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Research Paper

Survey of Riding Tractor Operating Comfort in Nueva Ecija, Philippines

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聞きとり調査によるフィリピンの水田地帯での乗用トラクタの操作性評価

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1. Introduction

In consonance with the present administration's guiding vision and philosophy that is aimed towards the transformation of the Philippine's smallholder agriculture sector into modern technology- and science-based, particular attention should be focused, not only on agricultural productivity, but also on the welfare of the ever neglected farm labor. The 2002 data on average labor utilization for different farm operations in the Philippines indicated that about 2.2, 4.82 and 3.51 man-days per hectare are utilized for seedbed preparation, plowing, and harrowing, respectively (Philippine Rice Research Institute-Bureau of Agricultural Statistics, 2004). These represent 3.4, 7.5 and 5.5% of the total labor requirement for a hectare of rice land. Moreover, hauling consumes 2.0 man-days or 3.1% of the total labor requirements (PhilRice-BAS, 2004). The pursuit of these activities are increasingly being aided by the proliferation and widespread use of agricultural machines—more specifically, the agricultural tractors. This is much more emphasized in the Province of Nueva Ecija, the largest of the seven (7) provinces of Central Luzon and has some of the most productive agricultural lands, not to mention the home of a projected 2000 population of 1.65 Million people (Provincial Trade and Industry Office, 2002 ; Libosada, 2003).

Any and all information related to the farm tractor operators are important because farm tractor operators represent a grossly disregarded but highly influential farm labor group in terms of agricultural productivity. Moreover, due to the low turnover in this farm labor group, many of these individuals either remain in the same profession for a considerable span of time, or belong to the same family which had been doing the same kind of work for generations, and thus have similar genetic make-up. The role and welfare of this labor group is

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a crucial issue that designers of agricultural machineries must confront.

In consideration of the above, this study was undertaken to complement the previous researches on walking and riding tractor conducted in Japan by the authors (Sicat, J.C.V. *et al.,* 1999, 2001, Mitarai, M. *et al.,* 2005, Kinoshita, O. *et al.,* 2007). The data presented here will eventually benefit the riding tractor design engineers who have special interest on ergonomics or human factors engineering. This report relied on data collected throughout the Science City of Muñoz in the province of Nueva Ecija, Philippines in 2001–2003 and described the current riding tractor operators' population in that area.

2. Methods

1) Survey Area

The survey was conducted in the Science City of Muñoz in the province of Nueva Ecija, Philippines'. Muñoz is situated 147 kilometers north of Manila. It is traversed by a national road going to Cagayan Valley, and by a secondary national road going to the town of Lupao towards the province of Pangasinan and other areas of Region 1 and the Cordillera Administrative Region (Science City of Muñoz, 2003). The Science City of Muñoz has a total land area of 15,778.59 hectares (approximately 158 square kilometers) and is subdivided into 37 political units or barangays. It is a third class city with annual local government budget of 182 million pesos. Of the 65,586 population of the Science City of Muñoz in 2003, more than 63% live in the rural areas (City Planning and Development Office, 2003).

2) Survey Method

The survey was conducted using sites' area sampling to obtain an evenly distributed representative group of 76 riding tractor operators. A sample of 2 to 3 riding tractor operators in each of the city's agricultural barangays was selected based on their activity status.

The survey questions and necessary input were guided by the survey questionnaire. This questionnaire was developed solely for the purpose of this research. All of the physical measurements needed were done on site by the interviewer teams which were properly equipped and previously trained on the proper measurement methods based on those described by the Japan National Institute of Bioscience and Human Technology (Kouchi, M. *et al.,* 1994).

3. Results and Discussion

1) Demographics

The survey indicated that 75% of the riding tractor operators are married. Furthermore, average age was 36.7 years with a standard deviation (SD) of 11.7. The age group with most number was the 43 year-old group with an occurrence rate (OR) of 6.6% among the operators surveyed. Height and weight averaged 165.7 cm (SD＝6.8) and 62.8 kg (SD＝10.4), respectively. The most common operator height and operator weight are 165 cm (OR＝19.7%) and 65 kg (OR＝9.2%), respectively (Table 1).

The physical measurements of the existing riding tractor operators were likewise determined to have averages of 43.8, 39.0, 38.9, 29.5 and 26.3 cm for the shoulder width, thigh, leg, arm and forearm lengths, respectively. The vertical distance of the ankle from the sole of the foot is 7.2 cm. The average foot measured 25.1 cm long and 10.1 cm wide. Palm length and palm breadth were 10.3 and 8.6 cm, respectively.

The left hand of the operators had average measurements of 6.3, 6.9, 7.8, 7.1 and 5.7 cm for the thumb, index, middle, ring, and small fingers, respectively. Meanwhile, the right hand had average measurements of 6.2, 6.9, 7.7, 7.1 and 5.7 cm for the thumb, index, middle, ring, and small fingers, respectively.

Average experience in riding tractor operation was 3.3 years (SD＝5). However, 40.8% of the respondents had only one-year experience. This indirectly implied the recent boom in the

Table 1 Body specifications of the riding tractor operators

	RIDING TRACTOR OPERATORS						
	Min	Max	Median	Mode	MF	SD	Mean
Age (year)	19	64	35	43	6.6	11.7	36.7
Height (cm)	136	183	165	165	19.7	6.8	165.7
Weight (kg)	42	95	63	65	9.2	10.4	62.8
BODY DIMENSION (cm)							
Shoulder width	35.0	50.0	44.0	46.0	14.5	3.2	43.8
Leg length	34.0	46.0	39.0	40.0	18.4	2.7	38.9
Thigh length	34.0	50.0	38.0	38.0	21.1	3.2	39.0
Ankle to sole	6.0	8.0	7.0	7.0	77.6	0.4	7.2
Foot length	21.0	32.5	25.0	25.0	26.3	1.8	25.1
Foot breadth	6.6	11.4	10.2	10.3	5.3	0.7	10.1
Arm	23.0	37.0	30.0	31.0	21.1	2.9	29.5
Forearm	22.0	37.0	26.0	27.0	21.1	2.5	26.3
Palm length	9.1	11.9	10.4	10.6	5.3	0.6	10.3
Palm breadth	7.2	9.5	8.7	8.3	3.9	0.5	8.6
LENGTH OF LEFT HAND FINGERS (cm)							
Thumb	5.5	7.2	6.3	6.3	3.9	0.4	6.3
Index finger	6.0	7.9	6.9	6.6	6.6	0.4	6.9
Middle finger	6.8	9.1	7.8	8.0	5.3	0.4	7.8
Ring finger	5.9	8.2	7.1	7.3	3.9	0.4	7.1
Small finger	5.0	6.8	5.7	5.1	7.9	0.4	5.7
LENGTH OF RIGHT HAND FINGERS (cm)							
Thumb	5.3	7.1	6.2	6.4	3.9	0.4	6.2
Index finger	5.9	7.7	6.9	6.9	2.6	0.4	6.9
Middle finger	6.6	9.0	7.8	7.8	5.3	0.5	7.7
Ring finger	6.0	8.1	7.1	7.6	3.9	0.4	7.1
Small finger	4.9	6.7	5.7	5.5	3.9	0.4	5.7

MF-frequency of the mode
SD-standard deviation

use of 4-wheel tractors in the Philippines that could be due to the liberalization of the procedures for importation of affordable but second hand agricultural machines.

2) Tractor Specifications

The most widely used riding tractor size is the 11 kW power unit (26.3%) although the overall average engine size is 16.6 kW (SD=9.26) (Fig. 1). The most widely used tractor brands were the Kubota and Iseki riding tractors which account for 63.2% and 21.1% of the total units surveyed, respectively. Furthermore, the L1500 and the L2000 models were the most numerous, representing 35.4% and 20.8% of the Kubota riding tractors, respectively.

Fig. 1 Typical riding tractor in the Philippines

3) Working Conditions

Analysis of the survey results also showed that only 1.4% of the operators had an alter-

nate operator. A clear majority did all the tractor operations by themselves. Likewise, riding tractor operation was mainly concentrated on primary tillage operation with 100% of the operators surveyed having experienced such kind of work. Only 24.3% did secondary tillage using riding tractors. This clearly showed the Filipino farmers', or at the very least the Science City of Muñoz farmers', preference for using walking tractors in secondary tillage operations.

4) Problems Encountered

The problems encountered by the riding tractor operators were initially grouped into the following classifications : engine related, chassis based component related, wheel related, implement related, and others. Majority of the problems were engine and chassis based component related which comprise 30% and 39% of the operator responses, respectively (Fig. 2). Meanwhile, 5%, 22% and 4% of the responses were problems related to wheel, implement and others, respectively.

(1) Engine Related Problems

With respect to the engine related problems, excessive engine generated heat was the foremost problem encountered by the riding tractor operators. A total of 86.8% of the respondents mentioned having experienced excessive engine heat convection to the operators' feet and legs (Fig. 3). The operators had expressed concern over the effect of such unwanted heat on their long-term health condition. Excessive noise and the need to improve the engine cooling system both comprised 10% of the total engine related problems enumerated by the operators. The operators also found a need to bring down the noise intensity generated by the tractor engines to a level that is tolerable to the human ears. Likewise, they pointed out that increasing the radiator size and cooling fan blades could help bring down the engine temperature that apparently presented a hazard particularly to the operators' feet and legs. Meanwhile, 10.5% of the respondents mentioned were concerned with the breaking of the exhaust pipe near or at the base. In the operators' opinion, this was partially caused by the engine vibration coupled by weak material used in the fabrication of the exhaust pipe. The remaining problems that made up this category were broken engine parts and problems with high fuel consumption that comprised 15% and 1%, respectively.

(2) Chassis Based Component Problems

More than half of the responses (59.2%) expressed a need for operator cover or some sort of protection against heat and sunlight. Majority of these responses directly requested for tractor roof/cover while the rest mentioned the need for a whole cabin, heat-insulating ma-

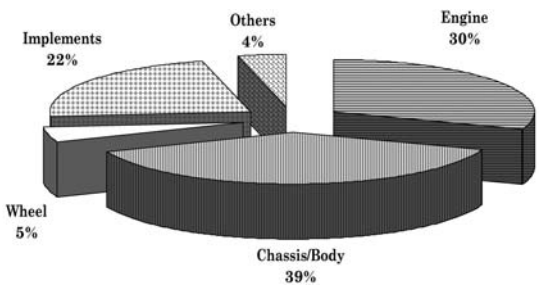

Fig. 2　Relative distribution of the problems encountered by the riding tractor operators

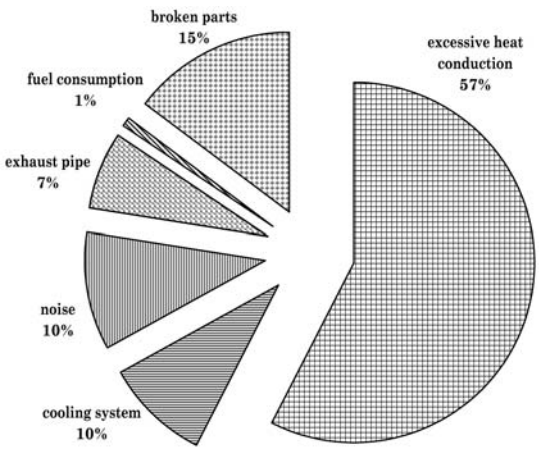

Fig. 3　Distribution of the engine related problems

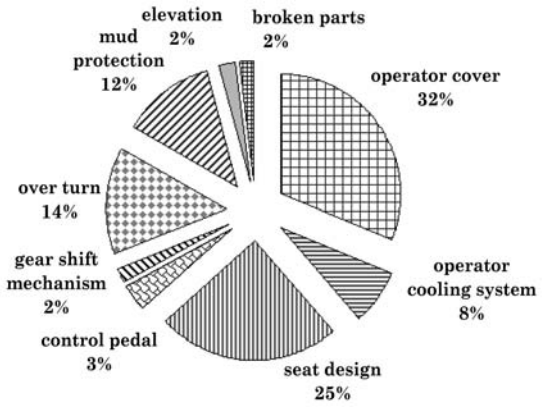

Fig. 4 Distribution of the chassis related problems

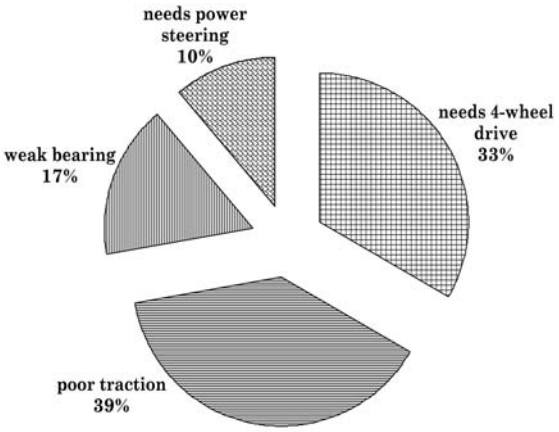

Fig. 5 Distribution of the wheel related problems

terial for the roof and sturdier roof posts. Overall, the need for operator cover was the most widely mentioned problem within this category. It comprised 32% of the total chassis based component related problems that were mentioned (Fig. 4).

Coming in at second was the need for a new seat design that garnered 25% of the responses in this category. The respondents mentioned the need for adjustable seat position, higher backrest, softer cushion and provision for shock absorption. Concerns for tractor overturning due to insufficient counter weights and wheel base widths, and problems regarding insufficient protection from mud comprise the remaining bulk of the responses. Sporadic responses regarding control pedal design, gearshift position, chassis elevation and broken parts comprised the rest of the chassis related responses.

(3) Wheel Related Problems

Wheel related problems were also enumerated during the survey. A clear majority of these comments were related to poor conveyance on the field. The bulk of the responses (39%) in this category mentioned the need for incorporating the cage wheel design or a similar attachment to the rubber wheels in order to increase the traction capability (Fig. 5).

The operators noted that the riding tractors available in the field had encountered difficulties in moving efficiently over wet, muddy fields. This observation was even bolstered by 33% of the comments in this category that further noted the need for a 4-wheel drive capability. The rest of the comments just mentioned the poor durability of the wheel bearings and the need for a power steering system.

(4) Implement Related Problems

Implement related problems could be broken down into two major categories : workmanship and design. More than three quarters (76%) of the implement related comments delved on poor workmanship/durability of the implement. This represented 85.5% of the total riding tractor operator-respondents. The respondents noted worn implement parts such as the gear and chains of the rotor drive, oil seal and drive axle. Alleged excessive wear of the rotor blades, bearings, and cross-joints were also mentioned. Meanwhile, 20% of the total responses in this category cited the operators' desired design modifications such as the provision for a depth control gauge and an increased effective width of the implement. Interestingly, the operators find it difficult to control the depth of cut of the rotary tillers attached to the riding tractor. On the other hand, the effective width of the rotary tillers was mainly dependent on the

source of power or the engine size. The rest of the comments that comprised the remaining 4% reflected operator's preference for the traditional disc type tillers, and a desire to have auxiliary use for the rotating shaft of the tillers, such as battery charging capability.

(5) Other Problems

As mentioned earlier, 4% of the problems enumerated by the riding tractor operators could be classified into the previous four groupings and thus enumerated in this section. Around 26% and 20% were related to the need for an adjustable side mirror and the desired availability of additional lighting systems, respectively (Fig. 6).

Apparently, the provision of a well situated and adjustable side mirror could relieve stress on the operator by reducing the need to bend and look at the back and sides of the tractor while operating in a backward motion. Likewise, the provision of additional lighting could reduce the risks of operating the tractor at night, specially since most operators sometimes work on the field way past sunset. The other sporadic comments included problems regarding spare parts availability, relatively slow forward speed, and the need for a windshield. Comments regarding a relative inadequacy of the tractor size, a need for a sound system, and a need for multipurpose use likewise surfaced during the conduct of the survey.

(6) Across Classifications

Looking at all the enumerated problems from the macro level, the problems mentioned by the riding tractor operators were top billed by excessive engine heat conduction, problems with implement workmanship/durability, and the need for operator cover/protection from unfavorable weather with 86.8%, 85.5%, and 59.2% of the operators mentioning such problems, respectively.

The need for a better seat design came fourth over-all with the backing of 47.4% of the survey respondents (Fig. 7).

As a final analysis of the data, all the ergonomic related problems enumerated during the survey were extracted and tabulated for comparison. It turned out that 31% of all the ergonomic related problems pertained to excessive engine heat convection.

A total of 66 operators or 86.8% of the total respondents had mentioned excessive engine heat convection as a potential health problem particularly for the operators' feet and legs. Ranking second in terms of operator concern was the need for operator cover/protection from unfavorable weather with 59.2% of the operators mentioning such problems. The third most popular ergonomic related problem was

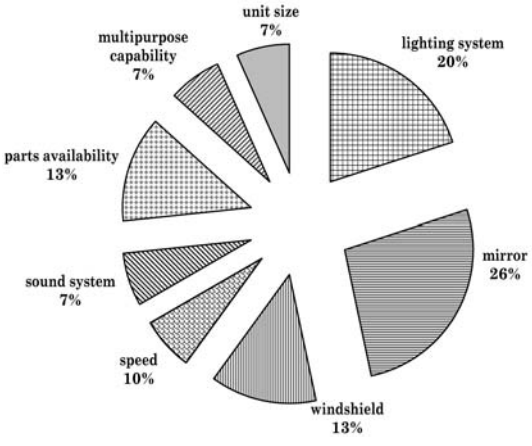

Fig. 6　Distribution of other problems related to riding tractor operation

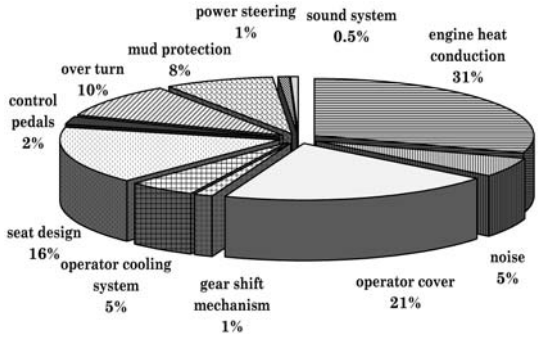

Fig. 7　Distribution of the ergonomic related problems encountered by the riding tractor operators

the apparent need for a better seat design. This concern comprised 16% of the ergonomic related comments that were tabulated. The other ergonomic related concerns that came up during the survey were the problems regarding overturning, mud protection, operator cooling system, excessive noise, control pedal design, gear shift mechanism location, provision for power steering and recreational sound system.

Summary

The body measurements of 76 riding tractor operators as well as the mechanical problems and operating comfort associated with their profession were investigated at the Science City of Muñoz, Nueva Ecija, Philippines in 2001–2003. As a result, the characteristic and detailed body measurements of the typical riding tractor operator in the aforementioned area in the Philippines was established. The study likewise revealed that 100% of the riding tractor operators were male with an average riding tractor operation experience of 3.3 years. The most widely used riding tractor brands were the Kubota and Iseki tractors which accounted for 63.2% and 21.1% of the total units surveyed. The average engine size was 16.6 kW. The most prevalent problems mentioned by the riding tractor operators were excessive engine heat conduction, implement workmanship/durability and the need for operator cover with 86.8%, 85.5% and 59.2% ratings, respectively. Ergonomic related problems were top billed by excessive engine heat convection (86.8%), need for operator cover/protection from unfavorable weather (59.2%), and better seat design (47.4%).

Key Words

Riding tractor, operators, operator comfort, Philippines, survey, ergonomic

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要　旨

フィリピンの乗用トラクタ作業における人間工学的な諸問題についてオペレータ 76 名から直接聞き取り調査を行った．また，乗用トラクタの設計要素を人間工学的に検討するための基礎資料としてオペレータの身体計測を同時に行った．調査

はフィリピンの水田農業地帯であるヌエバ・エシハ・ムニョスで 2001–2003 年に実施した．その結果，乗用トラクタのオペレータは男性が 100% を占め，使用している乗用トラクタの出力は平均 16.55 kW（SD＝9.26）で，クボタ（63.2%），イセキ（21.1%）が多く，運転経験年数は平均 3.3 年（SD＝5）であった．また，乗用トラクタにおける問題点としては作業機の製作技術と耐久性（85.5%）が上げられ，人間工学的な問題としては運転席への強いエンジン熱放射（86.8%），過酷な太陽光からオペレータを守るための保護カバーの必要性（59.2%），座席設計（47.4%）等であることが明らかになった．

キーワード

乗用トラクタ，運転者，快適性，フィリピン，調査，人間工学