New Type of Grass Meter for Pasture Yield Estimation

By TATSURO NOMOTO

Grassland Planning Division, National Grassland Research Institute

Grass meter (herbage meter), which was deviced by Fletcher and Robinson[1] and tested or improved by Campbell et al.[2], Johns et al.[3], Alcock et al.[4] Back[5),6)], and Lovett et al.[7], was tested by Sekiyama and others[8] in Japan. Methods of eliminating interferences caused by moisture on plant surface or soil moisture were deviced, and it is now in practical use as Nodenken-type of grass meter. However, owing to a big volume of electrode portion, difficulties have been felt in carrying the meter over a wide, sloped grassland, and hence sites of measurement are limited in number.

To solve this problem, plane electrode, which is smaller and lighter than previous rod-shaped electrode, was deviced, and by combining plane electrode, electrostatic capacity meter, and recorder as one set, a walking type of grass meter with automatic recording has been designed. Thanks are due to Mr. Tetsuo Sekiyama, a research scientist of Nodenken (Bio-Environment Laboratory, Central Research Institute of Electric Power Industry) for his cooperative works on electronic aspects.

Plane electrode type of grass meter

The plane electrode is composed of an aluminum plate and an acrylresin insulating plate (Fig. 1). When distance (referred to d) between these two plates and that (referred to D) between the aluminum plate and ground surface are kept constant, an electric capacity, C_0, between the electrode and ground surface can be expressed as follows:

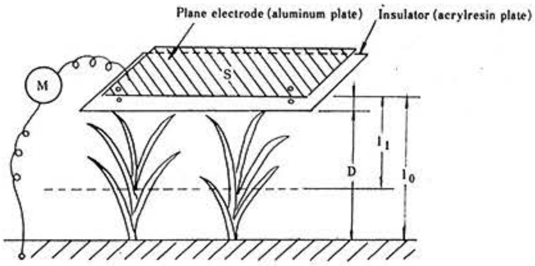


Fig. 1. Principle of plane electrode

$$C_0 = K\frac{S}{l_0}$$

where

S=area of electrode plate

$l_0 = D + d$

K=constant related to vacuum dielectric capacity and relative dielectric capacity of air, etc.

Pasture crops growing on the ground surface exhibit an effect as if the ground surface approaches to the electrode. If this apparent distance at that state is referred to l_1, the electric capacity, C_1, is expressed by the following equation:

$$C_1 = K\frac{S}{l_1}$$

Assuming that in general there exists a certain relationship between amount of pasture crop (x) and apparent distance (l) as given by $l = f(x)$, the amount of pasture crop can be estimated by knowing electric capacity, Cx, as shown below:

$$Cx = \infty\frac{1}{f(x)}$$

However, the apparent distance, l, might be influenced by species or plant type of crops. Therefore experiments were carried out to examine in detail the relation between electric capacity reading and amount of crop actually harvested with different species, growth stages and growing season, by changing D and d. The result showed that:

1) Sensitivity of measurement increased with decreasing D and d, but when D became too small so that plants were pushed down the sensitivity decreased.

2) Accuracy of measurement was highest when D was adjusted just equal to an average plant height. With D above or below that the accuracy decreased (Table 1).

Table 1. Performance of plane electrode

D (cm)	l (cm)	Sensitivity (P_F/g)	Accuracy (corrlation coefficient)
50	1	0.02	0.833
	3	0.02	0.833
	5	—	—
40	1	0.12	0.920
	3	0.06	0.919
	5	0.03	0.865
30	1	0.51	0.865
	3	0.14	0.916
	5	0.08	0.883
20	1	0.45	0.930
	3	0.08	0.930
	5	0.05	0.808

Orchardgrass field measured on 21 Sept. 1972
Average plant heigh=32 cm

3) With $d \fallingdotseq 2$–3 cm and $D \fallingdotseq$ plant height, accuracy of the plane electrode was similar to that of rod-shaped electrodes, showing $\gamma=0.9$ between meter readings and actual amount of crops.

4) Only little difference was observed with different species and growth stages. However, accuracy of measurement decreased considerably with crops lodged, as in the case of rod-shaped electrode.

5) Measurable range was limited only up to 5–10 cm around the area under the plane electrode (Table 2).

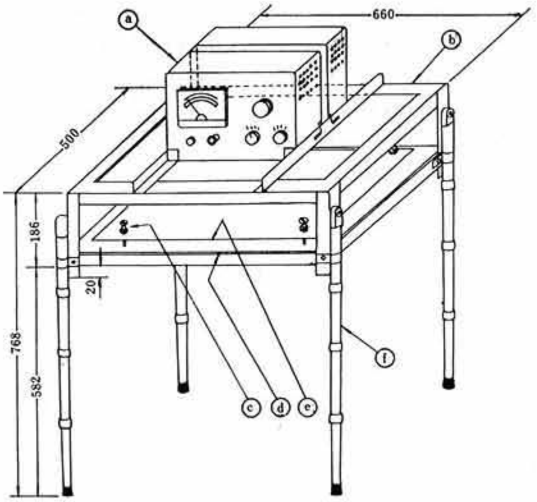
Thus, it was proved that accuracy of plane electrode was comparable to rod-shaped electrode. Therefore, a grass meter of plane electrode type as shown in Fig. 2 was constructed. It is not only simple in structure, light in weight and easily transported but also manufactured with less cost.

1) Specification: Aluminum plate of 400 × 565 × 1 mm is placed in parallel to acrylresin plate of 500×660×5 mm at a distance of 30 mm. Acrylresin plate is fixed to a rectangular frame (made of aluminum) with tetrapod of adjustable length. Meter for reading is placed on the frame.

2) Method of measurement: After a connection of electrode—meter for reading—ground wire is done, zero-point adjustment is made on a plane open land. Then, zero-point adjustment and measurement are made on grassland by adjusting the distance between acrylresin plate and ground surface to plant height. When plant height is not uniform, an average is taken.

Table 2. Extent of area to be measured (9 Oct. 1972)

Plot	Item	Without circumference	With circumference		
		(30×60cm)	(40×70cm)	(50×80cm)	(60×90cm)
1	Reading (P_F)	43.0	47.0	45.5	47.5
	Plant fresh weight (g)	327	463	551	707
2	Reading (P_F)	10.5	12.0	13.5	12.5
	Plant fresh weight (g)	127	211	255	360
3	Reading (P_F)	5.5	6.0	5.5	5.5
	Plant fresh weight (g)	81	147	214	273



ⓐ Grass meter
ⓑ Aluminum frame (Angle 30×30×3 mm)
ⓒ Screw to adjust distance between electrode and insulator
ⓓ Acryl plate (part of insulator) 660×500×5 mm
ⓔ Aluminum plate (part of electrode) 565×500×1 mm
ⓕ Tetrapod of adjustable height

Fig. 2. Plane electrode grass meter (experimentally developed)

3) Calibration: As readings express electric capacity, P_F, they must be converted to weight of pasture by using regressions between readings and weight of pasture harvested from 50 × 66 cm areas of land. Calibration has to be made when plant type, vegetation structure, and growth stage are different, but a same calibration can be applied when species, vegetation component and growth stage are same. Even when vegetation is not uniform such as on grazing grassland, a same calibration can be used except for extreme case.

4) Limitation in use: It can not be used when it rains, or when plants are wet soon after rainfall or with a dense fog. Accuracy lowers with plants lodged or trampled down.

Walking type of grass meter

By utilizing the plane electrode, a grass meter of walking type was designed.

1) Methods of recording

Electric capacity between plane electrode and ground surface is transformed to D.C. voltage, and which is recorded by cell type recorder. In using a grass meter of walking type with automatic recording, a problem of how to identify the sites where measurement was made should be solved. There are three possible ways to solve it.

(1) Synchronized continuous recording: Feeding of recording paper is synchronized with the rotation of running wheels.

(2) Intermittent recording: Speed of feeding of recording paper is kept constant, and the recording is made for every one rotation of wheels.

(3) Continuous recording with marking: Continuous recording is made at a constant feeding speed of recording paper. Rotation of wheels is also recorded on the paper by use of a marker attached to the recorder.

By the first method, relation between amount of pasture crops and corresponding location of measurement can most easily be identified, and total amount of crop grown in areas where the grass meter travelled can be estimated simply by integrating the record. However, this method requires a special mechanic for feeding recording paper at a speed synchronized with that of wheel rotation.

In the second method, an usual recorder is used and number of measurement itself indicates distance of travel. But the method has disadvantages such as electric interferences caused by the use of microswitch in the circuit for detecting electric capacity, or a time lag in response of recorder that makes record reading less accurate.

Therefore, the author adopted the third method, in which circuit for recording electric capacity and that for recording sites of measurement are separated. Electric capacity corresponding to amount of pasture crops is continuously recorded and sites of measurement can be made by checking records of rotation of wheel. In practice, a supplementary wheel (1 m run for one rotation) attached with more than ten rod-shaped protrusions (50 mm long) is used for keeping the wheel always contacting to ground surface. Rotation of this wheel is detected by a waterproof microswitch, which operates a marker equipped inside the recorder.

An example of record obtained by this method is shown in Fig. 3.

2) Measurements taking while running

Measurements were taken while the grass meter was running, and pasture crop was harvested from each site of measurement. As shown in Fig. 4, very high correlations were found between readings of the meter and actual weight of pasture crops harvested, indicating a high accuracy of the measurements taken while the meter was running.

3) Reproducibility of measurements

Results of measurement carried out repeatedly on a same pasture field are given in Fig. 5, which shows a high reproducibility except in areas with great amount of pasture crop, where the supplementary wheel stamped down the crop and site of measurement was more or less shifted in successive measurements.

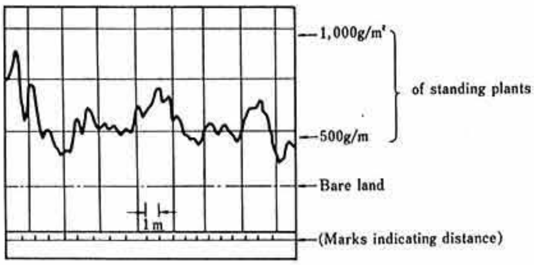


Fig. 3. An example of continuous recording

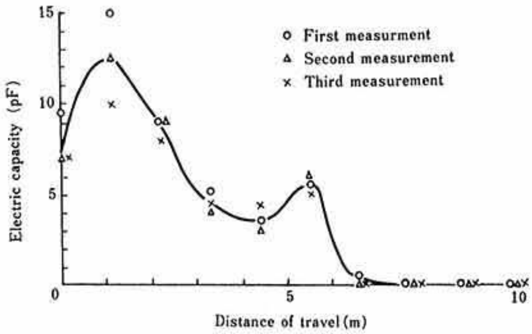
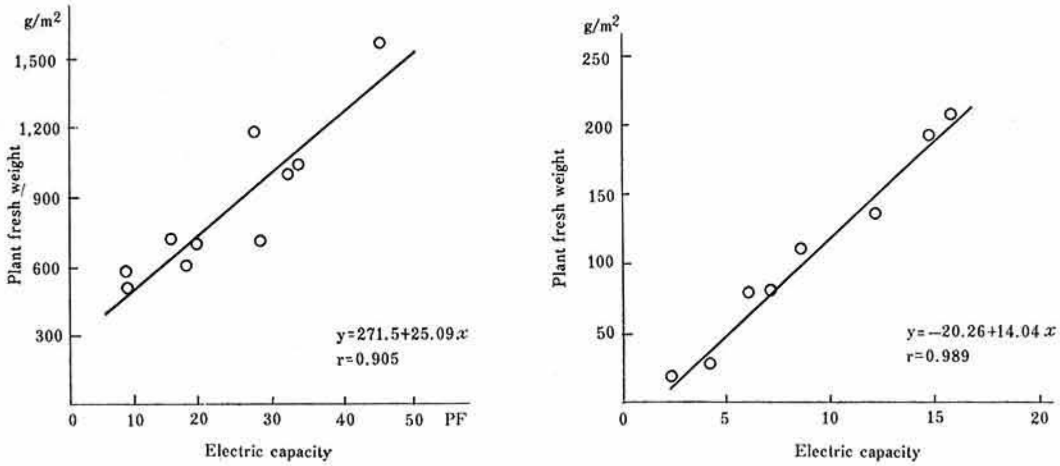
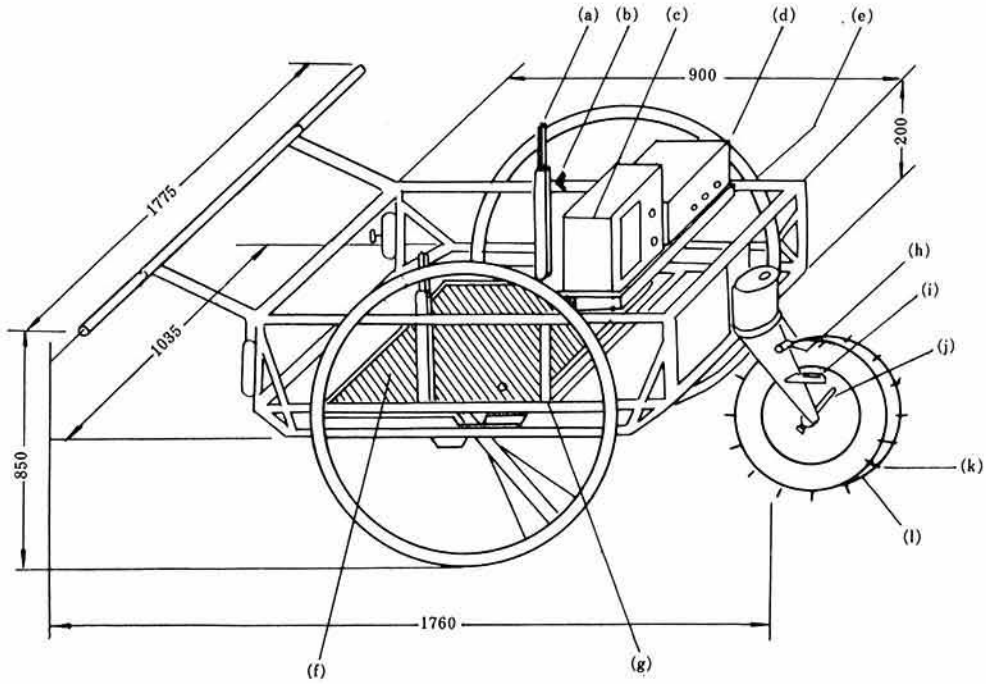


Fig. 5. Reproducibility in repeated measurements



Left: Measured on 8 Aug. 1974. Mixed sown plot (Orchardgrass as dominant)
Light: Measured on 15 Apr. 1974. Mixed sown plot (Orchardgrass and Tall fescue as dominant)

Fig. 4. Performance of walking type grass meter



(a) Rod to adjust height of electrode
(b) Screw to adjust height of electrode
(c) Recorder
(d) Converter
(e) Spring for protecting machine
(f) Electrode portion
(g) Screw to adjust distance between electrode and insulator
(h) Connecting point
(i) Switch
(j) Lever for operating switch
(k) Rods (15 in number) for contacting ground surface
(l) Rear cart

Fig. 6. Diagrammatic illustration of walking type grass meter (experimentally designed)

4) Specification

The newly developed walking type grass meter consists of plane electrode, electrostatic capacity meter, and recorder, all of them are mounted on a two-wheeled rear cart with a supplementary wheel (Fig. 6).

(1) Cart is drawn by manpower at a working speed of 2 km/hr
(2) Easy to disassemble and assemble: convenient for transportation.
(3) Area of plane electrode is 0.25 m^2 (450 × 555 mm) as a standard.
(4) Plane electrode moves up and down according to plant height.
(5) Electric power source for electrostatic capacity meter and recorder is of a battery system, which has to give satisfactory responsiveness and shock resistance.
(6) A supplementary wheel has to contact continuously with ground surface.

Methods of measurement, calibration and limitation in use are almost similar to those of the plane type grass meter.

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