 000

Supplier: Farm Equipment India Ltd., Madras

Fig. 1 Working of the rotavator at work in dry land.

Fig. 2 Working of the rotavator at work in wet land.

Transplanters

Transplanting is one of the most tedious operations in paddy cultivation where the bending posture in conventional hand-transplanting consumes 30 percent more energy than a standing posture (Vos, 1973). A large number of transplanting aids and machines both for conventional seedlings and mat type seedlings have been developed and tried. Of these two machines, the self-propelled, 8-row Chinese type VST transplanter (**Fig. 3**) was tested and found promising. The washed root type conventional nursery was not successful for machine transplanting; only the mat type nursery gave satisfactory performance. The performance details of these transplant-

Table 4. Features of Modified 6-Row IRRI Manual Transplanter

Overall dimensions (L x W x H)	94 x 146 x 53.2 cm
Weight	27.4 kg
Planting mechanism	Inertia controlled picker arm and fingers
Type of nursery	Mat type
Row spacing	20 cm
Operator	1 man
Planting depth	3-5 cm
Operating speed	1-1.25 kmph
Field capacity	0.0162 ha/h
Field efficiency	56.87%
Plants per hill	3-4
Hill spacing	10-12 cm
Missing hills	5.55%
Labour requirement	50 man hour/ha
Cost of machine	Rs.1 750/-
Cost of operation	Rs.432/ha

Suppliers:
1. M/s. Swathi Industries, P.N. Pudur, Coimbatore
2. CIAR-IRR Industrial Extn. Project, TNAU Campus, Coimbatore

Table 5. Features of Riding-type, 8-Row, Chinese Model Transplanter

Overall dimensions (L x W x H)	2 410 x 2 297 x 1 200 cm
Weight	305 kg
Riding mechanism	Single wheel driven
Road speed	8.2 kmph
Planting mechanism	Separated crank driven, pivoted link system with seedling pusher
Row spacing	23.8 cm
Hill spacing	10-12 cm
Hill density per m²	34-42
Seedlings per hill	2.25 (average)
Missing hills	7.3% (average)
Cost of machine	Rs. 80 000/-
Power source	3 hp single cylinder Diesen Engine.

Supplier: M/s. V.S.T. Tillers Tractors Ltd., Banglore
* A steel wheel is available for field use and pneumatic rubber tyre for road.

Fig. 3 Self-propelled 8-row Chinese type VST transplanter in action.

Table 6. Details of Paddy Harvesters (VCRs)

Item	A	B	C
Effective width (cm)	95	155	210
Power source	5 hp air cooled engine	8-12 hp power tiller	35 hp tractor
Fuel consumption (ℓ/h)	0.80	1.50	4.00
Labourers required (Number)	2	3	4
Actual field capacity (ha/h)	0.15	0.24	0.38
Outputs (ha/man-hour)	0.075	0.089	0.095
Cost of harvester (Rs)	35 000	12 000	20 000
Rate of hiring (Rs/hour)	80	100	150

Suppliers:
1. M/s Swathi Industries, P.N. Pudur, Coimbatore
2. M/s Union Forgings, Focal Print, Ludhiana, Punjab
3. M/s Bharat Industrial Corporation, Moga

Legend
A. 5 hp self-propelled reaper;
B. Power tiller-operated paddy reaper; and
C. Tractor-mounted paddy reaper.

Note: The 5-hp VCR and Tractor-mounted reaper are found satisfactory working in the paddy fields.

ers are shown separately in **Tables 4** and **5**.

Harvesters

Though the harvesting and threshing were done manually, recently there were incidences in Kerala that the crop was unharvested and lost in the field for want of timely availability of labourers. Harvesting should be done at a very critical time before the grain is fully ripened at a moisture content of 20% to minimize shattering loss and grain cracking.

Vertical Conveyor Reaper (VCR)

Paddy reaper windrowers have been successfully modified and field tested in various research stations. This will be an ideal harvester for Indian conditions. The details, including the performance evaluation of three types of VCRs Viz. 5 hp self-propelled VCR, tractor-front-mounted VCR and power tiller-mounted VCR are shown in **Table 6**. The performance of the self-propelled (5 hp) and tractor-front-mounted reapers are shown in **Figs. 4** and **5**.

By these machines, the crop can be harvested and windrowed in a row, which can then be collected and taken to the thresher. Though these harvesting machines are working quite satisfactorily in farm fields, they are not fully successful in flooded, heavy fields or in totally lodged crop. Attempts have been made to mount the reaper attachment to the power tillers. After detaching the rotavator assembly, the extra weight of the reaper in front creates too much unbalancing and consequent vibrations at the handle. This needs further modifications for farmer acceptance.

Modifications Incorporated in 5-hp Self-Propelled VCR

The 5-hp self-propelled VCR machine is basically an IRRI design, but when used as such in the wet lands of Kerala, many problems like difficulty in turning in the small plots, slipping of the twisted V-belt, excessive vibration at the handle, improper balancing and consequent 'dozing' of the cutter bar were noticed. The following modifications were, therefore, incorporated to make the machine acceptable to Kerala farmers:

1. Left and right side clutches were provided and thus improved the maneuverability to a large extent.
2. The mounting structure for the 5-

Fig. 4 The 5-hp self-propelled VCR at work

Fig. 5 The tractor-front-mounted VCR at work.

hp diesel engine was modified so that the belt adjustment was easy and the position of the engine could be reversed for mounting a rotavator, hence the machine can be used as tiller. This also avoided the additional balance weight.

3. The simple tube handle was replaced with a double tube reducing the vibration at hold-grips considerably.
4. The crop dividers were modified.
5. A rotavator attachment was attempted for multipurpose use of the machine.

Modifications Incorporated the Tractor-front-Mounted VCR

The tractor-front-mounted VCR machine was purchased from Punjab, a northern State, where this model is extensively used for wheat and paddy in dry conditions. When

Fig. 6 Modified crop divider-starwheel and knife guard of cutterbar.

introduced in Kerala, problems of wrapping the straw beneath the star wheel, frequent failure of crop dividers and entangling of wire ropes were experienced. As a result, the following modifications were incorporated after which the machine became very well accepted by the farmers:

1. Steel conical cups were provided beneath the star wheels to avoid the wrapping of straw around them (**Fig. 6-A(1)**).
2. The mounting brackets of the crop dividers were re-designed by proper extension from the frame. This gave stable and durable service (**Fig. 6-A(2)**). The existing versions are shown in **Figs. 6-B** and **C**.
3. Suitable guides were provided for the wire ropes for smooth engagement and vertical movement to the cutter bar by the hydraulic linkage.
4. The mounting frame of the power transmission pulley and rear end of under shaft were reinforced to avoid excessive vibration and to impart more stability.
5. The weight transfer to front wheels due to the addition of the VCR was studied to ascertain its magnitude and to see that it is within the stable limits.

Threshers

The paddy threshing machine has not posed much problem, when compared to other operations. The high capacity, through-feed motorized threshers are popular among paddy farmers.

Raspbar Flow Through Thresher

Though the IRRI axial flow thresher is a good machine, the straw is beaten several times and so gets damaged. In places where the straw is used for roof thatching such damaged straw is not acceptable to farmers. A raspbar flow through thresher with modified concave has been found satisfactory for such areas. The performance of the thresher is shown in **Fig. 7**. The crop harvested by the VCR can be collected and fed directly to this thresher. It is provided with a set of sieves, straw walkers and blowers for simultaneous separation of clean grains, chaff, straw, stones, dust and sand in separate outlets. With a 7.5 hp power source, it delivers 1 200 kg of clean grain per hour with a threshing efficiency of 99% and winnowing efficiency of 97%. The features of these threshers are shown in **Table 7**.

Fig. 7 Demonstrating the raspbar flow through thresher.

Table 7. Details of Raspbar Flow Through Thresher

Size (L x W x H)	340 x 120 x 165 cm
Transport mode	Pair of bullocks, tractor or jeep hitch
Cost of machine	Rs 35 000
Feeding method	Manual contiment feeding of whole crop
Winnowing	Straw walker and blower fan
Output	1 200 kg/h (0.25 ha/h)
Man-hours	20 for crop of 1 ha
Hiring cost	Rs. 600 /ha

Supplier:
M/s Sri Bhuvaneswari Industries, Coimbatore

Fig. 8 Modified concave of raspbar flow through thresher.

Modifications in Flow Through Raspbar Type Thresher

The flow through raspbar type thresher are quite popular and has been in use for long in many parts of India. However, when introduced in Kerala, and paddy with a large moisture content was fed to it, the crop could not move freely through the concave, it choked too much and gave a very unsatisfactory performance. The concave was then redesigned using flat bars (**Fig. 8-A**) instead of round bars (**Fig. 8-B**). This modification permitted the use of paddy crop of greater moisture content range. Unlike the spike tooth and wire loop drums, the raspbar type did not break the straw and the Kerala farmers wanted the uncut, straight straw, which has very good market here.

Conclusion

The use of machinery for rice production has been accepted by the Kerala farmers to a large extent. The spring type 9-tyne and 11-tyne cultivators are the most popular soil working tool for dry land preparation. On the other hand, the full cage wheels are used for wet puddling. Rotavators are found to be the recently accepted soil working tool for both dry and wet land cultivations. The manual 6-row IRRI transplanter and Chinese 8-row riding type transplanter with mat type nursery proved quite satisfactory in most of the areas. The 5-hp walking type vertical conveyor reaper and tractor-front-mounted reaper windrower are quite successful for Kerala conditions. The raspbar flow through type thresher also performs well with rice crops of this State. The popularization of these machineries are expected to be materialized soon.

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A Simulated Animal for Studying Ventilation and Allied Problems

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Abstract

A simulated cow was designed, constructed and tested for its heat productions, surface temperature and obstruction that it could make to the air flow in a building. The design which was based on past experience and empirical relations was tested for its practicality. A metallic drum filled with air and an air heater inside was considered to effect the simulation. Surface temperatures were recorded using sensors and data logger. Air flow patterns were studied with the model cow inside a psychrometric chamber and the results obtained were promising to represent those in actual studies.

Introduction

The principles of similitude and dimensional analysis have been used extensively, not only for ventilation but also for many other areas of scientific research and analysis. Model studies of various ventilation systems are advantageous when the cost of building a prototype is expensive or when it is difficult or impossible to study the actual condition due to its size or other technical difficulties. For many design and operating conditions, the ventilation data obtained from the model studies are similar to those observed in actual conditions. Young D.F. (1968) noted that simulation techniques will continue to be successfully applied in research design and analysis.

Pattie and Milne (1966) used a 1:10, Dybwad and Hellickson (1974) used 1:20, Frohelic and Hellickson (1975) used 1:16, Eagan and Hellickson (1978) used 1:20 scale model buildings to study various ventilation arrangements and allied problems.

J.M. Randall (1975) studied the air flow pattern and the resulting micro-climate using simulation techniques. He used 28 simulated pigs of shape, size, surface temperature and heat release similar to that of real pigs. From such simulation studies remarkable results were obtained which held true for actual studies. Bruce J.M. (1979) also developed a model of heat production using a simulated pig.

In the study of air flow patterns, essential factors include the heat dissipated by the livestock and the obstruction that the livestock presents to the flow of air. The heat will affect both the climatic of the building, by raising the temperature generally, and also the micro-climate in the vicinity of the stock by conduction, convection and radiation. The obstruction to air flow presented by the stock can be expected to deflect air currents under some conditions which will in turn affect the micro-climate near the stock and possibly the overall pattern of the air movement in the building.

It can be further argued that, provided the simulation is accurate as regards shape, size and heat dissipation, simulated stock are preferable to livestock for some experiments because the mobility and behaviour of the latter would make impossible many measurements that could be made using simulated stock. Coupled with this, tropical breeds like Zebu are aggressive and bad-tempered which would most likely create inconvenience for recording environmental parameters in their vicinity.

In this research it was decided to simulate the heat and moisture production, size, surface area and surface temperature of a dairy cow. The research reported in this paper had the following objectives: 1) To design and construct a model cow; and 2) To test the simulation for its heat productions, surface temperature and other parameters which are assumed to have an effect on ventilation studies.

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Design and Instrumentation

Sensible Heat Loss

The sensible heat loss from a cow is made up of three parts: convective, radiative and conductive.

The convective loss of heat can be calculated using a simple expression (ASHRAE 1966):

$$Q_c = h_c A v^n (T_1 - T_2) \quad (1)$$

More conventionally, the convective heat exchange equation from Newton's Law of cooling is:

$$Q_c = h_c A (T_1 - T_2) \quad (2)$$

In which the velocity factor is included in the convective coefficient along with other physical factors. The coefficient h_c is dependent on the geometric factors of animal size and shape, air velocity, air temperature, and properties of the air such as density, viscosity and thermal conductivity.

The convection coefficient h_c can be found experimentally by the use of dimensionless parameters of

Nusselt Number, $Nu = h_c d/k$ (3)
Reynolds Number, $Re = \rho v l/\mu$ (4)

From McAdams (1954) the relation between the dimensionless numbers for cylinders is given in the form

$$Nu = CRe^n \quad (5)$$

From this $h_c\, d/k = C(\rho v l/\mu)^n$ (6)

The value of C and n depend on Reynolds Number and are determined empirically. Wiersma and Nelson (1967) found with an experimental inanimate, cylindrical bovine that

$$Nu = 0.590\, Re^{0.537} \quad (7)$$

From equation 6

$$h_c = Ck/d(\rho v l/\mu)^n \quad (8)$$

Radiant energy is emitted from the surface at a rate proportional to the fourth power of the absolute temperature.

The net long wave radiation between the surface of the animal and an enclosure is calculated by Stefan - Boltzmann Equation. Short wave radiation is neglected because the animal is presumed to be housed in a windowless, ventilated shelter.

$$Q_r = \sigma A Fe(T_1^4 - T_2^4)$$

Stefan-Boltzmann Equation (9)

Conduction losses were considered negligible as the cow is assumed to be standing.

$$\text{So } Q_t = Q_c + Q_r \quad (10)$$

Surface Area Determination

For the purpose of this model the surface area can be calculated using the relation

$$A = 0.15W^{0.56} \quad (11)$$

The above equation is adopted from Elting and Brody (1926) which they found after measuring 96 pure Holstein and Jersey cows.

For a 500-kg dairy cow the surface area is calculated to be 4.9 m^2. A metallic cylinder filled with air and an air heater inside placed in a psychrometric chamber was considered as a potential model cow (**Figs. 1, 2** and **3**). The detailed design of the chamber is indicated in Assefa M. (1991)

The surface area of the cylinder is given by

$$\Pi d^2/2 + \Pi dl \quad (12)$$

This should be equal to the surface area of the cow

$$\Pi d^2/2 + \Pi dl = 4.9 \quad (13)$$

Since the shape and size of a solid object is influenced by both surface

Fig. 1

Fig. 2

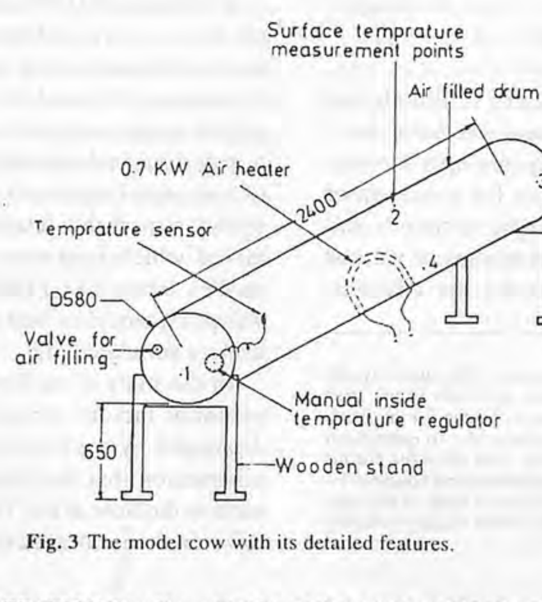

Fig. 3 The model cow with its detailed features.

area and volume it was important to equate the two volumes.
Volume of the cylinder = volume of the cow.

$\Pi d^2/4$ = Mass of cow/Mean density of cow (14)

The mean density of a cow is about 900-1 000 kg/m^3.

From equation 13 and 14 a cylinder with an average diameter of 58 cm and 240 cm length was obtained.

The convective coefficient h_c, was calculated using equation 8 with the above dimensions and a linear air velocity of 0.15 m/s and found to be 6.4 w/m^2 K and the convective heat loss of 345 W resulted.

T_1 was interpolated from the graph on **Fig. 4**. At 20°C ambient temperature the surface temperature (T_1) was around 31°C for Holstein cows.

The radiative heat loss was also calculated to be 228 W. In this case T_1 and T_2 are in absolute temperatures. The shape factor for a cylinder can be considered as 1 (Barre and Sammet 1988) and the emissivity of metallic surfaces at high temperatures ranges from 0.50-0.9 depending on the surface condition (Esmay 1980).

From both heat losses the total sensible heat loss was to be 573 W.

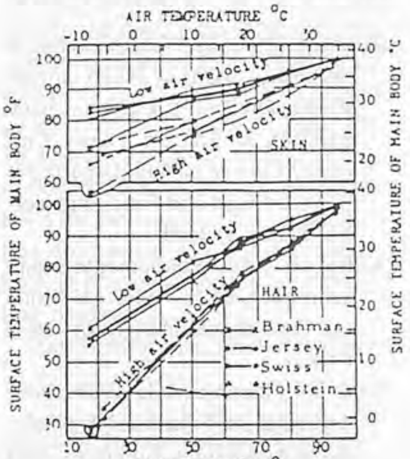

Fig. 4 Skin and hair temperatures of cows at high and low air velocities at various environmental temperatures. (Adopted from Thompson et al., 1954).

This amount of heat loss corresponds with the amount measured by the researchers (Yeck and Stewart 1959 and McQuity 1980) for a given size, breed and ambient temperature.

Insensible Heat Loss

The evaporative or insensible heat loss from the cow is the heat the animal loses due to the latent heat of vaporization of moisture from its respiratory tract and of water on the animal's surface. This heat will vary depending on the ambient temperature. This part of heat loss can be simulated by the air conditioner attached to one side of the building which can provide air with different ranges of dry-bulb temperatures, relative humidity and air flow rate.

The relation is:
Moisture production = 1.2 (Q, m^3/sec x Absolute humidity) (15)
(kg of water/sec) = kg of moist air/sec x kg of water/kg of air
= kg of water/sec.

The absolute humidity can be interpolated from the psychrometric chart once the dry-bulb temperature and relative humidity of the air from the air conditioner is known.

Regarding the simulation of the cow in terms of shape and size, it is acknowledged that a cylinder is not ideal to represent a cow's shape, however, it is reasonable.

To effect this simulation a metallic drum with the right dimensions was constructed and an air heater rated 700 W was placed at the centre. A thermostat which can sense temperature from 30-100°C was situated in an appropriate place.

To uniformly distribute the heat inside the drum it was important to fill the cylinder with air. The inflation pressure was optimum as coupled with the pressure rise due to temperature can damage the valve fittings and other seals. The pressure rise due to the temperature of the air inside the drum was estimated from Gas Laws and found to be small to cause any serious damage.

Once the physical dimensions and heat production of the model cow are found, the next step was to maintain the surface temperature at required level for actual heat exchange with the ambient air of 20°C which was the average generalized room temperature.

The core temperature of the model was set at 32.5°C and the corresponding surface temperature was recorded using sensor and data logger from four points on the model cow. **Figure 5** shows these readings.

The data logger starts to record

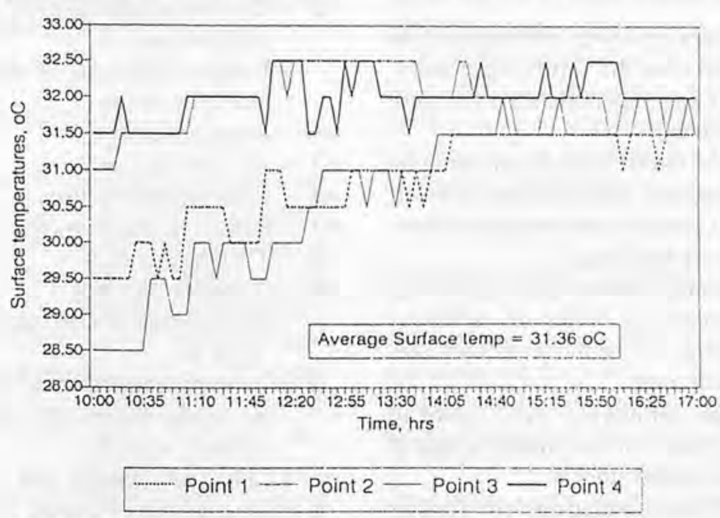

Fig. 5 Surface temperature vs. time core temperature = 32.5°C.

readings half an hour later after the heater is on. All the readings were recorded every five minutes and logged for seven hours.

Results and Discussion

The surface temperature readings for the selected core temperature tends to increase and shortly stabilizes and maintain an approximately constant temperature. Point 2 and 4 appears to have high readings since they are in the vicinity of the heater but this will decrease as the heat tries to convect to the surrounding. Core temperature of 32.5°C maintain surface temperature between 31 and 32°C.

The simulated cow was also tested whether or not it can represent the heat production and obstruction in air flow pattern ventilation systems and other allied problems studies. The results especially air flow patterns obtained from the above studies correspond with those from full scale studies. **Figures. 6-10** show the photographs of air flow patterns using the model cow in a psychrometric chamber for different inlet arrangements in the mechanical ventilation system.

Conclusions

From the design and testing of the model cow the following conclusions and recommendations were forwarded:

- The model animal can easily be used and helpful in environmental control considerations of livestock building;
- Though the surface temperatures appear to differ on different points on the model, it stabilizes later; and
- The simulation with regard to obstruction was similar to that of the actual studies.

Recommendations for further considerations include:

Fig. 6

Fig. 7

- The principle of simulation should extend and consider other animals, too; and
- Other materials and media should be considered to attain a more uniform surface temperature.

Notations

A = Surface area of Cow, m^2
C and n = Empirical constants depend on Reynolds Number
d = Diameter of the body, cylinder, m
e = Emissivity of cow's surface
F = Shape factor
h_c = Convective heat transfer coefficient, w/m^2k
K = Thermal conductivity of air = 0.025 w/mk
l = Length of the body or equivalent cylinder, m
Nu = Nusselt Number
Q = Air flow rate, m^3/s
Q_c = Convective heat loss, w
Q_r = Radiative heat loss, w
Q_t = Total heat loss, w
Re = Reynolds Number
T_1 = Temperature of cows surface, °C or K
T_2 = Average temperature of inside air, walls, floors and ceiling surface, °C or K
v = Linear air velocity, m/s
W = Live weight of animal, kg
μ = Kinematic viscosity = 1.45×10^{-5} m^2/s
ρ = air density, kg/m^3
σ = Stefan-Boltzmann constant = 5.67×10^{-8} w/m^2k^4

Fig. 8

Fig. 9

Fig. 10

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(Continued on page 53)

Development and Distribution of Low-cost Dryer in Vietnam

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Abstract

A 1-ton dryer, named SRR-1, was designed using the one-stage, low-temperature, in-store drying principle. Target users are small-holder farmers (<0.5 ha) living in areas where electricity is available. The dryer consists of three main components: a 1/2-hp, two-stage, axial-flow fan; a 1 000-watt resistor to supply heat at night or during heavy rain; and a drying bin made of two concentric bamboo mats.

Thirty units were installed at Ho Chi Minh City, Long-An, and in other provinces in Vietnam. Tests conducted during the 1995 wet season showed that 1 ton of high-moisture rice (26-30% moisture content) could be dried down to 14.5% in 70-80 h, with an energy consumption of 50-55 kWh for the fan and 20-25 kWh for the resistor. The final moisture differential was within 1.5%. A high head rice recovery was therefore obtained.

Test results with other crops such as maize and peanut showed that the capacity, quality, and drying costs have been acceptable to farmers.

The investment for the dryer was very low, only US$59.00, including US$43.00 for the fan and motor assembly, and US$16.00 for all the other parts. The cost of drying rice, calculated with test and actual data, was US$6.00 t^{-1} (equivalent to 4% of paddy value), of which US$4.00 was for electricity.

From the enthusiastic response of farmers in demonstration sites and from successful stories among buyers of the dryer, it is anticipated that thousands of this very-low-cost dryer can be distributed throughout Vietnam in the coming years.

Introduction

Drying of rice harvested during the wet season is still an urgent problem in Vietnam. The concern is to reduce losses due to grain deterioration. Current dryers used in Vietnam are medium- sized and are suitable only for areas with a fairly large production. The smallest among these are the popular 4-t batch^{-1} flat-bed dryers; 600 units are currently used in the Mekong Delta under a contractor's system for farmers having 1-2 ha each. For the majority of small farmers cultivating less than 0.5 ha (as in Ho Chi Minh City suburbs, Tien Giang and Ben Tre provinces of the Mekong Delta, southern and eastern provinces, the central coast, the northern provinces and others), no dryer, so far, has been cheap enough to be accepted.

Rural electrification in Vietnam has been accelerated recently. New hydropower plants with ample water supply in the rainy season would provide more energy to the agricultural sector. For example, in Thai Binh, a major rice-producing province in the Red River Delta in the north, 100% of the villages already have power lines.

To meet the need of the above target users, the University of Agriculture and Forestry (UAF) in Ho-Chi-Minh City developed a low-cost dryer, the SRR-1.

Design of SRR-1 Dryer

The design of the SRR-1 dryer was based on the principle of low-temperature in-store drying. Ambient air with a relative humidity (RH) of 70-85% is blown through the grain bulk. Grain is dried slowly using the drying potential of the

Acknowledgment: This work has been part of the Project "Postharvest Technologies for Rice in the Humid Tropics," which is financially supported by the German Agency for Technical Cooperation (GTZ) and carried out in cooperation with the International Rice Research Institute (IRRI) in the Philippines.

ambient air until it reaches the equilibrium moisture content (14% wb[1] at about 75% RH). At night or when it rains, supplemental heat is needed to raise air temperature by 2-3°C and to reduce RH.

The technology of low-temperature in-store drying has long been applied in temperate climate countries. It was introduced to Asian countries some years ago (Kim et al., 1989). Tests at the International Rice Research Institute (IRRI) showed that rice with high moisture (26% wb*) could be dried to 14% in one stage without adversely affecting grain quality (Mühlbauer et al., 1992, Gummert 1994).

The dryer has three components (**Figs. 1** and **2**): a bamboo-mat drying bin; a two-stage axial fan; and an electric heater.

1. The drying bin is made out of concentric inner and outer bamboo-mat cylinders with 0.4-m and 1.5-m diameter, respectively, and 1.1-m height. The inner cylinder is supported by a frame made of 6-mm steel rods. The bin can contain 1 ton of rice.
2. The axial fan is driven by a 1/2-hp, single-phase, 2 800-rpm electric motor. Two 350-mm diameter, seven-blade rotors are mounted on both ends of the motor shaft located inside a steel cylindrical casing of the same diameter as the inner bamboo-mat cylinder in the drying bin. Plastic rotors are locally made and readily available in the market as car radiator parts. The fan is positioned on top of the inner bamboo-mat cylinder which serves as a plenum chamber. At 400 Pa static pressure, the fan airflow is 0.3 m^3s^{-1}.
3. The heater is a 1 000-watt resistor of the same type used in an electric stove. It is mounted beneath the lower rotor. Supplemental heat from the resistor is used at certain nights or at daytime during continuous rain.

In January 1996, a stove for burning pulverized-and-compressed coal (locally called "honey-comb coal") was added as an optional heat source. Especially designed for the northern provinces (**Fig. 3**), the stove was introduced for the following reasons:

- Coal is very cheap (this region is exporting several million tons of coal annually).
- Ambient air is very wet (90-100% RH) even during daytime. Use of electricity would mean a high power cost.
- Local people are reluctant to spend much for the electric bill.

The heated flue gas from the stove is sucked through a pipe to the fan inlet and is mixed with ambient air. The stove consumes 0.9-1.0 kg of coal h^{-1}. The interval between fuel refills is 3 h. The lower calorific value of this pulverized-and-compressed coal is about 25 MJ kg^{-1}. Temperature rise using the stove is 5-9°C, which corresponds to lowering the cold ambient RH from 95-100% to 65-75%.

Operation of the SRR-1 Dryer

To reduce energy consumption, these procedures are followed when operating the SRR-1 dryer (based on local weather data):

- During daytime (from 8 AM to 6 PM), the fan is turned ON, and the resistor is turned OFF;
- During the first night, the fan is ON while the resistor may be ON or OFF. If the resistor is used, drying time is reduced but more energy is consumed;
- On the second night, both fan and resistor are ON. Without supplemental heat, rice near the inner cylinder might be low enough to be re-wetted by ambient air, which has high RH; and
- On the third and on succeeding nights, both fan and resistor are turned OFF. By this time, moisture content has been reduced to a level low enough to safely allow waiting for the next daytime to use the air's heat content.

Drying of other crops such as maize, peanut, and coffee follows a similar procedure with slight modifications in heater management (continuous firing is used for coffee and peanut).

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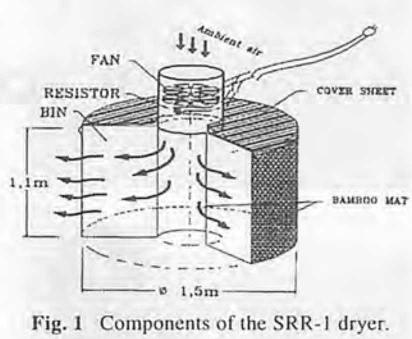

Fig. 1 Components of the SRR-1 dryer.

Fig. 2 SRR-1 dryer in operation with rice.

Fig. 3 Stove using pulverized and compressed coal as heat source for SRR-1 dryer, shown with peanut in the bin.

[1] *wb = wet basis; all moisture contents are on wet basis.

Experimental Procedures

Operation for Rice

The SRR-1 dryer was installed at the Bay Tu Rice Mill in Long-An Province and was tested using four batches of rice in the 1995 wet season harvest. From August to September 1995, 15 units of SRR-1 were installed in Ho Chi Minh City and in the provinces of Long-An, Tien-Giang, Dong-Nai, and Hue.

Operation for Other Crops

One unit of SRR-1 was brought to the National Maize Research Institute at Ha-Tay Province (about 2000 km north of Ho-Chi-Minh City) for testing with maize-on-cob and maize grain. Hybrid maize production has been increasing rapidly in recent years, and maize is viewed as the second most important crop.

Another unit was brought to Daklak, the "coffee capital," located in the Central Highlands of Vietnam, for testing with coffee.

Tests were also made with peanut in Cu-Chi District of Ho-Chi-Minh City. This district, together with some other districts of the neighboring eastern provinces, constitute a major peanut area in southern Vietnam.

When testing with maize-on-cob in very damp weather or to accelerate drying of peanut or coffee, the coal stove was fired continuously.

Test Procedures

The following parameters were measured: energy consumption for fan and for heater, moisture content of grain at six locations (**Fig. 4**) at fixed intervals. The instruments used were a balance for determining mass, timer and watt-hour meter for determining energy consumption, and Kett moisture meter for monitoring moisture content.

In most experiments, a Fluke Hydra data logger was used for monitoring temperature variations at various points in the grain mass (**Fig. 4**) and in the plenum chamber, as well as ambient dry-bulb and wet-bulb temperatures. A maximum of 11 channels has been used.

Head rice recovery was analyzed in the Postharvest Laboratory of UAF with standard equipment. For maize and peanut, samples were sent to the Food Control Center at Ho Chi Minh City for analyzing aflatoxin contents.

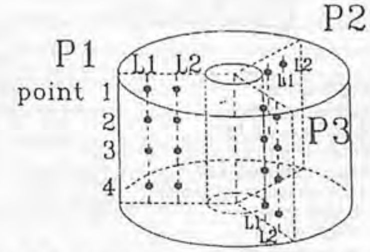

Fig. 4 Sampling points for determining temperature and moisture content of crop in the drying bin of the SRR-1 dryer.

Results and Discussion

Tests with Rice

Results of drying four batches of rice at Bay Thu Rice Mill are summarized in **Table 1**.

Moisture reduction of rice — A typical drying graph showing moisture content versus drying time is shown in **Fig. 5**. Locations for sampling P1, P2, and P3 are three positions of rice in the circular drying bin; L1 and L2 are the bottom and top layer of rice, respectively (**Fig. 4**). It can be seen that high-moisture rice (>26%) can be brought down to 14-15% within 4 d. The moisture differential among various points in the grain mass was within 1.5%.

Temperature variation — **Fig. 6** shows a typical variation of temperature during a drying experiment. It can be seen that

- peak temperatures corresponded to near and after noon time.
- the average difference between plenum and ambient temperature was about 2°C. This is due to blower losses which result in the conversion of electric energy to thermal energy.

Milling and head rice recovery — **Figs 7** and **8** show the milling and head rice recovery of two batches (18/8-24/8/1995 and 25/8-28/8/1995). Head rice recovery was comparable with that obtained from shade drying. The difference in head rice recovery between the two batches was due to the variety used and the quality of input grain. With freshly harvested rice (**Fig. 7**), head rice increase was about 2% com-

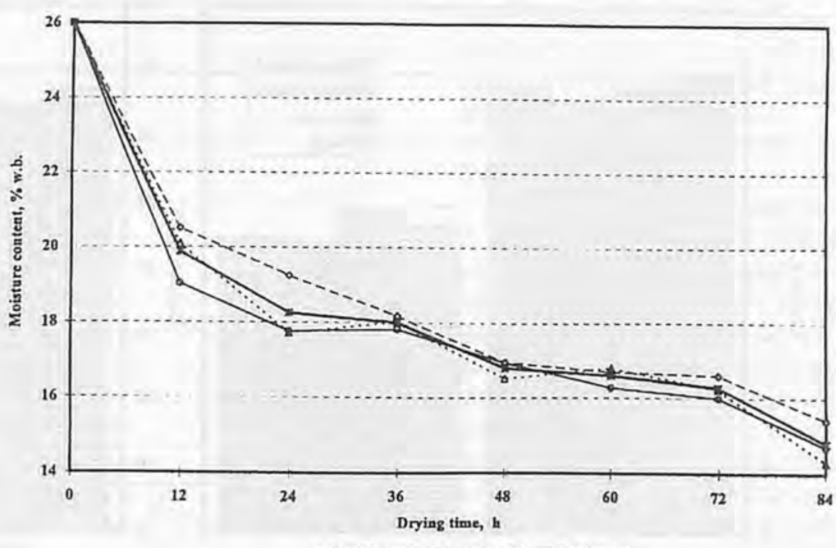

Fig. 5 Moisture reduction over drying time (SRR-1: Paddy, Second Batch, 28/7-2/8/96).

Table 1. Test Results of Rice Drying with SRR-1 at Bay Thu Rice Mill, Long An Province (20 Jul-30 Aug 1995)

	First batch	Second batch	Third batch	Fourth batch
Loading date	20/7/95	28/7/95	18/8/95	25/8/95
Unloading date	24/7/95	2/8/95	23/8/95	30/8/95
Initial weight, kg	963	1 006	1 004	1 000
Final weight, kg	867	845	835	—
Water removed, kg	96	161	169	~163
Average moisture content				
Initial, % wb	20.0	26.0	29.0	28.6
Final, % wb	13.6	14.5	14.5	14.5
Drying time, h	60	84	98	84
Energy consumption				
Fan, kWh	35.8	56.0	63.6	50.4
Heater, kWh	66.3	12.0	26.5	68.5
Diesel, liter[a]	3	1.5		
Specific energy requirement, kWh/kgH_2O	1.06	0.42	0.53	~0.72

[a]For running back-up generator during power interruption (for testing only).

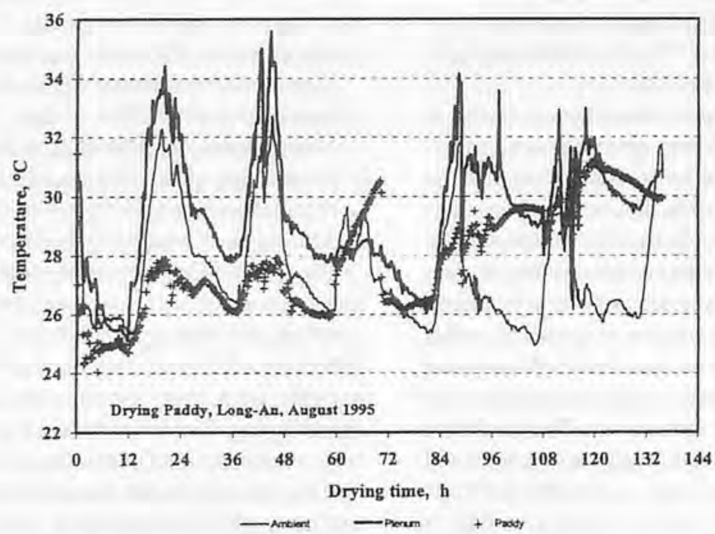

Fig. 6 Temperature variation during a typical paddy drying experiment.

pared with sun drying under good weather conditions.

Tests with Maize

Test results with maize are summarized in **Table 2**.

From **Table 2** and from temperature variation and moisture reduction curves (typically shown in **Figs. 9** and **10**), it can be seen that:

a) Drying maize-on-cob is a time- and energy-consuming process because the cobs have to be well-dried. It is, therefore, recommended only for drying seed, where seed germs need to be protected from damage due to shelling at high moisture content; and
b) Drying shelled maize using coal as heat source with a temperature increase of 7-10°C was not strictly low-temperature drying. Since it involves labor (for fuel refill), drying could not be extended without increasing drying cost. Nevertheless, the final moisture differential was within 2.5%, which is acceptable under local conditions.

Results of aflatoxin analysis — The results of the aflatoxin analysis (by thin-layer chromatography method) showed that all samples had less than 3.5 ppb aflatoxin, and

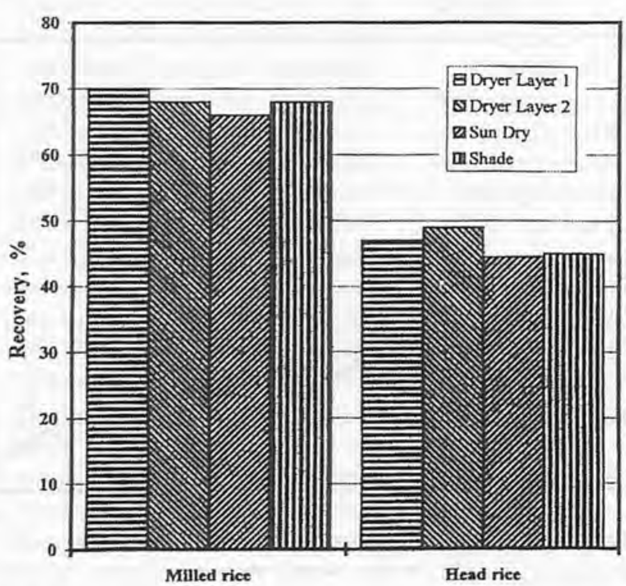

Fig. 7 Results of milling quality analysis (SRR-1: 18/8-24/8/1995).

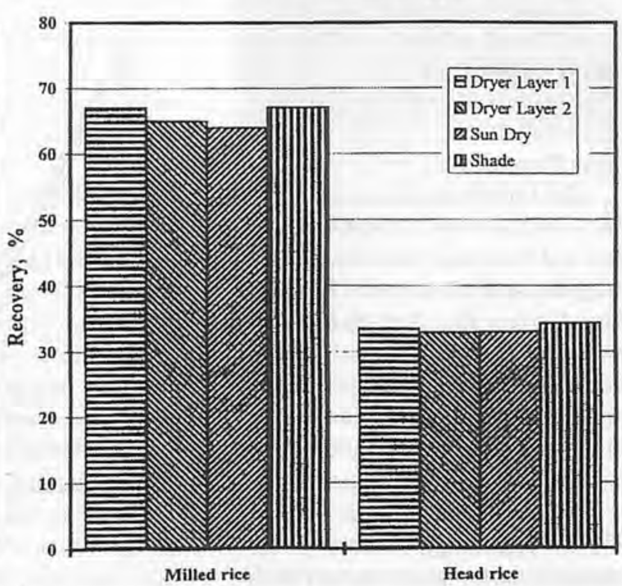

Fig. 8 Results of milling quality analysis (SRR-1: 25/8-30/8/1995).

Table 2. Test Results Maize Drying with SRR-1 in Ha-Tay Province

	Maize-on-cob	Shelled maize grain	Shelled maize grain
Date	1-5 Feb. 1996	5-7 Feb. 1996	9 Feb. 1996
Ambient air temperature, °C	13-18	13-18	13-18
Ambient air RH, %	60-95	60-95	60-95
Variety	LVN 10-PK88	LVN 10-PK88	LVN 10-PK88
Initial moisture content, % wb	34.5[a]	24.7[b]	31.2[c]
Final (average) MC, % wb	24.7	13.8	14.1
Drying time, h	96	36	39
Drying temperature, °C	Fig. 9	25-34	
Static pressure, Pa	40-150	200-260	
Input grain quantity, kg	~2 000 grain and cob	1 050	1 095
Output grain quantity, kg	1 507 grain and cob	935	850
Bin size, m (inner diam*outer diam*height)	0.75*2.6*1.1	0.4*1.4*1.1	0.4*1.4*1.13
Radial layer thickness, m	1.1	0.5	0.5
Electric power consumption, kWh	68	25	26
Coal consumption (total), kg	126	36	41

[a]Maize-on-cob had been harvested 1 d earlier and husked manually.
[b]Input maize grain was shelled from the maize-on-cob drying batch.
[c]Maize-on-cob had been harvested 1 d earlier, then shelled by machine.

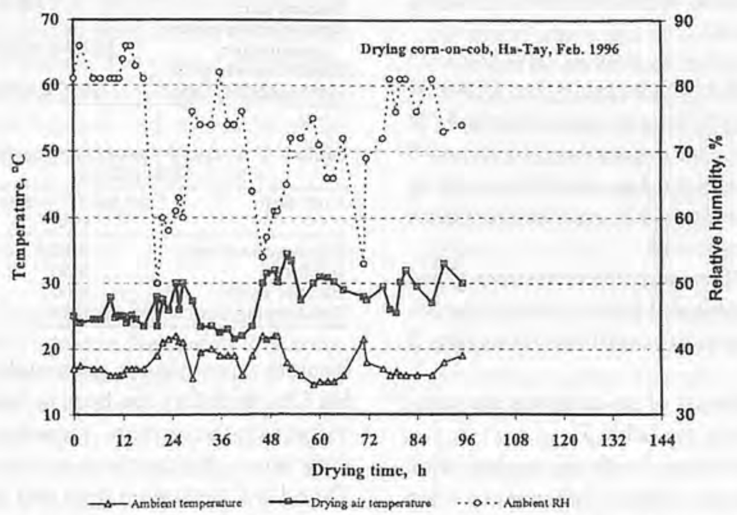

Fig. 9 Temperature and RH variation during a typical corn-on-cob drying experiment.

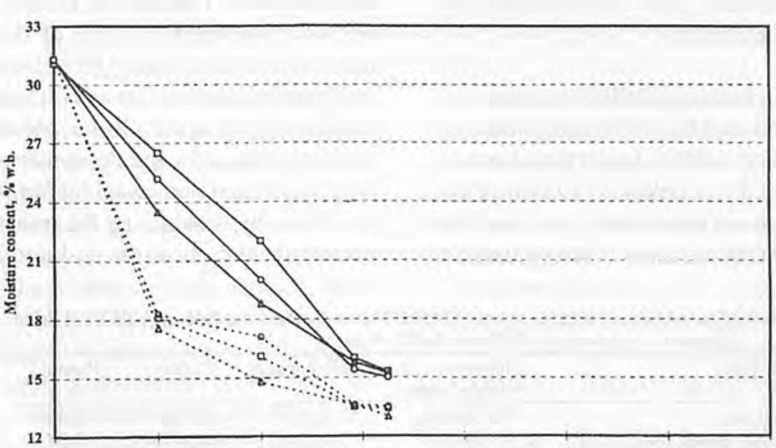

Fig. 10 Moisture reduction over drying time (SRR-1: Shelled Corn, Ha Tay, Feb. 1996).

were thus perfectly adequate for human consumption and for animal feed. For example, the Japanese standard specifies 10 ppb as the maximum level for human food, while it is 10 ppb for dairy cattle feed and 20 ppb for cattle/pig feed (Van Egmond, 1991).

Tests with Coffee and Peanut

The test results are summarized in **Table 3**.

The amount of water evaporated in drying peanut is comparable with that in corn. The final moisture differential of 3% is still acceptable. Extending the drying time at a slightly lower temperature would shift this differential to a narrower range.

Compared with grain, coffee requires a considerably higher quantity of moisture to be evaporated (wet to dry ratio of 4:1). The non-uniformity of the final moisture content (5%) was due to non-uniform husking. Coupled with the industrial nature of the coffee trade, the SRR-1 is perhaps not the solution for coffee growers. The test data thus offered more technical than practical value.

Analysis of aflatoxin in dried peanut — The results of aflatoxin analysis in peanut using the same dryer design were similar to those obtained in maize. A level of less than 3.5 ppb indicated that dried peanut is safe as human food.

Test with Cashew Nut

In April 1996, at Long-An Import-Export Company, a SRR-1 dryer was used to dry 1.63 t of cashew nut down to 1.37 t, the equivalent of good sun drying. Hence, the company has purchased 15 units for use during rainy weather. Drying cost was calculated to be about US$0.0073 kg^{-1}, while labor cost for sun drying was US$0.0036 kg^{-1} (not including depreciation of the existing drying yard).

Table 3. Test Results of Drying Coffee and Peanut with the SRR-1 Dryer

	Coffee (husked)	Peanut (in shell)
Date	20 Jan 1996	6 Mar 1996
Location	Daklak	Ho-Chi-Minh City
Ambient air temperature, °C	18-24	25-35
Ambient air rel. humidity, %	57-98	54-92
Variety	*Arabica*	
Initial moisture content, % wb	63.4	37.0
Final (av) moisture content, % wb	21.1	8.8
Final moisture differential, % wb	5	3
Drying time, h	94	64
Drying temperature, °C	22-30	29-37
Static pressure, Pa	70-110	180-210
Input grain quantity, kg	~800	~750
Output grain quantity, kg	200	530 (in shell)
Bin size, m (inner diam*outer diam*height)	0.4*1.4*1.0	0.4*1.9*0.7
Radial layer thickness, m	0.5	0.75
Electric power consumption, kWh	65.8	40
Coal consumption (total), kg	102	32

Table 4. Cost of SRR-1 Dryer Components and Total Investment Cost Including Fabrication Cost and Profit for the Manufacturer

Item	VN dong	Equivalent US$
Motor 1/2 hp	310 000	28.00
Fan and heater assembly	170 000	15.50
Bamboo mat and accessories	170 000	15.50
Total	650 000	59.00

US$1 = 11 000 VN dong
(Sep 1995-Apr 1996)

Table 5. Assumptions Used in Calculating Costs for Drying Rice

Data	
Capacity (28% MC wb down to 14%)	1 t
Drying time	80 h batch^{-1}
Investment	US$59.00
Economic life	3 600 h (5 yr*30 days of operation yr^{-1}*24 hd^{-1})
Interest rate	18% yr^{-1}
Total electric power consumption	80 kWh batch^{-1}
Electric power price (for household use)	US$0.0 kWh^{-1}

Table 6. Calculated Cost of Drying Rice with the SRR-1 Dryer

Cost item	Cost batch^{-1} = cost t^{-1} US$
Depreciation and repair	1.40
Interest	0.60
Electric power	4.00
Total drying cost	6.00

Investment and Drying Cost

Investment cost— The investment cost for SRR-1 was estimated using prices in January 1996 at Ho-Chi-Minh City (**Table 4**).

The US$59.00 worth dryer holds the record for being the mechanical dryer with the lowest cost in Vietnam (SRR stands for "very cheap dryer" in Vietnamese). The optional coal stove and duct cost about US$11.00 which does not significantly increase the investment.

Drying cost for rice — Drying cost, shown in **Table 6**, was calculated with data and assumptions listed in **Table 5**.

The calculated drying cost of 65 000 VN dong t^{-1} (or US$6.00 t^{-1}) is acceptable to farmers in places where the dryers have been installed.

The economic benefits of using the SSR-1 dryer can be summarized as follows: a higher selling price of US$2.50 t^{-1} due to increased head rice; a labor saving of US$2.50 t^{-1} (either as labor rent or as opportunity cost of owner); no investment for sun drying yard equivalent to a saving of US$150.00 t^{-1}; and an assurance of not losing rice to quality deterioration, valued at US$10-20 t^{-1}.

Drying cost for other crops — For ease of comparison, the following assumptions are made:

a) The same per-hour fixed cost (depreciation, interest) is assumed; in the case of rice, US$ 1.90 for every 80 h. Calculated fixed costs for maize, coffee, and peanut differ according to drying time;
b) Uniform prices of US$0.05 kWh^{-1} of electricity and US$0.04 per briquette coal are used. In practice, prices vary slightly with location due to differences in transmission or transportation costs; and
c) When using the coal stove, some additional labor cost must be included for refilling fuel every 3 h.

Results of calculations are summarized in **Table 7**.

Compared with the market value of the products, all drying costs are reasonable. The decision to use the SRR-1 dryer will depend on factors other than cost, such as timeliness and capacity.

Distribution of SRR-1 Dryer

As of May 1996, more than 60 units of SRR-1 dryers have been installed throughout Vietnam. Two-thirds of this number are used for rice. The extension strategy used for farmers in provinces surrounding Ho Chi Minh City has been to bring a dryer (at the farmers' request) to their house (by car or motorbike). Then UAF personnel load and dry one batch of the farmers' own crop for a number of days. After drying this batch and if the farmer is satisfied with the performance of the unit, then he pays US$59.00 to own it. If the farmer does not want it, we bring back the dryer. So far, all of the dryers used in the demonstrations have been purchased by farmers. Thus, by subsidizing the transportation and through technical

Table 7. Cost of Drying Maize-on-cob, Shelled Maize, Coffee, and Peanut (US$ t^{-1} of dried product) Compared with Grain Market Price

Cost item	Maize-on-cob + shelled maize	Shelled maize	Coffee	Peanut
Fixed cost	2.18+0.82	0.91	11.36	2.88
Electric power cost	3.18+1.18	1.55	16.45	3.77
Heat cost (coal)	5.32+1.38	2.00	20.55	2.31
Labor cost	3.64+1.82	1.82	18.18	2.73
Total cost	14.32+5.20 19.52	6.28	66.54	11.69
Grain market price (Hybrid seed maize) in US$ t^{-1}	2 000	170	1 400	340

backstopping with the UAF fund for extension, the SRR-1 dryer has been firmly anchored in the farmer's land and mind. It becomes his/her dryer for the family's own business.

Three test-and-demo units went to the Maize Research Institute at Hanoi, and to Thai Binh, a major rice-and-maize province north of the Red River Delta. Farmers who have observed the dryer operation have shown interest in it. More orders are expected for the next drying season.

A program to extend the use of SRR-1 in the provinces in central Vietnam is under way, using the same procedure followed in Ho Chi Minh City. Seven units have been installed in Hue, the ancient capital of Vietnam. The pooled transportation and technical advice along the 1 000 km national road reduces the extension cost per unit.

Conclusion

The testing and actual use of the SRR-1 dryer have shown that it has met the needs of poor small farmers for a dryer with adequate capacity which produces high-quality dried grain at reasonable drying cost. The SRR-1 dryer has been used to dry a wide range of crops, from rice to maize and peanut. From actual purchases of 50 units within an 8-month period and from the enthusiastic responses, comments, and inquiries made so far by hundreds of other farmers throughout northern, central, and southern Vietnam, we anticipate that in the coming years, thousands of SRR-1 dryer units will be operated by these small farmers.

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Design Modification for Dual-fueling a Diesel Engine with Producer Gas

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Abstract

A 10.44 kW, 0.673 cc naturally aspirated air-cooled diesel engine has been tested on producer gas generated by gasifying Douglas fir wood blocks using laboratory-scale gas producer. A simple control system to meter the producer gas to the engine was developed.

Gas use caused a 10-percent reduction in maximum torque as compared to that with diesel fuel alone, and as much as 15-percent increase in indicated thermal efficiency. Up to 72% of the fuel energy at intermediate torque levels could be supplied from producer gas, and with the controls, it is possible to achieve a cost savings of up to 18% of the cost of using the engine in the diesel mode.

Introduction

Agriculture, as one of the prominent consumers of power in most parts of the world and, particularly, in some tropical countries, will in the near future be plagued by the endemic shortages of petroleum supply and the escalating prices of natural gas unless efforts are made to develop technology of alternative fuels for agricultural production. Utilization of agricultural residues in the gasification process offers potential advantages to supplement such unstable supply of liquid fuel. However, some gaseous fuels (particularly producer gas) have a storage problem (very high pressure is required to get them liquified). They tend to have high octane and low cetane ratings which makes the high combustion efficiency of high compression spark ignition engine possible. In compression ignition engines, ignition delay may be a problem. But this can be reduced or eliminated with properly designed control devices. It is worth noting however, that gaseous fuels generally tend toinimize the build up of carbon deposits and mix more thoroughly with the combustion air. In order to verify the potential of dual-fueling diesel engines, the approach used was to first study the performance characteristics of the engine in diesel fuel mode. This was followed with the use of producer gas with diesel fuel as pilot fuel for ignition purposes.

Past experimental works in the area of producer gas fueling have been with spark ignition engine. Ortiz-Canavate et al., (1981) modified diesel engine to operate on biogas. They found that the efficiency of the dual-fueled engine at medium speed and high torque was as good as with diesel fuel only. Mazed et al., (1985a, b) worked with two single cylinder diesel engines with direct and indirect injection fuel systems, equipped with a dual-fuel provision. They burned vegetable oil-diesel fuel blends from which they found that fuels with 10 to 25% (by volume) of vegetable oils performed satisfactorily with no fuel related failure. Spiers (1942) studied the performance of a gasoline engine operating on producer gas and found that an important factor which affected engine performance was the variation of gas quality and that this factor required a wide range of ignition timing for optimum results.

Kawaguchi et al., (1972) found that combustion noise could be reduced considerably by using certain ranges of pilot injection and hence, it was found desirable to inject pilot fuel at the end of the exhaust stroke of previous cycle or just before the main. The test reported here to study the combustion characteristics in diesel engine was basically on diesel fuel alone with the main injection timed later than the pilot injection. Ogunlowo et al., (1981), Cruz et al., (1980) dual-fueled two different types of single cylinder diesel engines. With the set-up in their works, maximum engine torque values were 10% lower with producer gas than with diesel fuel alone. Also, they reported that maximum engine efficiency was slightly greater with their dual-fueling system than with diesel fuel alone. The work reported in this paper outlines detailed procedures necessary to operate a small diesel engine on producer gas with minimum alterations to the engine. With this minimum alterations for dual-fueling with producer gas, only minor modifications will be required that will allow the engine to operate on diesel fuel alone in periods of fuel availability.

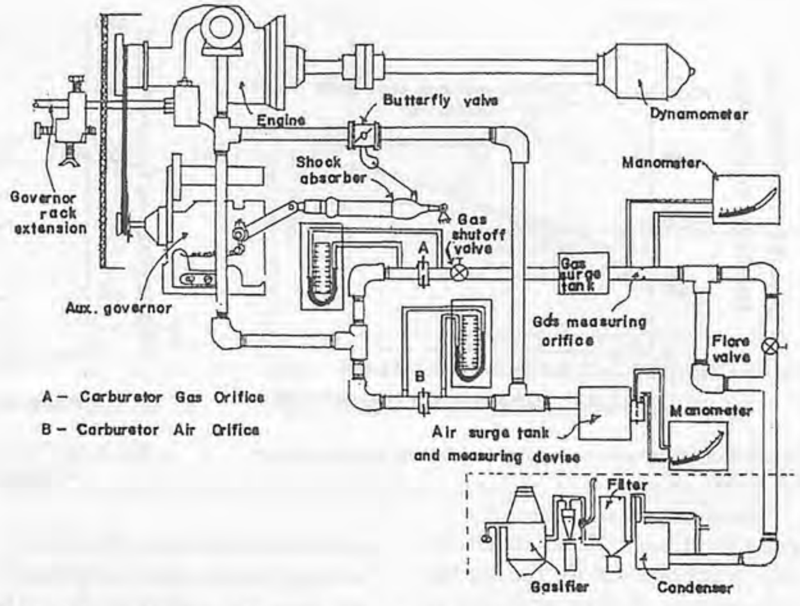

Fig. 1 Schematic diagram of the producer gas supply system.

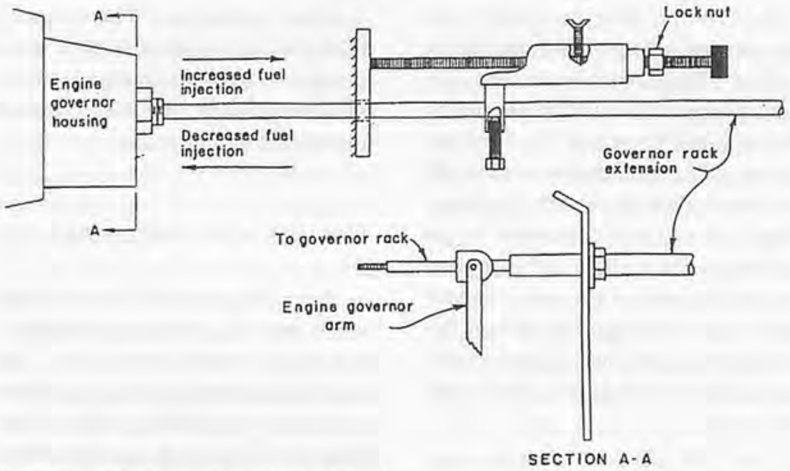

Fig. 2 Diesel fuel control mechanism sketch.

Experimental Procedures

Test Engine

The engine used was similar to the one reported in Ogunlowo et al., (1981). In this work, emphasis was placed on the controls and test procedures and relative performance for dual-fueling a diesel engine and operating on diesel fuel alone. This engine was a Deutz MAG FIL 210D, single cylinder, naturally-aspirated air-cooled diesel engine. In addition to the description of the engine given above, it also has the following specifications:

Engine tared output power .... 10.44 kW (14 hp)
Engine max. speed .... 3 000 rpm
Idling speed .... 800-850 rpm
Bore .... 95 mm
Displacement .... 673 cc(41.09 cu.inch)
Compression ratio 17:1

The fuel injection started 24° before top dead center. The inlet valve opened at 23° before top dead center and closed at 63° after bottom dead center while the exhaust valve opened at 63° before bottom dead center and closed at 23° after top dead center.

Gas Supply

Gas was supplied using a laboratory gas producer fueled with dry wood block. The gas quality of the wood block used ranged between 4.841 and 5.958 MJ/m^3 (130 to 160 BTU/ft^3). In order to establish the homogeneous mixture of the fuels, the chemical constituents of producer gas were analyzed for combustion air requirements. The air-gas mixing device or carburetor was designed to give a gas to air ratio of approximately 1:2 based on calculation of air required for complete combustion of producer gas.

Control Device

Figure 1 illustrates all the basic interconnections between the engine and the controls. An auxillary governor-controlled butterfly valve assembly was mounted on the engine. The main function of this unit was to serve as a regulatory device for the basic mixture of air and producer gas in order to prevent excessive gas intake that will stall the engine. Gas and air flows were measured by orifice meters as shown in the schematic diagram. To ensure that the flow quantities indicated by the air and gas measuring systems approximated the actual values, the air and gas orifices were connected to the engine through intermediate surge tanks used to even out the air and

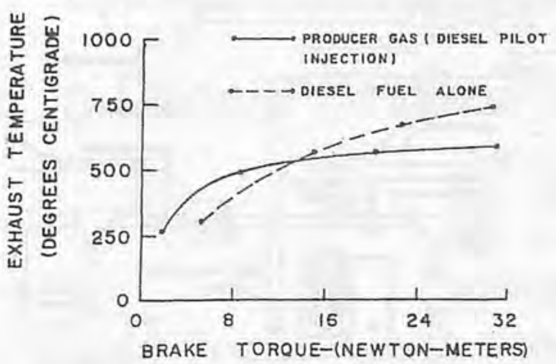

Fig. 3 Comparative behavior of diesel fuel alone and producer gas.

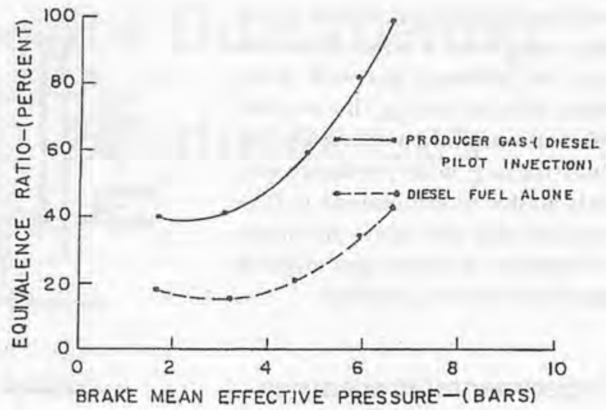

Fig. 4 Relationship between the break mean effective pressure and equivalence ratio.

gas pulsations. Diesel fuel flow rate was obtained by timing the consumption of 100 cc and 15 cc of fuel from a pipette for tests on diesel fuel alone and tests using producer gas with pilot injection, respectively. Engine speed was determined using an automatically timed revolution counter. To control the amount of diesel fuel at the amount required for ignition alone, some alterations were made to the diesel governor housing, **Fig. 2**. A rod was connected to the diesel governor rack of the engine, and at the end of the rod a thumb screw was arranged to preset the minimum diesel fuel injection rate at the amount required just to idle the engine.

Test Procedure

For all tests, the compression ratio of the engine was unchanged, at 17:1. For the performance tests of the engine on producer gas using pilot injection of diesel fuel for ignition, the speed of the auxillary governor was set at a slightly higher level than that for diesel governor. The auxillary governor coupled to the butterfly valve was used as a fuel leaning device for the basic mixture of the fuel (air and producer gas). As the producer gas was turned on, the engine tended to overspeed slightly. As excessive speed developed, the auxillary governor would open the butterfly valve to allow excess combustion air into the engine to lean the mixture so the engine output torque would match the engine torque requirement at the speed set on the auxillary governor. The dynamometer was equipped with a strain gauge transducer to measure the restraining force and thus continuously determine torque.

Results and Discussion

By using the 12.7 mm carburetor orifice, it was possible to maintain the leaner than the stoichiometrically correct mixtures at high speeds. For complete combustion of producer gas, the air/gas ratio is approximately 2:1 by weight. Using a carburetor orifice, 14.29 mm in diameter for the producer gas line while an orifice of 19.05 mm was used for air, the mixture deviates from this value by 3% only. The initial problems encountered appeared to be associated with ignition delay characteristics of the air-producer gas mixture. From these tests, it could be deduced that misfiring was accentuated by:

(a) Rich mixtures, since the engine control system response to increased torque was to admit less excess air, this action caused an accentuated increase in mixture richness. Any subsequent misfiring caused governor controls to further respond as it torque had increased;

(b) Low cylinder temperatures and/or pressures (**Fig. 3**). At light loads, the average cylinder pressure (and thus corresponding cylinder temperatures as indicated by exhaust temperature) were low causing misfiring at idling. Additional pilot fuel under these conditions prevented stalling. Exhaust temperatures at 1 800 rpm while using producer gas with these controls could be represented by the equations:

$$Ln(T_{EG}) = 5.564 + 0.26\ Ln\ (Q_{EG}) \quad ...(1)$$

$R^2 = 0.8858$

where,

T_{EG} = Exhaust temperature with producer gas (o_C)

Q_{EG} = Torque with producer gas (N-M)

and the corresponding relationship when diesel fuel was used was:

$$Ln(T_{ED}) = 4.752 + 0.58\ Ln\ (Q_{ED}) \quad ...(2)$$

$R^2 = 0.9473$

where,

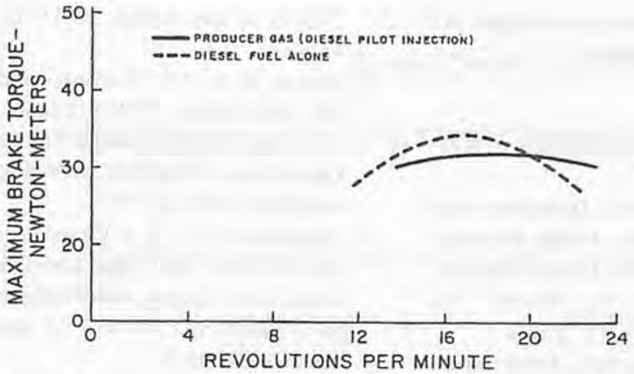

Fig. 5 Comparative torque values for diesel fuel alone and producer gas.

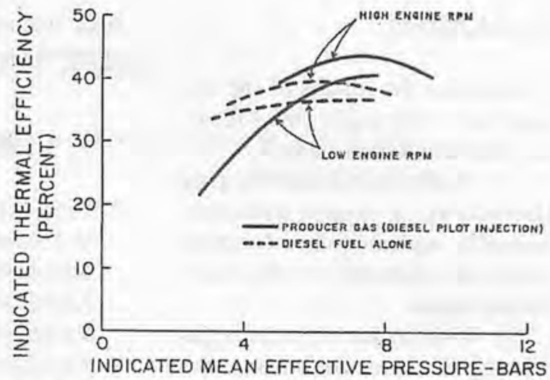

Fig. 6 Influence of cylinder pressure on ignition delay.

T_{ED} = Exhaust temperature with diesel alone, (o_C)
Q_D = Torque with diesel alone (N-M);

(c) high engine speeds allowed limited time for combustion reactions; and
(d) low level pilot injection.

Figure 4 shows the relationship between the break mean effective pressure and equivalence ratio at engine speeds approximately 1 770 rpm. The equivalence ratio used for these plots are those computed assuming that the pilot fuel alone was utilizing the combustion air in the cylinder. For the producer gas plot, the same equivalence ratios for the composite used, as in **Fig. 3** discussed earlier was used. Equivalence ratios at 1 770 rpm while using producer gas could be represented by the equation:

$$E = 54.494 - 1.455\,(BMEP + 0.0323\,(BMEP)^2 \quad ...(3)$$
$$R^2 = 0.9094$$

whereas, for the pilot fuel alone,

$$E = 30.089 - 1.056\,(BMEP + 0.0186\,(BMEP)^2 \quad ...(4)$$
$$R^2 = 0.9302$$

where,
E = Equivalence ratio (%)
BMEP = Break Mean Effective Pressure (Bars).

The dependence of the equivalence ratio on cylinder pressure was significantly limited with producer gas using pilot fuel and hence operation with diesel fuel alone was not sensitive to ignition delay problems, thus efficiency did not change greatly with changes in equivalence ratio.

The fact that the engine could operate at higher equivalence ratios with producer gas than with diesel fuel alone was responsible for limiting the decrease in maximum torque values to approximately 10% when producer gas was used, as compared to torque values with exclusive diesel fueling (**Fig. 5**). At higher torques, the carburetor-governor system delivered to the engine gases which contained approximately 70% of the oxygen that would normally enter the engine with exclusive diesel fueling. The presence of producer gas permitted full utilization of all oxygen in the cylinder for combustion as opposed to the approximately 80% utilization in the case of exclusive diesel fueling. Cylinder pressure (in terms of indicated mean effective pressures) tended to have an influence on ignition delay with producer gas and thus on the mechanical energy obtainable from the combustion process. This is illustrated in **Fig. 6**. Low cylinder pressure and associated low cylinder temperatures were linked to much lower efficiencies with producer gas use than with diesel fuel use alone. At higher cylinder pressure, with which ignition was not a problem, the reverse was true. Efficiency values with diesel fuel operation appeared to be little affected by cylinder pressure levels.

Table 1. Comparative Costs of Dual-fueling a Diesel Engine with Producer Gas

Items	Diesel Operation (N/Year)	Dual-Fueling (N/Year)
Cost of gasifier	0.00	41 264.86
Interest and depreciation on engine	15 580.00	19 484.02
Lubrication and repairs	4 920.00	6 152.46
Annual petroleum fuel cost	105 186.32	33 340.38
Cost of residues	0.00	3 309.52
Engine investment	82 000.00	102 545.92
Total (Variable costs of operating the engine daily)	125 686.32	103 551.24

Table 1 shows the cost analysis for dual-fueling a diesel engine with producer gas. The annual cost benefits available from a producer gas operation using pilot fuel equal N22 135.08 exclusive of the initial capital investment of engine. This results in about 18% annual saving when dual fueling a 10.44 kW engine. As a result, the cost required to modify the engine and purchase a gas producer for a small diesel engine can be recovered from the cost savings accruing from dual-fueling the engine.

Conclusions

Based on the results of the test reported in this paper, the following conclusions are made:

(1) With minimum engine alterations, a single cylinder, naturally aspirated diesel engine could be operated in the dual-fueling mode.

(2) With the use of producer gas instead of diesel fuel alone: (a) maximum torque will be reduced slightly; (b) maximum fuel efficiency will be increased slightly; and (c) producer gas may constitute from 50 to 70% of the fuel energy.

(3) The control system as finally developed was capable of achieving satisfactory engine performance with producer gas fuel under a broad ranges of operating conditions.

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Development of a Power Tiller-drawn Pineapple Plant Dressing Machine

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Abstract

After the first harvest in developing countries, pineapple plants are dressed manually, which is a very time-consuming and back-breaking job. To overcome this problem, a low cost power tiller-drawn pineapple plant dressing machine, suitable for two rows, was developed. It was mounted at the front of a 8.6 kW power tiller (two wheel tractor). A special transmission mechanism was developed to power the rotary blades of the dressing machine by the engine. The machine was tested at different blade and forward speeds. The field testing revealed that it could dress an average area of 0.11 to 0.15 ha/h. The average field efficiency and cutting efficiency were found to be 73.28 and 90.10%, respectively. The machine was capable of dressing six to eight times the area covered manually. The estimated cost of dressing with the developed machine was $12.20/ha which was one-third of the cost of the traditional manual method.

Introduction

Labor scarcity in developing countries is increasing due to migration of agricultural labors to the industrial sector. To overcome this problem, it is desired to have mechanization of at least labor intensive farm operations. Affordable mechanization plays an important role in modern crop production. It is a major factor in maximizing land and labor productivity through the timeliness of operation. It has also an important role in reducing drudgery and back-breaking toil. Also, meaningful mechanization can remove the tedium of farm work and provide the agricultural worker with dignity and some of the opportunities of his or her urban counterparts.

Pineapple is an important tropical fruit that has a high export demand. Pineapple plants, after the first harvesting, need to be dressed for good ratoon crop growth and for healthy shoots for planting. Pineapple cultivation in developing countries is done by traditional methods. Pineapple plant dressing, which is done manually, is one of the most labor intensive tasks during pineapple cultivation. The crop duration and growth of the pineapple plant depends on the weight of the planting. There are three types of plantings used for pineapple cultivation: shoots; crown; and slips. Cultivators always like to transplant healthy shoots, as they give higher yield compared to others. To get healthy shoots it is necessary to dress the pineapple plants immediately after harvesting. Dressing also facilitates collection of pineapple shoots for further planting in other fields and for the ratoon crop growth.

Currently, the major cost component in pineapple production is the labor cost. Farmers dress the plant manually with a long knife, which is hard work and one of the most costly operations in pineapple cultivation. There is no suitable mechanical device available for pineapple plant dressing. Therefore, there was a need to develop a pineapple plant dressing machine which was cheap and could be fabricated by artisans and operated with widely available power sources. The developed machine was intended to be attached to a power tiller (Roy, 1996).

Literature Review

The development of a pineapple plant dressing machine was a new approach. Therefore, it was necessary to consider the different parameters of the pineapple plant to be used in the design. There are many varieties of pineapple available, some of these produce slips and others do not. The most widely grown cultivar for commercial production, canning and export is Cayenne (Purseglove, 1988). For this variety, flower initiation can take place at any time of the year, but shortening days hasten flower production in young plants. Stems of pineapple are short and thick, 200 to 250 mm long, with a diameter of 20 to 30 mm at the base, broadening to 55 to 65 mm near the apex with short internodes. Leaves are crowded on the stem in a bushy rosette and the number of functional leaves will be 70 to 80 with shorter and older leaves at the base, gradually increasing in length to a maximum, above which lie younger leaves decreasing in length. It is cultivated at a wide range of plant spacing (Purseglove, 1988).

Guzel and Zeren (1990) studied the theory of free cutting and application on cotton stalks. The rotary cutter was a blade system which pivots horizontally on the vertical shaft. Power taken from the p.t.o. after passing over the conical gear box is transferred to the blade shaft. The cutting system consists of four blades with a clearance of 90°.

Oduori (1988) developed a revolving knife type of sugarcane basecutter. Four smooth-edged blades of twenty-degree edge angle were used and blades were fixed with a disc of minimal diameter of 400 mm. He conducted laboratory tests to determine the optimum combination of basecutter rotational speed, tilt angle and the blade's oblique angle. The results obtained indicated a tilt angle of about 27°, oblique angle of about 35° and a rotational speed between 600 to 800 rpm (knife peripheral velocity between 14 to 18 m/s at the basecutter's nominal diameter) to be the most suitable at a feeding velocity of 0.225 m/s.

Persson (1993) developed and tested a rotary counter-shear mower. It consisted of a set of two concentric counter-rotating discs, one with collecting counter shear fingers and the other with knives in close contact with the counter-shears. The shape of the active edges and relative velocities of the rotors were originally selected through computer analysis such that favourable cutting would occur, including minimum deflection of the crop before cutting. He found that the oblique angle should be between 45° and 85° for good tip entry in the standing crop. The cutting section of the finger must have a clip angle to the knife edge smaller than 35° for grass in order to prevent the crop from being pushed out instead of being cut (Persson, 1987). A clip angle between 5° and 25° was advantageous for an even cutting force. The highest knife velocity was found to be 20 m/s.

Materials and Methods

General Information

The information about pineapple cultivation practices in Thailand was collected by visiting pineapple plantation sites. Pineapples are generally grown in two rows on one bed with a plant spacing of 250 mm from one plant to another in the same row. The distance between two rows on one bed is 600 mm, while the distance between two rows on two adjacent beds is 700 mm. The average height of the ridge is generally 150 mm. The pineapple plants are generally dressed at a height of 250 mm and 300 mm above the bed in the wet and dry season, respectively. The physical properties of pineapple plants were measured. The average height of the pineapple stem, diameter and shear strength were found to be 388 mm, 37 mm and 807 kN/m^2, respectively.

Design of the Machine Components

Based on the human power required in manual dressing, it was assumed that the power requirement for the machine would be about 0.53 kW. Selection of different parts of the machine was made using the standard formula, procedure and properties of materials.

Considering the assumed power requirement and adequate safety factor, the power transmission shaft was designed to transmit 2 kW of power. Its speed was estimated to be 330 rpm. According to the ASME Code, a cast iron shaft with diameter of 25.4 mm was selected for the transmission shaft.

The bevel gear was selected based on limiting endurance load, the dynamic load and the wear load. The selected gear was a 14.5° full depth involute cast iron bevel gear. The module (ratio of gear diameter and teeth) of the gear was 5 and width of the teeth was 15 mm. The gear ratio was 1:1.6. Bearings were subjected to two kinds of load, thrust and radial. The bearing was selected with the help of equivalent load, which was found from the relationship of thrust and radial load. The selected bearing was 200 series "04" (Faires, 1965). Considering the service factors of chain loading the chain number "40" was used.

The frame of the machine was fabricated with mild steel hollow square tubing, the selection of which was made on the basis of maximum bending moment and moment of inertia of the cross section of the frame. The blades were commonly used grass cutter blades with a diameter of 254 mm and a knife type blade. The cutting blades were fastened with a mild steel circular plate of diameter 90 mm and 8 mm thickness. The knife type blade cutting system consisted of four blades with a clearance of 90°, fixed to the plate at an oblique angle of 45°. Also, approximately 5° disc angle was provided to facilitate adequate clearance and reduce the friction between blade and plant. The edge angle of the blade was 20°, recommended for the economic life of blades.

The power tiller is one of the most popular power sources used in agriculture in Thailand. Therefore, the pineapple plant dressing machine was intended to be operated by a power tiller. The machine was powered by a power tiller diesel engine of 8.6 kW. A special power transmission system was developed to transmit power from the gear box of the power tiller to the blade of the machine. The schematic diagram of the developed machine is shown in

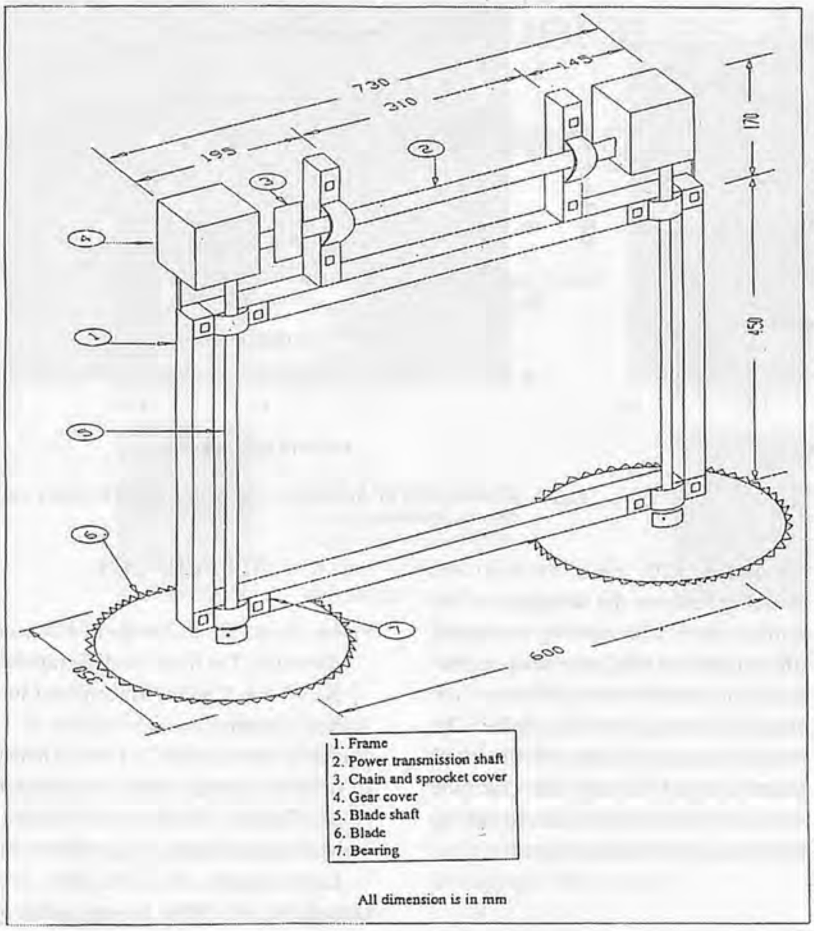

Fig. 1 Schematic diagram of the developed machine.

Fig. 2 The machine in the field.

Fig. 1.

To reduce the stress on the operator, a support wheel was provided at the front of the power tiller. Weight was added at the back of the machine for balancing. All moving parts were well shielded to protect the operator. The machine was mounted in front of the power tiller to provide the operator with a work space at the back.

To test the performance of the machine, the pineapple field was divided into small plots. These small plots were numbered randomly. The machine was tested at three different forward and cutting speeds at two different locations. **Figure 2** shows the pineapple plant dressing machine mounted at the front of the power tiller with circular saw teeth blades in operation in the field.

Results and Discussion

Preliminary tests were conducted for each type of blade before the final test. The testing of the machine with knife type blade was abandoned after the preliminary trials because the quality of dressing was not satisfactory to the farmers. Detailed field trials were conducted with only circular blades. **Table 1** present various operational conditions and their impact on the field capacity, field efficiency and cutting efficiency of the machine.

Theoretical field capacity, effective field capacity, field efficiency and cutting efficiency of the machine varied from 0.16 to 0.23 ha/h, 0.11 to 0.15 ha/h, 67.7 to 80.2% and 82.5 to 93.9%, respectively. The data in the table also indicate that field capacity and cutting efficiency increased with the increase of forward speed and cutting speed, respectively, but the field efficiency decreased with the increase of forward speed. The cutting efficiency was higher at location II (short plant height) compared to location I (tall plant height).

Figures 3 and 4 present the relationship between theoretical and effective field capacity vs forward speed, and field and cutting efficiency vs forward speed, respectively. Based on the test results, the following models were developed to estimate different parameters.

$$Y_1 = 0.13 X_1 \quad (R^2 = 0.99) \qquad \text{Eq. 1}$$

where,

Y_1 = theoretical field capacity, ha/h

Table 1. Performance Details of the Developed Machine with Saw Teeth Circular Blades

Location	Rotating speed (rpm)	Forward speed (km/h)	Theoretical field capacity (ha/h)	Effective field capacity (ha/h)	Field efficiency (%)	Cutting efficiency (%)
	530	1.24	0.16	0.11	67.69	89.69
	670	1.21	0.16	0.12	76.43	91.92
I	800	1.27	0.16	0.13	80.24	92.53
	800	1.53	0.20	0.15	74.40	85.32
	800	1.74	0.23	0.15	68.07	82.55
	530	1.40	0.18	0.13	70.13	91.94
II	670	1.36	0.18	0.13	70.56	92.60
	800	1.38	0.18	0.14	78.75	93.95

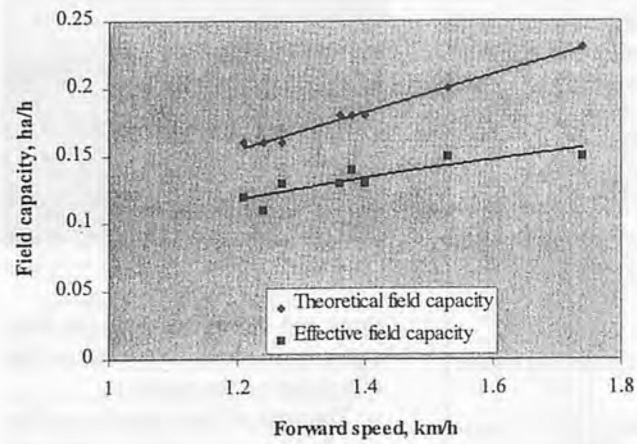

Fig. 3 Relationship of forward speed with theoretical and effective field capacity.

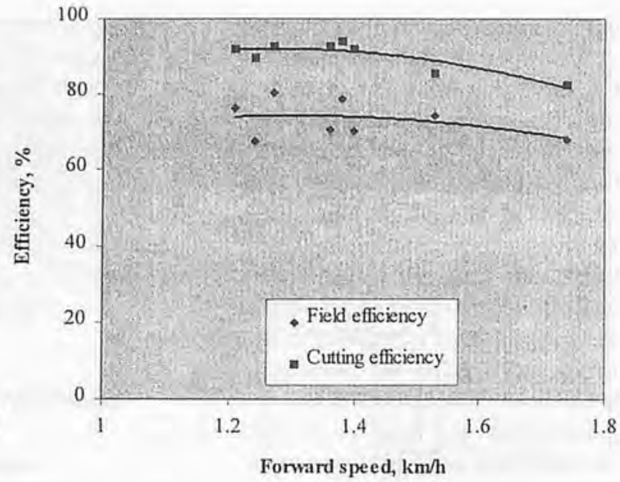

Fig. 4 Relationship of forward speed with field efficiency and cutting efficiency.

X_1 = forward speed of the machine, km/h

$Y_2 = 0.07X_1$ Eq. 2
($R^2 = 0.76$)

where,
Y_2 = effective field capacity, ha/h

Statistical analysis of the test results of the machine revealed that the plant height at different locations affected the field efficiency significantly, but it did not affect the cutting efficiency of the machine. There was no significant relationship between blade speed and cutting efficiency, but the blade speed of 800 rpm was found to be optimum. There was a strong relationship between cutting efficiency and forward speed, and field efficiency and forward speed. The cutting efficiency in 1st gear (1.2 to 1.4 km/h) was found to be optimum.

The capacity of manual dressing was 0.16 ha per man-day (8 h), but the capacity of the machine was 0.88 to 1.20 ha/day (8 h). The machine was found to be economical compared to the manual dressing method. Approximate cost of the machine including a two wheel tractor was \$1520. Also, mechanized dressing reduces the drudgery of the human labor. Considering economic life and yearly use, the yearly capacity of the machine was 70 ha and the cost of dressing was \$12.20/ha. The break-even area of the machine was found to be 11 ha only. The machine was simple in design, so it can be fabricated by local artisans.

Conclusions

The developed machine was a new approach to the pineapple plant dressing adaptable by small scale farmers. The capacity of this machine was about 6 to 8 times that of manual dressing depending on the plant condition. The cost of dressing by this machine was one-third of the traditional method. This machine can replace the existing manual pineapple plant dressing method. The field capacity of the developed machine was 0.11 to 0.15 ha/h, average field efficiency was 73.28 %, and average cutting efficiency was 90.1 %. The machine can be fabricated with locally available materials by local artisans.

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Rice Husk Briquette as Alternate Fuel in Bangladesh

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Abstract

A study was conducted at Sylhet, Chittagong, Khulna and Dinajpur districts of Bangladesh in order to identify the problems and prospects of rice husk briquette as an alternative fuel.

Shortage of rice husk, high cost of electricity, interruption in electricity supply, unskilled manpower and lack of credit facilities for the manufacturers were the main constraints towards the production of rice husk briquette.

It was estimated that the total cooking fuel requirement of the country is about 36.5 million tons (mt). At present about 23.5% (8. 58 mt) of cooking fuel is being supplied from wood source. At least 50% of total wood (4.29 mt) may be replaced by 2.57 mt rice husk briquette. The market prices of 4. 29 mt wood and 2.57 mt briquette were US$322 million and US$ 129 million, respectively. By using rice husk briquette instead of fire wood, U$ 193 million may be saved annually. The annual potential production of rice husk briquette was estimated at 2.59 mt. However, it has been assumed that about 50% of the total husk of the country would be available to produce 2.57 mt briquette.

To produce 2.57 mt of briquette 17 390 people will be employed daily. To reduce consumption of wood for fuel and decrease pressure on fuel wood, rice husk briquette technology may be introduced throughout the country.

Introduction

Rice is the staple food for the people of Bangladesh. The total annual production of paddy is about 28 mt (FAO, 1992). About 20% of this (5.6 mt) is rice husk. About 10% of the people eat unparboiled rice and the rest 90% consume parboiled rice.

It has been calculated that about 38 mt of firewood is required for cooking purpose annually in Bangladesh. These include firewood, straw, leaves, dried cowdung, husk, saw dust, bark of tree, jute stick, bagasse, etc. (IFRD, 1992). The total population of the country is about 120 million and the growth rate is about 2.0%. With the increasing rate of population the use of conventional cooking will also be increased.

In order to maintain natural balance it is necessary to have 25% forest of the total land of any country, whereas Bangladesh has only 9% of forest area which is environmentally not sound. Moreover, the climate of the country is continuously changing and as a result the county is facing the problems of serious drought, irregular rainfall and flood.

In the past, crop residues like straw, leaves, bagasse etc. were left in the soil for decomposition to increase the soil fertility. At that time straw, leaves and cowdung were widely used in the soil. But presently people collect cowdung, leaves, straw etc. from the field for cooking. As a result the soil is losing its fertility and the crop production is also getting reduced. A policy for energy using fire wood should be formulated to protect forest, natural environment and increase soil fertility. However, the demand for fire wood is increasing and people are cutting the trees for fire wood. Consequently, afforestation programme of the Government is not matching the deforestation rate.

Bangladesh is one of the poorest countries in the world with a per capita income of about US$220 and per capita consumption of energy totalling 167 kg of oil equivalent of which nearly 65% is traditional energy (mostly biomass). With this low energy subsistence level of economy, the country is burdened with a high density of population and the country is frequently met with natural disaster like flood, drought, storm, cyclone and tidal surges (Hossain, A, 1995).

In Bangladesh there are about 56 000 units of Engleberg rice mills. These mills produce mixtures of rice, husk, bran and germs as well. It is very difficult to use this as fuel for cooking. This mixture of husk is not suitable for the production rice husk briquette. However, if paddy is hulled by rubber roll huller, quality husk would be produced and the husk could be used to manufacture rice husk briquette.

About 90% of rice is consumed as parboiled. In order to produce 1 ton parboiled paddy about 25 000 Kcal energy is required: 20% husk of one ton paddy is enough to provide the required energy to produce 1 tone of parboiled paddy. The unparboiled rice husk is suitable for producing briquette. Available literatures reported that a mixture of unparboiled and parboiled husk in a ratio of 1:1 could also be used for manufacturing rice husk briquette. At present about 90% and 10% of the people in Bangladesh use parboiled and unparboiled rice, respectively. If the use of unparboiled rice could be increased to another 40% that will help to produce quality briquette in the country. The price of unparboiled rice is higher than parboiled rice but the nutrition, storability and milling outturn of parboiled rice is higher than unparboiled rice. However, in order to make the country environmentally sound to protect the forest the government must provide some subsidy and facilities to briquette manufacturing sector for producing briquette throughout the country.

Many developed and developing countries are passing through the stage of energy crisis. It is true in developing countries where high population increase, development activities and limited resource of energy have built up an acute pressure on all developmental workers (Lali et al., 1993).

Food and energy are the two main requirements of mankind. The demand for these two basic needs is going to increase with the increasing population all over the world. The increased demand for food has been met to a large extent through the introduction of modern technology, farm mechanization and modernization of agriculture. But there is still a shortage of all types of mineral fuels as well as fuels from plant sources. Moreover, the prices of these fuels are high and even beyond the reach of many people.

The world energy consumption in 1975 was 8 002 mt of coal equivalent which increased to 12 500 mt in 1985 and 18 850 mt in 1990. This is expected to increase to 27 400 mt of coal equivalent in the year 2000. There is a reason that scientists of all over the world are working hard on the optimum utilization of the existing resources of fuel (Sethi, P. S et al., 1994).

The non-commercial fuels required for cooking are crucial for human survival as the fuel energy needs of the domestic sector are location specific. For household cooking, conventional fuels like firewood, coal, crop residues, dung cakes, kerosine oil and biogas are mostly used depending upon the locality and availability of fuels.

Energy is a vital input for the development of living standard of the people of a society. The problems of energy shortage that surfaced in many countries of the world is due to rapid increase of population and technological development. Such demand will place heavy strains on the limited resources of a country. The growing dependency on traditional sources of energy like fossil fuels has led to problems of scarcity of wood, deforestation and competitive land use. It is, therefore, necessary to take stock of energy sources which are underutilized, conserve them and consider the possibility of harnessing other sources which are not utilized at present (Sehgal, B. et al., 1995).

According to Girja Saran (1994) on an average, a household uses about 42 kg of fuel a week for cooking. The average per capita energy consumption for domestic cooking was 15. 59 MJ/day.

Maheshwari, et al., (1990) reported that energy consumption from noncommercial fuel for cooking in villages amounts to 20 MJ/day. Rice husk is an efficient fuel for drying purpose compared with fuel oil. Some 3 kg of rice husk is equal to 1 kg of fuel oil (Sing, et al., 1980).

However, to prevent environmental hazard caused by rapid deforestation activities in the 3rd world, rice husk briquette may be introduced as an alternative fuel which is smoke free, less hazardous, has high calorific value and comparatively cheap.

Storage of Rice Husk

The husk is to be well dried and stored in a dry place for producing briquette. About 12% moisture content of husk is suitable for briquette production. It is essential to store the husk in a dry place and near the factory (**Fig. 1**). Unparboiled rice husk is suitable for briquette making due to the presence of crude oil. During processing the briquette, the oil acts

Fig. 1 Storage of rice husk.

Fig. 2 Briquette production in a machine.

Fig. 3 Briquette storage.

Fig. 4 Transportation of briquette from a trader.

Fig. 5 Selling marketing of briquette along with other cooking fuel.

as binding material.

Briquette Machine

The briquette machine is operated by 2 persons. One is skilled technician and other is unskilled labour. The cost of a machine is about $1 500 which is made locally with local expert. A 15-hp motor is needed to operate the machine. The hopper is filled with dried rice husk and passed through the screw conveyer and briquette is produced in a pressurized chamber with partial burning (**Fig. 2**).

Storage and Transport of Briquette

The store house of briquette should be located near the roadside so that the rickshaw, van and other transport can easily carry the charcoal any time. Like husk, the charcoal also is stored at safety and dry place (**Fig. 3**). Damp weather or rain may deteriorate the quality of briquette.

Marketing Channel

Considering, quick supply of charcoal, a viable marketing channel is necessary. However, middlemen or traders carry the products from producer by rickshaw or van (**Fig. 4**). The trader sells the charcoal to small businessmen who sell all kinds of fuels like husk briquette, bamboo splits, dried cowdung, wood pieces etc. at a small scale (**Fig. 5**).

A recent survey study in sylhet, Chittagong, Khulna and Dinajpur revealed that the charcoal business is a promising and profitable one. The Government should provide financial and logistic supports for the briquette manufacturers.

Environment

To keep the environment healthy, the factory may be installed in a separate place, apart from the residential area. Abundant property may be allocated for this businessmen at a low cost. However, a proper chimney should be installed for exhausting of smoke.

Research and Development

Research and development programmes should be undertaken for the following purposes.

1. Alternate to raw husk: Research should be conducted on parboiled husk, straw, saw dust, water hyacinth and other materials as substitute of unparboiled rice husk;
2. Low power consumption;
3. To develop improved and appropriate machine;
4. Marketing: To develop a proper marketing channel;
5. Socio-economic impact: To study the socio-economic aspects of manufacturers and end users; and
6. To study the environmental effects of briquette production.

Employment Opportunity

The briquette manufacturing business undoubtedly will create job opportunities. On an average, 2 people for production and 2 people for marketing purpose may be employed in briquette business.

The briquette production target/year = 2. 57 mt;

Production/month = 0. 214 mt;

Production/day = 7 134 t;

Average production capacity/factory/day = 0. 821 t (from **Table 3**)

Number of factory = 7 134/0. 821 = 8 695

Total job opportunity = 2 x 8 695 = 17 390

Materials and Methods

Sylhet, Chittagong, Khulna and Dinajpur districts were selected for this study. The survey samples were selected randomly. The briquette producers of those areas were interviewed through a questionnaire and data on briquette machine, spare

Table 1. Percent of Household Using Fuel from Different Sources

Fuel source	Country total	Urban	Rural
Straw, Leaves, Cowdung	71.75	19.54	78.61
Husk	0.20	0.93	0.11
Wood	23.50	50.43	19.97
Kerosine	1.87	13.79	0.30
Gas	1.40	11.71	0.04
Electricity	0.33	1.62	0.17
Others	0.94	1.98	0.80
Total	100.00	100.00	100.00

Source: BBS, 1991

Table 2. Estimates of Energy Supplied by Traditional Fuels During 1987-1988

Fuel sources	t of coal equivalent
Cow dung	1 807 000
Jute stick	526 000
Rice straw	1 448 000
Rice hull	1 975 000
Bagasse	628 000
Fire wood	475 000
Twigs and leaves	1 270 000
Other wastes	1 056 000
Total	9 185 000

Source: BBS, 1991

parts, cost of husk, cost of electricity and labour, marketing and socio-economic aspects were collected. All data were analyzed in respect of production cost, selling price and net profit of briquette.

Table 3. Cost of Briquette Machine, Husk and Production Capacity of the Machine

Location	Cost of machine (Tk)	Prod. capacity (t/day)	Cost of husk (Tk./t)	Source of husk and spare parts	Type of husk
Sylhet	54 600	0.888	650	Local	Raw
Chittagong	52 000	0.711	600	Local	Raw
Khulna	65 000	0.958	550	Local	Raw
Dinajpur	70 000	0.725	500	Local	Parboiled
Mean	60 400	0.821	575		

Results and Discussion

In Bangladesh, straw, leaves, cowdung, rice husk, wood, kerosine, gas, electricity etc. are used as fuel sources for household cooking. In urban areas, about 0. 93% and 50. 43% of the household use rice husk and wood for their cooking fuel, respectively, whereas in rural areas, 0.11% and 19.97% households use the same for the same purpose (**Table 1**). The traditional fuels like rice husk, cowdung and firewood gave 1.98 mt, 1.80 mt and 0.48 mt of coal equivalent energy (**Table 2**). The energy value of husk has been increased by making it briquette in a solid form. The price of briquette machine and rice husk of four locations are shown in **Table 3**. The cost of a machine ranged from Tk 52 000.00-Tk 70 000.00. These machines are being made in Sylhet and Chittagong. The spare parts of these machines are available and made locally. The production capacities of these machines range from 0.711-0.958 t/day. All manufacturer use locally available unparboiled rice husk for briquette production except in Dinajpur where use the parboiled rice husk is used.

However, the cost of husk ranges from Tk 500-Tk 650 /t. The fixed cost of machine/t ranges from Tk 50-Tk 79 (**Table 4**). The production costs (Tk/t) of rice husk briquette of four locations ranges from Tk 1 221-Tk 1 362 (**Table 5**). The husk, electric and labour costs for briquette production in the reported areas vary. At Sylhet, the husk and electric cost is high but the labour cost is low whereas at Chittagong the electric cost is low but the labour cost is higher.

The average production cost, selling price and net profit per ton of briquette were Tk 1 291, Tk 2 078 and Tk 787, respectively (**Table 6**). The net profit (Tk/t) of briquette of four location ranged from Tk 567-Tk 1 064. The proportion of husk, briquette and firewood utilization per person consumption is shown in

Table 4. Fixed Cost (Tk/yr) of Briquette Machine

Items	Locations			
	Sylhet	Chittagong	Khulna	Dinajpur
Depreciation cost	4 914	4 680	5 850	6 300
Interest (10%)	3 001	2 860	3 575	3 850
Repair, maintenance, tax, and insurance (15%)	8 190	7 800	9 750	10 500
Total fixed cost/yr	16 107	15 340	19 175	20 650
Fixed cost/t	50	59	55	79

Table 5. Production Cost (Tk/t) of Rice Husk Briquette

Items	Sylhet	Chittagong	Khulna	Dinajpur
Fixed cost/t	50	59	55	79
Cost of husk/t	774	714	655	596
Cost of electricity/t	450	425	425	450
Cost of skilled labour/t	45	94	52	55
Cost of unskilled labour/t	34	70	42	41
Total	1 353	1 362	1 229	1 221

Table 6. Cost and Profit of Briquette Production

Location	Production cost (Tk/t)	Selling price (Tk/t)	Net profit (Tk/t)
Sylhet	1 353	2 099	746
Chittagong	1 362	1 929	567
Khulna	1 229	2 000	771
Dinajpur	1 221	2 285	1 064
Mean	1 291	2 078	787

Table 7. Ratio of Consumption of Husk, Briquette and Firewood Utilization per Person

Location	Husk:Briquette	Briquette:Fire wood
Sylhet	1:0.83	1:1.80
Chittagong	1:0.95	1:1.80
Khulna	1:0.91	1:1.53
Dinajpur	1:0.67	1:1.50
Mean	1:0.84	1:1.67

Table 8. Cost of Fire Wood and Briquette per Family/Day

Fuel	Size of family (number)	Weight of fuel (kg)	Rate (Tk/kg)	Total cost (Tk)
Fire wood	2	1.5	3	4.5
Fire wood	4	2.5	3	7.5
Fire wood	6	5	3	15.0
Briquette	2	1	2	2.0
Briquette	4	2	2	4.0
Briquette	6	3.5	2	7.0

Table 7. One kilogram rice husk provided on an average 0.84 kg of briquette. Moreover, 1 kg briquette is equivalent to 1. 67 kg of fire wood in terms of energy.

The prices of fire wood and briquette are shown in **Table 8**. 1.5 kg, 2.5 kg and 5.0 kg fire wood are needed for cooking for 2, 4 and 6-member family, respectively, whereas 1.0 kg, 2.0 kg and 3.5 kg briquette are needed for 2, 4 and 6-member family for the same purpose. The price of the dry fire wood is two times higher than that of briquette.

In the early 80s the cost of a machine was more than Tk 100 000.00 but now these are made locally and the price has been lowered to Tk 52 000-Tk 70 000 only. Presently the traders from different districts procure machines from Sylhet and Chittagong. The name of the briquette machine is Fire Stone Charcoal Compressor. During operation the electric power consumption is about 10-15 kW/t. It may be noted that a few years ago the unparboiled husk was thrown into the rivers. Now no body throws it for it is a costly materials. About 20-25 t of husk may be obtained from 100 t of paddy. It has been reported that charcoal made by raw husk is an improved one. The parboiled husk contains dust which is not suitable for charcoal production. It is necessary to make the husk dust free and dry. The moisture content of husk should be around 12%. However, some owners have their own dryer where they dry their husk. Some people report that 50% mixture of raw and parboiled husk may be used for briquette production.

The rice husk briquette is more or less smoke free. As a result it can be used in village and urban household cooking without smoke in the kitchen. It has been known that the use of briquette has been increasing throughout the country. It has been reported that housewives like the rice briquette due to efficient burning during cooking. Moreover, during burning the briquette does not provide any black colour on the cooking pots. During firewood burning, occasionally it needs blowing through a tube or mouth but briquette does not. However, the large pieces of firewood need to make smaller pieces for burning which is troublesome but the briquette is in uniform size which is ready to use without any difficulty. It is possible to do other works after is lit. the furnace with briquette whereas it is very difficult with firewood. Rice husk briquette may be used for movable furnace which is cheap and less hazardous. However, presently people have been using the rice briquette as alternative fuel with satisfaction. This briquette has been used not only by general people but also by restaurant, brick field, rice miller, trader and road contractor.

It is known that bagasse, coconut husk and saw dust may be used for briquette production. However, proper research and development work in this direction should be undertaken. Some 8. 58 mt of fire wood were used annually for household cooking costing about US$ 643.50. At least 50% of total wood (4.29 mt) may be replaced by 2.57 mt rice husk briquette. The market prices of 4.29 mt wood and 2.57 mt briquette were US$ 322 million and US$ 129 million, respectively. By using rice husk briquette instead of fire wood, U$ 193 million may be saved annually. The annual potential production of rice husk briquette was estimated at 2.59 mt. However, it has been assumed that about 50% of the total husk of the country would be available to produce 2.57 mt briquette.

To produce 2.57 mt of briquette 17 390 people will be employed daily. Therefore, by introducing rice husk briquette throughout the country Bangladesh could create a successful example of decrease deforestation without using any wood for cooking purpose.

Calculation of Cost Requirements of Fuel, Firewood and Briquette

Total population in Bangladesh = 120 million

6-member family=120/6= 20 million nos.

Total cooking fuel requirement/family/day = 5kg (**Table 8**)

Total cooking fuel requirement in Bangladesh/year = 20 million x 5 x 365 x 10 x^{-3} = 36.56 mt

From **Table 1**, 23.5% wood is used for cooking purpose.

Total wood = 23.5% x 36.5 mt = 8.58 mt

At least 50% wood may be replaced by the rice husk briquette.

50% wood = 8.58mt x 50% = 4.29 mt

Cost = 4.29 mt x 3 000 (**Table 8**), U$ = Tk 40.00 = U$ 322 million

4.29 mt wood is equivalent to briquette = 4.29 mt/1.67 (**Table 6**, Briquette:wood = 1:1.67)

The total briquette = 2.57 mt

Total cost = Tk 2.57 mt x 2 000 (**Table 8**) = U$ 129 million

Saved by producing rice briquette: U$322-U$129 = U$ 193

Suppose about 50% of total husk of the country will be available to produce 2.57 mt of briquette.

Total paddy production = 28 mt (FAO, 1992)

Total husk production = 22% x

28 mt = 6.16mt

50% husk = 6.16 x 50% = 3.08 mt

Total potential of briquette production = 3.08 x 0.84 = 2. 59 mt

Total briquette requirement for target production in Bangladesh = 2.57 mt

Constraints

The following constraints have been identified for briquette production in the country:

1. Disrupted power supply and its high cost;
2. Shortage of husk and store house;
3. Importing of milled rice;
4. Limited capital;
5. Lack of credit facility;
6. Staff problems;
7. Unskilled manpower;
8. No separate area for this factory;
9. No subsidy;
10. Lack of public awareness;
11. Lack of appropriate machine;
12. Lack of training facility;
13. No smooth service from power sector.;
14. No R/D programme; and
15. Lack of government support.

Recommendations

In order to maintain a healthy environment, the following recommendations are made.

1. Government should undertake a programme for installing rubber roll huller instead of Engelbrg in order to produce quality rice, husk, bran and germ. Moreover, bank loan facility and subsidy should be provided in this sector for smooth production of briquette throughout the country.
2. Separate area should be provided for this factory with a view to avoiding pollution.
3. Domestic rate of electric charge should be introduced for encouraging producers to produce more quantity of briquette.
4. If necessary, government should import paddy instead of milled rice in order to keep the processing machinery in operation, including briquette factory.
5. Extension message of briquette technology should be broadcast through mass media to create awareness.

Conclusions

From the above discussion, it may be concluded that inspite of shortage of husk, transport problems, technical manpower problem, électric disruption, unstable market, still its a profitable trade. Fire wood is one of the daily needs so without any judgement people are cutting the tree and the tree population is gradually disappearing. With the purpose of making the environment healthy and afforestation programme successful, the rice husk briquette may be introduced throughout the country.

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AgEnergy '99 — Energy and Agriculture Towards the Third Millennium

June 2-5, 1999
Athens, Greece

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Fax.: +30-1-529-4023
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CIOSTA and CIGR V-XXVIII International Congress on Work Sciences in Sustainable Agriculture

June 14-16, 1999
Horsens, Denmark

Contact:
CIOSTA-CIGR V Congress
Danish Institute of Agricultural Sciences
Department of Agricultural Engineering, Research Centre Bygholm
P.O. Box 536
DK-8700, Horsens, Denmark
Tel: +45-75-60-22-11, Fax: +45-75-62-48-80, E-mail: mph6@sh.dk or Villy.Nielsen@sh.dk

2nd European Conference on Precision Agriculture

July 11-15, 1999
Odense, Denmark

Contact:
The Society of Chemical Industry
14-15, Belgrave Square
London, SEIX 8 PS
United Kingdom
Fax: (44-171) 235 7743, E-mail: conferences@chemind.demon.co.uk
http://www.sh.dk/~cgs/ciosta

ASAE and CSAE Annual International Meeting

July 18-22, 1999
Toronto, Canada

Contact:
ASAE, c/o Sharon McKnight
2950 Niles Road
St. Joseph, MI 49085-9659, USA
Tel: +1-616-429-0300, Fax: +1-616-429-3852, E-mail: mcknight@asae.org
http://www.asae.org

World Engineering Congress and Exhibition WEC 99

July 19-22, 1999
Kuala Lumpur, Malaysia

Contact:
WEC 99 Technical Committee
Attn: Dr. Mojd Saleh Jaafar
c/o Faculty of Engineering
University of Putra Malaysia
43400 UPM Serdang
Malaysia
http://eng.upm.edu.my/wec99

2nd International Conference on Multiple Objective Decision Support System for Land, Water and Environmental Management

August 1-5, 1999
Brisbane, Australia

Contact:
Dr. Paul Lawrence
Information and Decision Support Resource Science Center
Department of Natural Resources
Meiers Road 3896 9898
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E-mail: paul.lawrence.dnr.qld.gov.au
http: www.dnr.qld.gov.au/events/modss99

2nd Symposium on Operationalization of Remote Sensing

August 16-20, 1999
Enschede, The Netherlands

Contact:
Ms. Loes Colenbrander
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P.O. Box 6
7500 AA Enschede
The Netherlands
Tel: 31-53-487 4534, Fax: 31-53-487 4466, E-mail: colenbrander@itc.nl
http://www.itc.nl/ags/research/events/symposium.htm.

International Symposium on Remote Sensing and GIS for Monitoring Soils

August 22-27, 1999
Kathmandu, Nepal

Contact:
Mr. Khruba P. Shrestha
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P.O. Box 6
7500 AA Enschede
The Netherlands
Tel: +31 (0) 53 487 42 46, Fax: +31 (0) 53 487 43 99, E-mail: dhruba@itc.nl

Conference — Food and Forestry: Global Change and Glo-

bal Challenges

September 20-23, 1999
Reading, UK

Contact:
Food and Forestry Secretariat
Elsevier Science Ltd.
The Boulevard
Langford Lane
Kidlington, Oxford OX5 1GB, U.K.
Tel: 44-1865 843 691, Fax: 44-1865 843 958, E-mail: sm.wilkinson@elsevier.co.uk http://www.elsevier.nl/locate/gete99

10th World Conference of Food Science and Technology

October 3-8, 1999
Sydney, Australia

Contact:
P.O. Box 1493
North Sydney NSW 2059, Australia
Tel: (61-2) 9959 4499, Fax: (61-2) 9954 4327, E-mail: iufost10@aifst.asn.au
Website: www.aifst.asn.au

AIT 40th Year Anniversary: Civil Environmental and Rural Engineering Conference — New Frontiers and Challenges

November 8-12, 1999
Bangkok, Thailand

On the occasion of His Majesty Bhumibol Adulyadej, the King of Thailand's Sixth Cycle in the Year 1999, the Asian Institute of Technology (AIT) would like to recognize this very significant and highly memorable occasion by organizing an International Conference in Civil Environmental and Rural Engineering. Also, the event coincidentally celebrates the Institute's 40th Anniversary.

The SEATO Graduate School of Engineering which originated in 1959 and transformed as the Asian Institute of Technology (AIT) in 1967 has now produced more than 8 500 Alumni who are active in teaching, research and practice in Asia and elsewhere. By 1967, the Institute had full-fledged Graduate Programs in Civil, Natural Resources and Environmental Engineering. The 40th Year Anniversary Event in 1999, in a sense, looks ahead for New Frontiers and Challenges. This is envisaged in the form of a truly international worldwide gathering of some of the finest academicians and practitioners in the area of Civil, Natural Resources and Environmental Engineering to convene at AIT and take part in an International Conference which consists of Keynote Addresses, Special Lectures and Original Research Presentations.

The major themes of the Conference are in the areas of Agricultural Aspects of Rural Engineering and Development; Water Engineering and Management; Environmental Technology and Engineering; Structural Engineering and Construction including Built Environment; Transportation Engineering and Infrastructure Management and Planning; Geotechnical and Geoenvironental Engineering, Aspects of Urban and Rural Environments with respect to Natural Resources Development and Natural Hazards and Disaster Preventions and Management are also considered as interdisciplinary fields.

Correspondence

All correspondence regarding the conference should be directed to:
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'99 International Conference on Agricultural Engineering ('99-ICAE)

December 14-17, 1999
Beijing, P.R. China

The 99-ICAE, Beijing aims at providing a new opportunity for researchers, scholars, managers and other professionals to exchange latest information, and provide a discussion forum on how to promote scientific and technological creation on Agricultural Engineering for the 21st Century. The topics of the conference will cover essentially all the fields of Engineering for Agriculture. It is sponsored by China Agricultural University and co-sponsored by many international and domestic societies and institutions.

Topic include:

- Power and Machinery, Agricultural Mechanization
- Soil and Water Engineering, Water-Saving Irrigation Technology
- Rural Structures, Bio-environment and Waste Treatment Engineering
- Post-harvest Technology and Food Engineering
- Farm Electronics, Information Technology and Precision Agriculture
- Biomass Engineering and Rural Energy
- Aquacultural Technology
- Agricultural and Biosystem Engineering Education Development
- Strategies for Sustainable Agriculture
- Workshops on Special Subjects

Convenor, Prof. Maohua Wang, Academician of Chinese Academy of Engineering, Vice President of CSAE, Honorary President of CSAM.

Contact Address:
Secretariat of 99-ICAE, P.O. Box 101, China Agricultural University (East Campus), Qinghua Donglu, Beijing 100083, China. Tel: +86 (10) 62336490, Fax: +86 (10) 62336908, E-mail: icae@bjaeu.edu.cn

4th International Conference on Soil Dynamics (ICSD-IV)

March 26-30, 2000
Adelaide, South Australia

The 4th International Conference on Soil Dynamics (ICSD-IV) is to provide a forum for discussion and information transfer of current research, new achievements and practical applications in all fields of soil dynamics. An improved understanding of soil dynamics is necessary to maintain proper soil management, to efficiently and effectively operate machines on and through soil, and to learn more about soil-plant-machine interactions. Following the successful Conferences on Soil Dynamics, which took place in Auburn, Alabama, USA (1985), at Silsoe College, United Kingdom (1994), and in Tiberias, Israel (1997), the 4th International Conference on Soil Dynamics (ICSD-IV) will be held in Adelaide, South Australia, on 26-30 March 2000.

It is anticipated that the Australian location will attract many attendees and contributors from Asia, allowing full discussion on soil dynamics from dryland soil environments to wetland soil conditions.

Conference Theme

Held at the outset of the new millennium, ICSD-IV will provide opportunities to reflect on past achievements and to highlight prospects and new directions for future soil dynamics research. "Serving the industry needs" will be promoted as a conference theme and presentations which will emphasise the applied aspects of soil dynamics research and the practical outcomes reached to solve specific problems faced by the related industry, are particularly encouraged. Thus, papers may address a broad range of topics related to the understanding, the characterization and the prediction of soil reactions to mechanical forces, whether induced by plants or machines.

Such topics include:
Soil characterization; Soil-machine interaction; and Soil-biological and environmental interactions.

Further Information

Further details about the conference registration, costs, program and conference tours, will be sent to those who have returned the Expression of Intent form. Participants are requested to send their poster/paper abstract(s) by the 1 September 1999 deadline. For technical enquiries about papers and topics, please contact the Conference Coordinators.

For all administrative dealings, please contact the Conference Administrators at the address below.
Conventions Worldwide (ICSD-IV)
PO Box 44, Rundle Mall, Adelaide South Australia 5000. Tel: 61 8 8363 0068, Fax: 61 8 8363 0354, E-mail: satconv@camtech.net.au Attention: Mr. Trevor Keeling, Mrs Pam Hammond.

International Conference on Rational Use of Renewable Energy Sources in Agriculture

April 9-15, 2000
Budapest, Hungary

This Conference is organized by the Hungarian Electrotechnical Association, in cooperation with the 4th Section of CIGR and the Hungarian Society of Agricultural Sciences in Budapest in the year of the 1000th Anniversary of the foundation of the State of Hungary, and the 70th Anniversary of CIGR.

The purpose of the Conference is to exchange experiences of the economical use of regenerative energy sources for production of heat and electricity in the agriculture, regarding the environmental effects and the limitation of harmful emissions. Energy saving technologies will also have a special position in the programme.

Topics of the Conference

- Regenerative energy sources for the developped countries, economic use.
- Regenerative energy sources for the agriculture of the developping countries, economic use.
- New role of the use of heat-pumps in the agriculture.
- Use of every form of biomass in the agriculture.
- Energy saving technologies in connection of the regenerative sources.

Correspondent Address:
Conference Secretariat of the Hungarian Electrotechnical Association (MEE)
H-1372 Budapest, Pf. 451. Tel: 36 1 353 0117, 36 1 312 0662, Fax: 36 1 353 4069.

EurAgEng International Conference on Agricultural Engineering into the Third Millennium, AGENG Warwick '2000

July 2-7, 2000
University of Warwick, UK

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Agri-Food 2000, Key to the Future

July 15-19, 2000
Winnipeg, Canada

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Biorobotics II — 2nd IFAC/CIGR International Workshop on Bio-Robotics, Information Technology and Intelligent Control for Bioproduction Systems

November 25-26, 2000
Osaka, Japan

The first international workshop on bio-robotics was held in Gandia, Spain, in September 1997. Its aim was to promote exchange on studies on the use of robotics and automated machinery in bioproduction systems around the world. This announcement is for the second workshop, which is intended to develop and expand the domain of bio-robotic research toward a unified system of information-oriented agriculture/horticulture in the 21st century

The purpose of the "BIO-ROBOTICS II" workshop is to provide a forum for the presentation of new approaches and results in the study of bioproduction robots, including automated and autonomous machine systems with or without manipulators, information-oriented technology to deal with variability, and intelligence technology for bioproduction systems. The discussions in this workshop are expected to lead to the development of new automated bioproduction systems and to the commercialization of various robots. To realize automated bioproduction systems, such as cultivating a field, many kinds of sensing system are obviously required to describe or recognize complex objects, and similar applications are needed in many areas of bio-robotics research. Precision farming and greenhouse technology are new integrated applications that use a systems approach to manage the spatial and temporal variability that is inherent in bioproduction systems.

Contributions should present information on the feasibility and availability of bio-robotics and information technology in the development of bioproduction systems. The International Program Committee desires original papers on theoretical issues related to fundamental methodology in bio-robotics and complexity management, on different technologies such as automation, machine vision, and variable-rate technology, and on practical applications. Papers should include a description of significant results in ongoing research, the implementation of new technology, or critical analysis of existing systems and approaches.

Sponsored by IFAC and CIGR

In cooperation with SHITA and many others

Important dates

Call for papers: November 1, 1999
Abstract: February 1, 2000
Notification of Authors: April 1, 2000
Full Papers: July 1, 2000.

IAMFE News 2 '98

By Prof. Egil Øyjord, President and Founder of IAMFE

IAMFE/ARGENTINA '98

The most important event in 1998 was the arrangement of IAMFE/ARGENTINA '98, Nov. 23-26 at the INTA Instituto de Ingenieria Rural in Castelar, Buenos Aires. This was the first Latin American Conference and Exhibition on Mechanization of Field Experiments. 82 participants from 15 countries participated in this event. The proceedings is an impressive book, covering 49 papers on 338 pages. Most of the papers are in Spanish with English summaries.

The IAMFE/ARGENTINA '98 Conference was very successful and can be considered as a basis for the establishment of a IAMFE Branch for the Spanish speaking countries in Latin America. It is proposed that the Headquarter for this Branch shall be established in co-operation with INTA at the INTA Institut de Ingenieria Rural in Castelar, Buenos Aires and that it shall become a IAMFE Centre for all Spanish speaking countries in Latin America. Shortly after year 2000 IAMFE wishes to organize the Second Latin American Conference and Exhibition on Mechanization of Field Experiments in Brazil. The main language of this Conference will be Portuguese. Brazil, which has 155 mill. people, is the only country in Latin America with Portuguese as a national language.

IAMFE/AAB, UK2000

As announced in the IAMFE NEWS 1 '98 in July, our 11th International Conference and Exhibition on Mechanization of Field Experiments will be arranged at Writtle College, University of Essex, Chelmsford, England, July 10-14, 2000.

There is no doubt that IAMFE/AAB, UK2000 will be a success and I hope you will start planning for your participation in this event,

The Norwegian IAMFE/CHINA Project

Prof. Guo Peiyu, President of the Chinese Branch of IAMFE, and Prof. Ai Yinqian, Leader of China Agricultural University, visited Norway at the end of August and beginning of September. With assistance of IAMFE, an agreement of co-operation between the Agricultural University of Norway and China Agricultural University was signed on August 27, 1998.

Prof. Guo and Prof. Ai were guests on the vegetable farm of Morten and Leif-Thore Bjertnæs, who, in co-operation with IAMFE since 1995, have welcomed Chinese students for practical training and social programmes. These programmes are under further development in a close co-operation between the Bjertnæs brothers and China Agricultural University.

Belarus: International Scientific — Practical conference "Increasing of the Effectiveness of Farm Machinery Using"

On Nov. 10-12, 1998 the above conference was successfully arranged in Belarus. The Belarussian Branch of IAMFE was especially active in the conference section "Mechanization of Field Agricultural Experiments". In this section, 16 reports were given, including presentations from visitors from Minsk and Latvia. Our Belarussian branch has also reported that, in October 1998, the Belarussian Agricultural Academy in Gorki (where the branch secretariat is located) was visited by officials from Writtle College, UK. This college is hosting IAMFE/AAB, UK 2000.

The Russian Branch of IAMFE

Dr. Vladislav Minin, IAMFE Representative for Russia and Executive Secretary of the Russian Branch of IAMFE, has been very busy in the work for the Russian Branch of IAMFE. An Interregional Association for Assistance of Field Experiments and Investigations (AAFEI) has been established. A Department of International Agroecological Research (DIAR), established at St. Petersburg State Agrarian University (SPSAU), has developed a close co-operation with the Swedish University of Agricultural Sciences and Ohio State University. In a co-operation between DIAR and the Agrophysical Research Institute (APhI), AAFEI takes care of the coordination of the IAMFE Programme in Russia.

Further Reports from the IAMFE Branches

Our Executive Secretary, Torbjörn Leuchovius, will give further information about the IAMFE activities.

Club of Bologna — Conclusions and Recommendations the 9th Meeting

Sixty-nine experts from 37 countries and two experts representing international organizations (FAO and OECD) attended the 9th meeting of the Club of Bologna, held under the auspices of CIGR on the 15th-16th November 1998 to discuss the following topics:

1) Soil cultivation: new methods and new technologies.
2) Official testing and evaluation of tractors and implements: a tool to assist farmers in assessing performance, safety and environmental factors.

A brief session was also devoted to the Indian tractor industry as preliminary information on a subject that will be discussed at the meeting next year.

The meeting unanimously agreed the following:

1. Soil Cultivation: new methods and new technologies

This important topic was discussed on the basis of keynote papers presented by L. Cavazza (Italy), H.J. Heege (Germany), W.C.T. Chamen (U.K.) and El H. Bourarach (Morocco) representing the research sector and by P. Celli (Italy), H. Weiste (Germany) and M. Hodge (U.K.) representing the viewpoint of agricultural machinery manufacturers.

The views expressed in the papers reflected the different soil and climatic conditions that characterize each speaker's region of origin. In the opening presentation L. Cavazza discussed the wide range of soil tillage systems ranging from complex multi-pass systems based on deep soil inversion to minimum or zero tillage and direct seeding systems. He concluded that with such a wide range of mechanized tillage options and their crucial interaction with agronomic, soil, topographic, climatic and economic factors it was not possible to identify a single "best" system. Farmers or operators decisions on the best method to use would be based on their knowledge of these factors (perhaps through expert systems) and on local circumstances at the time and would always be strongly influenced by their own experience. Some reduced tillage systems are useful in erosion control and in improving stable soil structure although under some conditions a negative effect of low germination can occur as a result of poor drainage and low soil surface temperatures. He indicated that recent evidence suggests that there has been a worldwide increase in the area of land prepared using minimum or zero tillage techniques. Future trends will be influenced by developments in genetically modified plants and chemical weed and pest control methods that reduce environmental pollution to more acceptable levels. However the most important criteria for the farmer in selecting the most appropriate tillage system will continue to be labour and equipment costs, as well as the agronomic, soil, climatic and other factors already mentioned. In heavy clay soils traditional use of the plough may well continue to be the preferred option. In the context of environmental protection public administrators are increasingly interested in possible interventions to encourage the use of those tillage systems that are beneficial to the environment. Although some of the alternatives to conventional ploughing can have benefits in terms of run-off, soil erosion and watercourse pollution restrictive public intervention will be difficult until our knowledge of the processes involved is improved.

H.J. Heege addressed a number of the underlying reasons for cultivating. In particular he discussed the need to adjust soil bulk density and soil particle size and distribution for efficient plant growth; weed control and crop residue management options and the problems of straw residue in seeding operations. He indicated that there were more than adequate options in tillage techniques available for any given weather condition but that there was considerable room for improvement in the precision of weather forecasting to enable operators to select the appropriate implements and methods for the weather conditions. There would be further reductions in the use of the plough for mechanical weed control due to advances in herbicides and genetic engineering. There was a need for greater understanding of the relative merits of PTO driven and other tined implements in achieving appropriate soil bulk density and particle distribution and in improving energy efficiency with lower tractor wheel slip. Reduced acceleration of soil particles to lessen particle separation in the case of mounted PTO driven tools also needed to be understood better. Techniques for handling straw residues left on the soil from the previous crop were already available including improved seeder designs, methods for lifting the straw from the soil during the seeding operation and improved straw shredders.

W.C.T. Chamen emphasized the importance of reducing the unit cost of production whilst minimizing the environmental impact of cultivation. He stressed the importance of reducing compaction and energy inputs and of adopting a system approach. Soil compaction creates waste in terms of unnecessary energy inputs, inefficient water use, crop yield depression and causes soil erosion, organic matter loss and the production of greenhouse gases. Modifications to existing tillage systems such as reducing depth of ploughing, increasing the implement working width, selecting more appropriate tyres and tyre pressures or adopting zero tillage where feasible may help. However he strongly favoured consideration of the permanent separation of cropped and wheeled areas through controlled traffic systems based on gantry tractors as the most cost effective and practical way of addressing compaction and environmental impacts whilst reducing the level of inputs. The development of appropriate knowledge-based decision support systems for farmers and operators was also considered to have considerable potential.

Finally El. H. Bourarach in a review of current tillage equipment and systems also considered that future development of decision support systems for users will be more important than new designs of implements. His paper described the wide range of currently available implements, their design parameters and methods of use and adjustment, effects of wear and tear on performance and highlighted the need for standardization in terminology in order to enhance the dissemination and application of research results. The main factors to consider are: type of tool, hitch type, type of action (passive or active), operative mode, soil engaging components, angle of installation of engaging components and their arrangement etc. Research on the effects of mechanical condition of implements and on the degree of wear of soil working components and their influence on the quality of work should be encouraged.

The three speakers representing implement manufacturers, P. Celli, M. Hodge and H. Weiste described some of the technical advantages and commercial difficulties of introducing innovative new technologies in soil tillage. Examples given included the press roll and its use in conjunction with disc harrows, the PTO driven spading machine and the combination of tillage implements and pneumatic seeders. The speakers expressed their willingness to develop any technology proposed by the research sector although innovation alone was not enough for a company to be successful today. In fact, for commercial success it was important to analyze all aspects of design, manufacture, distribution and marketing before launching a new product. The need for closer cooperation between companies within the manufacturing industry as well as between the industry and public sector research institutions was stressed.

Wide-ranging discussion followed by presentations and participants concluded that in this important but complex area of soil tillage systems and equipment there were no simple universal solutions. They recommended that every effort be made to improve integrated, multidisciplinary exchanges between researchers and between the research sector and the equipment manufacturers to define more clearly the options available to farmers for specific climatic and soil conditions. Particular importance was attached to assisting farmers to reduce the costs of production in the face of declining crop prices and in reducing soil compaction and environmental pollution. The potential benefits of improving the availability of information and designing advanced decision support software and control systems (including the use of GPS and GIS) for tillage operations in particular and precision agriculture in general was highlighted. The participants also recognized the gap existing between developed and developing countries particularly in respect of the availability of information on improved tillage systems. They emphasized the need for more widespread dissemination of information to developing countries and for practical field demonstration campaigns to be organized. In some circumstances introduction of government policies to promote more frequent replacement of outdated tillage equipment would be appropriate and would encourage introduction of more advanced tillage systems to the benefit of farmers and the manufacturers.

2. Official Testing and Evaluation of Tractors and Implements: a tool to assist farmers in assessing performance, safety and environmental protection

Keynote reports on this topic were presented by H. Takahashi (Japan), H.H. Bertram (Germany) and S. Liberatori (Italy). The subject was chosen in the light of recent developments in this sector in Europe. The aim was to identify a common approach to the development of testing and evaluation facilities for tractors and machinery in a period characterized by increasing market globalization.

All the speakers agreed on the importance of certification. H. Takahashi discussed the formal testing of tractors as carried out in Japan whilst H.H. Bertram and S. Liberatori covered the testing of agricultural implements in Europe. To date testing of agricultural implements and equipment other than tractors has only been undertaken in some countries and only on a voluntary basis with the results only being valid in the country where the tests were carried out. This is not the case for tractors, which are tested under standardized procedures agreed both nationally and internationally through hte OECD. The recent successful initiative to set up a European Network of Agricultural (ENTAM) implement and machinery testing centres was described. Currently the 7 countries involved have decided to harmonize their standard testing procedures for various machines and components in order to assure mutual recognition of their national certifications. In this way the certifications acquire international validity for all the countries belonging to the network.

The tests carried out concentrate on the performance, safety and durability of each machine as well as providing an assessment of the environmental impact of its use. This information is also of great interest to manufacturers, who on the basis of the test results obtained have the opportunity of improving their products both technically, functionally and from the safety and environmental point of view.

After in depth discussions, the participants stressed the importance of carrying out tests on implements and machinery as well as on tractors, in order to provide farmers and contractors with a clear, impartial comparative assessment of each machine's performance, to assist in purchase decisions. Furthermore, in view of the progressive globalization of markets, the participants recommended that every effort be made to extend the Network of testing and certification centres for agricultural machinery, both within Europe and in other continents, following the footsteps of the OECD experience for tractors. Given the importance of the issue, the participants decided to regularly review progress of this initiative. The Club's Technical Secretariat was assigned the task of actively monitoring the development of the sector and preparing annual progress reports to be presented at future Club meetings. This would also facilitate the preparation of a policy document for the promotion of this important activity and assist the authorities in countries considering joining the Network to quickly take the appropriate decisions and actions.

3. Indian Tractor Industry

This preliminary presentation by G. Singh gave a brief analysis of the present situation in the Indian tractor manufacturing industry and the impressive progress achieved in the last 30 years. The situation is continuing to change rapidly and at present almost 15 factories are producing tractors some through joint ventures with well established manufacturers from other countries. This interesting report convinced the participants that the subject of tractor manufacture in Asia and the Far East should be discussed in greater depth at the meeting of the Club next year.

UNACOMA presentaiton of the results of the agricultural mechanization, gardening and earth moving market in 1998

This was a record year for production and exports for the Italian agricultural machinery and earth moving industry. The agricultural sector, which includes gardening, rose 3% over 1997 to reach 919 000 tons with a value of 11.86 trillion lire (six billion, 125 million euros) for an increase of 2% over 1997. The earth moving sector gained 2.5% over '97, up to 492000 tons, for a value of 4.4 trillion lire (two billion, 272 million euros), an increase of 3% over the previous year. The sales data were presented by Aproniano Tassinari, the President of Unione Nazionale Costruttor; Macchine Agricole (UNACOMA), the association which represents the industries in this sector and a member of the Confindustria employers association. The figures showed growth on the internal market and a sustained increase in exports. The foreign markets took up 62% of the national production of agricultural machinery to bring in a trade surplus of 5.1 trillion lire (two billion, 634 million euros), and exports of earth moving machinery accounted for 86% of total production for a trade surplus of 1.685 trillion lire (about 870 million euros).

A look at the trends for the single compartments on the internal market disclosed an increase in tractor sales with 31 300 units sold compared to 29 000 units in '97, and a gain in agricultural machinery, indications provided by registrations (Transport Ministry data) show grow growth of 13.8% for tractors well as for combine harvesters, up 15%, trailers, ahead 4%, and a drop of 12.5% in self-powered farm machinery.

With 15 760 units sold, the earth moving sector rose 14%, over '97, with an upwards trend for the traditional lines, mini-excavators and skidloaders, and a decline for back-hoe loaders. During the conference, President Tassinari also provided a general picture of mechanization in Italy. According to the yearbook of statistics completed by UNACOMA on registration data provided by MIPA and the regions, there were a total of 1 553 673 tractors in use in Italy at the end of 1996 with average hose power of 56.80 on a total of 8 900 000 ha of croplands. The national average of these figures is one tractor for every 5.73 ha, with power equal to 10 hp/ha, but the differences between the regions still appears significant. We have in the north the occurrence of one tractor per 3.91 ha where in southern Italy and on the islands the ratio is one tractor for every 9.55 ha and power according to land surface which comes to less than half that in the northern regions.

The amount of financing used is still low in the government incentive program aimed at encouraging the trade-in of old machinery for further the process of the technological renewal of machinery to boost safety, ergonomic features and compatibility with the environment. In the first eight months of application of the law, only 18 billion lire have been paid out of 100 billion allocated for the two-year period 1998-99.

The outlook for the trend in the sector in the present year must take account of economic conditions at the world level and the economic, social and political and weather variables which have impact on agriculture. Tassinari said, "Stabilization measures applied by the government, with the involvement of international organizations, may produce positive effects but the continuing decline especially in intermediate and capital goods in many countries is likely to continue". On the basis of data now available, it appears that the European market will hold out well enough in '99 and that the national market will remain stable, especially for equipment, while a decline can be expected in the North and South American markets and there could be recovery in the markets of the Far East and North Africa.

In the near future, the industry in this sector will have to work in a framework of greater stability but one which is also more competitive, as dictated by the European single currency. Among other things, these industries will have to come to terms with important transformations in the sales and distribution system. "The figure of the importer is radically changed whereas the distributor will become more professional so as to become somewhat of a partner with the manufacturer", Tassinari said. On the issue of distribution, UNACOMA, has announced a study project aimed at shedding a light on the future of this system.

The association will be on hand in European and international quarters to help define the norms on the road circulation and the safety of agricultural machinery on the job. In the area of activities for the promotion of the national industry, important initiatives have been announced in cooperation with the Foreign Ministry and ICE (the Foreign Trade Institute) and field trials will be held for the first time in Sicily with EIMA IN THE FIELD scheduled for May. Then, the 30th edition of EIMA will be held from November 13 to 17, a great specialized review organized in cooperation with the Bologna Trade Fair. The edition marketing the 30th anniversary will include international initiatives and conferences and highlight how the events in Bologna encompass now only technical and business features but range to cultural exchanges between farmers, technicians and institutional representatives.

Precision Farming in Focus at Agritechnica '99

A Key topic in focus at the next Agritechnica '99, to be held from 9 to 13 November 1999 in Hanover, will be the subject "Precision Farming". With scientific support from Prof. Dr. Hermann Auernhammer of the Technical University Munich in Freising-Weihenstephan, the organizer, German Agricultural Society (Deutsche Landwirtschafts-Gesellschaft, DLG), is setting up an Agritechnica "special" on this topic. In doing so, the DLG is catering to the great interest shown by farmers in this theme. In the Agritechnica special "Precision Farming", the latest techniques and services for exploiting in full the yield potential at every point of a field and for avoiding spreading of superfluous quantities of fertilizer and plant protection agents will be shown. The objective is to provide the farmer visitors with a swift and comprehensive overview of the complex technology of precision farming at a central location in the exhibition grounds. The Agritechnica special plans to show and illustrate the entire information circuit. Where and how are the necessary data measured? How do they have to be edited so that the farmer can use them for important decisions?

However, the "Precision Farming" special intends to show not only the technology required. In addition to the agricultural machinery components, such as e.g. machines for harvesting, fertilizing and plant protection, the necessary information-specific components such as GPS sensors, yield measuring systems and yield and fertilizer maps on the basis of geographical information systems or techniques for remote sensing and soil sampling are to be presented. Information packages providing various forms of access to this technology (on-farm investments/services) will also be shown. Discussion forums on economic and ecological aspects, as well as on the strength and weaknesses of the entire technology will round off the new Agritechnica special "Precision Farming".

Further information on the Agritechnica special "Precision Farming" is available from the Deutsche Landwirtschafts-Gesellschaft (DLG), Eschborner Landstr. 122, D-60489 Frankfurt am Main, Tel. ++(0) 69/24788-301, Fax. ++(0) 69/24788-114 or from Mr. Hans Peter Römer, Institut für Landtechnik, Am Staudengarten 2, D-85350 Freising, Tel. --(0) 8161/71-3447, Fax. ++(0) 8161/71-3895 or e-mail: H.P.Roemer@DLG-Frankfurt.de.

Why Was ALIA Created?

Tomaz Caetano Cannavam Ripoli[1]

The ALIA-Associacion Latinoamericana y del Caribe de Ingenieria Agricola (the Association of Latin American and Caribbean Agricultural Engineers) was created in 1994, in the city of Chillan, Chile by a group of 84 researchers from 12 Latin American and Caribbean countries. The Association's two main objectives are: 1) to be the center for which researchers in the area of Agricultural Engineering can exchange experiences and knowledge in a faster and more organized way and 2) to act more closely with agricultural products to activate technology transfers; to increase agricultural productivity; and to reduce costs through solutions offered by Agricultural Engineering.

The pretense of ALIA is justified by the fact that the region has suffered a decrease in teh quality of its citizens' lives over the past decades, due in part to the increased prices of agricultural products.

By January of 1999 ALIA had expanded to 194 members from 17 countries and in its short existence it already conducted two scientific congresses (in 1996, in Brazil, with 563 participants and 524 published works and in 1998, in Argentina, with 436 participants and 324 published works).

In addition, to meet the second main objective of ALIA, the association held four other regional seminars in Brazil, specifically with small- and medium-scale farmers, reaching 1 356 participants. It also promoted four technical trips to the USA, where 211 medium- and large-scale farmers visited fairs and industries of agricultural machinery and high technology farms.

The next scientific congress of ALIA will occur in the year 2000, in Mexico under the coordination of ALIA's current President, Agricultural Engineer Manoel Cabrera Xisto (e. mail: cabreraj@dulcinea.ugto.mex).

[1]ALIA's past President; ALIA's Regional Director for Brazil; Full Professor of University of São Paulo and CIGR's Executive Board. (e. mail: tcripoli@carpa.ciagri.usp.br)

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For more information about the new Alligator® Rivet round baler belt fastener, contact the Customer Services Department, Flexco, 2525 Wisconsin Ave., Downers Grove, Ill. 60515-4200. Tel: (630) 971-0150, Fax: (630) 971-1180 / Website: www.flexco.com. For free literature only, call the Flexco Literature Hotline at 1-800-872-5216.

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(Thailand)

Editors: V.M. Saloke and Zhang Jianxia

The International Agricultural Engineering Conference was organized at the Asian Institute of Technology, Bangkok, Thailand from 7-10 December 1998. The objective of this conference was to bring together scientists, engineers, researchers and experts in various disciplines of agricultural engineering for formal presentation and discussion on the topics of relevance in the coming years.

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The proceedings are available for sale. The cost of one set of proceedings (2 volumes) is US$180 (inclusive of air mailing charges). The orders can be placed, with a payment by bank draft or cheque payable to "Asian Institute of Technology", with:

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b. are relevant to the promotion of agricultural mechanization, particularly for the developing countries ;
c. have not been previously published elsewhere, or, if previously published are supported by a copyright permission ;
d. deal with practical and adoptable innovations by small farmers with a minimum of complicated formulas, theories and schematic diagrams ;
e. have a 50 to 100-word abstract, preferably preceding the main body of the article ;
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h. Express measurements in the metric system and crop yields in metric tons per hectare (t/ha) and smaller units in kilogram or gram (kg/plot or g/row).
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j. Convert national currencies in US dollars and use the later consistently.
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l. When numbers must start a sentence, such numbers must be written in words, e.g., Forty-five workers..., or Five tractors..." instead of 45 workers..., or, 5 tractors.

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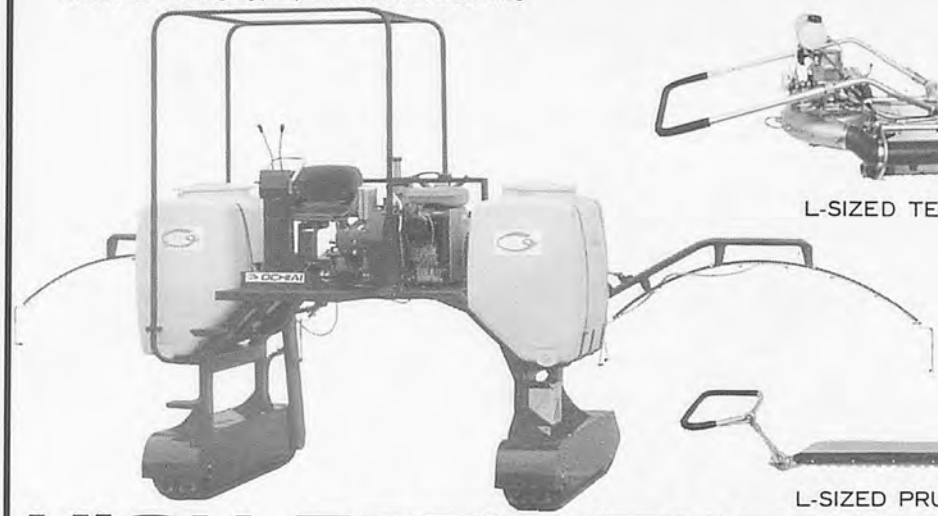

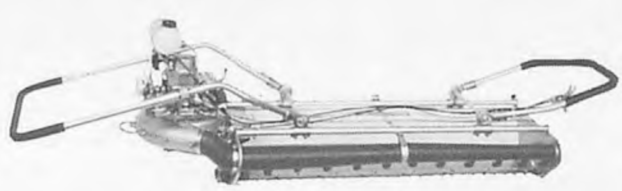

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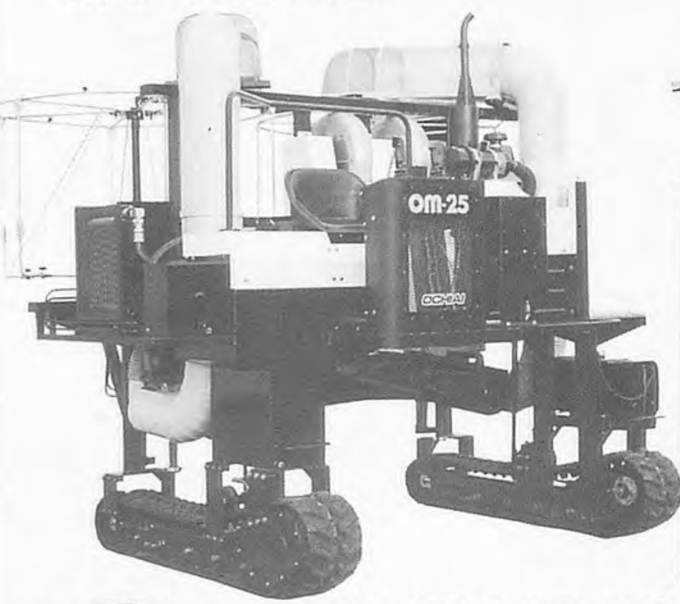

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