AESA 2009

ISBN 978-602-95924-0-5

International Symposium
AGRICULTURAL ENGINEERING TOWARDS
SUSTAINABLE AGRICULTURE IN ASIA

PROCEEDINGS

TABLE OF CONTENTS

OPTIMUM SOIL TILLAGE METHOD ON DRY LAND SUGARCANE CULTIVATION

Gatot Pramuhadi
Lecturer at the Department of Agricultural Engineering Faculty of Agricultural Technology, Institut Pertanian Bogor (IPB)
IPB Darmaga Campus PO Box 220 Bogor 16002
Telephone/Facsimile: +62 251 8623 026, h.p.: +62 8131 0989 617
e-mail: gpramuhadi@yahoo.com

ABSTRACT

The objective of the research was to analyse effectiveness and efficiency of soil tillage results and to determine optimum soil tillage method on dry land sugarcane cultivation. The research was conducted on September 2002 until August 2003 in an Ultisol dry land sugarcane area at Gula Putih Mataram Company, Sugar Group Company, Central Lampung, Sumatra Island, Indonesia. Six-soil tillage methods were applied and sugarcane seedlings of TC-9 variety were planted, and then soil physical conditions, tractors' performance, and sugarcane growth and productivity were measured and calculated. Soil dry bulk density before soil tilling is 1.40 g/cc in average, and after soil tilling is between 1.29 g/cc and 1.38 g/cc. Effective soil tilling causes an optimum soil dry bulk density of 1.29 g/cc up to 1.31 g/cc, or 1.30 g/cc in average. A highest average of sum of sugarcane sprouts (i.e. 3 stalks/bunch) is obtained on this soil physical condition. This case becomes a key for obtaining a highest average of sugarcane productivity of 63.08 ton/ha, so that average sugar productivity is highest too (i.e. 7.30 ton/ha). Optimum soil tillage, which result in maximum sugarcane growth and production, is obtained by applying minimum soil tillage methods. It produces a maximum temporary profit for sugar company of Rp 34966034,00/ha. Efficient soil tillage action produces minimum soil tillage operation time of 0.64 hour/ha and minimum soil tillage operation cost of Rp 57673,00/ha. A "subsoiling–plowing–harrowing–furrowing" method is an optimum soil tillage method on Ultisol dry land sugarcane cultivation.

BACKGROUND

People in household and food industry scales always needed sugar. This time its price reaches Rp 9500,00/kg approximately, so sugar factories in Indonesia attempted this commodity.

Sugarcane was a basic commodity for a sugar factory. In Indonesia, sugarcane was cultivated on a wet field ("reynoso" system) and on a dry land. Dry land sugarcane cultivation was generally applied on sugarcane plantations that managed by sugar factories.

It was noticed that 1.2 Mega ton/year up to 1.6 Mega ton/year, or 37% up to 48% of national sugar demands per year were still imported from abroad.

Indonesian Sugar Council showed that sugar import in 2004 was 1.29 Mega ton, but in 2008 was 1.61 Mega ton (Prabowo 2009).

Since several years ago sugar production was increased. A sugar contribution in 2003 was 51.7%, whereas in 2004 was 61.3%, and in 2008 was 63.0%. In this year, an estimated sugar production was 2.9 Mega ton, or 200 kilo ton over the sugar necessity for households consumption (Prabowo 2009).

Sugarcane production was a function of plant, growing media (soil), climate, and human activity. Climate was a factor that could not be changed, whereas plant and soil could be changed or manipulated by human activities. Maximum sugarcane production was achieved if the four factors, as above, were in optimum conditions.

Plant genetic factor that commonly influenced sugarcane production was genotype or variety. The usage of superior variety would result in high sugarcane growth and production.

Soil contributed as a media for sugarcane stalk upright and roots growth, and together with water contributed as a media for roots' nutrient absorption. Maximum sugarcane growth and production were achieved if soil was in optimum conditions.

Climate was a factor that influenced the availability of sunlight, air, and water. It contributed as a media for sugarcane to adapt and grow.

Human activities were a factor that contributed for sugarcane best growing in order to acquire a high sugarcane production. It was achieved by applying cultivation engineering that beginning from soil tillage, planting, and plant maintenance up to harvesting activities.

Soil tillage was the first activity, where its energy usage was the biggest, because it required big power to till soil. Its effectiveness and efficiency determined quality of the next cultivation results.

Soil tillage was a soil mechanical manipulation in order to reach a proper environment for plant growing. On dry land sugarcane cultivation, it was conventionally consisting of subsoiling, plowing, harrowing, and furrowing. Applying the intensities of plowing and harrowing to acquire the variation of soil physical conditions can do treatments. Optimum soil tillage method was determined by best soil physical conditions, which it produced maximum sugarcane growth and productivity.

Soil tillage in a dry land sugarcane cultivation area was mechanically conducted by means of four-wheel tractors. The tractors must had sufficient available power because when it were applied to till soil so that almost overall available power was used, thus it was very important to measure and calculate it's magnitude of fuel consumption and power.

OBJECTIVE

The objective of the research was to analyze effectiveness and efficiency of soil tillage results and to determine optimum soil tillage method on dry land sugarcane cultivation.

METHODS

The research was conducted on September 2002 until August 2003 in an Ultisol dry land sugarcane area at Gula Putih Mataram Company, Sugar Group Company, Central Lampung, Sumatra Island, Indonesia.

Main research variables which be used to analyze effectiveness and efficiency of soil tillage results and to determine optimum soil tillage methods on a dry land sugarcane cultivations are:

1. Soil dry bulk density, S_{BD}
2. Sum of sugarcane sprouts, S_{SS}
3. Sampling sugarcane productivity, S_{CP}
4. Sampling sugar productivity, S_{SP}
5. Fuel consumption per unit of tilled soil area, F_{CA}
6. Tractor power, P_{TR}.

Machines, tools, instruments, and materials for conducting research consisted of:

1. Two units of four-wheel tractor:
   FIAT (Fiatagri-New Holland 4WD type, 140 hp, 7140 kg) and JOHN DEERE (JD6250-4WD type, 100 hp, 3950 kg)
2. Soil tillage tools:
   A subsoiler plow (straight shank, 2 bottoms, 0.30 m depth), a disk plow (standard, 3 disks, 0.64 m disk diameter), a moldboard plow (long moldboard, 2 bottoms, 1.66 m width), a disk harrow (two-gangs heavy duty, 28 cutaway disks, 4.32 m width), and a furrower (adjustable wings, 3 bottoms, 4.00 m width)
3. Instruments:
   Some metal rings (EIJKELKAMP), a stopwatch, a measuring tape, a vernier caliper, a measuring glass, a thermometer, an analytical balance, an oven, and a waterbath
4. Materials:
   Sugarcane seedlings (variety of TC-9), diesel fuel, and water.

Research design was made to determine optimum soil tillage methods on dry land sugarcane cultivation, as seen in Figure 1. Six soil tillage methods were applied in a dry land sugarcane area of ± 8 ha. It can be seen in Figure 2. Tractor Fiat was used to pull a subsoiler plow, a disk harrow, and a furrower, whereas tractor John Deere was used to pull a disk plow and a moldboard plow.

On each soil tillage method application, volume of fuel consumption, fuel temperature, and soil dry bulk density were measured. The data were used to calculate variables, such as fuel density, weight of fuel consumption, tractor power, and specific fuel consumption. Growth variable was measured during the growing period, or it was similar 9 months. The variable was sum of sprouts. Sampling sugarcane and sugar productivities were measured and calculated before harvesting. Optimum soil dry bulk density was determined according to highest values of the sampling sugarcane and sugar productivities.

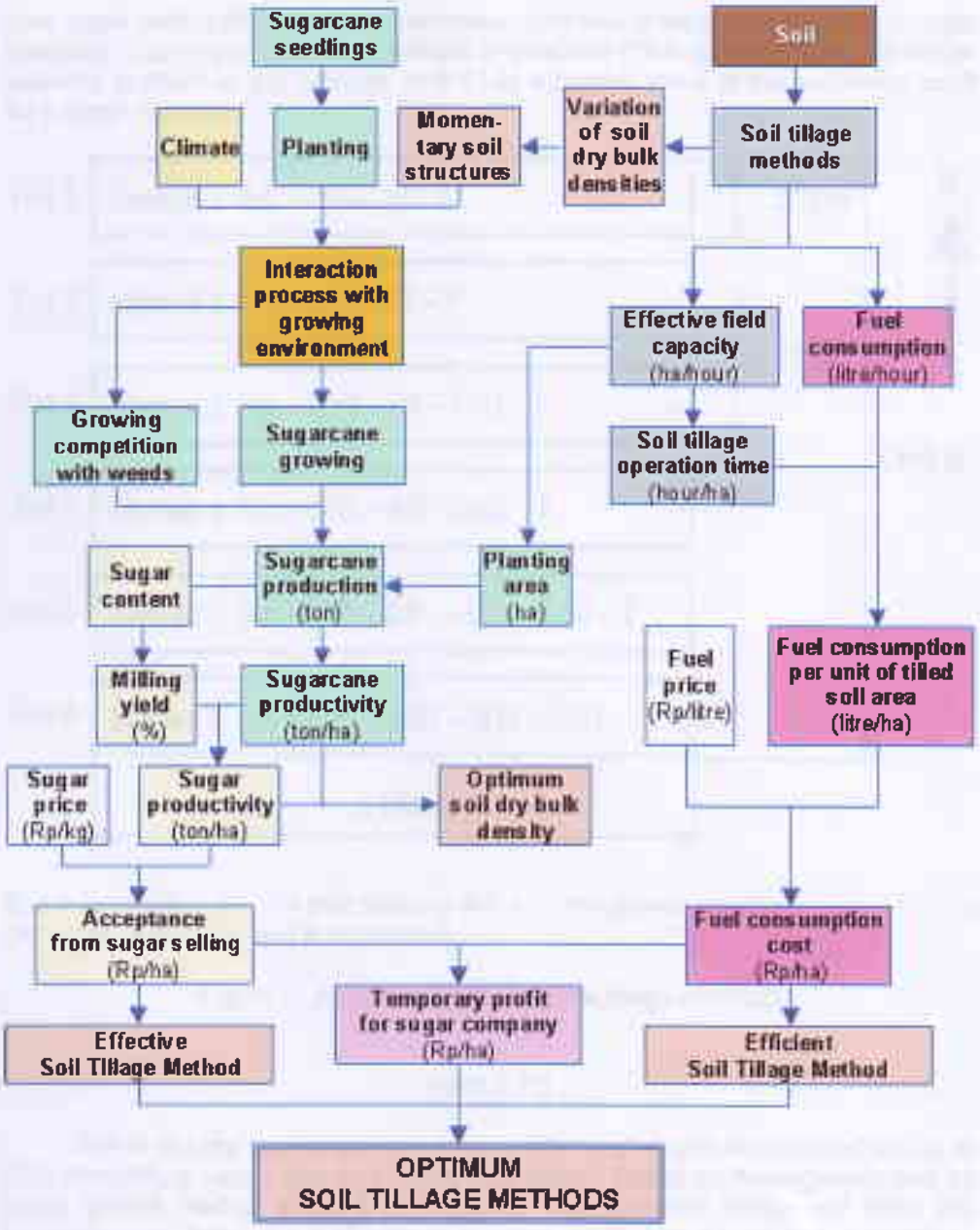
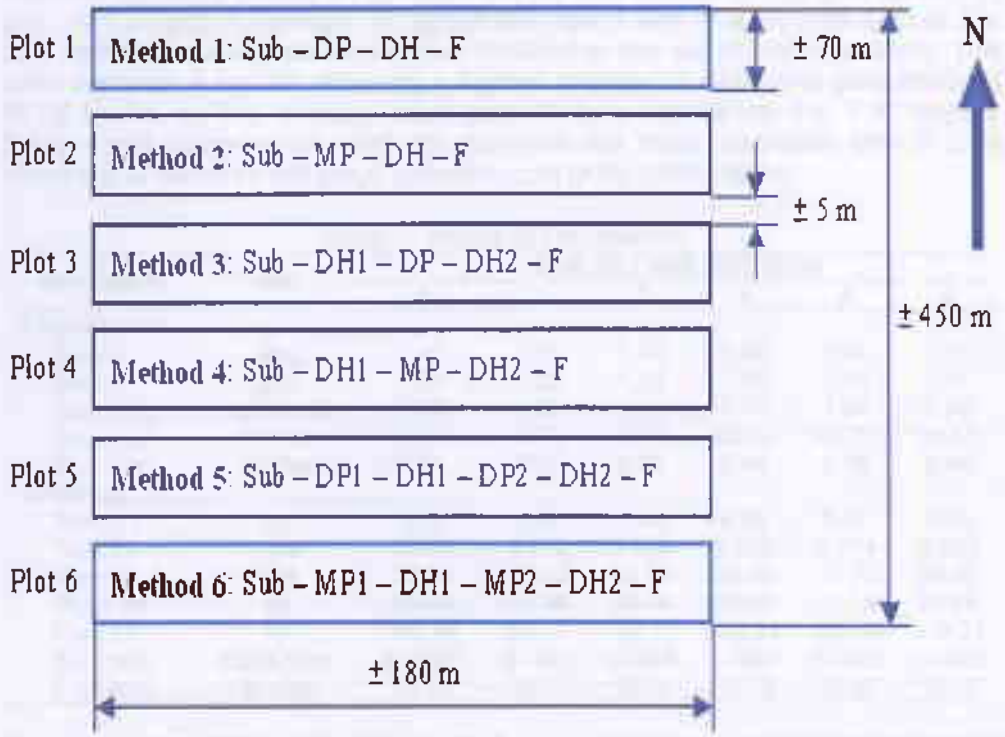


Figure 1. Research design to determine optimum soil tillage methods

Effectiveness of soil tillage results was valued according to amount of acceptance from sugar selling, whereas efficiency of soil tillage results was valued according to fuel consumption cost. A difference between the amount of acceptance

from sugar selling and the fuel consumption cost was a temporary profit for a sugar company. Optimum soil tillage method is obtained if the application of soil tillage methods is effective and efficient, or if it has a highest value of the temporary profit for a sugar company.



Sub = subsoiling, DP = disk plowing, MP = moldboard plowing, DH = disk harrowing, and F = furrowing

Figure 2. Application of the six soil tillage methods

RESULTS

Soil in the dry land sugarcane area is Ultisol. Soil texture from surface up to 0.60 m depth is sandy clay and sandy clay loam. Based on homogeneity test by using Bartlett method showed that soil dry bulk densities before soil tilling are homogeneous, those are 1.40 g/cc in average, so that its effects to the machines operation are uniform.

Result of the research to determine optimum soil tillage methods on dry land sugarcane cultivation can be seen on Table 1. Analysis results of soil tillage effectiveness and efficiency are shown on Table 2.

The increasing of soil tillage intensities will increase tractor power and fuel consumption, but it does not increase sugarcane productivity. There are many

compactions by the tractors and the implements during soil tilling, so that the soil dry bulk densities become increase. This condition will restrict sugarcane roots to grow and absorb nutrient.

Soil dry bulk densities after soil tilling are between 1.29 g/cc and 1.38 g/cc. Effective soil tilling causes an optimum soil dry bulk density of 1.29 g/cc up to 1.31 g/cc, or 1.30 g/cc in average. A highest average of sum of sugarcane sprouts (i.e. 2.56 stalks/bunch, or 3 stalks/bunch) is obtained on this soil physical condition. This case becomes a key for obtaining a highest average of sugarcane productivity of 63.08 ton/ha, so that average sugar productivity is highest too (i.e. 7.30 ton/ha). Efficient soil tillage action produces minimum soil tillage operation time of 0.64 hour/ha and minimum soil tillage operation cost of Rp 57673,00/ha.

Table 1. Result of the research

Parameters	Unit	SOIL TILLAGE METHODS					
		1	2	3	4	5	6
Effectiveness							
S_{BD} - 0	g/cc	1.40	1.40	1.40	1.40	1.40	1.40
S_{BD} - 1	g/cc	1.31	1.29	1.35	1.38	1.36	1.31
S_{SS} - avg	stalk/bunch	1.83	2.56	1.61	2.14	1.64	1.78
S_{CP} - avg	ton/ha	56.15	63.08	41.54	45.64	40.77	36.41
S_{SP} - avg	ton/ha	6.71	7.30	5.09	5.84	5.96	3.94
Efficiency							
A_{OT} - tot	ha	3.66	3.67	4.83	4.76	5.27	5.18
T_{OT} - tot	hour	2.640	2.872	3.099	3.065	3.574	4.023
V_{FC} - tot	litre	56.90	65.10	66.80	65.70	94.70	79.30
W_{FC} - tot	kg	46.42	52.98	54.54	53.60	77.14	64.64
P_{TR} - tot	hp	368.04	396.37	460.70	453.01	666.37	519.21
S_{FC} - avg	kg/hp.hour	0.1927	0.1925	0.1926	0.1927	0.1925	0.1925
F_{TS} - avg	litre/ha	15.45	17.61	13.78	13.73	17.85	15.22

S_{BD} - 0 = average initial soil dry bulk density, S_{BD} - 1 = average soil dry bulk density after soil tilling, S_{SS} - avg = average of sum of sugarcane sprouts, S_{CP} - avg = average sampling sugarcane productivity, S_{SP} - avg = average sampling sugar productivity, A_{OT} - tot = total tilled soil area, T_{OT} - tot = total field time, V_{FC} - tot = total volume of fuel consumption, W_{FC} - tot = total weight of fuel consumption, P_{TR} - tot = total tractor power, S_{FC} - avg = average specific fuel consumption, F_{TS} - avg = average fuel consumption per unit of tilled soil area

Table 2 intimated that the sugar company must prioritise effective dry land sugarcane cultivation, especially during soil tilling, so that obtained maximum sugarcane productivity. Optimum soil tillage, which result in maximum sugarcane growth and production, is obtained by applying minimum soil tillage methods. It produces optimum soil dry bulk densities of 1.29 g/cc up to 1.31 g/cc, or 1.30 g/cc in average.

Table 1 Analysis results of soil tillage effectiveness and efficiency

Method	S_{BD} (g/cc)	T_{ST} (hour/ha)	F_{CC} (liter/ha)	P_{SG} (ton/ha)	A_{SS} [1)] (Rp/ha)	C_{FC} [2)] (Rp/ha)	P_{SC} (Rp/ha)	Opt. seq.
S-DP-DH-F	1.31	0.72	15.45	6.71	32 208 000	64 873	32 143 127	2
S-MP-DH-F	1.29	0.78	17.61	7.30	35 040 000	73 966	34 966 034	1
S-DH-DP-DH-F	1.35	0.64	13.78	5.09	24 432 000	57 893	24 374 107	5
S-DH-MP-DH-F	1.38	0.64	13.73	5.84	28 032 000	57 673	27 974 327	4
S-DP-DH-DP-DH-F	1.36	0.68	17.85	5.96	28 608 000	74 974	28 533 026	3
S-MP-DH-MP-DH-F	1.31	0.78	15.22	3.94	18 912 000	63 927	18 848 073	6

S = subsoiling, DP = disk plowing, MP = moldboard plowing, DH = disk harrowing, F = furrowing, S_{BD} = average soil dry bulk density, T_{ST} = average soil tillage operation time, F_{CC} = average fuel consumption per unit of tilled soil area, P_{SG} = average sampling sugar productivity, A_{SS} = average acceptance from sugar selling, C_{FC} = average soil tillage operating cost, P_{SC} = average temporary profit for sugar company, and Opt.seq. = optimum sequence
[1)] Calculated according to average sugar price in 2005, that was Rp 4 800/kg
[2)] Calculated according to average diesel fuel price in 2005, that was Rp 4 200/litre

CONCLUSIONS

Effective soil tillage action is a minimum soil tillage action that produces an average optimum soil dry bulk density of 1.30 g/cc for maximum sugarcane growing so that obtained maximum sugarcane productivity of 63.08 ton/ha and maximum sugar productivity of 7.30 ton/ha. It produces a maximum temporary profit for sugar company of Rp 34966034,00/ha. Efficient soil tillage action produces minimum soil tillage operation time of 0.64 hour/ha and minimum soil tillage operation cost of Rp 57673,00/ha. A "subsoiling–plowing–harrowing–furrowing" method is an optimum soil tillage method on Ultisol dry land sugarcane cultivation.

SUGGESTIONS

It is recommended to till soil effectively by applying minimum soil tillage method on dry land sugarcane cultivation in order to acquire optimum soil dry bulk density for maximum sugarcane growing and production, so that obtained maximum profit.

REFERENCES

Prabowo HE. 2009. *Formerly Exporter, Now Importer*. Newspaper "Kompas", July 23th, 2009.

Pramuhadi G. 2005. *Optimum Soil Tillage on Dry Land Sugarcane Cultivation*. [Dissertation]. Bogor: Postgraduate School, Institut Pertanian Bogor.