



REVIEW ARTICLE

PERFORMANCE EVALUATION OF THE EXISTING YUKATO BRAND MINI POWER TILLERS IN BHUTAN

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ABSTRACT

Agriculture remains one of the main backbones of live hood and economy in every country, and therefore it is vital to make it a sustainable practice. One of the ways is by making availability farm machinery which are labor-saving technology that could help to reduce drudgery in the farming community. However, it is also very crucial to consider that the machines are safe and efficient for use especially for a country like Bhutan where agriculture lands are of smaller sizes and lying on rugged terrain. Five different types of Yukato Mini power tiller brands were evaluated for their performance in terms of engine power reduction, sound level, vibration level, and field capacity in context to Bhutanese agricultural field. The highest engine power reduction of 38.02 ± 0.86 % was recorded for engine model BS270 of YKT 110G model and lowest of 19.87 ± 2.31 for BS418 of YKT 140D mini tiller model. It can also be noted that the percentage of engine power reductions recorded are highest for engine driven by petrol compared to the engine driven by diesel. The highest vibration and sound level recorded are 10.12 ± 0.40 m/s² and 90.81 ± 0.26 dB(A) for UGT YUVA 7P and YKT 100G models respectively. In addition to the parameters above, fuel consumption for each of the machines were measured with YKT 140D as the most fuel efficient of 5.62 ± 1.43 l/day. Based on the performance ranking, mini power tiller model YKT110D is recommended to be the best among all the models. However, since this study didn't consider all other types of machine models, it is recommended to evaluate all types of existing models to recommend the most feasible and suitable machine for the agriculture land of Bhutan.

KEYWORDS

Mini Power Tiller; Engine Power; Vibration level; Sound level; Field Capacity; Fuel Consumption

1. INTRODUCTION

Bhutan remains predominantly an agrarian society, with 43.5% of its population employed in the agricultural sector. A substantial proportion of these workers, 65.3%, reside in rural areas. Interestingly, the sector sees higher female participation, with women making up 52.3% of the workforce compared to 37.3% for men (NSB, 2023). Agriculture in Bhutan has undergone significant transformation over the years. A decade ago, most farming was done on a subsistence level. However, with improved road networks and transportation, many farms have shifted towards commercial agriculture. Traditional methods, such as using oxen for ploughing, are being replaced by modern technologies like two- or four-wheel power tillers.

The shortage of labor in rural areas is one of the driving factors behind this transition to mechanization. In the past, traditional farming relied heavily on manual labor, but with fewer workers available, particularly as rural-to-urban migration increases, farmers are increasingly opting for modern tools. Improved market access has also motivated farmers to adopt mechanization, as they seek to boost production and shift from subsistence farming to a more entrepreneurial approach, which is now becoming more common in Bhutan (Dendup, 2018).

Despite these advancements, labor shortages remain a major challenge to agricultural modernization (Kantchede et al., 2022). However, Bhutan faces additional hurdles due to its challenging geographic conditions. The country's rugged terrain and limited arable land, with average land holdings of just 2.22 acres per household, make large-scale mechanization

difficult (National Statistics Bureau of Bhutan, 2018). Around 49.5% of Bhutan's land has a slope greater than 50%, which is prone to soil erosion and generally unsuitable for farming (Dendup, 2018). Furthermore, the migration of young people from rural areas to cities has added to the strain on agricultural progress, as fewer hands are left to work the land (Pelzom et al., 2017).

Farmers in Bhutan are increasingly using a range of labor-saving machinery, such as power tillers, mini-power tillers, reapers, bed-making machines, farm tractors, and various spraying equipment. Among these, the mini power tiller has become especially popular due to its versatility. It can perform multiple tasks, including tilling, rotavating, and harrowing on small farms, whether in dryland or wetland (Adamu et al., 2014). Additionally, it is more suitable for sloped agricultural landscapes, where other machines may struggle (Faleye et al., 2014; Kantchede et al., 2022). Any power tillers with horsepower less than 10.5 hp are categorized under mini-power tiller (Bhutan Standards, BTS 42, 2019).

As the demand for these machines grows, ensuring their safe and efficient use becomes crucial. The farm equipment provided to farmers must be reliable in both function and feasibility to the local conditions. To guarantee this, it is essential to test machines according to standardized procedures that assess their quality and performance. Thorough testing and evaluation of agricultural equipment will ensure that farmers have access to high-quality machines, which in turn makes farming more efficient and safer. This not only helps to boost agricultural production but also supports the growth of industries related to farming (Ademiluyi et al., 2009; Faleye et al., 2014; Kantchede et al., 2022).

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Thus, the objective of this study was to evaluate the performance of existing Yukato brand mini-power tillers in Bhutan. Yukato brand mini-power tillers are imported from Japan. This performance evaluation among the different models of Yukato brand mini-power tillers shall ensure to serve as a basis to decide best suited Yukato brand mini-power tiller models for Bhutanese agriculture conditions which could be encouraged for import, production and popularization. Additionally, this study shall form the basis for standard specification to be used by the manufacturers and distributors to suit the Bhutanese farmers (IARI, 2010).

2. MATERIALS AND METHODOLOGY

In this study, the performance of five different models of Yukato brand mini-power tillers (Table 1) was evaluated across several key parameters. These parameters included engine power reduction, vibration levels, sound levels, field capacity, and fuel consumption. Each of these factors is critical in assessing the overall efficiency and usability of the machinery. By measuring and analyzing these parameters, the study aimed to comprehensively score the machines, allowing for a performance-based comparison to identify which model offers the best balance of power, efficiency, and operator comfort.

Table 1: Different Models of Yukato Brand Mini-Power Tiller used in the Study

Sl. No	Machine Model	Engine Model	Rated Power (kW)	Rated RPM	Remarks
1	YKT 100G	BS225	4.80	3600	Petrol Engine
2	UGT YUVA 7P	BS21HT	4.84	3600	
3	YKT110G	BS270	6.70	3600	
4	YKT 110D	BS305	5.20	3600	Diesel Engine
5	YKT140D	BS418	6.80	3600	

2.1 Engine Power Reduction

The engine power is one of the most important aspects of farm machines as it determines the performance of machines in the field. The power output substantially varies with the altitude. As the altitude rises, the temperature and atmospheric pressure decrease whereby the internal combustion engines lose performance due to less fuel combustion per cycle (Martínez et al., 2021; Sivasankaran and Jain, 1988). As per the study, the power output of a diesel engine falls at the rate of about 1% for every 100 m altitude (Sivasankaran and Jain, 1988).

The engine power test in this study was carry out using electric dynamometer with data logger and the load transducer inside Agriculture Machinery & Technology Centre (AMTC) laboratory, located at 2,250 masl. The engine power output is computed using the equation (Eq. 1) given below:

$$P = (2\pi NT)/(60 \times 1000) \quad (1)$$

Where P , T , and N are the power in kilowatt (kW), torque in Newton meters (Nm) and the angular speed in rotation per minute (rpm), respectively.

2.2 Vibration Level Measurement

The use of agricultural machinery, particularly those controlled entirely by hand, has led to numerous occupational safety and health concerns for operators. These operators are frequently subjected to elevated levels of noise and vibration, which, over prolonged periods, can result in movement disorders and damage to various parts of the body. This includes hearing loss, spine and gastrointestinal issues, as well as neurological disorders. Continuous exposure to vibrating machinery can also cause ailments affecting the blood vessels, nerves, muscles, and tissues of the hands and arms. The symptoms of these conditions were first identified by Dr. Maurice Raynaud in 1862, leading to the condition being named Raynaud's phenomenon, also known as "white finger". Mini-power tiller operators experience vibration transmitted through the handles to their hands (Ahmadian et al., 2014). Among the agriculture workers, farm machinery drivers were reported to suffer from higher back pain as the spinal movements caused by the vibration were the main reason for the destructive injuries to the body, however actual reasons have not been provided so far (Futatsuka et al., 1998; Wang et al., 2004).

In this study, vibration levels were measured using accelerometers,

VP51LOOP VP-51L/2M by connecting the cables on the handle of the mini-power tiller as it is in direct contact to the operator's body part. The measurement was carried out in normal field operation for all the implements, operated at normal throttle position.

2.3 Sound Level Measurement

The intensity of sound and the length of time an operator is exposed to it are crucial factors, as prolonged exposure to loud noise can gradually lead to hearing loss. This typically occurs over time, often without the operator realizing it until the damage is significant and permanent. The allowable exposure time decreases as the sound intensity increases; higher noise levels require shorter exposure durations to prevent substantial hearing impairment (Table 2). It is therefore recommended to wear protective gears such as ear muffs if duration of exposure exceeds the permissible noise level.

Table 2: Permissible noise exposure

Duration per day, (hours)	8	6	4	3	2	1.50	1	0.50	0.25
Sound Levels, (dBA)	90	92	95	97	100	102	105	110	115

Source: Regulation on Occupational Health, Safety and Welfare (MoLHR; 2012)

This study used the sound level meter with microphone to measure the intensity of the noise reaching at operator's ear. The measurement was made at the distance of 50 mm from operator's ear.

2.4 Field Performance Test

The field test was carried out to evaluate the performance of machines in terms of capacity and fuel consumption. The parameters such as area and time of ploughing and rotavating were measured to evaluate the machines capacity in a field. Eight poles were installed at the distance of 10 m each from both end of field and subsequently 20 m as next poles to evaluate the travelling speed and confirm the mechanical condition of the machines. The fuel tank was filled to full capacity and the fuel consumption was measured using measuring cylinder after completing the experimental plot. The machine capacity was computed using the equation given below (Eq.2).

$$M/C = (A \times 3600)/(T \times 4047) \quad (2)$$

Where, M/C = Machine Capacity (Acre/day); A = Area of the test field (m^2); T = Total time taken for field operation (s).

2.5 Analysis of the data

The data analysis was carried out using analysis of variance (ANOVA) in a Microsoft excel. The significant difference among the mean results were computed using t-test method and subjected t-statistics at $p = 0.05$. The different letters in the table represent significant differences ($p < 0.05$) among different machine models.

In order to analyze the machine performances from the different model of mini power tillers, the data of mean value was analyzed based on weightage score. All the five parameters are considered critical in evaluating the performance of any tillage farm machinery. In this study, the highest rank of parameter was given 5 score and lowest rank was given 1 score since five models of mini-power tillers were compared. The sum of the scores were then used to rank the overall performance of the machine.

3. RESULTS AND DISCUSSION

3.1 Engine Power and Reduction

As altitude increases, better the engine with less power reduction. In this study, the percentage of engine power reduction of 38.02 ± 0.86 was recorded highest for engine model BS270 of YKT 110G model and lowest of 19.87 ± 2.31 for BS418 of YKT 140D mini tiller model. From the Table 3, it can be noted that the percentage of engine power reductions recorded are highest for engine driven by petrol and lowest for engine driven by diesel. The statistical analysis also showed the significant difference between engine driven by petrol and diesel however, the result showed no significant difference among the engines of same fuel. This maybe because although petrol and diesel engine operate on the same four-stroke cycle, they differ in ignition of the mixture of air and fuel in the cylinder. Both of these engines are sensitive to altitude and temperature but in a different

way (Motahari and Chitsaz, 2019). As per study, diesel engine ignites the air-fuel mixture by direct compression without the use of a spark plug and therefore have higher compression ratios than petrol engine, which allows to produce more torque at a lower rpm. Also, since diesel engine does not

have a throttle body, the fuel injectors directly supply diesel to create more power unlike petrol engine which have throttle body to allow air to flow into engine body before ignition ((Bazzad et al., 2021).

Table 3: The engine power reduction (%) with respect to altitude level.

Machine Model / Engine Model	Rated RPM	Manufacturer's Rated Power (kW)	Actual Engine Power (kW)	Engine Power Reduction (%)
YKT 110G / BS270	3600	6.70 ± 0.00	4.15 ± 0.06	38.02 ± 0.86 ^a
UGT YUVA7P / BS21HT	3600	4.84 ± 0.00	3.07 ± 0.08	36.67 ± 1.75 ^a
YKT 100G / BS225	3600	4.80 ± 0.00	2.98 ± 0.22	37.87 ± 4.59 ^a
YKT 110D / BS305	3600	5.20 ± 0.00	4.09 ± 0.08	21.27 ± 1.60 ^b
YKT 140D / BS418	3600	6.80 ± 0.00	5.45 ± 0.16	19.87 ± 2.31 ^b

3.2 Field Efficiency of the Machine

The field performance efficiency for the machines were carried out using two implements, which are tine and rotary, whereby field capacity and fuel consumption were calculated for each of the machine model. This was done by considering the actual field practice of the farmers whereby field is ploughed first followed by rotavating.

The highest field capacity of 1 acre/day using tine implement was recorded for YKT 110D mini tiller model. The statistical analysis also

showed the significant difference with other models. The lowest field capacity of 0.72 acre/day using tine was recorded for UGT YUVA 7P and YKT 140D. For the rotary implement, highest field capacity of 1.52 acre/day was recorded for YKT 100G mini tiller model, with statistically showing significant difference with other models. However, no significant difference was there among other models (Figure 1). The

variations in field capacity could have happened due to the field conditions such as hardness and moisture content of the field as these factors cause the wheel slippage and tractional loss during the field operation.

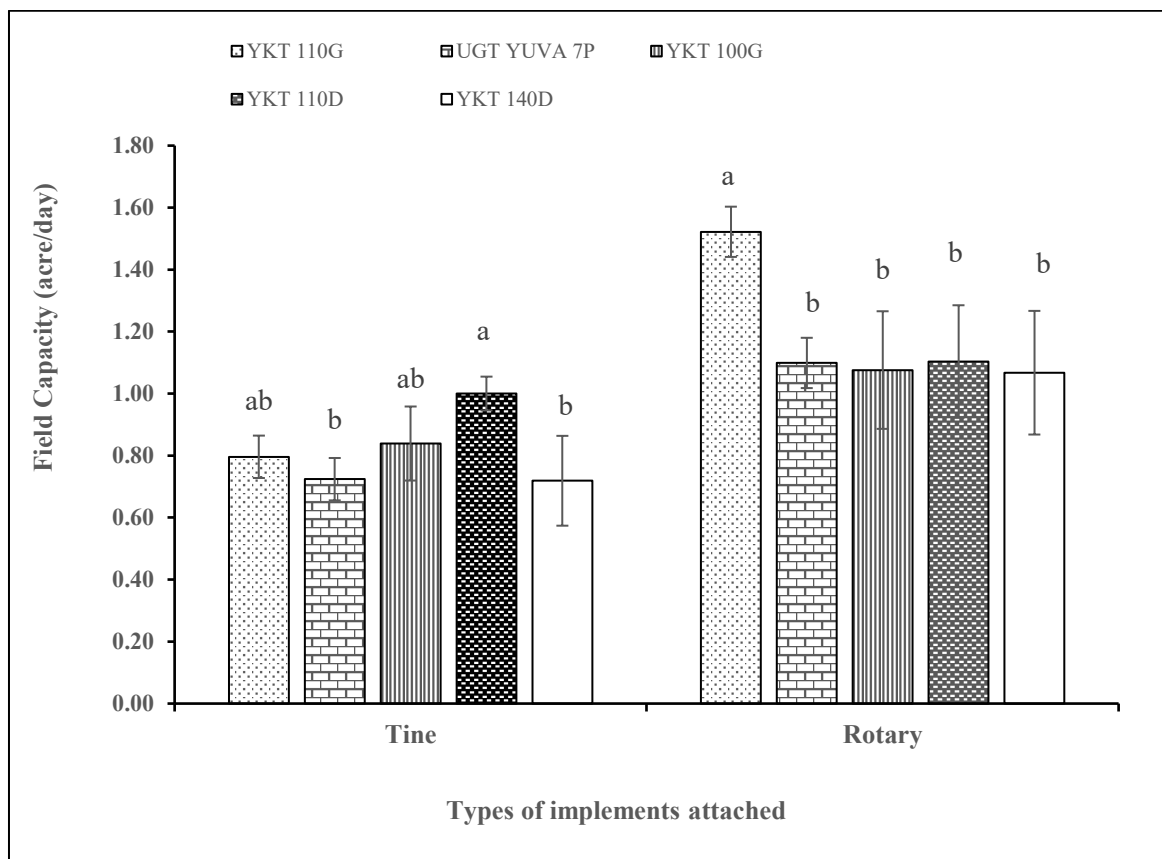


Figure 1: Field capacity of different mini tiller models for two different implements.

A mean fuel consumption of 9.21 ± 2.25 l/day is recorded highest for YKT 100G and lowest of 5.62 ± 1.43 l/day for YKT 140D. The data recorded is for the machine when operated under normal field condition (Table 4). As discussed under engine power reduction, engines driven by petrol needs to open throttle body to let air inflow for ignition and therefore requires more fuel and more power, thus, more fuel consumption by the machine models driven by petrol engine (Bazzad et al., 2021).

3.3 Vibration and Sound Level

Figure 2 shows the mean vibration level of the different model of machines when operated under normal field condition. The highest mean vibration level recorded are 10.12±0.40 m/s² and 9.80±0.70 m/s² for UGT YUVA 7P and YKT 100G models respectively. The lowest mean vibration level of 6.05±0.18 m/s² was recorded YKT 110D model. Statistically, the highest

and lowest vibration level showed significant difference.

Figure 3 shows the mean sound level observed for five different models of mini tillers used for this study. The highest sound level recorded are 90.81±0.26 dB(A) and 89.66±0.55 dB(A) for YKT 100G and UGT YUVA 7P respectively. The lowest sound level recorded is 80.86±0.27 dB(A) for YKT 110G. Although there is no significant difference between models of highest sound level, there is a significant difference among all other models.

The vibration level and sound level recorded for all the machine models are in conformity to BTS 42:2019 of (Bhutan standard, 2019) which states that the vibration level of mini tiller shall not exceed 15 m/s² at normal field operation while the sound level for mini tiller should not exceed 100 dB(A) for 2 hours of continuous operation.

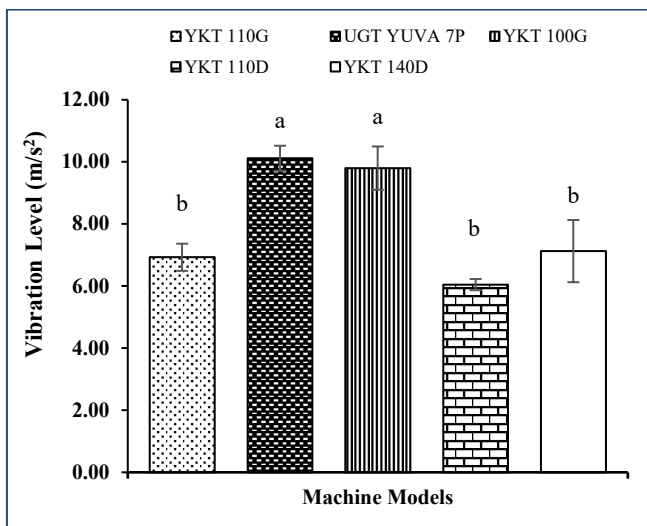
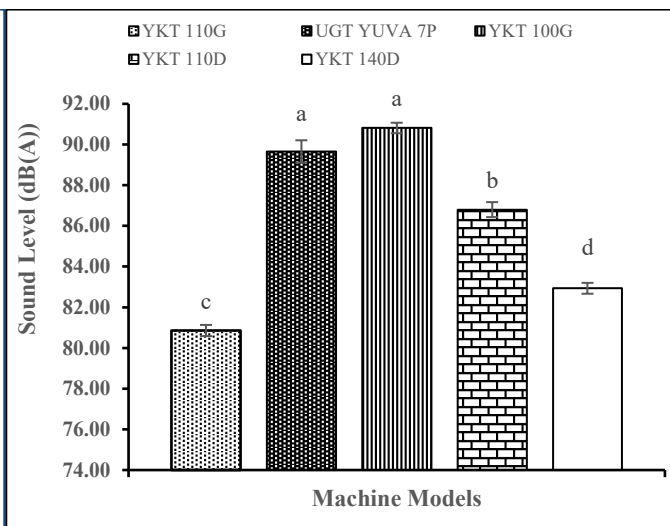
Figure 2: Mean vibration level (m/s²)

Figure 3: Mean sound level (dB(A))

3.4 Performance ranking

Given the importance of machine safety and efficiency in the field, five different models of mini-power tillers were evaluated based on five parameters and are ranked for their overall performance as per the weightage score. From the Table 4, mini-power tiller model, YKT 110D with engine model, BS305 is ranked as the best performer and mini-power

tiller model, YKT 100G with engine model, BS225 as the lowest among all other models. The result of all the parameters for YKT 100G has shown to be least performing compared to all other models. As observed in the Table 4, although the rated power of YKT 100G is 4.8kW and lowest among all other models, engine power reduction, fuel consumption, vibration level and sound level are recorded second highest which indicates lower performance.

Table 4: Performance ranking of the machine

Machine/Engine Model	Performance Parameter					Performance Ranking
	Engine Power Reduction (%)	Vibration Level (m/sec ²)	Sound level (dB (A))	Field Capacity (acre/day)	Fuel Consumption (l/day)	
YKT 110G / BS270	38.02 ± 0.86	6.93 ± 0.44	80.86 ± 0.27	1.16 ± 0.01	8.47 ± 1.67	2
UGT YUVA 7P/BS21HT	36.67 ± 1.75	10.12 ± 0.40	89.66 ± 0.55	0.91 ± 0.01	8.12 ± 0.61	4
YKT 100G / BS225	37.87 ± 4.59	9.80 ± 0.70	90.81 ± 0.26	0.96 ± 0.05	9.21 ± 2.25	5
YKT 110D / BS305	21.27 ± 1.60	6.05 ± 0.18	86.80 ± 0.37	1.05 ± 0.09	6.27 ± 1.32	1
YKT 140D / BS418	19.87 ± 2.31	7.13 ± 1.00	82.93 ± 0.27	0.89 ± 0.04	5.62 ± 1.43	3

4. CONCLUSION

Although all types of farm machinery are designed to reduce the drudgery, not all the machines are safe and efficient when used in the actual field. Performance and efficiency of the machine differs with various parameters such as engine power reduction especially at higher altitude, ability to generate vibration and sound which are considered to cause a health issue in a long run, and the field capacity and fuel consumptions of the machine as these two parameters are directly related to their cost efficiency for the farmers. To compare and select the best performing machine in terms of safety and efficiency, based on the selected parameters, five different models of mini-power tillers were evaluated. From the test result, it can be concluded that YKT 110D model and YKT 100G are ranked as the best and lowest performing among all the models, respectively. The highest engine power reduction, vibration level and sound level recorded are 38.02±0.86 %, 10.12±0.40 m/s² and 90.81±0.26 dB(A) for YKT 110G, UGT YUVA 7P and YKT 100G models respectively. It can also be observed that the YKT 100G consumes more fuel given its lower field capacity in comparison to other models. The lowest engine power reduction, vibration and sound level are recorded for YKT 140D, YKT 110D and YKT 110G with a value of 19.87±2.31 %, 6.05 ± 0.18 m/s² and 80.86 ± 0.27 dB(A) respectively. Based on the performance evaluation, mini-power tiller driven by diesel engines are observed to be significantly best performing than the machine driven by petrol engine.

RECOMMENDATION

This study carried out evaluation of only five types of mini-power tillers of same make and brand, and therefore recommendation made is only in comparison among the models used for this study. This study recommends evaluation of all other existing mini-power tillers or farm machineries in order to make recommendation for all types of agricultural land in Bhutan.

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