

METHODS OF INCORPORATION OF SOIL-APPLIED HERBICIDES

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Introduction

Although not many of the herbicides in use today are pre-emergent, the ones in use are of great significance, particularly for the control of wild oats. The successful use of these herbicides depends on the correct application and incorporation. Wasted chemical, damage to crops and poor weed control can result from incorrect application and incorporation procedures.

Some herbicides are available in either form, liquid or granular; the most common of these is triallate (Avadex BW) used for wild oat control. Successful use of pre-emergent herbicides begins with getting the correct amount onto the field. Not only must the correct amount be applied it must be applied uniformly, followed by uniform mixing at the correct location or depth in the soil.

The correct location may vary depending on the species of weed to be controlled and the crop which is to be grown. For example Treflan should be mixed relatively deeply for control of wild oats whereas a shallow incorporation is more satisfactory for control of green foxtail.

Application begins with the machine used to meter and distribute the herbicide on or into the soil. With liquids the familiar sprayer or sparyer attachment is used while granules require special applicators or modifications to existing granular applicators used for fertilizer.

Granular Applicators

There are not many granular applicators specifically designed for applying granular herbicides. Avadex BW is at present the only herbicide that is applied in significant quantities in the granular form. The following discussion therefore pertains primarily to the use of Avadex BW.

It is important to know the characteristics of granular applicators in order to get satisfactory results. The best known applicator at present include the Barber, the Spierco, and the Gandy; a lesser known unit the Nodet-Gougis utilizes pneumatic conveying and spreading.

The Barber is a full width machine 6.1 m, 8.5 m or 11.0 m (20, 28 or 36 feet) in width, and can be used for application of either granular herbicides or fertilizer. The metering mechanism consists of a feed screw; it is positive metering and shut off. The rate of application is relatively constant since the feed screw is ground driven and increases the output as the travel speed is increased. The delivery of Avadex BW granules from each opening is pulsating due to the pitch of the feed screw. Since adjacent openings are out of phase this characteristic does not seem to cause any difficulty in the field with Avadex BW. Avadex BW appears to even out or move within the soil. It is not known whether such variation might be a problem with other chemicals which do not move within the soil. Changing the application rate is made by changing sprockets in the feed screw drive.

The Spierco units are also ground driven, although the metering mechanism consists of an oscillating trough and is not considered to be a positive feed system. The Spierco units may be mounted as attachments on a variety of equipment such as tandem disc harrows, discers, cultivators or are available in trailer mounted multiple units.

Changing field and granule conditions can possibly change in the output of the Spierco. The very free flowing properties of Avadex BW granules make field roughness a factor in the output from the Spierco since vibration has a tendency to change the flowability of the granules. It is therefore important to calibrate these units frequently and at the travel speed used to ensure accurate application rates. Slower speeds to avoid bouncing of the machine will also ensure more even application. Each unit should be individually calibrated and adjusted. The rate setting adjustment is critical since a small movement on the adjusting cam causes a large change in application rate.

The Gandy applicator is made specifically for applying granular herbicides and is not suitable for applying fertilizer. The company however has combination units with two boxes for applying herbicide and fertilizer simultaneously. As with the Spierco these box units may be mounted on a variety of implements or are available in multiple trailer units.

The Gandy has a constant output for any given setting and therefore the travel speed must be held constant if a constant rate of application is to be maintained. The rotor speed of the Gandy is not critical in maintaining delivery and therefore can be driven in different ways either from the trailer wheels, from the wheels of the implement it is mounted upon or by hydraulic motors. The rate of application is determined by adjusting the size of the openings located beneath the rotor. The adjustment for setting the rate is relatively easy to make. After use or before using after storage the openings should be cleaned to ensure accurate delivery.

With all of the above mentioned units except some models of Spierco, deflector plates or devices are valuable to disperse the granules dropping from each spout. Granules should never be allowed to drop onto the soil in rows, since redistribution is necessary for best results.

The Nodet-Gougis applicator consists of a central positive metering system which delivers the granules into tubes extending outward on both sides of the hopper. A high pressure fan supplies air to each tube to carry the granules. At the end of each tube a deflector is present to cause the granules to disperse and spread over the distance between individual tubes and deflectors. A width of about 8.2 m (27 feet) is covered. The rate of application is changed by changing sets of gears which drive the metering mechanism. The metering mechanisms used for granular Avadex BW are changed when the machine is used for fertilizer. As with other units careful calibration is required. The dispersion of granules by some of the deflectors is interfered with by the hopper or frame of the machine.

#### Incorporation of Herbicides

The incorporation of herbicides into soil simply means mixing the chemical and soil. The simplicity stops there when it is remembered that in many instances we are attempting to mix one part of chemical with 26,000 parts of soil. Other complicating factors are that the location of the mixture of chemical

and soil is an important consideration, that dry soil will likely hinder the effectiveness of the treatment, some herbicides must be incorporated relatively soon after application and location relative to the seed of the crop to be sown in sometimes important.

The best location of the herbicide for optimum weed control may vary depending on the weed that is to be controlled. For example it is recommended that trifluralin (Treflan) used for wild oat control be incorporated to a depth of 8-10 cm whereas if green foxtail is the only weed of concern it would be of benefit to have surface incorporation.

The spring application of Avadex BW for wild oat control depends on the crop to be seeded. With barley Avadex BW can be applied before seeding whereas with wheat it is recommended that it be applied after seeding and that proximity to the wheat seed be avoided to prevent crop damage.

Other factors concerning each farmer using pre-emergent herbicides is the availability of suitable incorporation equipment, the condition of the fields, and the time available for the extra operation required. Ideally it would be desirable not to have to do any additional operations on the field. Extra operations can dry out the soil, may cause excessive pulverization, destruction of the trash cover which could lead to serious problems of wind or water erosion.

During the past three years studies have been made at the University of Saskatchewan to determine the incorporating abilities or characteristics of various machines. These machines are those available on many farms and have been used or can be used to incorporate pre-emergent herbicides. Machines included in the studies have been the tandem disc-harrow, harrows, heavy duty cultivator, light duty cultivator, discer and rod weeder. Measurements of the distribution, and depth of incorporation of both liquid and granule material were made. In addition with the discer the liquid and granules were applied both before and behind the discer gangs. Measurements were also made of the effect of travel speed, disc angle and combination of some machines.

#### Vertical Distribution of Granules

Referring to Figure 1 it is apparent that best mixing of granules to 7.5 cm depth in the soil was obtained with the disc type implements. Similar results have been reported earlier (Hulburt et al., 1953; Bode et al., 1969; Matthews, 1970; and Butler et al., 1972). There was no significant difference in the distribution between the tandem disc harrow and the discer.

Both cultivators followed by spike tooth harrows appeared to be quite similar in their ability to incorporate the granules. A higher percentage of granules were found in the top 2.5 cm layer and a smaller percentage in the third 2.5 cm layer. This difference between cultivators and disc type implements is thought to be due to the fact that discs cause soil inversion, whereas the cultivators only stir the soil.

Another effect of secondary distribution of granules was also observed with cultivators followed by harrows. The combined action of both the implements

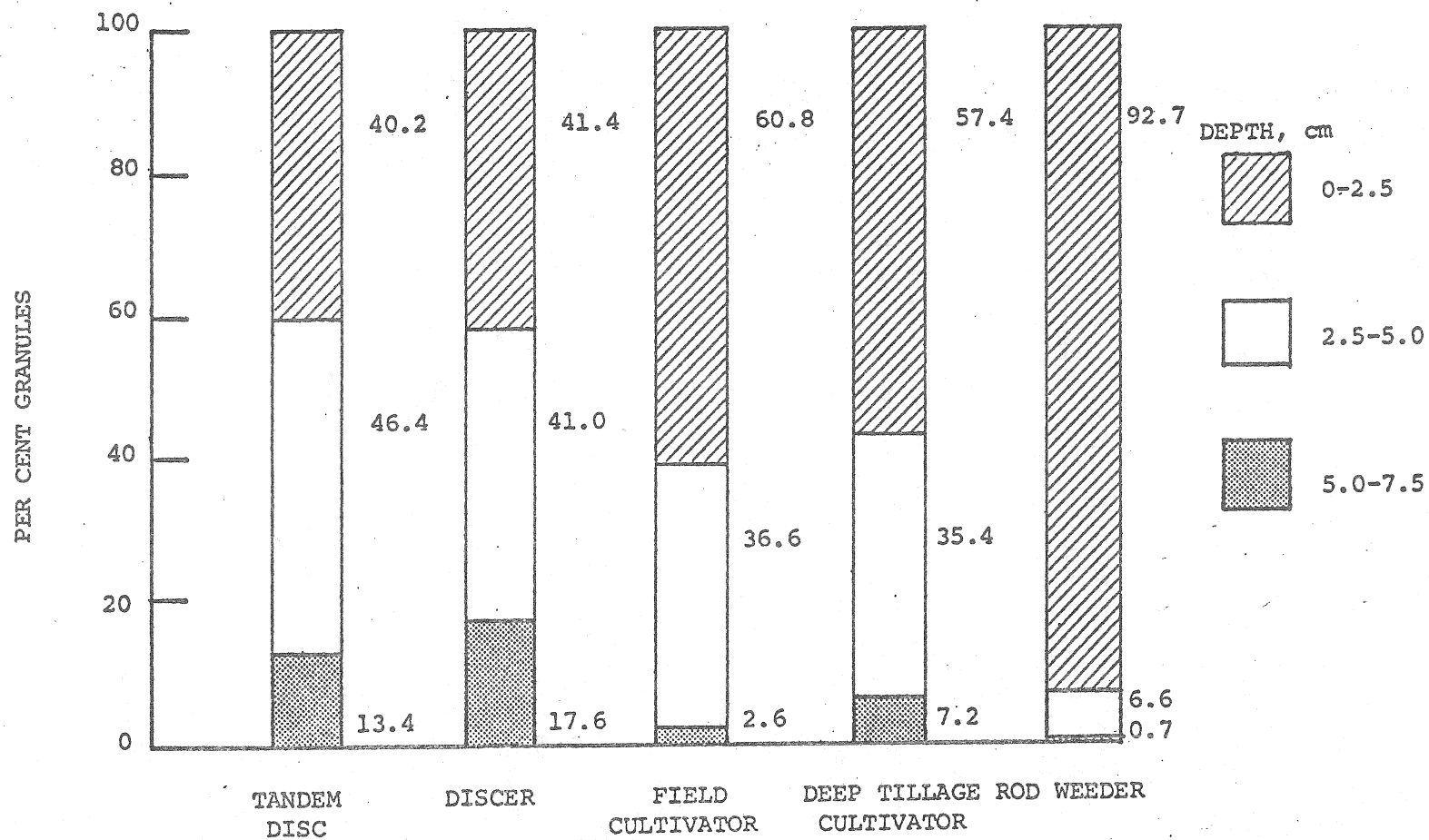


FIGURE 1. GRANULES INCORPORATION WITH VARIOUS IMPLEMENTS.

tends to place granules in ridges and leave furrows with little or no granules. This row effect was also observed in another experiment using Avadex BW (Triallate) on Harmon oats (Lal and Reed, 1976). Butler and Siemens (1972) also observed similar row effect with field cultivator.

The rod weeder caused little mixing and a very high percentage of granules remained in the top layer of soil with only a trace reaching the third layer.

#### Vertical Distribution of Liquid

Figure 2 shows the distribution of liquid spray for various implements at three depth intervals. The distribution of liquid within the soil was quite similar to that obtained with the granules. The disc type implements mixed to a greater depth than the cultivators or rod weeders.

One additional method included the use of Normand spray attachment for the discer or the one-way-disc harrow mounted behind the disc gang. This unit directs the spray into the turning or moving soil thrown up by the discs. In this case about 75 percent of the liquid remained in the top layer and a very small amount reached the third layer. This method appeared to give close to the same results as the rod weeder, but there is one important difference. This difference is that the top inch layer of soil from the discer is quite moist, while the same layer with the rod weeder is considerably drier under most circumstances. This difference in moisture could have a profound effect on the activity of the actual chemical utilization.

#### Lateral Distribution of Granules

Table 1 shows the range of the amount of granules expressed as the percent of the mean over the sampling width of 160 cm along with the coefficient of variation for each treatment. From the comparison of the coefficient of variation, the field distribution of the Gandy applicator was more even than that in the lab. This may be the result of the granules being bounced and dispersed more evenly when falling on to the ground. The light wind always present during the field experiments may also have helped in making the distribution more even.

Comparing the distribution of the Gandy applicator in the field with the distribution of four implements, their order may be arranged according to the degree of uniformity as follows:

- Cross harrowing
- Tandem disc harrow
- Discer
- Cultivator with harrows

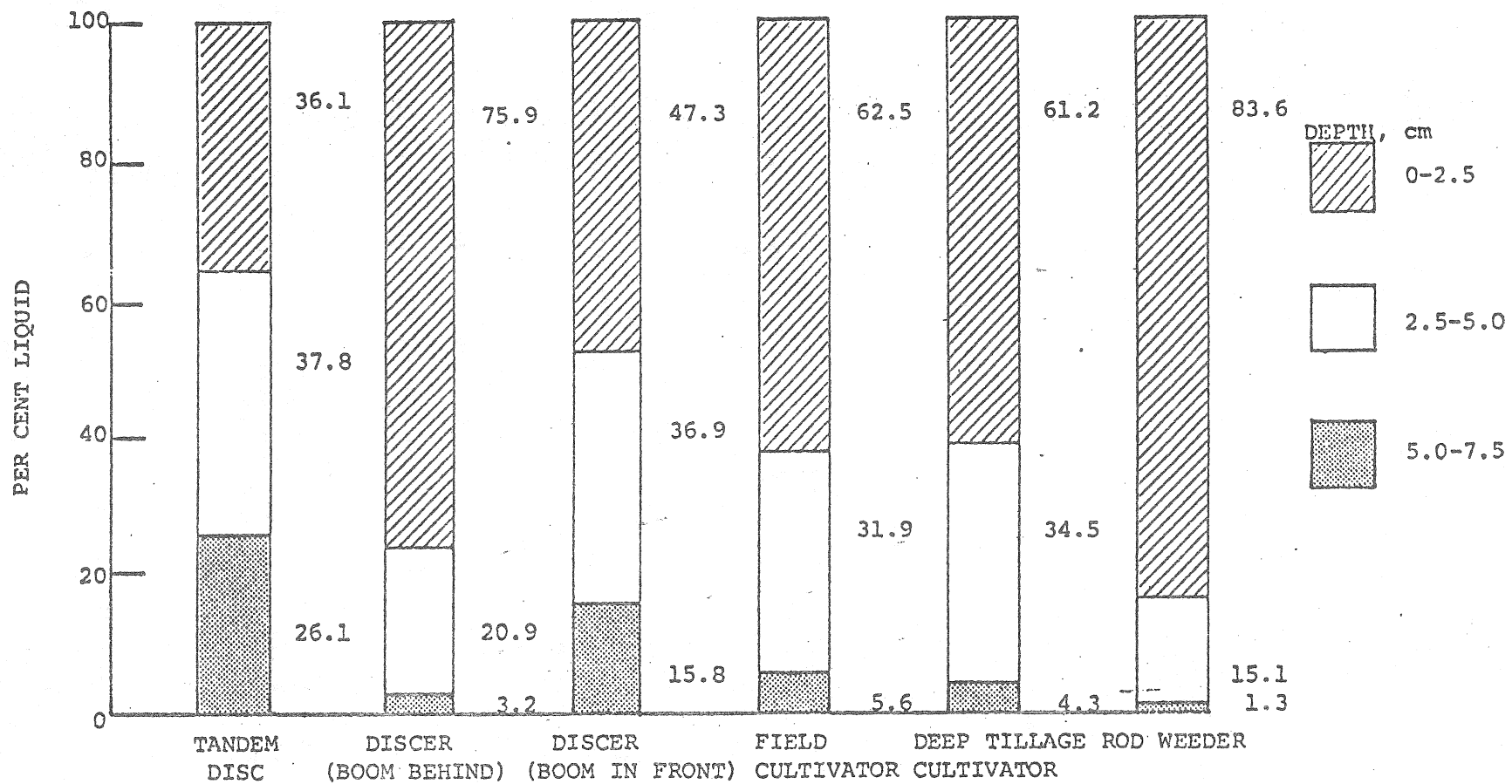


FIGURE 2. LIQUID INCORPORATION WITH VARIOUS IMPLEMENTS.

TABLE I

RANGE AND COEFFICIENTS OF VARIATION IN LATERAL DISTRIBUTION OF GRANULES WITH VARIOUS IMPLEMENTS

Treatments	Range % of mean	Coefficient of variation %
Gandy - calibration	59.5-165.4	25.4
Gandy - in the field	65.9-151.4	17.8
Cross Harrowing (2 passes)	67.0-189.2	19.8
Tandem Disc Harrow (one pass)	61.1-154.6	20.4
Discer	55.0-175.2	27.3
Cultivator	55.7-207.6	35.0

The minimum and maximum number of granules at any location depended on the applicator and incorporation implement. As shown in the Table 1, the range varied from 55 percent to 207.6 percent of the average value after incorporation while the range for the applicator was 65.9-151.4 percent before incorporation.

This indicated the variation in concentration of granules which at the lower concentration may not be sufficient for controlling wild oats while at higher levels may damage the crop. The range of concentration nearest to that of the Gandy attachment was obtained with the tandem disc harrow, followed by the discer, cross harrowing and the cultivator with harrows. Although the distribution of granules was more even for incorporation by cross harrowing, the range of granules was higher than that of the tandem disc harrow and the discer. This may have been caused by the concentration of granules in the rows.

Lateral Distribution of Liquid from Teejet 6502 and Floodjet TK 2.5 Nozzles

The objectives behind these trials were to compare distribution patterns of liquid at various stages of nozzle operation, i.e., calibration, field application before incorporation and after incorporation. The similarity of patterns and degree of dispersion were estimated from the range expressed as the percent of mean value and coefficients of variation which are given in Table 2.

The range of variation of chemical in the sampling width increased after incorporation by cross harrowing, but there is a similarity in the distribution patterns as shown in Figure 3 for the Teejet 6502 nozzle. The peaks seem to occur relatively at the same positions for the calibrated pattern and the field patterns. Stirring the top soil by cross harrowing did not seem to eliminate the original applied pattern. However, the uniformity decreased as indicated by the increased coefficient of variation. Since the distribution of chemical between the patterns obtained before incorporation and after incorporation is similar, it is best to apply the chemical uniformly over the field.

TEEJET 6502 NOZZLE

- CALIBRATED PATTERN C.V. = 17.3%
- BEFORE INCORPORATION C.V. = 18.9%
- - - - AFTER INCORPORATION C.V. = 25.3%

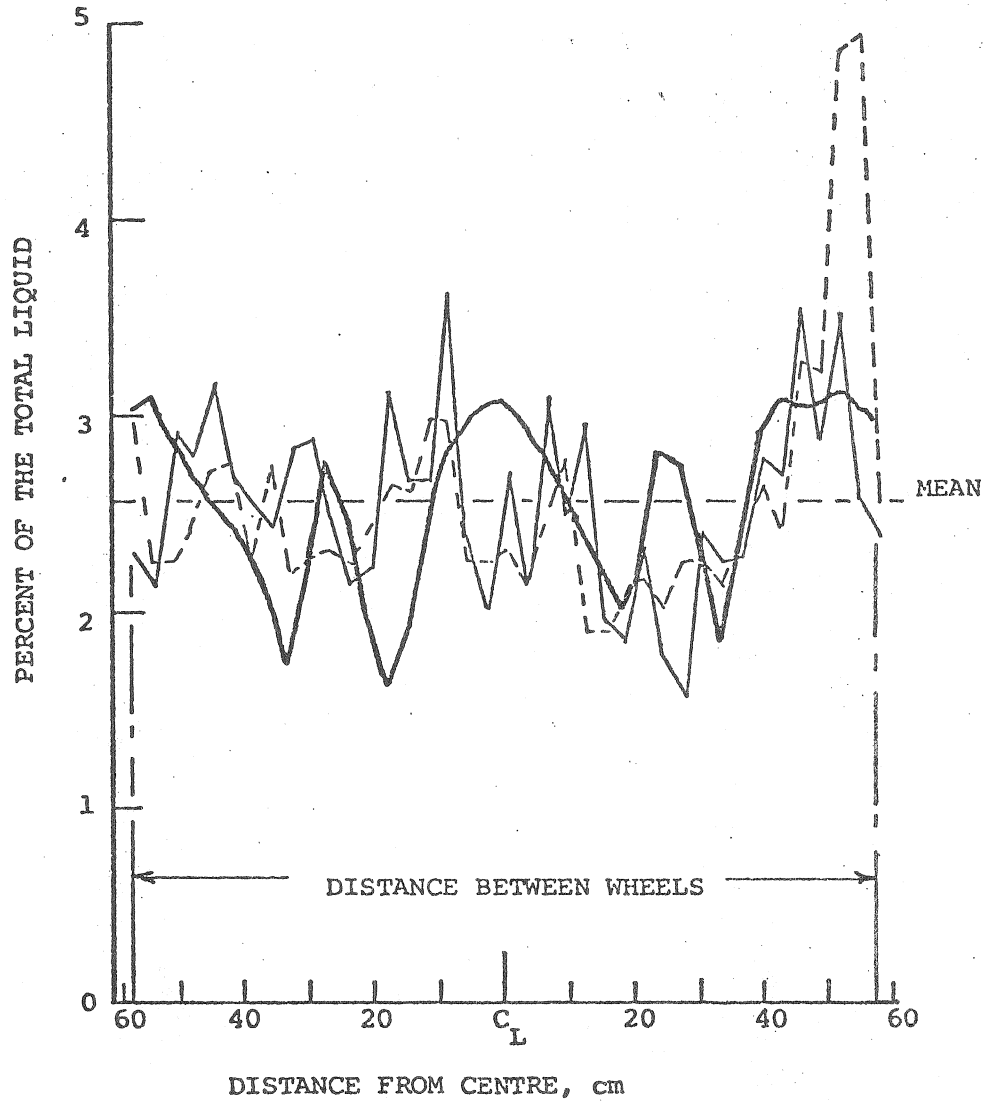


FIGURE 3. LATERAL DISTRIBUTION OF LIQUID WITH TEEJET 6502 NOZZLE.



TABLE II

RANGE AND COEFFICIENTS OF VARIATION IN LATERAL DISTRIBUTION OF LIQUID WITH TEEJET 6502 AND FLOODJET TK 2.5 NOZZLES

Treatment	Range % of mean	Coefficient of Variation %
Teejet 6502		
Calibration	62.1-120.7	17.3
Before incorporation	60.1-141.17	18.9
After incorporation by cross harrowing	71.9-192.5	25.3
Floodjet TK 2.5		
Calibration	51.6-157.0	31.3
Before incorporation	52.0-208.9	30.2
After incorporation by cross harrowing	47.3-177.3	41.0

Vertical Distribution of Granules following Incorporation with the Tandem Disc Harrow

Figure 4 shows the percent of granules mixed at various depths for different treatments with the tandem disc harrow. Statistically, there was no significant difference among various incorporation techniques of the tandem disc harrow.

Disc angle

Little or no difference was observed in the concentration of granules at various depth intervals between 16° and 20° disc angles either with a single or double pass. However, the uniformity of incorporation was improved significantly at the larger disc angles.

Speed of travel

Increasing the speed from 5 km/h to 8 km/h provided deeper incorporation of granules when a single pass was made. Comparisons after two passes showed no difference in the depth of incorporation or in quantity of granules deposited at various depth intervals. The uniformity of incorporation was improved at higher speed.

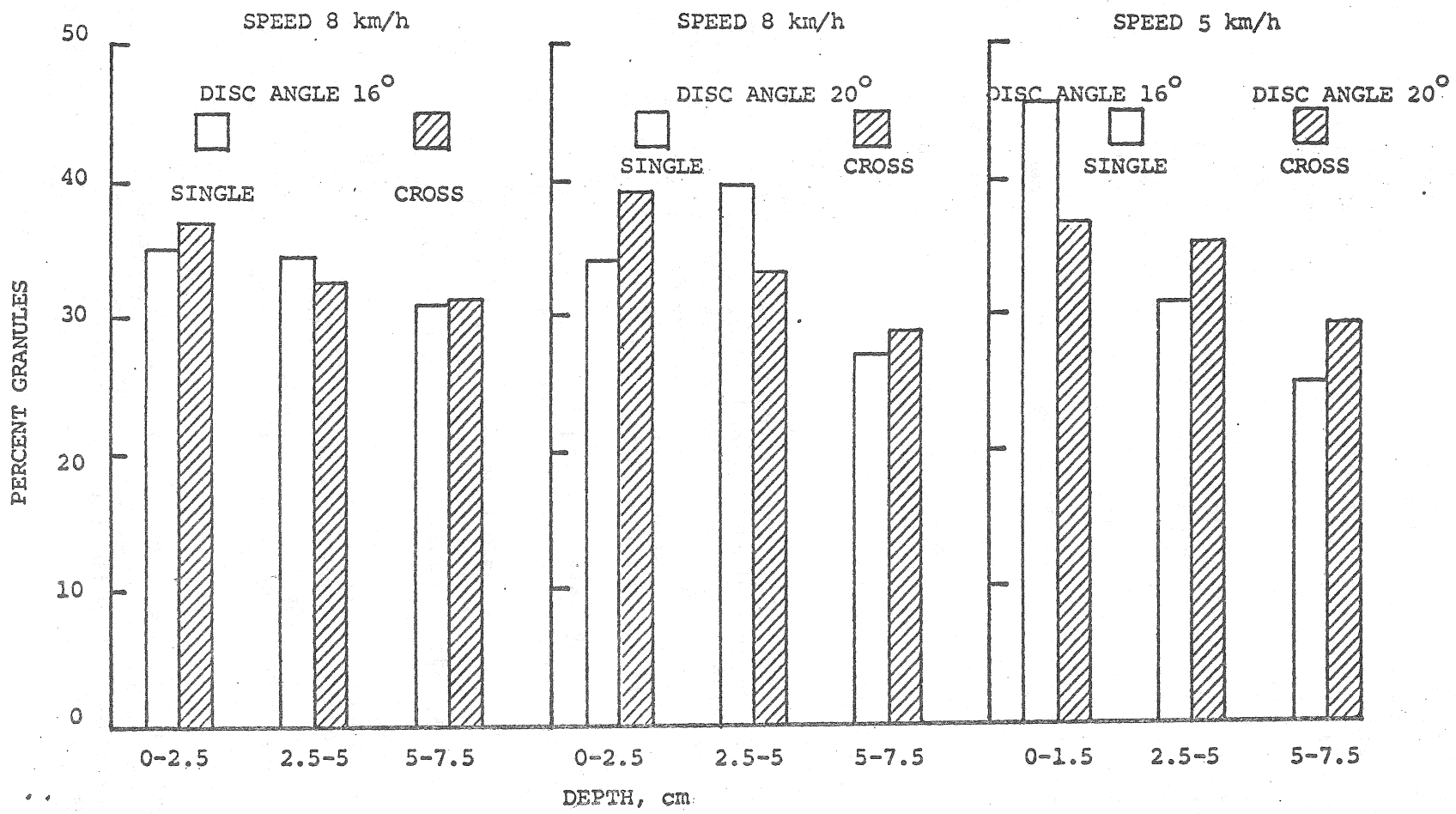


FIGURE 4. GRANULES INCORPORATION WITH THE TANDEM DISC HARROW.

#### Mode of incorporation

There was little or no change in the depth of incorporation at higher speeds between a single and a cross operation of the tandem disc harrow. The cross operation was two passes at right angle to each other. The single pass at a lower speed of 5 km/h resulted in a shallower incorporation. The cross operation improved the uniformity of incorporation slightly but not sufficiently to justify the time and expense required for the second pass.

Therefore, this study indicates that the granule distribution in various layers of soil is not affected by normal variations in the speed, disc angle, and the mode of incorporation when incorporated with a tandem disc harrow. However, the uniformity of incorporation was improved with the larger disc angle, higher speeds, and cross operation. The cross operation improved the uniformity of incorporation but it may not justify the time and cost involved or the damage that may be done to the soil.

#### Vertical Distribution of Liquid with the Normand Attachment on a Discer

Figure 5 shows the percent of liquid found at various depths for different treatments with the Normand attachment on the discer. Statistically, a highly significant difference was observed in the quantity of liquid deposited at each depth interval for all the treatments.

#### Boom position and spray angle

Bringing the boom closer to the discs increased the concentration of liquid at lower depth intervals, thus increasing the depth of incorporation. When the position of the spray boom of the Normand attachment was changed, the spray angle was also changed. As shown in Figure 6 three different horizontal positions of the boom in this experiment resulted in three different angles of spray. The percentage of liquid incorporated at these positions and the angles of spray at different depth intervals is shown in Figure 5.

Comparing the concentration of liquid in the top 5 cm layer, nearly 94 percent was incorporated at the boom position of 50 cm, 83 percent at 31.5 cm and 76.8 percent at 12.5 cm. The tendency of the liquid distribution among three depth intervals was toward a greater amount of liquid at lower depths as the boom was brought closer to the discs. However, the uniformity of incorporation decreased successively at each boom position.

Thus, the position of the boom was very important in determining the distribution of liquid and the depth of incorporation. For shallow incorporation it is important to maintain the boom in the further away position. It is also interesting to note that the closest position resulted in the incorporation nearly equivalent to cross operation with the tandem disc harrow.

#### Depth of tillage

Increasing the tillage depth from 7.5 cm to 10 cm reduced the amount of liquid deposited in the upper layer. At a speed of 8 km/h nearly 94 percent of the liquid was located in the top 5 cm when tilling 7.5 cm deep compared to 78 percent when tilling 10 cm deep. As expected the differences in the upper

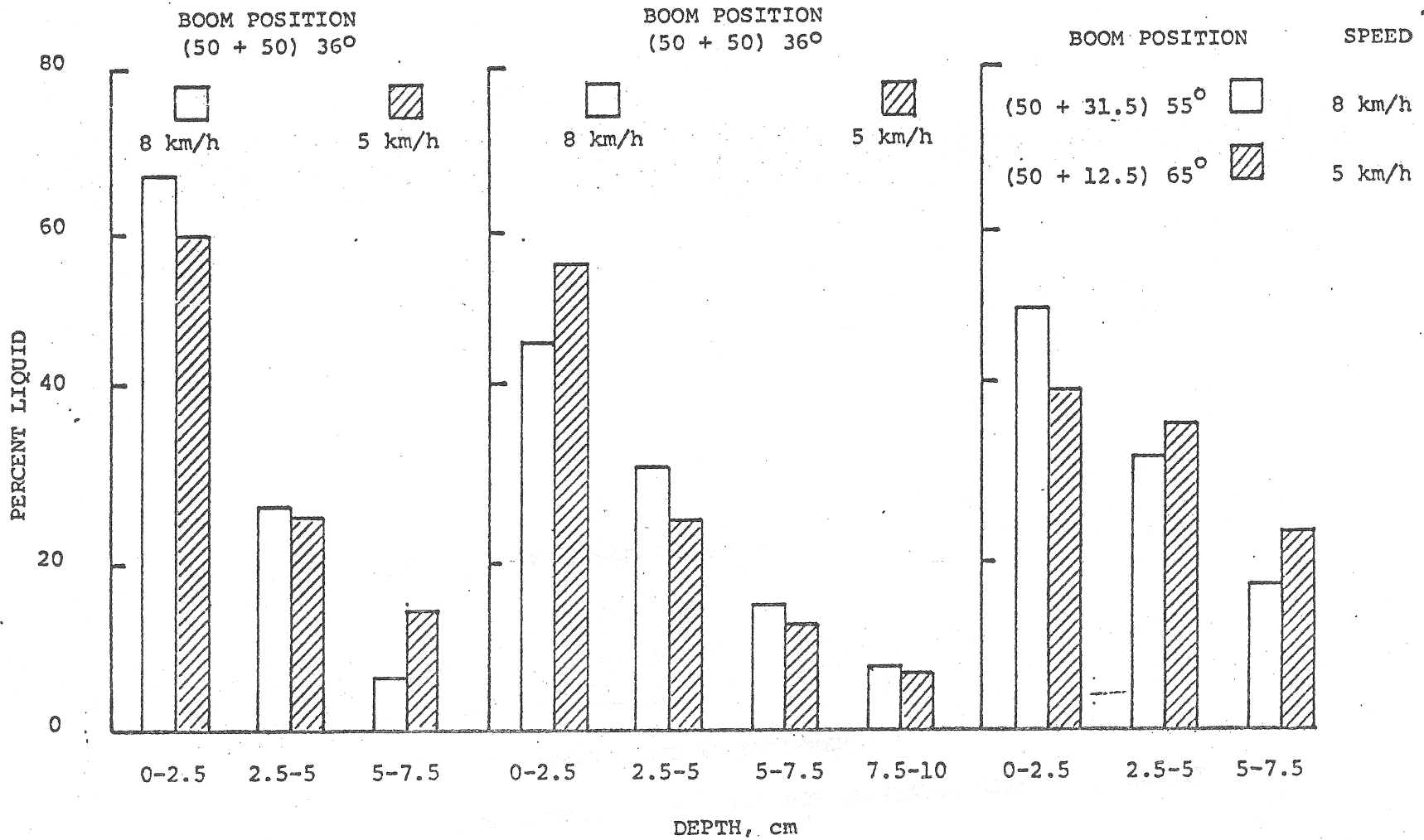
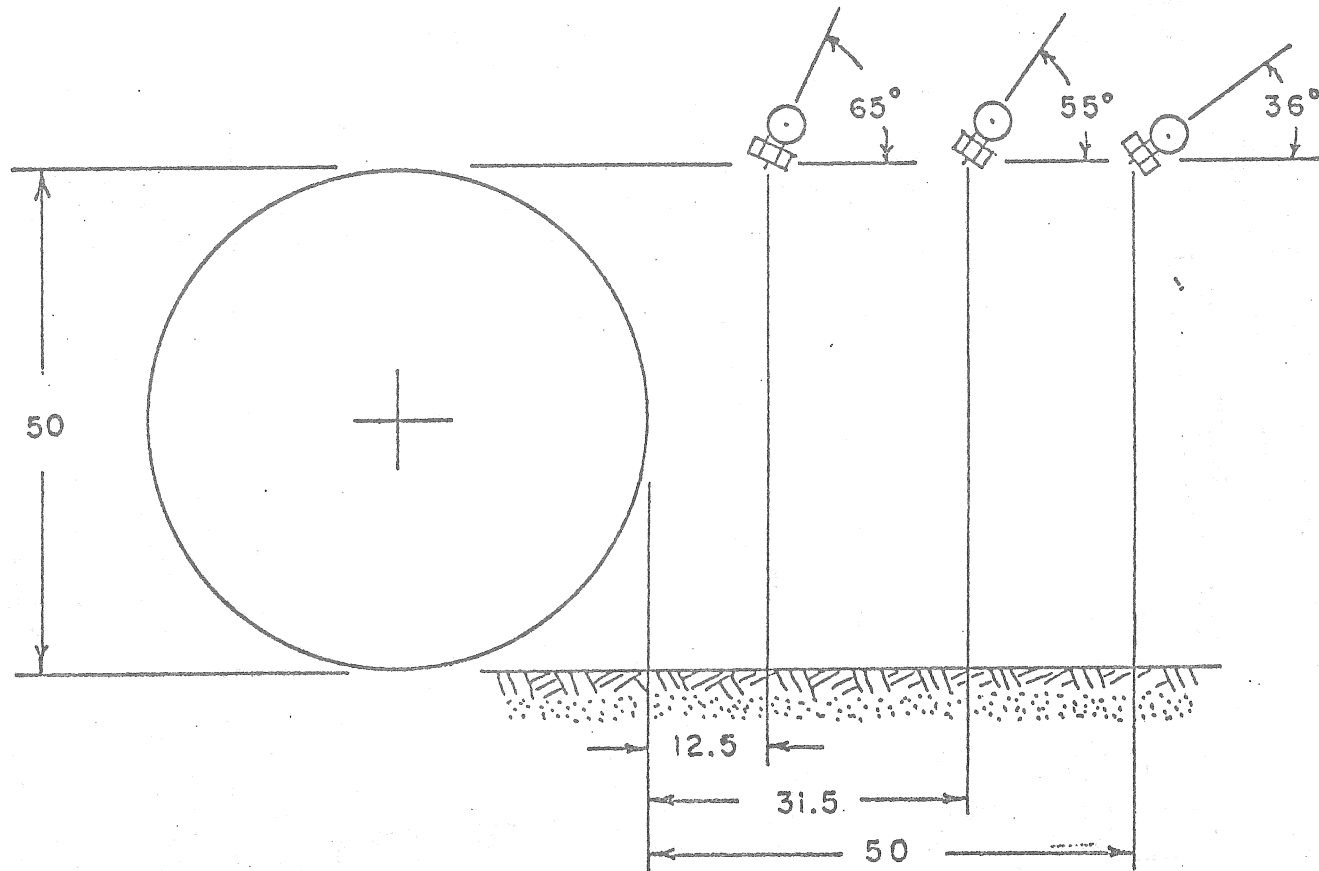


FIGURE 5. LIQUID INCORPORATION WITH THE NORMAND ATTACHMENT ON THE DISCER.



DIMENSIONS IN CENTIMETRES

FIGURE. 6. NOZZLE LOCATIONS FOR THE NORMAND ATTACHMENT.

layer resulted in similar differences at the lower levels.

At a slower travel speed of 3 km/h the difference was less marked with 86 percent of the liquid located in the top 5 cm layer while tilling at 7.5 cm and 81 percent when tilling at 10 cm deep.

Although the depth of incorporation increased with the depth of tillage, the uniformity of incorporation decreased and was much less uniform with the greater depth of tillage.

#### Speed of Travel

Little or no difference was observed in the concentration of liquid at various depth intervals between 5 km/h and 8 km/h speed of travel either at 7.5 cm or 10 cm tillage depth. However, a shallower incorporation was noticed at higher speed increasing the concentration of liquid in the top 2.5 cm layer at 7.5 cm tillage depth. But for 10 cm tillage depth, this trend was reversed at the top 2.5 cm layer although the difference was less marked with nearly 78 percent liquid deposited in top 5 cm layer at 8 km/h speed and 81 percent at 5 km/h speed. The uniformity of incorporation was better at higher speed.

Thus, in general, the depth of incorporation with the Normand attachment will depend on the boom position, depth of tillage and the speed of travel. In most cases, the depth of tillage is adjusted to give proper seeding depth with a discer and it is seldom that the seeding depth is the same as the tillage depth. So when applying and incorporating Avadex Bw while seeding, precautions must be taken to avoid deeper incorporation of chemical in order to prevent any crop damage.

#### Vertical Distribution of Granules with the Gandy Attachment behind a Discer

Figure 7 shows the percentage of the granules deposited at various depth levels for two positions of the Gandy applicator at the rear of the discer. Statistically, there was a significant difference in the quantity of granules deposited at various depth levels.

Deeper incorporation of granules was obtained as the spouts were moved closer to the disc. Nearly 52 percent of granules were deposited in the top 2.5 cm layer at the spout position of 2.5 cm away from the disc in comparison to 66 percent for the 15 cm position. The uniformity of incorporation was also better at the closer position of spout. However, there was a difference of only 7 percent granules in the top 5 cm soil between the two positions of spout location.

The spout position showed a similar trend to incorporation as the boom position of the Normand attachment. The spout position of 15 cm from the discs incorporated nearly the same amount of granules in the top 2.5 cm soil as the boom position of 50 cm for the Normand attachment.

It was also observed that with a light wind of less than 8 km/h granules were blown either toward the discs or away from the disc depending upon the direction of wind and the direction of operation. Wind velocities suitable for liquid spray will not be suitable for granules application because going

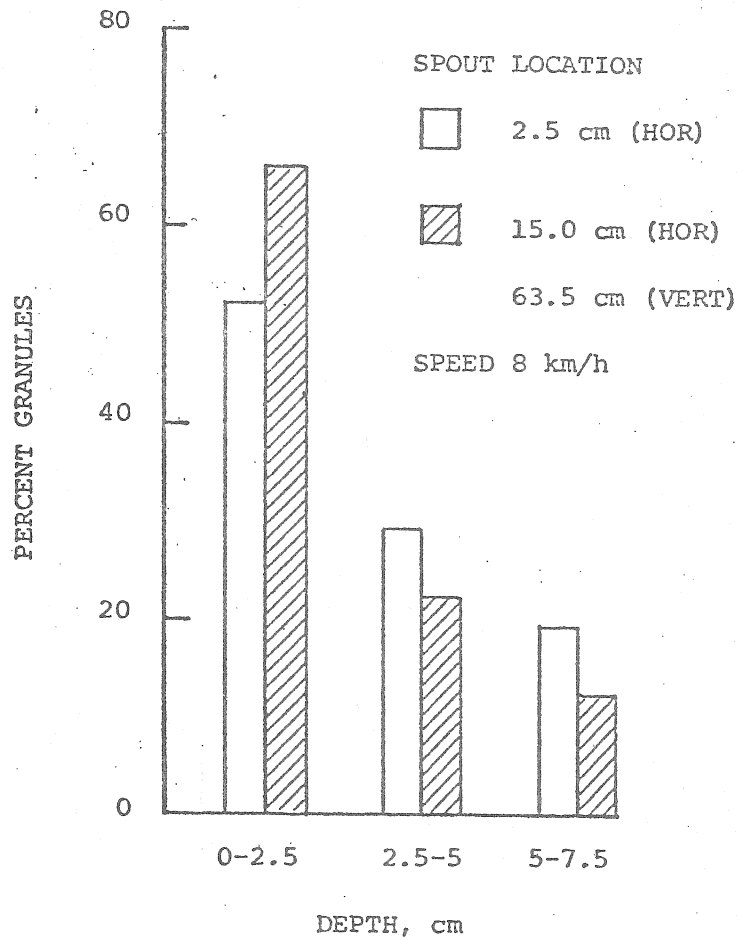


FIGURE 7, GRANULES DISTRIBUTION WITH THE GANDY ATTACHMENT BEHIND THE DISCER.

with the wind will result in deeper incorporation while going against the wind nearly all the granules will be deposited on the surface.

#### Effect of Cultivation Depth on Incorporation with Harrows

Figure 8 illustrates that increasing the depth of cultivation or tillage before the application of granules and incorporating with harrows (diamond) will result in deeper incorporation. The trials were conducted at a travel speed of 8 km/h while harrowing.

#### CONCLUSIONS

The results from the soil incorporation studies indicated substantial differences in the incorporation capabilities of various machines both as to depth and uniformity. In terms of uniformity of incorporation the descending order was as follows (1) harrows (two passes perpendicular to each other) (2) rod weeder, (3) tandem disc harrow, (4) one-way disc harrow or discer, (5) light duty cultivator with harrows and (6) heavy duty cultivator with harrows.

In terms of depth of incorporation the descending order was as follows. (1) tandem disc harrow, (2) discer, (3) light duty cultivator, (4) heavy duty cultivator, (5) harrows and (6) rod weeder. Increasing the depth of tillage before harrowing will result in deeper incorporation of the herbicide.

The disc type implements provided deepest incorporation because the soil was inverted or turned over by the disc action. Tine type implements which stirred the soil did not tend to give deep incorporation. The wider the spacing of the tines or shanks, the less uniform will be the results. The rod-weeder apparently did little as far as incorporation was concerned with over 80 percent of liquid or granules remaining in the top layer.

The tandem disc harrow provided the deepest incorporation with only one pass over the field. There was practically no change in the depth of incorporation (vertical distribution) by the second pass or operation with the tandem disc harrow, but uniformity of incorporation was improved. Speed of travel and disc angle of the tandem disc harrow likewise had little effect on the depth of incorporation. Since higher speeds, larger disc angles, and double operation all tend to pulverize the soil, serious problems with soil erosion could develop. Too high a speed will also cause soil ridging.

The discer equipped with the Normand spray boom attachment could be positioned to provide shallow or deeper incorporation nearly equivalent to two operations with the tandem disc harrow. The deeper incorporation was less uniform than the shallow incorporation. The higher speed of travel tended to give shallower but more uniform incorporation. As with other implements the depth of incorporation is controlled to some extent by the depth of tillage; for those herbicides requiring shallow incorporation the depth of tillage and position of the spray boom is important.

The discer with a rear mounted attachment for granules application resulted in satisfactory incorporation provided the spouts are positioned or the granules are directed correctly. The position determined the depth of incorporation if there was no wind. Moderately windy conditions could result in a erratic



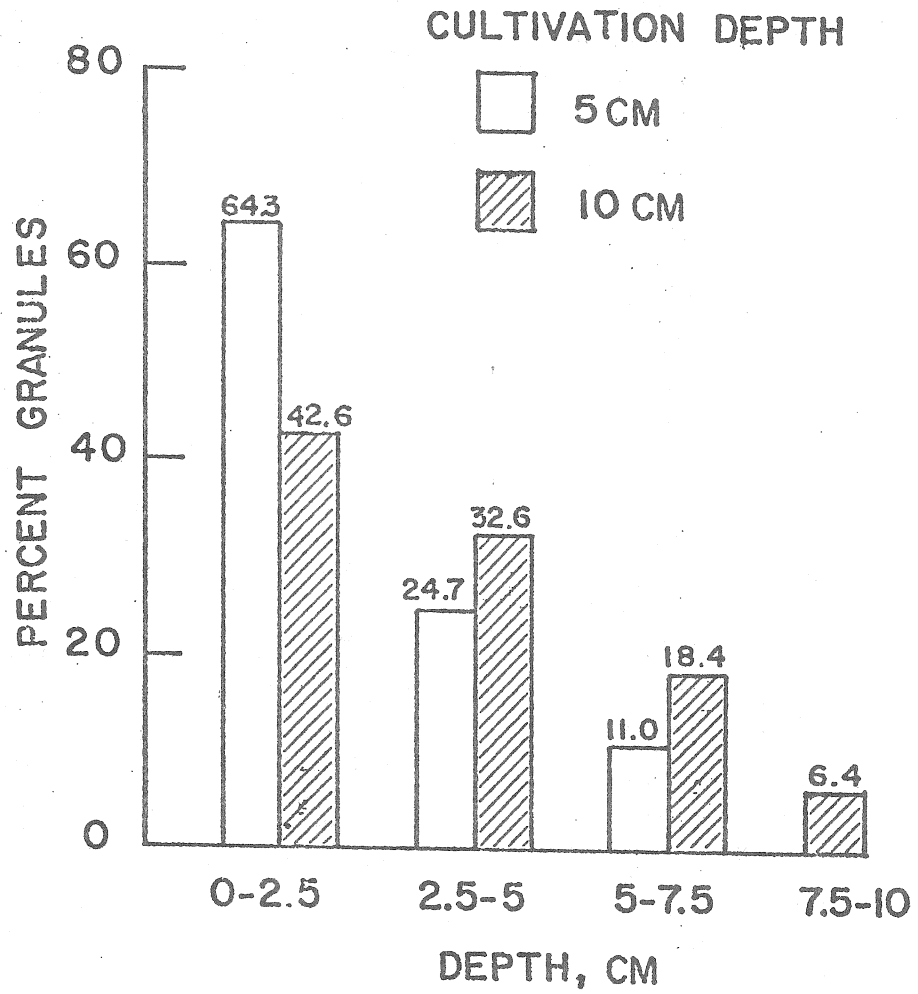


FIG. 8. EFFECT OF CULTIVATION DEPTH ON GRANULES DISTRIBUTION

incorporation since the granules are very easily blown about.

Uniformity of the application of liquid herbicides from spray nozzles onto the soil and granules from granule applicators is important. Measurements of the lateral distribution patterns from individual nozzle and granular applicators in the laboratory were similar to the measurements of the lateral distribution patterns in the soil after incorporation by harrows. In most cases the distribution after incorporation by harrows was less uniform than the distribution before incorporation.

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