American Journal of Engineering Science and Technology Research
Vol.2, No. 2, February 2014, PP: 1 - 8, ISSN: 2327-8269 (Online)
Available online at www.ajestr.com

Research article

Development and Testing of Spring Tine Attached to Small Tractor for Sugarcane Weeder in Thailand

Phakwipha Sutthiwaree[1], Minli Yang[2]

(1. College of Engineering China Agricultural University, Beijing 100083, P.R.China;
2. China Research Center for Agricultural Mechanization Development,
College of Engineering, China Agricultural University, Beijing 100083P.R.China)

E-mail: 1579541710@qq.com

Abstract

Removal of weeds from sugarcane fields is of utmost importance for optimizing sugarcane production. If weedsare not removed from sugarcane field at the right time, the yields are estimated fifty percent reduced. The traditional weeds control in sugarcane is chemical usage even though it is unsafely and unfriendly to environment. The mechanical weed control is one of the optimized methods of green technology; The spring tine cultivator attached to a small side riding tractor was developed by Agricultural Engineering Research Institute Five legs of coil spring tine were set in 2 rows; two and three tines in first and second row by arranging in different positions. Of the two types of developed spring tine cultivators, type I used a coil shank and a full sweep head tine is called coil spring type. The spring tine cultivator type II is called S spring type used S-shape shank was and Mcgregor head tine type. The field validation was in KhonKaen province, Thailand. The average field capacity of spring tine cultivator type I and type II were 0.5 and0 0.6 ha/hr. The weeding efficiency of spring tine cultivator type I and type II were 94.7 and 97.0 percent. The fuel consumption of spring tine cultivator type I and type II were 5.9 and 4.8 liter per hectare respectively. Two types of spring tine cultivator had high working capacity and high weeding efficiency but low fuel consumption. This equipment can be adequately used for weed control in sugarcane.

Keywords: spring tine cultivator, sugarcane, weeder

1 Introduction

At present, there is increasing awareness of “organic farming”, which avoids use of chemicals for crop production. The government of Thailand has more inclination towards reduction in use of chemicals in agriculture. During 2007- 2011 the policy target was to reduce use of chemicals in agriculture by thirty percent. Department of Agriculture has established a use of chemical guideline and the chemical reduction policy which supports the said government policy. Over the years, the import of pesticides has shown a progressive increase;

in 2008 the total imported herbicides for agricultural use were over 48,000 tons, which rose to over 104,000 tons in 2012. Of this fifty-seven percent of herbicides were used for weed control in sugarcane. The total cultivated area under sugarcane in the country in 2012 was 1.3 million ha producing 98.4 million tons of cane (Office of Agricultural Economics, 2012). Weed control is most critical early in the season. Three or four months after planting, the appropriate weed management must proceed; otherwise the yield reduction could be reduced up to fifty percent (Suwannarak, 1983). That agree with the report of weeds can reduce sugarcane yields by competing for moisture, nutrients, and light during the growing season. (D. C. Odero, 2009).Weeds also utilizes a part of nutrition and water resulting in decrease in sugar content. Heavy weed infestations can also interfere with sugarcane harvest by adding unnecessary harvesting expenses (D. C. Odero, 2009). The optimum chemical management for weed control in sugarcane required 2-3 applications per crop by using the herbicide; however, the type of herbicide selection depends on type of weed and there are limited kinds of herbicide appropriate for sugarcane (K Suwanarak, 1999). If it can contain the number of herbicide applications, it will reduce the volume herbicide used of the country. Ideally mechanical weed control should get preference over herbicidal control in sugarcane. At the present mechanical weeding is still in limited use. The chisel type attached to the walking tractor its low pulling power force and low efficiency that is the weak point to this kind of tool. The optimum tool for control weed should be able to uproot the weeds and break the soil after operation. The spring tine is a suitable tool for weeding, as it uses 2, 3, 4, 5 or 9 spring tine units attached to a 100 hp tractor but it is not convenient for working in sugarcane fields as the tractor runs over the sugarcane crop. There are many types of weeding tools have been developed for the local use. Oversea, most of weeding tools were used for attaching to large tractors which have working capacity more than 50 ha/day.

In this research two types of the spring tines were chosen for the prototype assemble attached to the small- medium size tractor. The first prototype was coil spring type and second one was S- type. The head of tine also used two types. The first was full sweep head type and second was McGregor head type (Figure 1).

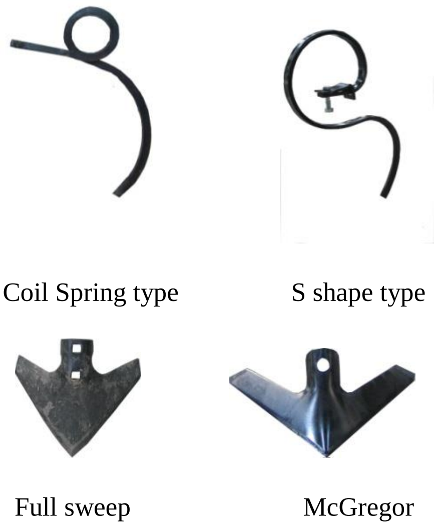

Figure 1: Type of tine shank and tine head

There are many type of weeding tool attached to the small tractor that are workable between sugarcane planted rows such as ① disc harrow (Figure2a), applied for weeding the optimum tillage angle of disc harrow is 15-25 degree (C.Culpin, 1992). The tilled soil after use of disc harrow contained large soil clods, which cause unsuccessful weeding. ② Spring tine small arrow head type (Figure 2b) optimized for weeding but its narrow working width caused un-effectiveness. ③ Rotary cultivator (Figure 2c) commonly optimized for land preparation. ④ Rigid tine (Figure 2d) is optimally used for weeding in sandy soil. Although the mentioned equipments were adopted for weeding but were not appropriate and it high operation cost. Culpin (1992) confirmed that the deep tillage is not necessary for weeding. The shallow tilling by the spring tine is enough for weeding and had low operational cost. The spring tine component of flexible spring steel is useful during working in the field. There are many kinds of head of spring tine that can be selected for the optimum soil and crop type. The research and development of optimum weeding equipment for improving the weeding technology for sugarcane production is necessarily needed. The designed and fabricated optimum weeding tool will facilitate the farmers for use as alternate method to herbicidal control of weeds and will be able to contain the excessive use of herbicides.

a. Disc harrow

b. Spring tine small arrow head type

c. Rotary cultivator

d. Rigid tine

Figure 2: The weeding equipment's for small tractor

2 Material and methods

The experiment was carried for consecutive two years (2009-2010) at two locations in sugarcane fields Thailand. The field validation is done in Rachaburi province covered with clay roam soil and KhonKhane province covered with sandy soil. The prototype was designed on the spring tine frame structure with selected the spring tine coil shank type and selected the full sweep type for tine head. It is attachable to the 27 hp tractor. The experimental contents were divided in three parts.

Part I, the first prototype was designed with three rows coil spring tine and the primary test was done. The second prototype was designed two rows coil spring tine according to the primary testing. The first and second prototypes were tested to compare with disc harrow, rigid tine and rotary cultivator. The experiment was done in 0.16 ha field size involving three repetitions of each equipment which attached to 27 hp riding type tractor. The experiment had been carried out and data was recorded for five months after sugarcane planting.

Part II, the third prototype spring tine S type and McGregor head tine were selected and designed and compared for performance with the two rows coil spring type (the second prototype of the first year) and locally made spring tine. The experiment was done in 0.8 ha field size with three repetitions of each equipment attached to 27 hp riding type tractor. The experiment was carried out and data was recorded for 4 months after sugarcane planting.

Part III, the data was analyzed as the following methods;

1. The effective field capacity (EFC, $hahr^{-1}$)

$$EFC=\frac{A}{T_p+T_l}\text{……………………………………………………(a)}$$

where; A = Total area ha

T_p = Productive time hr

T_l = Non-productive time hr

2. Weeding efficiency (WE,%)

$$WE=\frac{W_1-W_2}{W_1}\times 100 \quad \text{...(b)}$$

Where; W1 = weed count per 1 m^2 before operation

W2 = weed count per 1 m^2 after operation

3. Fuel Consumption (FC, liter/ha)

$$FC=\frac{V_b-V_a}{A} \quad \text{...(c)}$$

where ; FC = The fuel consumption Lha^{-1}
V_b = The used fuel volume before testing L
V_a =The used fuel volume after testing L

4. Soil moisture content (MC,%)

Moisture content on dry weight basis was considered. For measurement of soil moisture, the sample soil in the field test was drawn using 53mm diameter and 51 mm height core sampling. The sampling soil was oven dried at 105 degree for 8 hours.

$$MC == \frac{W_b-W_a}{W_b}\times 100 \quad \text{...(e)}$$

where; W_b = weight of soil sample before oven

W_a = weight of soil sample after oven

5. Operating cost = Fixed cost + Variable cost................................(f)

Fixed cost = Depreciation + Interest

where; Depreciation = $\frac{P-S}{N}$

Interest $=\frac{P+S}{2} x \frac{r}{100}$

where; P = purchase price

S= salvage price (10% of P)

r = interest rate (%)

Variable cost = Wage + Energy cost (fuel)+ Lubricant oil+ repairing cost

Annual Break Even point (ABEp, $hayear^{-1}$) = ...(h)

3 Result and discussion

Part I

The prototype I was designed with three rows coil spring tine combine to full sweep tine head assembling in V type (Figure 3). This prototype was used for comparison testing in different tine head size at Rachaburi province in the central plain of Thailand. There are three size of tine head; small size 150 mm, medium size 215 mm and large size 245 mm. The result showed that large size tine head was the best and weeding effective (85.34 %), the theoretical working width was 920 mm (Table 1). The large size of tine head was selected for the prototype. As the problem during testing, the frame structure of three rows had affected to overload of the tractor power. For reducing the load of tractor, the two rows frame structure was designed. The first row assembled 2 units and the second row assembled 3 units of spring tine with full sweep tine head in serrated pattern (figure 3). The comparable testing was conducted with rotary cultivator, rigid tine and disc harrow. The testing was operated in each month of 1-5 months after planting at Khonkhane province (Figure 5). The recorded data was analyzed for weeding efficiency, fuel consumption, working velocity, soil cone penetration force, soil moisture content and production yield. From table 2, the result showed that rotary cultivator did effective weeding, the weeding efficiency was 97.3 %, but the fuel consumption was 6.4 liter/ha.

Figure 3: Spring tine cultivator prototype I

Figure 4: Spring tine cultivator prototype II

Table 1: Comparative testing of three tine heads at Ratchaburi province in 2009

Tine head	Working width (mm)	Working capacity (ha/hr)	Weeding efficiency (%wb)	Fuel consumption (liter/ha)	Working speed (km/hr)
Small	820	0.29	74.14	5.06	2.19
Middle	870	0.21	82.76	5.38	1.82
Large	920	0.29	85.34	6.25	1.87

Even though the rotary cultivator was effective for weeding, but the highest fuel consumer as compared with other equipment. Although the rotary cultivator was found suitable land preparation, its use caused lowering in sugarcane yield as it buried the weeds and weed management was not proper.

The weeding efficiency, fuel consumption of rigid tine was 73.32 % and 4.19 liter/ha respectively. Even though there was lowest fuel consumption in case of rigid tine, but the weeding efficiency was lower than the developed spring tine.

a. Spring tine cultivator prototype (3rows)

b. Spring tine cultivator prototype (2rows)

c. Rigid tine

d. Rotary cultivator

e.Disc plough

Figure 5: Comparative testing on 5 types of weeding equipments

Table 2: Result of comparative testing on 5 types of weeding equipments at KhonKaen province in 2009

	MC (%wb)	WC (ha/hr)	WFEC (%wb)	FC (liter/ha)	Yield (ton/ha)
Spring tine cultivator prototype I (3 rows coil spring type)	2.31	0.53	80.67	4.63	83.06
Spring tine cultivator prototype II (2 rows coil spring type)	2.89	0.49	83.80	4.50	87.63
Rigid tine	1.09	0.51	73.32	4.19	77.56
Rotary cultivator	1.78	0.52	97.27	6.44	79.06
Disc harrow	1.99	0.51	74.20	5.38	87.94

The weeding efficiency and fuel consumption of disc plow was 74.20 % and 5.38 liter/ha respectively. Disc plow efficiency in term of weeding and fuel consumption was lower than the developed spring tine.

The weeding efficiency and fuel consumption of the spring tine prototype I and prototype II were 80.67 %, 4.63 liter/ha, 83.80 % and 4.50 liter/ha respectively. The results of revealed that the use of the prototype II (2rows coil spring type) optimized for weeding in sugarcane field. However, the weight of the spring tine prototype II was 110 kg, which over loaded when used in sandy soil of sugarcane field in the northeast of Thailand. This caused consumption of more fuel. The optimum tool for using in sandy soil should be reasonably light weight for decreasing fuel consumption and reducing cost.

Part II

The third prototype was designed in S shape 2 rows tine. The McGregor tine head type was assembled to the S-type spring tine (Figure 6). The third prototype's weight was 46 kg. The comparative testing between second prototype, third prototype and the local made spring tine (Figure 7) were conducted for 1-4 months in sugarcane field at KhoneKhaen province (Figure 8). The resulst are shown as table 3.

Figure 6: Third prototype S-type spring tine

Figure 7: Local made spring tine

Figure 8: The comparative testing between second prototype, third prototypeand local made spring tine

Viewing the comparative testing result, it was noted that the weeding efficiency, fuel consumption of the second and the third prototype were 94.66 %, 5.88liter/ha and 97.04 %, 4.81liter/ha, respectively. Both of the developed prototypes revealed 10.48 and 12.86 % higher effective weeding than local made spring tine which had 12.5 % higher fuel consumption than locally made spring tine.

Table 3: Comparative testing on 3 type weeding equipments at Khon Kean province in 2010

	MC (%wb)	WC (ha/hr)	WEFC (%)	FC (liter/ha)
Spring tine cultivator protoype II (Coil 2 rows)	1.74	0.54	94.66	5.88
Spring tine cultivator protoype III(s type)	2.45	0.60	97.04	4.81
Local made spring tine	2.09	0.53	84.18	4.88

Part III

Following the equation (h and g), the operation cost was analyzed by using the basic data from table 4. The annual break-even point of the spring tine cultivator (2 rows) was 12.86 ha/year in 7 year working life and manual weeding cost was 79.67 US$/ha. The annual break-even point of the spring tine cultivator S type 10.19 ha/year in 7 year working life and of manual weeding cost was 79.67 US$/ha.

Table 4: The basic data for analysis

	Tractor	Coil Spring tine type	Spring tine S type
Purchase price, US$	11,153.60	1,593.37	79.67
Working life, year	7	7	7
Working capacity, $hahr^{-1}$	-	0.54	0.60
Fuel consumption, $literha^{-1}$	-	5.88	4.81
Working hour per day ,hr	8	8	8
Operator wage, US$/day	12.75	-	-
Manual weeding cost, US$/ha	-	79.67	79.67
Salvage, % of purchase price	30	10	10
Repair & Maintenance,% of purchase price/100 hr.	1.2	6	6

4. Conclusion

Two types of weeding equipment attached to 27 hp riding tractor was designed for operation in sugarcane fields in Thailand. The first optimal effective weeding prototype was coil spring type attached to a full sweep tine head in 2 rows with arrangement in different positions. The field capacity, weeding efficiency and fuel consumption of first prototype were 0.54 ha/h, 94.66% and 5.58 liter/ha, respectively. The annual break-even point was 12.86 ha/year with 7 years working life. The second prototype was S spring type assembled to McGregor tine head with 2 rows arranged in different position. The field capacity, weeding efficiency and fuel consumption of this prototype were 0.60 ha/h, 97.04% and 4.81 liter/ha, respectively. The annual break-even point was 10.19 ha/year in 7 years working life condition.

References

[1] C.Clude. (1999). Farm machinery.

[2] D. C. Odero, J. A. (2009). Weed Managment in Sugarcane. Florida: University of Florida IFAS Extension.

[3] K Suwanarak, S. K. (1999). Tendency of Decreasing Herbicide Use in Sugarcane Field. National Conference of Crop Protection Society (pp. 230-233). Bangkok: Thai National Crop Protection Society.

[4] Office of Agricultural Economics. (2012). Annual Statistic .

[5] Suwannarak, K. (1983). Losses due to weed and weed management in sugarcan. Newsletter of Weed Science Society of Thailand No.3 .