Paper No. 39-1554
AN ASAE MEETING PRESENTATION

SURFACE TRASH DENSITY DETECTION

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Written for presentation at the
1989 International Winter Meeting
The AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

Marriott New Orleans Hotel
New Orleans, Louisiana
December 12-15, 1989

SUMMARY:

Two electronic stubble detection systems were developed which estimated surface trash using changes in light intensity. Light-dependent cadmium sulphide resistors measured changes in light intensity due to varying stubble density.

KEYWORDS: Measurement, Residue, Straw

American Society of Agricultural Engineers

St. Joseph, MI 49085-9659 USA

ABSTRACT

The Alberta Farm Machinery Research Centre developed two electronic stubble detection systems which estimate surface trash density using changes in light intensity. Light-dependent cadmium sulphide resistors (LDR) measured light intensity of the l2 volt lamps. In both detection systems, changes in light intensity due to changes in surface trash cover caused changes in the resistance of the LDR's. Resistance network circuits were used to measure the resistance changes in the LDR's. Voltage output from the resistance networks were amplified and displayed using a simple voltmeter. Calibration tests indicated that with minor design changes LDR applications could offer an accurate, reliable indication of surface stubble density. Results were graphed and recommendations made to improve future sensor designs.

INTRODUCTION

Evaluation and research projects done by the Alberta Farm Machinery Research Centre (AFMRC) necessitate an accurate, but simple method of measuring surface trash cover. An in-house research project was initiated to evaluate current research in stubble density detection and develop a low cost sensor to provide accurate density measurements.

Numerous methods and systems have been developed to detect surface stubble density. Image analysis, laser diffusion detection and infrared phototransistor reflectance have all been used to detect surface trash density with limited success. Based on principles developed by Kano, McClure and Skaggs (l985), two stubble density detection systems employing reflectance and intensity measurements were developed and tested.

Sensors were designed with the following three objectives in mind:

l. The sensor should use power sources normally available in the field.
2. Sensors should be relatively low cost.
3. Sensors should provide accurate trash measurements up to trash cover of 5000 kg/ha (4450 lbs/ac).

METHODS AND MATERIALS

Kano, McClure and Skaggs (l985) evaluated the design and performance of a near infrared reflectance soil moisture meter. The moisture meter measured reflectance using an integrated cylinder and two narrow band interference filters. Using the phenomenon of light movement and the principles researched by Kano, McClure and Skaggs (l985), a sensor was developed that measures the amount of light reflectance off the soil surface. The amount a substance reflects light depends on the total radiant flux incident upon the surface of a material and varies according to the wavelength distribution of the incident radiation. Since dark soil will absorb more light than straw or other surface trash, a relationship between the amount of reflected light off the soil surface and the change in resistance of LDR's was developed.

Measurement of light absorption through the vertical plane of a stubble field was also examined using electronic circuitry and similar sensor design as used in the reflectance measurement system. As the density of the medium between light source and sensor increases, the greater the amount of light absorption by the medium. Using this principle of light absorption, a constant light source provides excitation to fifteen LDR's. As the amount of material, surface stubble, increases between the light source and the LDR's, the intensity of light on the LDR's decreases. With a decrease in light intensity there is a corresponding increase in the resistance of the LDR's. A linear relationship between the resistance of the LDR's and the surface trash density was determined.

LIGHT DEPENDENT RESISTORS (LDR)

Light dependent cadmium sulphide resistors, FIGURE l.0, were a cost effective means, $3 each, of measuring light intensity. LDR's range in resistance from approximately 50 ohms in bright light to a maximum of 5 megohms in total darkness. In this application, the LDR's were placed in series to provide an average measurement of light intensity over a given area and to increase the sensitivity of the sensors over the range of light intensity. For this application the resistance in the LDR's varied from 400 ohms to 5 kilohms in the reflectance sensor and from 3 kilohms to 8 kilohms in the intensity sensor.

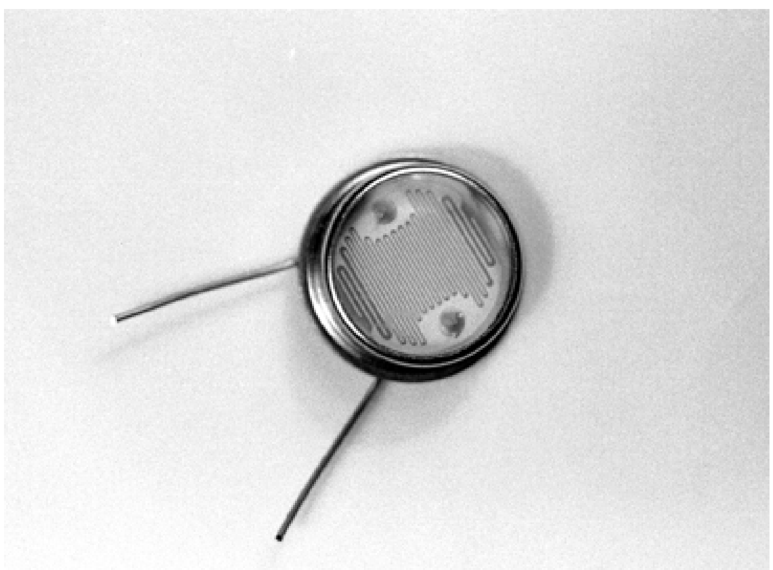

FIGURE l.0 Light Dependent Cadmium Sulphide Resistor

ELECTRONIC CIRCUIT DESIGN

In the reflectance sensor circuit, FIGURE 2.0, the resistance in the LDR's changes corresponding to the amount of light reflected from the soil surface. Resistance changes in the LDR's caused a differential voltage to be generated across the bridge in the resistance network. The positive and negative sides of the bridge are put into the positive and negative channels of an instrumentation amplifier. Output from the instrumentation amplifier is then channelled into an operational amplifier with two feedback resistance gains. Once the maximum range of output is set using a potentiometer, the output voltage of the circuit is measured from the final output pin of the operational amplifier using a simple voltmeter. The light source and the circuit are powered by two 12 volt batteries connected in parallel. Two l2 volt batteries are required since approximately l6 amperes of current are required to provide adequate light intensity. An automotive battery connected to an alternator also supplies enough power to run the sensor and is easily available in most field applications.

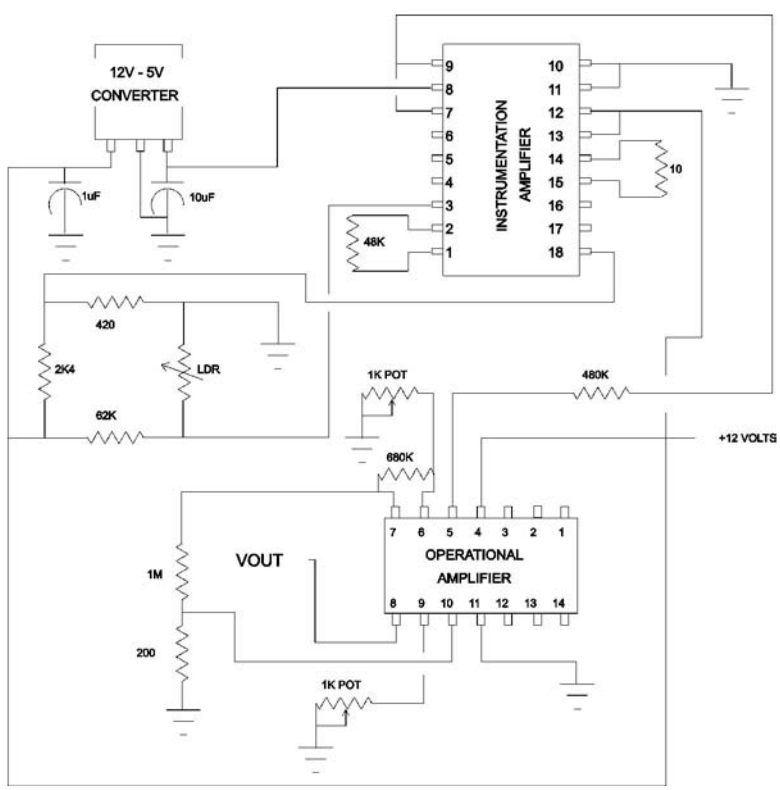

FIGURE 2.0 Reflectance Sensor Circuit

The intensity sensor circuit, FIGURE 3.0, uses the same principles as the reflectance sensor. Changes in light intensity on the LDR's changes the resistance of a resistor network. A voltage is measured in a resistance network and is compared to a reference voltage using a voltage comparator. Output voltage from the voltage comparator is then amplified using an operational amplifier. Using a voltmeter, final output from the operational amplifier is measured. Power is supplied to the lamps using a dc power supply. The lamps required 5 volts at 9 amperes. A l2 volt battery was used to power the measurement circuit. The two separate power supplies were used to decrease noise generation from the lights being transferred to the measurement circuit.

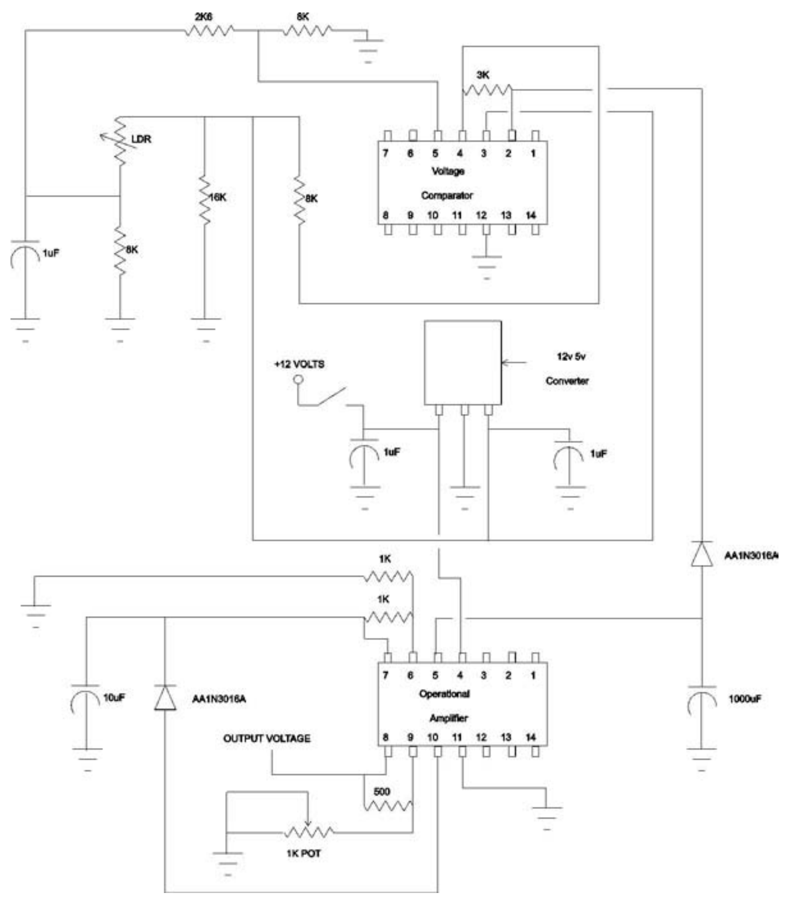

FIGURE 3.0 Intensity Sensor Circuit

REFLECTANCE SENSOR DESIGN

Light coloured objects reflect a greater amount of light than dark objects. This principle is the basis of the design of the reflectance sensor, FIGURE 4.0. Twelve LDR's and nine automotive lamps were mounted on the top of an aluminum hood facing toward the soil surface. LDR's and lights were located 35.6 cm (l4 in) from the base of the hood to provide adequate height when measuring a stubble field. The LDR's were spaced at l9.0 cm (7.5 in) from each other and 9.5 cm (3.74 in) from each light source. The spacing of the bulbs and LDR's provided adequate light reflectance and a wide range, 5 kilohms, of resistance in the

LDR's. As the amount of trash increased in the 0.3716 m^2 (576 in^2) area under the hood, the amount of light reflected to the LDR's increased. An increase in light reflected to the LDR's decreases the resistance in the LDR's. The 12 LDR's were connected in series and made up one arm of a bridge circuit outlined in FIGURE 2.0. The output signal from the analysis circuit was read using a simple voltmeter.

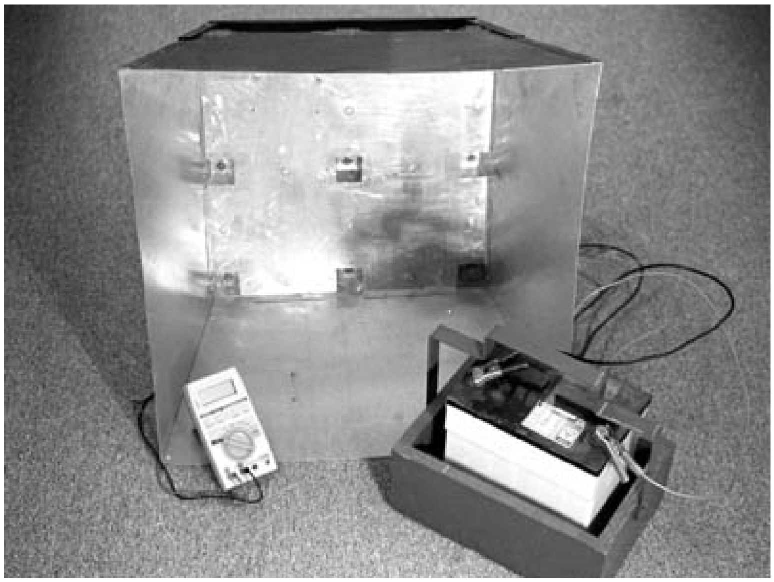

FIGURE 4.0 Reflectance Sensor

LIGHT INTENSITY SENSOR

The light intensity sensor, FIGURE 5.0, uses fifteen LDR's placed 45 cm (17.7 in) from nine 12 volt automotive lamps. The lamps and LDR's are placed in a triangular formation with the base of the triangle near the soil surface and greatest concentration of stubble. As the amount or density of surface trash increases, a decrease in light intensity on the LDR's results. Increased light received by the LDR's increased their resistance. The resistance changes of the fifteen LDR's in series changed the voltage output of the resistor network. The voltage output from the resistor network was then electronically adjusted and a corresponding voltage output recorded.

FIGURE 5.0 Intensity Sensor

RESULTS AND DISCUSSION

Calibration tests were performed on both detection systems. A known quantity of surface trash was placed under the detection unit and the input voltage to the circuit and lamps was recorded. With a supply voltage of l2 volts to the reflectance sensor lights and 5 volts to the intensity sensor lights, the output of the amplifying circuit was recorded.

REFLECTANCE DETECTION

Calibration using straw as reflectance material was done in two ways. First, a measured mass of straw was spread evenly over the entire area of the detection reflectance area and a reading taken. FIGURE 6.0 illustrates the results. Secondly, the measured mass of straw was compacted and placed in the detection area and a reading taken. Straw spread evenly over the entire detection area resulted in much larger amounts of reflectance than straw concentrated in a small area. The measurement of reflectance of straw in a horizontal plane does not allow for measurement of depth or thickness of the straw mat. Therefore, density was not measured, only percent cover. Once l00 percent of the detection area is covered, the sensor indicates the same voltage output regardless of the stubble density on the surface.

Calibration tests were performed on the reflectance sensor to determine if the depth of stubble caused a change in relative reflectance. Test results, FIGURE 7.0, show that depth of stubble does not change total reflectance enough to have a significant effect on the output. Thus, measuring surface trash density using reflectance is limited to trash concentrations of less than l900 kg/ha (l700 lbs/ac). Accurate measurements of surface trash using stubble reflectance assumes that the trash present is evenly distributed over the entire area of the sensor reflectance area. Detection of surface trash cover using reflectance is limited.

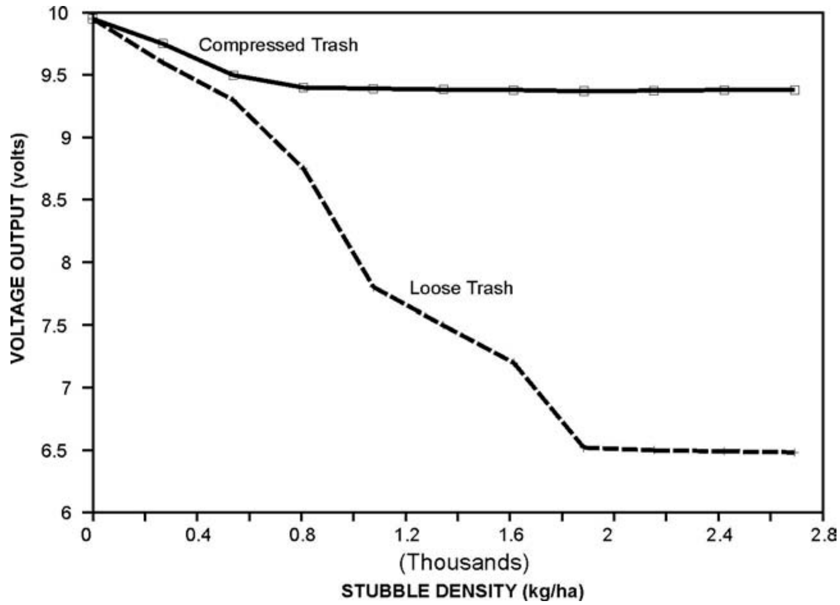

FIGURE 6.0 Reflectance Sensor Calibration

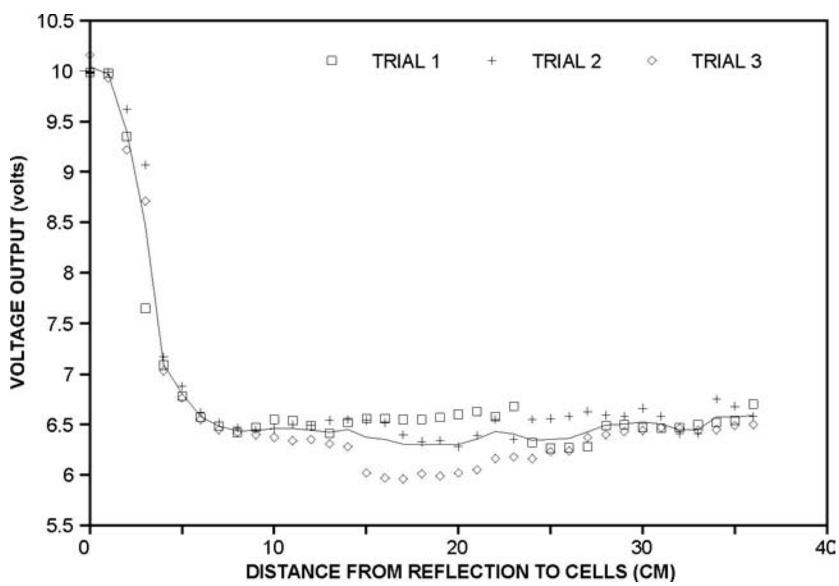

FIGURE 7.0 Stubble Depth Reflectance

INTENSITY DETECTION

Since detection of surface trash using reflectance has limitations, using a vertical plane of measurement provides more accurate results. Calibration of the intensity detection unit was performed using a styrofoam surface painted flat black and known quantities of straw. Flat black paint was used to eliminate reflectance off the surface and simulate a dark soil condition. After a known quantity of straw was placed on the black surface in such a manner as to simulate a stubble condition, a record of the output was recorded. With limited deviation, the concentration of straw between the LDR's and light sources caused a representative voltage drop. Calibration tests were made to a maximum surface trash cover of over 5000 kg/ha (4450 lbs/ac).

Field calibration test results on different soil colours were performed for barley, hard red spring wheat and soft wheat stubble. FIGURE 8.0 illustrates the calibration tests and field test results. A linear regression was performed on the calibration results, TABLE l.0 and FIGURE 8.0, and a coefficient of determination (R2) was 0.9705. A linear regression was performed on the combined field tests, TABLE 2.0. The linear regression resulting from the field tests was closely related to the calibration results as illustrated in FIGURE 8.0. Therefore, output from the intensity detection unit was concluded to be linear. Calibration tests indicate that stubble density measurement by intensity provides a superior means of detection over the reflectance method.

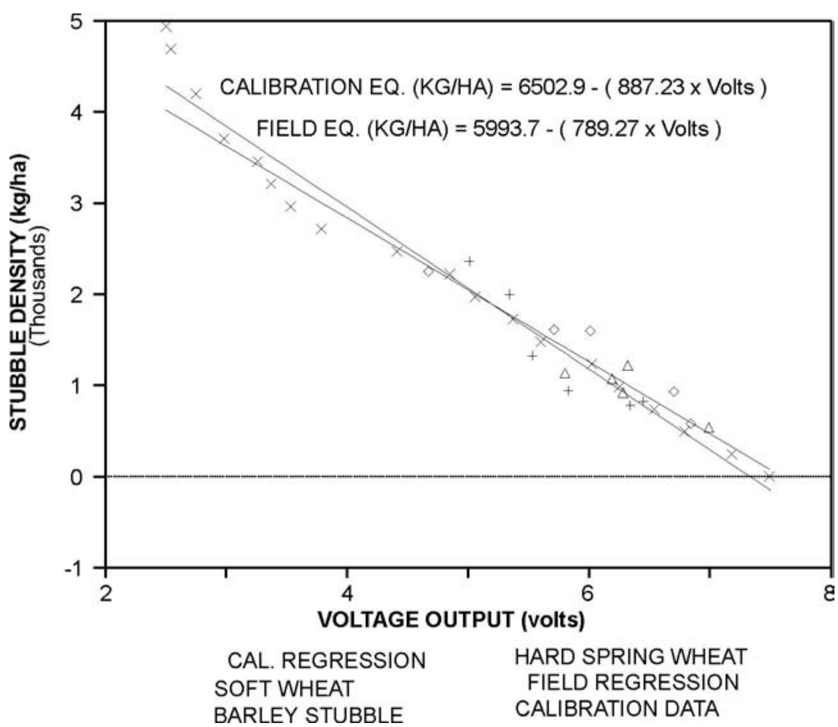

FIGURE 8.0 Intensity Detection Calibration

TABLE l.0 Stubble Intensity Sensor Calibration

TRASH COVER (kg/ha)	OUTPUT VOLTAGE (volts)	REGRESSION OUTPUT (volts)
0	7.49	7.25
247	7.18	7.24
494	6.79	6.71
741	6.54	6.44
988	6.25	6.17
1235	6.02	5.90
1481	5.60	5.63
1728	5.37	5.36
1975	5.06	5.09
2222	4.85	4.82
2469	4.41	4.55
2716	3.79	4.28
2963	3.53	4.01
3210	3.37	3.74
3457	3.26	3.47
3704	2.98	3.20
4198	2.75	2.66
4691	2.54	2.12
4938	2.50	1.85

TABLE 2.0 Field Test Results

CORRECTED VOLTAGE (VOLTS)	BARLEY DENSITY (kg/ha)	HARD RED WHEAT DENSITY (kg/ha)	SOFT WHEAT DENSITY (kg/ha)	CALIBRATION DENSITY (kg/ha)
4.67		2250		2360
5.01	2362			2058
5.34	2000			1765
5.53	1325			1597
5.71		1613		1437
5.80			1132	1357
5.83	945			1330
6.01		1598		1171
6.19			1070	1011
6.28			919	931
6.32			1221	896
6.34	783			878
6.45	829			780
6.70		953		558
6.84		580		434
6.99			538	301

Calibration tests were also performed to determine if straw type, stubble height and soil color affect the performance of the intensity detector.

As illustrated in FIGURE 8.0, straw type has little effect on the output results of the detection system. Hard red spring wheat, barley and soft wheat stubble were used for field calibrations. Results indicate variations in stubble light reflectance or absorption were not detectable for the type of straw used.

Tests were performed to determine if stubble height affects the voltage output of the intensity sensor. Ten grams (0.022 lbs) of stubble was used for four different stubble heights. Sensor output voltage measurements were taken at heights of 7.6, l5.2, 22.9 and 30.5 cm (3, 6, 9 and l2 inches). FIGURE 9.0 illustrates the results. To improve the accuracy of the detector for stubble height below 7.6 cm (3 in) the bottom row of lights should be placed close to the soil surface.

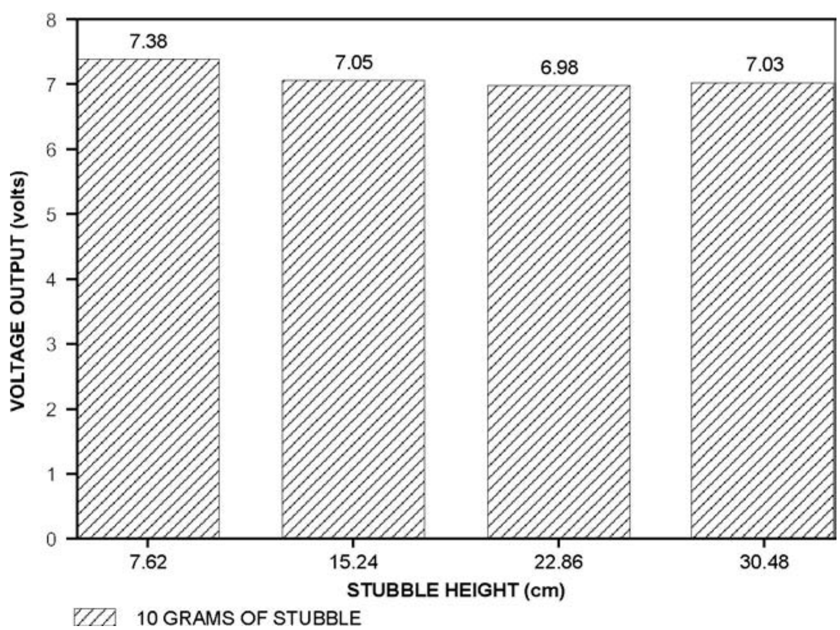

FIGURE 9.0 Stubble Height Effects on Intensity Sensor

Soil colour affected the output voltage of the sensor. As the soil became lighter, the voltage signal from the sensor increased. Tests indicated that increases in voltage of the sensor output was constant through the range of the sensor. When field measurements were taken a measurement of the sensor output reading on bare soil was taken. The voltage difference between the bare soil and the base voltage used in the calibration (7.5 volts) was used to adjust the field stubble readings.

RECOMMENDATIONS

Problems occurred with both the reflectance and intensity sensing devices. Measurement of surface reflectance was dependent on not only the reflectance of the straw, but also the soil and the soil properties. The amount of light which was absorbed and reflected by the soil surface was dependent on the soil moisture content, soil organic matter and green material in the trash.

The reflectance and stubble density detection unit caused high current draw (l6 amp) from the power source. Such a high current draw caused a voltage drop to occur on the automotive batteries used as power sources. Since a constant voltage is not supplied to the circuit and lamps, two major problems occurred. As the voltage dropped across the lights, their intensity decreased. As the light intensity decreased, the measured output of the circuit decreased. In addition, due to the large amplification of the output, a small voltage drop in the circuit causes a large change in the output voltage. Possible solutions to the high power requirement are as follows:

l. Use a light source with a decreased power requirement such as a DC powered fluorescent light.

2. Employ a high capacity voltage regulator to maintain the input voltage.

3. Employ a high capacity voltage regulator to maintain the input voltage.

4. Drop the voltage to the lamps and redesign the circuit as done in the intensity sensor.

Problems occurred in placement of the sensor near the soil surface. While the reflectance sensor only records a horizontal plane and is not adversely affected by poor placement, the intensity sensor requires that a vertical plane of measurement be used. The edge of the intensity sensor should be on the surface of the soil to ensure accurate measurements of stubble density. A design which would penetrate the stubble is required. Use of a cutting edge around the sensor area perimeter may solve the placement problem.

Neither of these methods can take into account partially buried surface residues. As interest grows in stubble mulch farming and conservation practices, the measurement of surface and subsurface residues will be useful in the design of tillage and planting equipment. Further research in this area is required.

CONCLUSIONS

The reflectance measurement system gives accurate measurements of surface reflectance but for this application is affected by straw distribution uniformity and straw density. Reflectance systems should be employed where only one plane of measurement is required, such as plant canopy light interception measurement, cultivator guidance systems or soil moisture measurements.

With some minor design alterations, light intensity measurements used to measure surface stubble density provides an accurate and reliable solution to the problem of measurement of surface trash. In addition to measuring trash concentrations in-situ, qualitative comparative estimates could be made and used to evaluate implement tillage trash incorporation, compare crop residue cover, or estimate crop growth.

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