Field Evaluation of Subsoiling and Liquid Fertilizer Injection for Minimum Tillage of Sugarcane Planter (Part 1) -Effects of Subsoiling and Liquid Fertilizer Injection on Germination Test

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Abstract

Field evaluation of subsoiling and liquid fertilizer injection under minimum tillage practice of sugarcane planter has been tested. This experiment has been conducted at the field of National Agricultural Machinery Center (NAMC), Kasetsart University and Flying Training School, RTAF, Khampaengsaen in 2010. The seeding of the field performance was done with three models of sugarcane planter including a conventional sugarcane planter (CP), subsoiling sugarcane planter (SP) and combination of subsoiling with liquid fertilizer injection sugarcane planter (SFIP). Significant of the three different models of the sugarcane planter, soil types and seeding depths has been discussed. Comparative study on this experiment under rain-fed condition found that the significant of soil types and different models of sugarcane planter were found in the germination percentage under this specific field trial. These come from the fact that subsoiling and liquid fertilizer injection can improve areration, infiltration, drainage rate, the moisture in soil and subsoil improvement lead to increase the germination of seeding under minimum tillage practice.

Keywords: planter, sugarcane, minimum tillage, subsoiling, fertilizer injection, germination percentage

1. Introduction

Sugarcane (*Saccharum* spp L.) has been become a major crop in Thailand and its economic importance has increased in the last decade. Northeast Thailand is a typical area of rapid development of intensive agricultural cash crops on soils that are predominantly sandy in texture and the water in this region are highly deficit. Since the 60s, agricultural production has increased sharply at a regional level due to the rapid expansion of cultivated areas as a part of strategy to develop an agricultural export driven economy plus the nation sugarcane-base ethanol program in conjunction with international commitments to reduce the emissions of greenhouse gases should lead to increase in the production of that renewable energy crop. This has had a significant effect in negative impact on soil quality at the field level [8, 9]. However, sugarcane yields are highly dependent on rainfall pattern and sufficient water viability in the region. With the increase of the use of heavy machinery in conventional sugarcane cropping, the degradation of soil physical conditions like hardpan, soil organic matter and soil moisture are becoming problems in Thailand. In recent years, minimum tillage practice is now popularly used for field resource management and efficient management systems.

The term of minimum tillage is defines as the specific tillage practices where minimum or no disturbance of the soil taking in place at the field and the slot was formed for successive of seeding operation. Also the remaining part of the field is left of an undisturbed and also some scattered residue around the field surface. Development of the planter machine need some necessitate technological improvements that are pertinent to the dynamic of soil-seed-implement interaction. The slot characteristics need to have a consideration effects on the stable plant growth including the soil texture, the drainage rate, infiltration, aeration and also the degree of soil compaction [1, 2]. Several studies have been showed that soil compaction has negative impact on plant and root development [3, 10]. The increasing of the minimum tillage practice, which can help to improve the environment of the soil, reduces the requirement of the labor and fuel consumption and less time in land preparation.

Accordingly, it is necessary to make the efforts to simplify the tillage sequence and also to reduce the number of times in land preparation of the machine, taking into account of the advantage of subsoiling treatment. Consequently, under these considerations, a new working mechanical attachment that enable carrying out of subsoiling, liquid fertilizer injection and planting simultaneously, has been developed; subsequently, fuel consumption and effects on seeding germination of the crop were studied in comparison with conventional systems, in this research activity.

2. Materials and methods

2.1 Field preparation

The information on minimum tillage of sugarcane cultivation is scare in literature. Although the study was only carried out over 1 year, our experimental dataset might be useful understanding for the next following research study of sugarcane cropping system under rain-fed condition. Weed compete with seeding for nutrients, soil moisture etc. Using chopping or mowing machine equipment for proper field trial in minimum tillage practice for sugarcane cultivation is the alternative way in this study. As a result, moisture conservation was kept as a criterion managed to keep it as a targets requirement of this practice.

(a) Mowing or chopping implement

(b) Three disc plow for conventional land preparation

Fig. 1 Implement in used

2.2 Experimental tests and site description

A cone penetrometer (Daiki Rika Kogyo Co., Ltd., Japan, Model DIK 5500) was used for measurement of soil hardness with a 30° cone apex angle and 78.57mm^2 base area at three places in each plot.

Before testing, soil were sampled at the depth of 100mm by using a 50mmø soil core sampler and then brought to the laboratory for the measurements of soil moisture content and its distribution of each treatment. Then, soil samplers were dried at 110°C for 24h to determine the moisture content and the dry bulk density. The particle size distribution of the soil was analyzed by the pipette method using a kohn-type pipette analyzer. Accordingly, the laboratory results of the percentage finer found that the tested soils were found to consist of 13.73% clay, 31.76% silt, and 54.51% sand in the field of NAMC and 17.25% clay, 32.99 silt, and 49.76% sand in the field of RTAF respectively. Therefore, the soil types were classified falling into sandy loam and loam respectively.

The fields test were conducted at the research field of national Agricultural Machinery Center, Kasetsart University, Khampaengsaen Campus Nakorn Prathom, Thailand (latitude 14° 1′ 53.63″N, longitude 99° 58′ 6.88″E) and Flying Training School, RTAF, Khampaengsaen, Nakorn Prathom, Thailand (latitude 14° 5′ 6.16″N, longitude 99° 55′ 53.74″E) from April 2010-May 2011.

Summarized items of soil properties of the tested soils with different values of soil particle size distribution, organic matter and moisture content of the soil has been represented in Table 1.

Table. 1 Summarized items related with the field measurements

Item	NAMC		RTAF	
	Tillage practice	Minimum tillage practice	Tillage practice	Minimum tillage practice
Sand; [%]	54.51		49.76	
Silt; [%]	31.76		32.99	
Clay; [%]	13.73		17.25	
Soil texture	Sandy Loam		Loam	
OM [%]	0.91		1.37	
MC [% d.b.]	14.51		12.39	
Bulk density [Mg/m^3]	1-1.4		1.06-1.43	
CI [MPa]	1.4	1.7	1.4	1.75
Seeding depth [mm]	75, 100		75, 100	

2.3 Functional features of the developed sugarcane planter

Three different models of sugarcane planter composed of a conventional sugarcane planter (CP), subsoiling sugarcane planter (SP) and subsoiling with fertilizer injection sugarcane planter (SFIP) have been tested to evaluate the performance in this field experiment. The new working attachment was developed through the modification of the commercial sugarcane planter attachment as a base. The structure of the newly development is illustrated in Fig. 2(a). The subsoiling implement has been attached in front of the commercial sugarcane planter. The working depth of the subsoiling has been set at 300mm from the ground surface. The 25mmø with 300mm of length of the stainless tube has been attached at the rear side of the subsoiling for liquid fertilizer injection. The tank of 1000 liters of liquid fertilizer has been taking placed on the roof of the tractor under the supportive structure as shown in Fig. 2(b). This experiment has been blended the fertilizer of 0-52-34 formula of 1kg with 200L of water for liquid fertilizer. This fertilizer aimed for germination improvement, nutrient accumulation and stable growth of the crop. The submersible pump has been installed inside the tank with the setting of the capacity of the liquid fertilizer at 2l/m. Designed of subsoiling has been aimed toward low soil disturbance to minimize soil moisture loss from the slot, aeration, infiltration and subsoil improvement for better seedbed preparation after the seeding process. The slot making in which desirable seedbed condition could be created to meet the requirement of better seedbed preparation lead to stable plant growth.

(a) Subsoiling and liquid Fertilizer Tube

(b) Supportive fertilizer tanks

Fig. 2 Developed sugarcane planter

2.4 Experimental design

Three different type of sugarcane planters were evaluated with the seeding performance tests regarding with fuel consumption, germination percentage. The field experiment at both sites has been subdivided into 6 plots. Each plot was 15×50m^2 to perform in this specific field trial. The reported data of fuel consumption of each tillage sequence can be done using the re-filled method. The target of the traveling speed of the tractor was set at 2.5m/s with 75 and 100mm deep of the working depth. A 2 × 2 × 3 factorial experiment in completely randomized design was conducted for each operational trial. Each treatment was replicated five times each and the mean values of the treatments were analyzed using Least Significant Difference (LSD) method. A statistical analysis was performed using the SAS statistical software. The results of these analyses on seeding performance tests were satisfactorily expected to assess the capability of the machines tested.

(1) Effect of subsoiling and liquid fertilizer injection of developed sugarcane planter on germination percentage

In many coarse textured soils, such as an Arenic Acrisol soil texture in Northeast Thailand, limited root development and biomass production are attributed to adverse physical condition in the subsoil and subsoil degradation is increasingly being recognized as a scares problem to achieving sustainable sugarcane crop production on the range of soil type [4, 5, 6, 11]. Rehabilitation technique using subsoil has been aiming to warded low subsoil loosening resulted in an increased root length below plowing depth in irrigated plot and up to 13% of total water uptake was supplied by capillary rise to the root zone [7]. Thus, to maintain agricultural productions in marginal agro-eco-zones are donated by very poor farmers, subsoil rehabilitation techniques that are efficient and low cost are required. The effect of subsoiling and liquid fertilizer injection of the developed sugarcane planter has been observed at 30DAP. Before substantial tests, two rows of the boarder side and 5 meters apart from each hedge of each subdivided plot has been omitted to prevent the edge effects. The five remaining rows with 5m of length of each inside of the subdivided plots have been selected for this experiment. Then, taking into account of the average germination percentage of each treatment of the selected sub-plot in the inter-rows of the seedling can be done. The un-germinated seedling has been observed in each selected rows by taking the vacant in places. Field observations of the germination of the seedling after machine operation at alls treatment were comparatively discussed in conjunction with the developed sugarcane planter.

3. Results and discussion

Three different types of sugarcane planter were comparatively studied in relation to germination percentage in the six subdivided plots at two locations. Consequently, average fuel consumption in each activity of land preparation at both sites had been measured. Germination percentage was mainly use to confirm its contribution towards the improvement of the machine for the next research study.

(a) Chopped arable weed on the field

(b) Mechanical behavior on field tested

Fig. 3 Represented of covered residue in the field and onsite mechanical action

Table. 2 Fuel consumption of the sugarcane cultivation system

Field condition	Method of field preparation	Fuel consumption	Total, L/ha
Minimum tillage practice, SP	Mown implement	5L/ha	18.51
	Subsoiling planter	13.51L/ha	
Minimum tillage practice, SFIP	Mown implement	5L/ha	18.50
	Subsoiling with liquid fertilizer injection	13.50L/ha	
Conventional practice	Three disc plow	17.63L/ha	73.51
	Three disc plow	17.63L/ha	
	Seven disc plow	24.94L/ha	
	Conventional sugarcane planter	13.31L/ha	

Table 2 has been represented about the breakdown dataset of two different methods of sugarcane cultivation. Minimum tillage practice has been represented a highlight of saving fuel. Similarly of breakdown data has been showed among three different models of sugarcane planter in the table.

Mown or chopping implement showed minimum fuel consumption for minimum tillage practice whereas three disc plow and seven disc plow showed the consumption of the fuel at 17.63 and 24.94L/ha respectively and the amount of 55L/ha of fuel can be save in this both field trial. This result could be guaranteed that minimum tillage practice not only conserved the soil and moisture but also showed something specific in saving fuel in land preparation.

(1) Effect of subsoiling and liquid fertilizer injection of sugarcane planter on germination percentage

The germination of the sugarcane seeding of each field trial has been done at 30DAP. Subsoiling and liquid fertilizer injection showed satisfactorily observed as represented in Fig. 4.

(a) CP at 75 and 100mm of seeding depth

(b) SP at 75 and 100mm of seeding depth

(C) SFIP at 75 and 100mm of seeding depth

Fig. 4 Represented of germinated seedling at 30DAP

Figs. 5-6 showed similar trend of the germination percentage between both locations with different of seeding depths (75, 100mm). In general, with an increasing of seeding depth, it could be found that SP showed significant results compared with CP in both locations. However, with an increasing of seeding depth, germination percentage has been decreasing except under SIFP condition. This come from the fact that the moisture in the liquid fertilizer could enhanced the germination of the seeding. The increasing rates of the germination percentage fluctuate irregularly because of the effect of soil surface and the pertinent of different of soil types.

For the case of CP, minimum germination percentage obviously observed under this practice. Under this tillage practice, pore space in soil texture has been performed by using intensive tillage implements. Moisture regime under aggregated tillage zone area has been loosen that induced lower germination percentage of these practices.

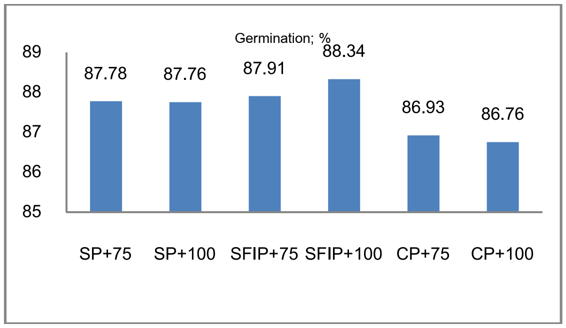

Fig. 5 Germination percentage at sandy loam soil tested field

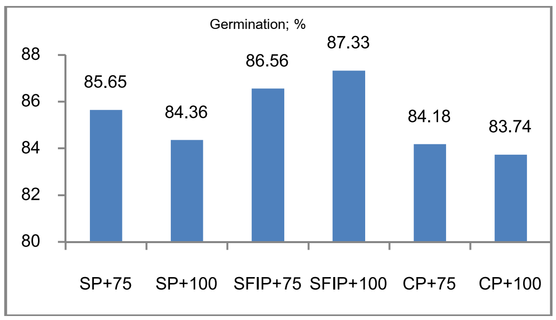

Fig. 6 Germination percentage at loamy soil tested field

Table. 3 ANOVA results related to germination percentage

	Degree-of-Freedom	Sum of Squares	Mean Square	F
Treatment	11	138.90	12.63	3.04*
A (Soil type)	1	77.73	77.73	18.71*
B (Planter type)	2	45.48	22.74	5.47*
C (Depth)	1	0.22	0.22	0.05ns
A×B	2	9.04	4.52	1.09ns
A×C	1	0.60	0.60	0.14ns
B×C	2	4.22	2.11	0.51ns
A×B×C	2	1.62	0.81	0.20ns
Error	48	199.44	4.16	
Total	59	338.34		

*significant at P=0.05

Furthermore, variation analysis has been used to verify the practical effectiveness, as shown in Table 3. The results from ANOVA indicated that the major factors of soil type and three different models of sugarcane planter were falling to be found significantly different at P=0.05. The statistical analysis showed no significant difference in the interaction parameters and seeding depth, thus implying an engineering concept for improving the major design experimental research variables. In fact the modification of the prototype of subsoiling sugarcane planter had been proposed as an ideal model for minimum tillage of sugarcane planter. But the designs of the machine need some adjustment of the implement for the success of the planting mechanism.

A comparison based on mean values using LSD method represented in Table 4. From the analysis of this experiment, it could be emphasized that subsoiling can perform to induce the germination percentage after the operation of SP and SFIP under the entire combination.

These results came from the fact that subsoiling device can aggregated seeding zone before seeding operation for a better seedbed preparation in terms of aeration, infiltration, drainage rate and subsoil improvement especially under drought condition. Highest values of germination percentage data could be observed in the results of SFIP. This came from the fact that the moisture in liquid fertilizer has been improved the germination of the seeding in this experiment in alls entire combination. This result could be used to conclude that the configuration of SFIP representation was satisfactory done under the entire combination.

Table. 4 Comparison between mean values of germination percentage

Soil type	Depth	Mean value		
		CP	SP	SFIP
Sandy loam	75	86.53^{a-c}	87.78^{ab}	87.9^{ab}
	100	86.76^{a-d}	87.76^{ab}	88.34^{a}
Loam	75	84.18^{de}	85.65^{b-e}	86.56^{a-d}
	100	83.74^{e}	84.36^{c-e}	87.33^{ab}
LSD 0.05			2.59	
CV. (%)			2.36	

Note: Means followed by the different superscript in the same row indicate significant difference between the mean values at P=0.05.

Means followed by the different superscript in the same column indicate significant difference between the mean values at P=0.05.

In the case of CP, unsatisfactory results in terms of germination percentage could be observed in both types of the tested soil. The moisture in soil has been loosen from the aggregated seeding zone area after tillage practice.

For the case of SP, improvement of the germination percentage results could be observed after the seeding trial due partly to the advantageous of minimum tillage practice and subsoil improvement compared with CP.

4. Conclusions

This research has been conducted to clarify the performance test of subsoiling and liquid fertilizer injection of minimum tillage of sugarcane planter by taking into account of the advantage of subsoiling treatment, fuel consumption and effects on seeding germination of the sugarcane crop had been discussed extensively based on the field test. Selected finding conclusions can be drawn as follows.

(1) Minimum tillage practice showed the highlight benefit of saving fuel consumption in this experiment.
(2) Subsoiling sugarcane planter could perform to improve the germination percentage compared with conventional sugarcane planter. This come from the fact that moisture conservation in the soil, aeration, infiltration and the drainage rate could be created for better seed-soil contact whereas conventional sugarcane planter showed unsatisfactory done in this experiment. Loosing moisture in the soil after intensive tillage practice showed the disadvantage of the germination percentage.
(3) Subsoiling in conjunction with liquid fertilizer injection sugarcane planter was confirmed to be effective regarding in germination percentage under entire combination. This machine demonstrated practical significant and recommendable performance of minimum tillage sugarcane planter in which desirable seedbed preparation could be created to meet the requirements of stable plant growth.
(4) Subsoiling device proved in practice applicable regarding soil-seed-implement phenomenon. Without a subsoiling device, seedbed preparation could not be done that lead to unstable circumstance of the germination of the seeding. In addition, modification of the design criteria in regarding the relative setting position of this device was found to improve the field performance even with an uncultivated soil profile.
(5) Under this field experimental trial, germination percentage tends to depend on the pertinent of the soil properties and the different models of sugarcane planter.

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