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Title: HERBICIDAL EFFECTIVENESS OF TRIFLURALIN AS INFLUENCED BY METHODS OF INCORPORATION INTO THE SOIL AND DEPTH OF WEED SEED GERMINATION

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This study was conducted to compare the effectiveness of four methods of incorporating the herbicide trifluralin into the soil, and to determine the interaction between depth of incorporation of trifluralin and depth of weed seed germination.

Field experiments on green and dry peas were established in Oregon and Idaho. Trifluralin, applied at four rates, was incorporated by a rototiller, tine-tooth harrow, spike-tooth harrow or double-disked, prior to planting. At time of harvest, yields were taken and plots were evaluated for weed control. On dry peas, only the tine-tooth harrow gave unsatisfactory incorporation of trifluralin. Increasing the rate of trifluralin, regardless of the method of incorporation, reduced the yield of dry peas, indicating injury. On green peas, both the double-disk and rototiller satisfactorily

incorporated trifluralin. However, yields from the rototiller plots were slightly less than those from the disk plots. No injury was noted with increasing rates of trifluralin.

Greenhouse experiments were conducted at Corvallis to determine the effect of increasing the depth of incorporation and depth of weed seed germination on the herbicidal activity of trifluralin. Trifluralin, applied at three rates, was incorporated to four depths and planted at three depths to pigweed (*Amaranthus retroflexus* L.) and barnyardgrass (*Echinochloa crusgalli* (L.) Beauv.). Pigweed was not affected when planted below the trifluralin-treated zone. Only pigweed plants whose roots grew into the trifluralin were controlled. Shoot uptake appeared to be more effective than root uptake by barnyardgrass. When trifluralin was incorporated over 1.5 inches, weed control was reduced, indicating a dilution effect.

Results of this study indicate that the weed species to be controlled will be of major importance when determining the depth and method of incorporation of trifluralin.

Herbicidal Effectiveness of Trifluralin as Influenced by Methods of Incorporation into the Soil and Depth of Weed Seed Germination

by

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HERBICIDAL EFFECTIVENESS OF TRIFLURALIN AS INFLUENCED BY METHODS OF INCORPORATION INTO THE SOIL AND DEPTH OF WEED SEED GERMINATION

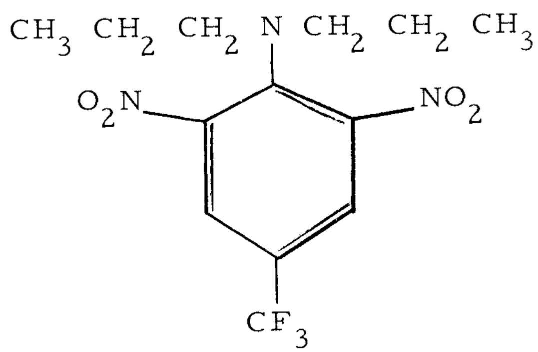
INTRODUCTION

Incorporation of herbicides into the soil is important in areas of low or uncertain rainfall, where furrow irrigation is practiced, or when the herbicide may be deactivated from volatilization, photodecomposition, or both, when left on the soil surface. Considerable research has been done on the reasons for incorporation, but little is known about the benefits of optimum placement, which may be a critical factor. Optimum placement, in turn, is dependent on the physical and chemical properties of the herbicide, soil characteristics, climatic factors, and the site of herbicide uptake and action in the plant species.

Trifluralin (a, a, a-trifluoro-2, 6-dinitro-N, N-dipropyl-p-toluidine) is a widely-used herbicide requiring incorporation into the soil to prevent loss and to assure contact between the herbicide and the appropriate plant parts under adequate moisture conditions. The objectives of this thesis were (a) to compare the effectiveness of four methods of incorporation presently employed in agronomic practices and (b) to study the interaction between depth of trifluralin incorporation and depth of germination of two weed species. Experiments were conducted both in the field and in the greenhouse.

LITERATURE REVIEW

Physical and Chemical Properties of Trifluralin



$C_{13}H_{16}F_3N_3O_4$ M. W. 335.28

trifluralin

(a, a, a-trifluoro-2, 6-dinitro-N, N-dipropyl-p-toluidine)

The physical and chemical properties are summarized in a technical bulletin from Eli Lilly and Company (19). Pure trifluralin crystallizes in yellow-orange prisms and melts at 48.5-49^{o}C. It is readily soluble in organic solvents such as acetone, xylene, and aromatic naphthas. The solubility in water is 1 ppm at 27^{o}C. The vapor pressure was found to be 1.99 x 10^{-4} mm of mercury at 29.5^{o}C. and the boiling point at 0.18 mm of mercury is 96-97^{o}C. and 139-140^{o}C. at 4.2 mm mercury. It is formulated as an emulsifiable concentrate containing four pounds of trifluralin per gallon, to be mixed with water and applied as a spray.

Behavior in the Soil

Wright (55) found that if trifluralin was incorporated immediately after application, it required three to four times less chemical to achieve the weed control obtained when trifluralin was not incorporated. He concluded that trifluralin volatilized from the soil surface, was inactivated by photodecomposition, or both. When trifluralin was exposed to direct sunlight for two hours after being sprayed on the soil surface and then incorporated, weed control was reduced by 40 percent. When incorporation was delayed for a period of four hours, 15 to 20 times as much trifluralin was required to achieve similar results compared to immediate incorporation (54, 55). Studies have shown volatilization to be an important source of loss, the greatest rate of loss occurring during the first few hours after application. High soil and air temperature as well as high humidity also increased this rate of loss. However, no distinction was made between volatility or photodecomposition effects in any of these studies.

Harris (27) found trifluralin to be immobile in both sandy loam and silty clay soils at rates up to 12 pounds per acre. Eshel and Warren (20) also found trifluralin to resist both horizontal and vertical movement. This lack of movement was the reason for the poor weed control when trifluralin-impregnated cloth was compared to other chemicals (15).

Trifluralin was found by several workers (9, 11, 24, 50) to persist for nine months when sprayed at rates of more than one pound per acre and incorporated to a depth of one inch. An increase in persistence with increasing depths of incorporation was noted by Oliver (43). When trifluralin was sprayed at five times the recommended rate, some biological activity was noted after one year (11). Most workers, however, found trifluralin to cause no injury to succeeding crops if the soil was thoroughly mixed prior to planting.

There is some disagreement among workers on the effect of organic matter content of the soil on the toxicity of trifluralin. Colby (13) and Martin (40) found that the addition of manure to the soil decreased the toxicity of trifluralin, while Bardsley (8) stated that toxicity and organic matter content were directly related and that increasing the organic matter content increased the toxicity. Bardsley, however, used charcoal to increase the organic content. He postulated that this carbonaceous material retained trifluralin vapor, which is more toxic to plants than is the solution, and that the vapors of the chemical were released upon breakdown of the charcoal. Ahrens (1) found that charcoal banded at 500 ppmw did not reduce injury from trifluralin on oats.

The loss of trifluralin was significantly greater when free water was allowed to stand on the soil surface than when the soil was not saturated. Under anerobic conditions, decomposition of trifluralin was complete in 14 days at 76°F., whereas 80 percent of the initial level was present in treatments exposed to 38°F. for the same length of time (19, 37).

Herbicidal Use

When trifluralin is used as a preemergence herbicide, fields must be free from existing weeds, because the herbicide controls only those weeds germinating after application. A list of susceptible weeds and tolerant crop species may be obtained from Eli Lilly and Company.

The use of trifluralin as a preemergence herbicide was first reported by Alder *et al.*, in 1960 (2). Kuratle and Rahn (35) found no increase in biological activity of trifluralin when used with any type of surfactant. Espinoza (21) found an interaction existing between trifluralin and atrazine residues in the soil. The injury occurring from 4.5 ppm of trifluralin was reduced to zero when the herbicide was incorporated into a soil containing 0.6 ppm of atrazine. No reasons, however, were given for this deactivation.

Cotton seedlings were found to be more susceptible to seedling blight disease when planted in trifluralin-treated soil than those planted in the untreated control (4). The cool (45°F.) and wet (85% field capacity) soil was ideal for the disease and the stunting occurring from trifluralin under these conditions made the seedlings more susceptible.

Mode of Action

Recent studies by Appleby (6) and Nishimoto (42) indicate that the site of uptake and mode of lethal action should be of primary concern when deciding where the herbicide should be located for optimum results. No effects on shoot growth were noted by Knake (33) when one ppm of trifluralin was applied to the root zone of green foxtail (*Setaria viridis* L.). When applied at one ppm to either the shoot or root and shoot zones, however, 100 percent control resulted. Nishimoto (42) obtained similar results with oats (*Avena sativa* L.), concluding that shoot uptake was the most effective for that species.

Work by Parker (46) with sorghum (*Sorghum vulgare* Pers.) showed a 50 percent reduction in root growth with the application of 0.065 ppm of trifluralin to the root zone and a 50 percent reduction in shoot growth from 2.7 ppm applied to the shoot zone. No significant reduction in the growth of cotton was obtained when trifluralin was applied to either the root or shoot zones. Another study by Standifer (51) with johnsongrass (*Sorghum halpense* (L.) Pers.) showed that trifluralin was not translocated, but was readily absorbed by the internodes of established plants. It is evident from the literature that the site of uptake of trifluralin varies among the plant species.

Effect of Incorporation

Incorporation places trifluralin into a more intimate contact with the weed seeds and increases its activity, thus decreasing the rate required for satisfactory control (55). Incorporation may also prevent loss of the chemical from sheet erosion (51). Uniform incorporation is a necessity for satisfactory control, otherwise the herbicide may be left in bands, leaving weeds to grow unchecked. Lyons (39) noted that even tolerant plant species were either severely stunted or killed when the roots had to grow through one of these bands of trifluralin.

There is some disagreement as to the effect depth of placement has on activity. Knake (33) found 100 percent control of green foxtail seeded uniformly in the upper three inches of the soil, when trifluralin was incorporated to the depth of one inch, and 85 and 72 percent control at two and three inches of incorporation, respectively. Schweizer and Holstun (50) also pointed out that increasing depths of incorporation had a dilution effect of the herbicide on oats. Owen and Weise (44), however, found no decrease in control of oats when trifluralin was incorporated from one to nine inches.

Incorporation Methods

Soil incorporation implements, the depth and speed at which they are operated, and the soil type and its condition, will influence the depth to which a chemical will be incorporated (5, 30, 45).

Hulbert and Menzel (30) working with labelled phosphorus, determined the depths to which several presently used implements incorporated labelled phosphorus. They obtained the following results:

	percent of P^{32} in zone depth	
	0-2"	2-4"
Disk-once	64.5	18.25
Disk-cross	55.75	17
Spike-tooth harrow	36	11
Spring-tooth harrow	64.25	15
Rototiller-once	56.5	42.25
Rototiller-twice	41	43
Corrogated roller	25.25	--

From these data, it appears that the spring-tooth harrow incorporated the chemical to the same degree as the disk method. This may have been due to the sandy loam soil in which the experiment was conducted. Similar results were obtained by Page (45).

It was also noted that a disk incorporated the chemical one-half the radius of the blade if the disk was buried to the hubs. The rototiller proved to yield the best dispersion of the P^{32} throughout the incorporated zone, which tends to explain the lower amount of labelled phosphorus that was found at the two depths.

FIELD EXPERIMENTS COMPARING THE EFFICIENCY OF FOUR INCORPORATION METHODS

Methods and Materials

Field experiments were conducted in the spring of 1967 at two locations, one in Lewiston, Idaho, on dry peas and one in Milton-Freewater, Oregon, on green peas to determine the efficiency of four types of incorporation methods.

Trifluralin was surface-sprayed with a Hypro-pump system, belly-mounted on a tractor operated at 3.8 miles per hour. The system was PTO driven at 1000 rpm, with a water carrier of 21 gallons per acre at 30 psi, sprayed through four T-Jet 8004 nozzles on a 7.5 foot boom. The trifluralin was incorporated with the various individual implements employed simultaneously with application. The four types of incorporation equipment were:

1) A John Deere six-foot tandem disk with 18-inch blades;
2) A Northwest rototiller with 14-inch "L" shaped blades;
3) A Clark tine-tooth harrow with 12-inch tines;
4) A John Deere spike-tooth harrow with six-inch teeth.

To insure adequate mixing with the soil, the disk plots were double disked at right angles, incorporating the herbicide to approximately a three-inch depth. The rototiller incorporated trifluralin about two inches deep and the spike- and tine-tooth harrows incorporated the material to a depth of one to two inches.

The plots were 50 by 100 feet replicated three times in a randomized block design. Yields were taken on a 10 by 20 foot section after swathing. Dry peas were threshed with a portable thresher and green peas with a stationary deviner. Weed control was evaluated by the author at the time of harvest on a 0 to 100 percent control basis.

Results

Dry Pea Experiment

The yields from the double-disk, rototiller, and spike-tooth harrow plots were significantly higher than yields from the control plots at all three rates of trifluralin. Only at the 1.0 pound per acre rate, however, did the yield from the tine-tooth harrow plots differ significantly from the control plots (Table 1).

Increasing the rate of trifluralin, however, regardless of the method of incorporation, decreased the yield of the dry peas. Though weed control improved with increasing rates (Table 2), it appeared that injury also increased, resulting in decreased yields.

Green Pea Experiment

The double-disk plots yielded significantly higher than the

Table 1. Average yield of dry peas with four incorporation methods and three rates of trifluralin.

Method of incorporation	Average yield in pounds per acre		
	Rates of trifluralin (lbs./A.)		
	0.5	0.75	1.0
double-disk	1543a*	1436a	1330a
rototiller	1497ab	1389a	1361a
spike-tooth harrow	1361ab	1361a	1285a
tine-tooth harrow	1316bc	1285ab	1300a
control	1118c	1104b	1118b

*Different letters denote differences at the 5% level of significance with Duncan's multiple range test.

Table 2. Visual weed control ratings on dry peas.[1]

Method of incorporation	Percent control		
	Rates of trifluralin (lbs./A.)		
	0.5	0.75	1.0
double-disk	97	97	99
rototiller	97	100	100
spike-tooth harrow	85	93	90
tine-tooth harrow	82	92	85
control	0	0	0

[1] Only weed present was wild oats (*Avena fatua* L.).

other three methods of incorporation and the control at the 0.5 and 0.75 pound per acre rates. Only at the 1.0 pound rate did yield from plots of the other methods of incorporation differ significantly from the control (Table 3).

There appeared to be no injury to the green peas as the rates increased, though weed control improved as the rates were increased (Table 4).

Table 3. Average yield of green peas with four incorporation methods and three rates of trifluralin.

Method of incorporation	Average yield in pounds per acre		
	Rates of trifluralin (lbs./A.)		
	0.5	0.75	1.0
double-disk	2749a*	2668a	2921a
rototiller	2413b	2559b	2648a
spike-tooth harrow	2232b	2468b	2975a
tine-tooth harrow	2232b	2559b	2777a
control	2132b	2257b	2132b

*Different letters denote differences at the 5% level of significance with Duncan's multiple range test.

Table 4. Visual weed control ratings on green peas.[1]

Method of incorporation	Percent control		
	Rates of trifluralin (lbs./A.)		
	0.5	0.75	1.0
double-disk	96	96	99
rototiller	94	97	100
spike-tooth harrow	93	94	97
tine-tooth harrow	90	90	94
control	0	0	0

[1]Weeds present included witchgrass (Panicum capillare L.), wild oats (Avena fatua L.), lambsquarter (Chenopodium album L.) and pigweed (Amaranthus retroflexus L.).

THE EFFECT OF INCORPORATION DEPTH ON HERBICIDAL PROPERTIES OF TRIFLURALIN

Methods and Materials

A greenhouse study was conducted in the fall of 1967 at Corvallis, Oregon, to determine: (a) the effect of increasing the depth of incorporation on the biological activity of trifluralin; and (b) the effect of planting depth on the herbicidal properties.

The Woodburn silt loam soil used in the study was collected in the field, air dried, and screened through a 0.25-inch mesh screen. Analysis of the soil showed a content of 13.9% sand, 50.2% silt, 35.9% clay, 3.32% organic matter, a CEC of 15.3%, and a pH of 5.2.

Trifluralin was applied at 0.25 and 0.5 pounds per acre and the positions of the herbicide were as follows: surface with no incorporation, incorporated 0.75 inches, incorporated 1.5 inches and incorporated 3.0 inches. The no-incorporation treatment was sprayed with a greenhouse bench sprayer with the equivalent output of 50 gallons per acre at 20 psi. To simulate incorporation, a rotary conical blender was used. The soil was placed in the blender and sprayed while rotating for a period of 10 minutes. Equal amounts of water were used for all treatments. Barnyardgrass (*Echinochloa crusgalli* (L.) Beauv.) and pigweed (*Amaranthus* retroflexus L.) were planted at depths of 0.75 inches, 1.5 inches, or mixed throughout the soil profile. This allowed for both shoot contact and root and shoot contact with the herbicide. Plastic pots 4.25 inches high and four inches wide were then sub-irrigated with tap water. Previous studies by Harris (27) had shown tha trifluralin does not readily move with water in the soil profile. Treatments were replicated four times in a completely-randomized design.

To compare treatments, seeds were also planted at the three depths in untreated soil. Fresh weights of the top growth were taken at the end of four weeks. Fresh weights of the shoots in the treated soil were then compared to fresh weights from the control with the corresponding planting depth.

Results

Under the described conditions, root exposure to trifluralin was the only method for controlling pigweed and there was no injury when the pigweed was planted below the zone of chemical. Trifluralin was more active on barnyardgrass when the shoot grew into the chemical zone than when both the root and shoot zones contacted the trifluralin, indicating that trifluralin is more effective from shoot absorption than from root absorption in this species (Tables 5, 6, 7, and 8).

Weed control was reduced when trifluralin was incorporated more than 1.5 inches, indicating a possible dilution effect. The higher rate of trifluralin performed better, but the dilution effect was still evident as illustrated in Figures 1, 2, 3, and 4.

Table 5. Pigweed control from 0.25 pounds of trifluralin per acre.

Depth of incorporation	Depth of planting (inches)	Average fresh weight of top growth as percent of control
none	.75	104a*
none	1.5	101a
none	mix	107a
.75	.75	100a
.75	1.5	102a
.75	mix	98a
1.5	.75	66d
1.5	1.5	100a
1.5	mix	79c
3.0	.75	64d
3.0	1.5	68d
3.0	mix	87b

*Different letters denote differences at 5% level of significance with Duncan's multiple range test.

Table 6. Pigweed control from 0.5 pounds of trifluralin per acre.

Depth of incorporation	Depth of planting (inches)	Average fresh weight of top growth as percent of control
none	.75	103a*
none	1.5	100a
none	mix	98a
.75	.75	99a
.75	1.5	99a
.75	mix	97a
1.5	.75	10c
1.5	1.5	98a
1.5	mix	14c
3.0	.75	20b
3.0	1.5	25b
3.0	mix	26b

*Different letters denote differences at 5% level of significance with Duncan's multiple range test.

Table 7. Barnyardgrass control from 0.25 pounds of trifluralin per acre.

Depth of incorporation	Depth of planting (inches)	Average fresh weight of top growth as percent of control
none	.75	97a*
none	1.5	99a
none	mix	97a
.75	.75	49e
.75	1.5	82b
.75	mix	64d
1.5	.75	50e
1.5	1.5	46e
1.5	mix	51e
3.0	.75	83b
3.0	1.5	53e
3.0	mix	73c

*Different letters denote differences at 5% level of significance with Duncan's multiple range test.

Table 8. Barnyardgrass control from 0.5 pounds of trifluralin per acre.

Depth of incorporation	Depth of planting (inches)	Average fresh weight of top growth as percent of control
none	.75	95a*
none	1.5	97a
none	mix	98a
.75	.75	16d
.75	1.5	14d
.75	mix	17d
1.5	.75	26c
1.5	1.5	1e
1.5	mix	16d
3.0	.75	34b
3.0	1.5	11d
3.0	mix	23c

*Different letters denote differences at 5% level of significance with Duncan's multiple range test.

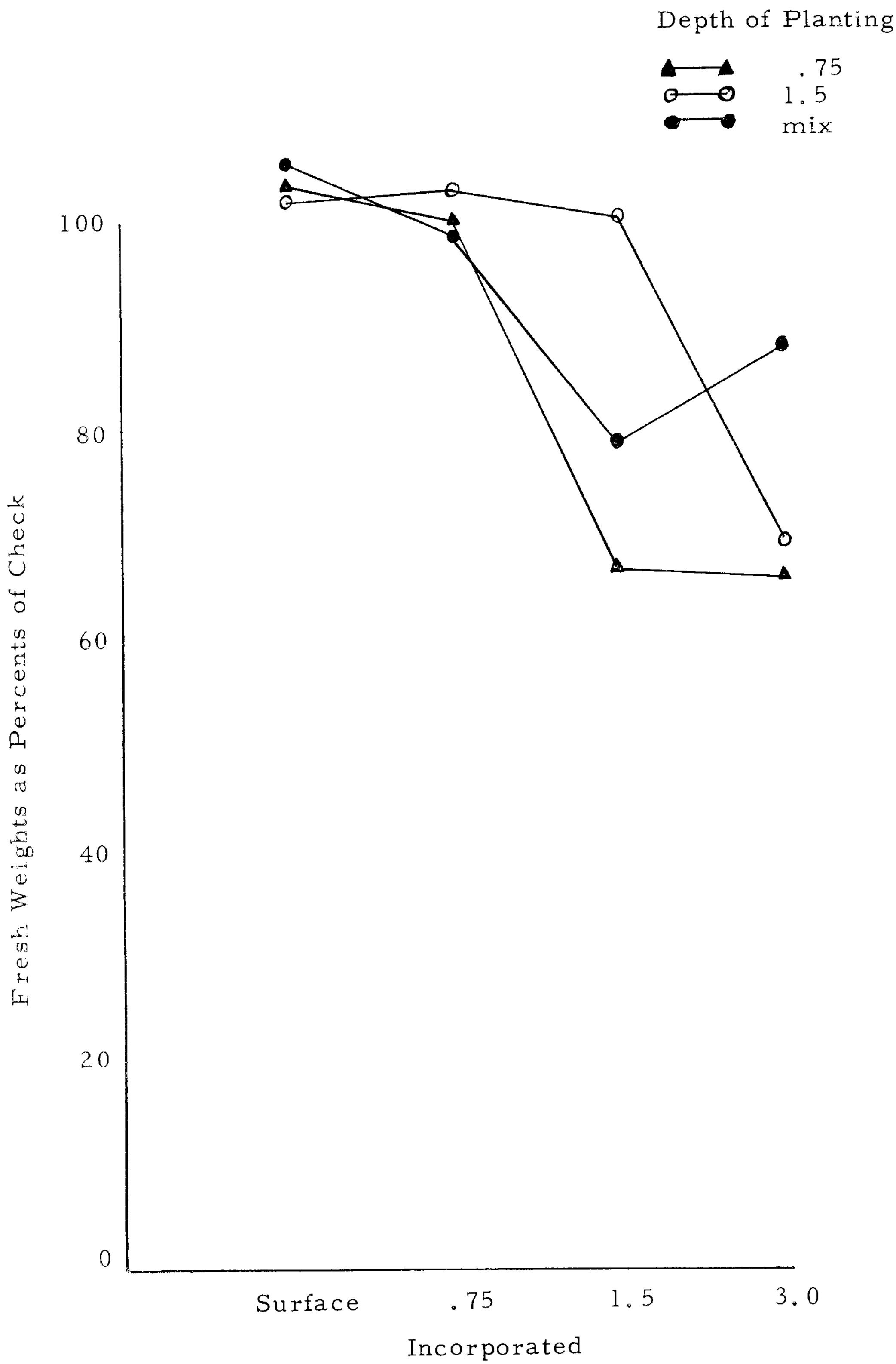


Figure 1. Average fresh weights of pigweed as percents of control with three planting depths and four incorporation depths at 0.25#/Acre trifluralin.

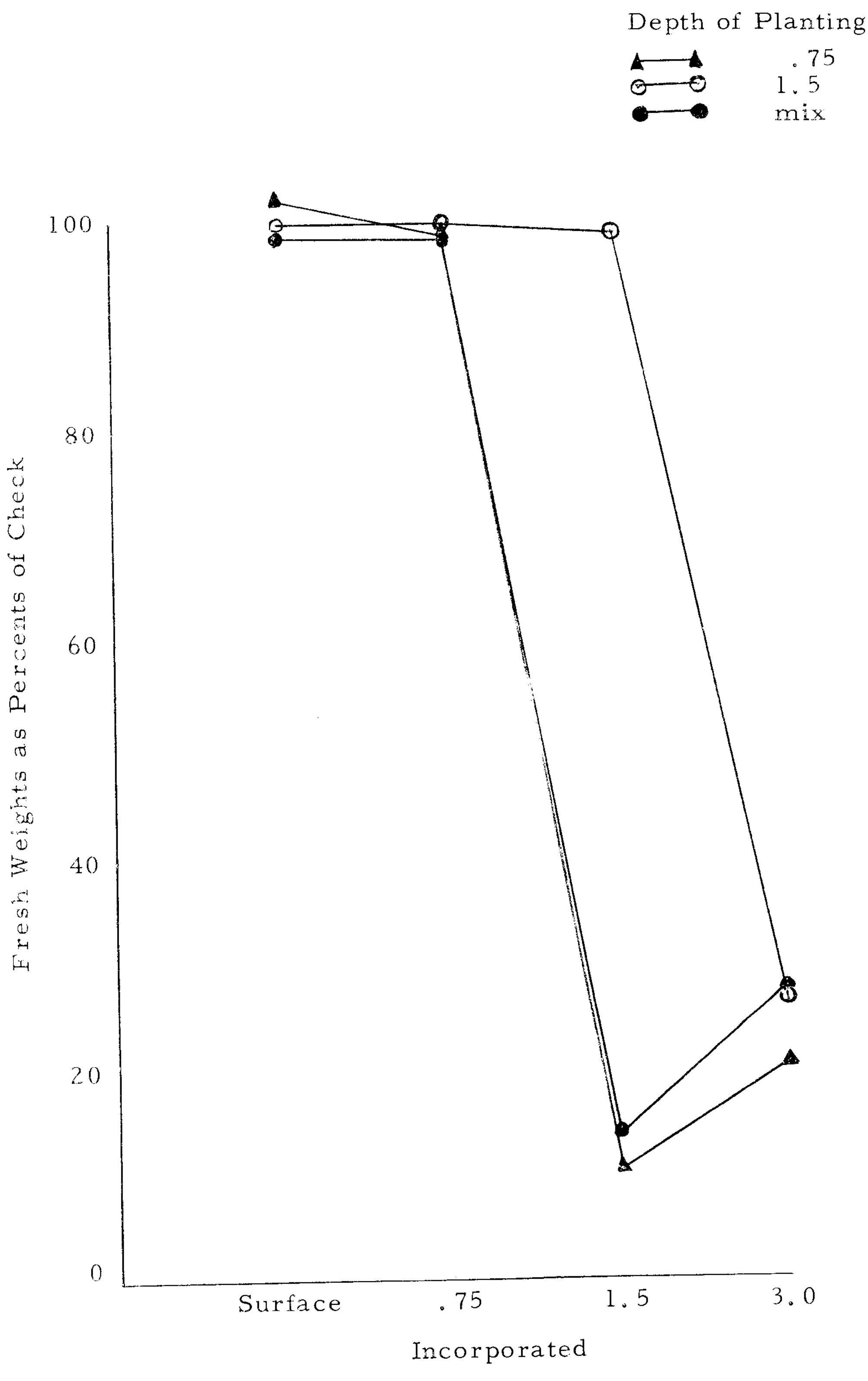


Figure 2. Average fresh weights of pigweed as percents of control with three planting depths and four incorporation depths at 0.5#/Acre trifluralin.

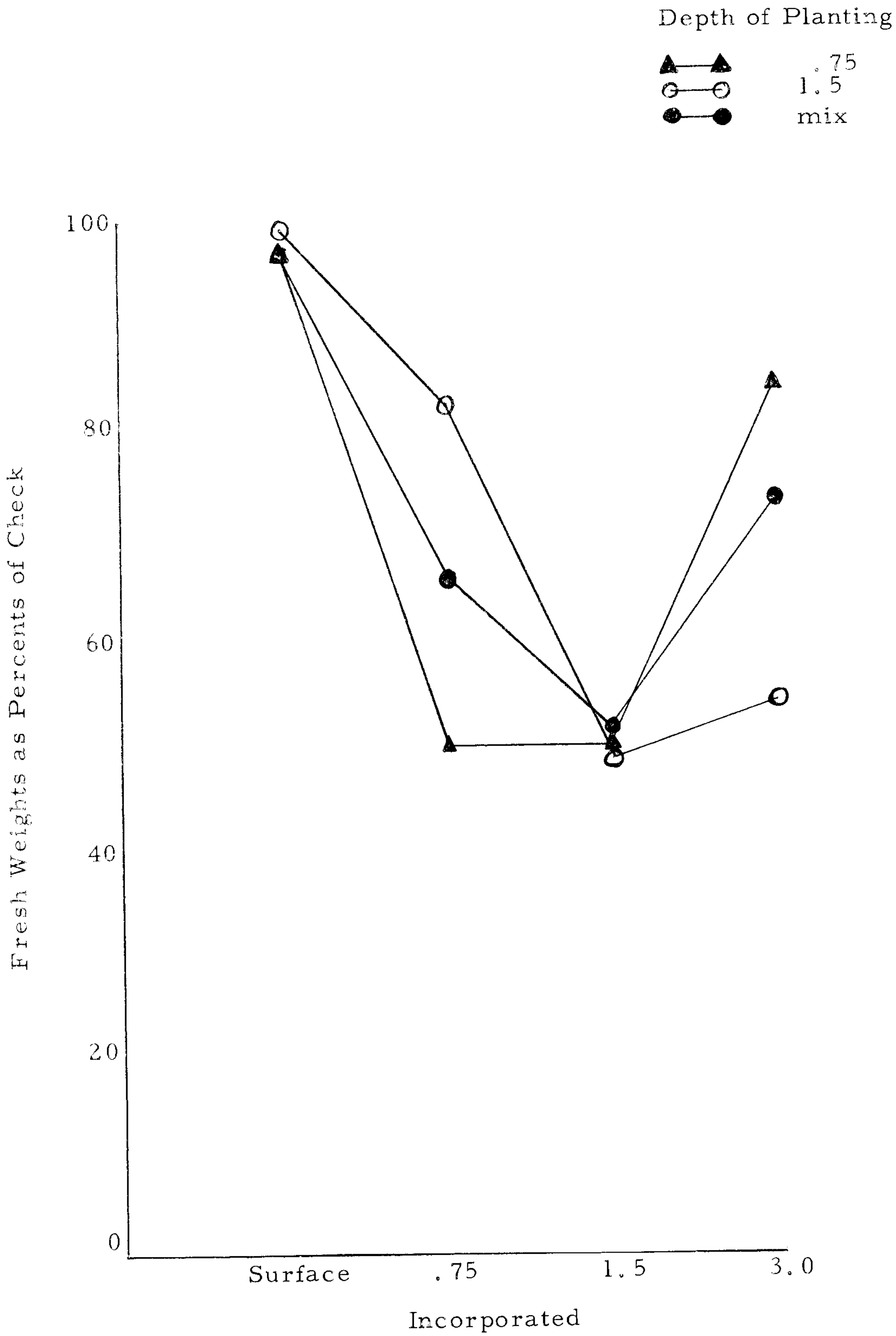


Figure 3. Average fresh weights of barnyardgrass as percents of control with three planting depths and four incorporation depths at 0.25#/Acre trifluralin.

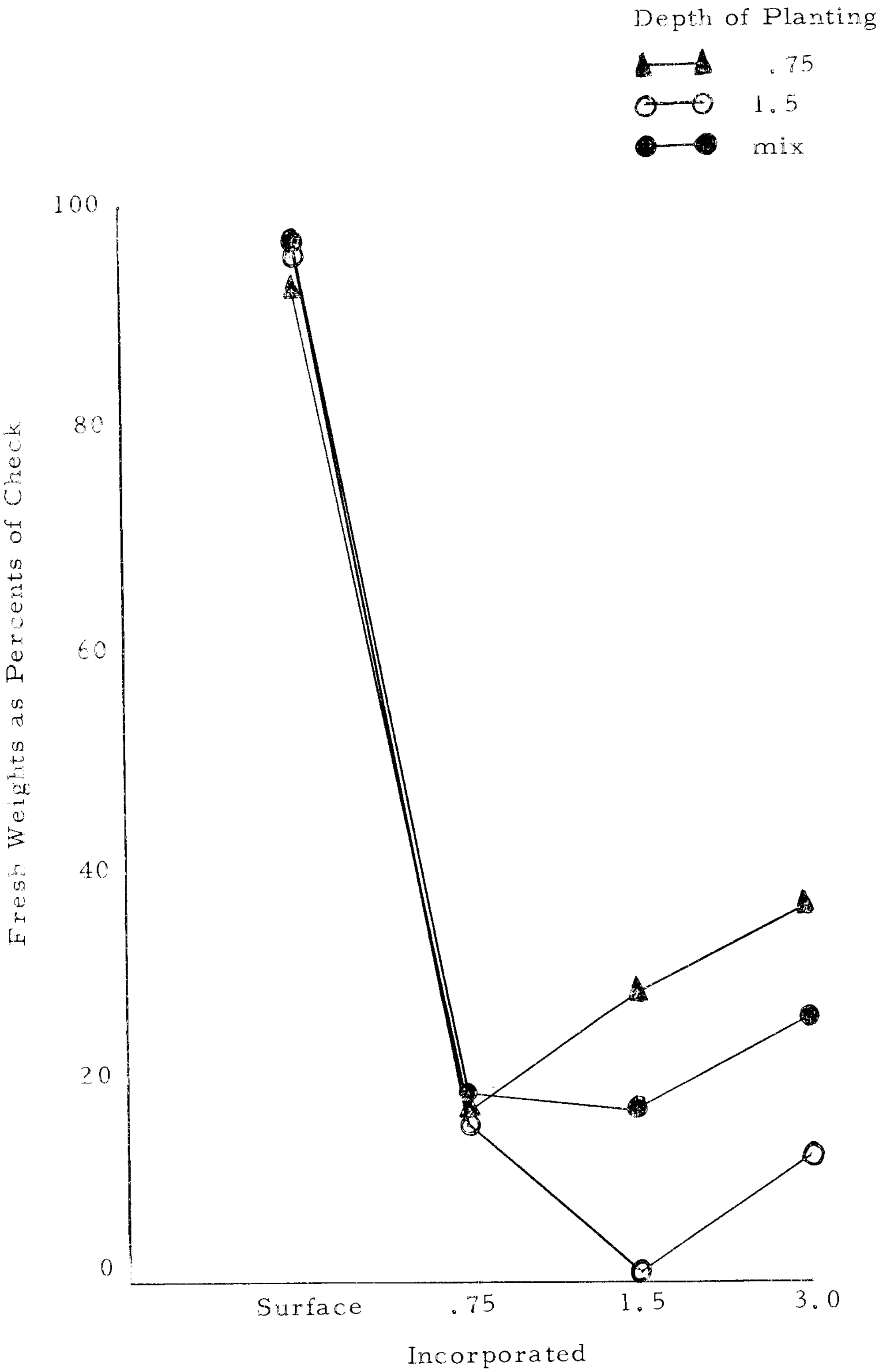


Figure 4. Average fresh weights of barnyardgrass as percents of control with three planting depths and four incorporation depths at 0.5#/Acre trifluralin.

DISCUSSION AND CONCLUSIONS

Results from the greenhouse showed a decrease in weed control when trifluralin was incorporated more than 1.5 inches, indicating a possible dilution effect. In the field, however, there was little difference in weed control between the double-disk and rototiller methods of incorporation, which incorporated trifluralin 3.0 and 1.5 inches, respectively. This would indicate no dilution effect up to three inches of incorporation. Yield differences in green peas between these methods of incorporation, however, were significant. There is a possibility that incorporation to the three-inch depth did dilute the trifluralin enough to allow the peas to grow through the chemical zone without injury, thus the increased yield. It is also possible that the rototiller incorporated trifluralin so well, that the peas growing through the trifluralin were slightly injured, causing the decreased yield and the excellent weed control. More work should be done on this factor of dilution.

Increasing the rate of trifluralin in the dry peas improved weed control, but resulted in decreased yields, indicating injury. Lower rates of trifluralin should be considered if trifluralin is to be applied to dry peas.

An important find in the greenhouse was the indication of a primary difference in the mode of effective uptake of trifluralin between pigweed and barnyardgrass. Though thought to be primarily a root inhibitor, trifluralin was shown to be more effective when placed above the barnyardgrass seed, allowing the coleoptile to grow through the chemical zone. This agrees with Nishimoto's work on oats (42) and Knake's results on green foxtail (33). How-ever, these results may not apply to all grasses. Visual observation in the field has indicated that wheat and barley are not appreciably affected by trifluralin if planted below the treated area and only when the roots grow into the trifluralin is there growth reduction. The main visual difference between wheat and oats is in the way the coleoptile grows from the seed. In the wheat plant, the first internode does not elongate and the coleoptile extends directly from the seed to the soil surface. This growth is primarily by elongation of cells. In oats, on the other hand, the first internode elongates as well as the coleoptile, forcing a node into the soil above the seed. This internode is a meristematic region, where cell division as well as elongation is occurring. Trifluralin has recently been found to cause cessation of cell division, yet has little or no effect on cell elongation (13). It is this property which enables the wheat coleoptile to grow through the triflualin zone without appreciable injury at the same rates at which growth of the oat coleoptile is inhibited.

When pigweed germinated below the zone of trifluralin, no growth reduction of either root or shoot occurred. Only when the roots grew into the herbicide-treated zone was there control of the pigweed. Growth of the hypocotyl in the hook stage, common to broadleaved plants is from cell elongation and not cell division. Because trifluralin does not affect cell elongation, growth through the chemical zone continues without injury or control. Root growth, however, occurs in the meristematic region of the root tips where both cell division and elongation are occurring, and growth into trifluralin-treated soil is arrested.

The weed species to be controlled will therefore be of major importance when determining the depth and method of incorporation of trifluralin.

SUMMARY

Field studies were conducted to compare the effectiveness of four methods of incorporation presently used in agronomic practices. Greenhouse studies were conducted to study the effect of depth of incorporation on trifluralin and the effect of planting depth of two species on the herbicidal properties. The following results were obtained:

1. The only method of incorporation that did not appear successful in incorporating trifluralin was the tine-tooth harrow. The disk, rototiller and spike-tooth harrow could satisfactorily be used for the incorporation of trifluralin.
2. In greenhouse trials, incorporation three inches deep was less effective in controlling both barnyardgrass and pigweed, than when incorporated 1.5 inches, indicating a possible dilution effect.
3. Two weedy species differed in the mode of effective uptake of trifluralin, pigweed absorbing only through the roots and barnyardgrass primarily through the coleoptile. A band of trifluralin directly above the barnyardgrass proved to be more effective than one surrounding the seed, while pigweed was controlled only when the roots grew into the chemical zone.

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APPENDIX

Table 1. Yield of dry peas with 0.5 pound per acre of trifluralin.

Method of incorporation	Weight of 10 x 20 plots				Yield in #/A
	I	II	III	Avg.	
disk	8.5	8.75	8.25	8.5	1542.8c**
rototiller	8.25	8.0	8.5	8.25	1497.4bc
spike-tooth harrow	7.25	7.5	7.75	7.5	1361.2bc
tine-tooth harrow	7.0	7.25	7.5	7.25	1315.9ab
control	4.5	7.75	6.25	6.16	1118.0a

Analysis of variance

Source of variation	df	SS	MS	F value
replications	2	1.51	.76	1.24
treatments	4	10.19	2.55	4.18*
reps x treatments	8	4.28	.61	
total	14	15.98		

*Significant at 5% level.
**Different letters denote treatments differ at 5% level.

Table 2. Yield of dry peas with 0.75 pounds trifluralin.

Method of incorporation	Weight of 10 x 20 plots				Yield in #/A
	I	II	III	Avg.	
disk	7.75	7.25	8.25	7.91	1435.6b*
rototiller	7.0	7.5	8.5	7.65	1388.5b
spike-tooth harrow	7.5	8.0	7.0	7.5	1361.2b
tine-tooth harrow	6.75	7.25	7.25	7.08	1285.0ab
control	6.25	6.0	6.0	6.08	1103.5a

Analysis of variance

Source of variation	df	SS	MS	F value
replications	2	2.16	1.08	1.59
treatments	4	5.05	1.26	1.85
reps x treatments	8	5.47	.68	
total	14	12.68		

*Different letters denote treatments differ at 5% level.

Table 3. Yield of dry peas with one pound rate of trifluralin.

Method of incorporation	Weight of 10 x 20 plots I	II	III	Avg.	Yield in #/A
disk	7.5	7.0	7.5	7.33	1330.3a*
rototiller	7.5	8.0	7.0	7.5	1361.2a
spike-tooth harrow	6.75	7.25	7.25	7.08	1285.0a
tine-tooth harrow	7.0	7.0	7.5	7.16	1299.5a
control	5.5	6.75	6.25	6.16	1118.0

Analysis of variance

Source of variation	df	SS	MS	F value
replications	2	1.35	.67	3.94
treatments	4	6.72	1.68	9.88**
reps x treatments	8	1.38	.17	
total	14	9.45		

*Different letters denote treatments differ at 5% level.
**Treatments different at 1% level.

Table 4. Yields of green peas with 0.5 pound rate of trifluralin.

Method of incorporation	Weight of 10 x 20 plots				Yield in #/A
	I	II	III	Avg.	
disk	10.25	12.6	15.0	12.6	2748.6a*
rototiller	11.0	12.75	9.5	11.0	2413.2b
spike-tooth harrow	8.75	11.75	10.25	10.25	2232.4b
tine-tooth harrow	10.0	10.5	10.25	10.25	2232.4b
control	9.0	9.75	10.0	9.59	2132.3b

Analysis of variance

Source of variation	df	SS	MS	F value
replications	2	12.57	6.28	4.67
treatments	4	16.57	4.07	3.77
reps x treatments	8	8.67	1.08	
total	14	37.51		

*Different letters denote treatments differ at 5% level.

Table 5. Yield of green peas with 0.75 pound rate of trifluralin.

Method of incorporation	Weight of 10 x 20 plots				Yield in #/A
	I	II	III	Avg.	
disk	13.5	10.5	12.75	12.25	2668.1b*
rototiller	12.75	9.75	12.75	11.75	2559.2a
spike-tooth harrow	11.75	12.0	10.25	11.33	2467.7a
tine-tooth harrow	14.0	9.5	--	11.75	2559.2a
control	10.25	9.5	10.0	9.75	2157.3a

Analysis of variance

Source of variation	df	SS	MS	F value
replications	2	5.83	2.91	1.11
treatments	4	12.76	3.19	1.22
reps x treatments	8	20.99	2.62	
total	14	39.58		

*Different letters denote treatments differ at 5% level.

Table 6. Yield of green peas with one pound rate of trifluralin.

Method of incorporation	Weight of 10 x 20 plots				Yield in #/A
	I	II	III	Avg.	
disk	14.0	12.75	13.5	13.41	2920.7a*
rototiller	11.75	13.75	11.0	12.16	2648.4a
spike-tooth harrow	11.25	15.0	14.75	13.66	2975.1a
tine-tooth harrow	12.75	13.5	12.0	12.75	2776.9a
control	10.25	9.0	10.0	9.79	2132.3

Analysis of variance

Source of variation	df	SS	MS	F value
replications	2	6.44	3.22	2.09
treatments	4	32.15	8.04	5.22**
reps x treatments	8	12.35	1.54	
total	14	50.94		

*Different letters denote treatments differ at 5% level.
**Significant at 1% level.

Table 7. Visual weed control ratings on green peas.

Rate of trifluralin	Method of incorporation	Replications I	II	III	Avg.
.5	disk	95	98	95	96
.5	rototiller	96	97	90	94
.5	spike-tooth harrow	95	90	95	93
.5	tine-tooth harrow	90	90	90	90
.75	disk	98	95	95	96
.75	rototiller	98	97	98	97
.75	spike-tooth harrow	95	93	95	94
.75	tine-tooth harrow	90	87	92	90
1.0	disk	100	98	100	99
1.0	rototiller	100	100	100	100
1.0	spike-tooth harrow	98	93	98	97
1.0	tine-tooth harrow	95	93	93	94
	control	0	0	0	0

0 = no control, 100 = 100% control.

Table 8. Visual weed control on dry peas.

Rate of trifluralin	Method of incorporation	Replications			
		I	II	III	Avg.
.5	disk	98	98	95	97
.5	rototiller	100	95	98	98
.5	spike-tooth harrow	85	85	85	85
.5	tine-tooth harrow	80	85	80	82
.75	disk	95	100	95	97
.75	rototiller	100	100	100	100
.75	spike-tooth harrow	95	90	95	93
.75	tine-tooth harrow	85	95	95	92
1.0	disk	98	100	100	99
1.0	rototiller	100	100	99	100
1.0	spike-tooth harrow	85	95	90	90
1.0	tine-tooth harrow	80	90	85	85
control		0	0	0	0

0 = no control, 100 = 100% control

Table 9. Pigweed control from .25 pounds of trifluralin/A.

Depth of incorporation (in.)	Depth of planting (in.)	Average fresh weight as % of control				
		I	II	III	IV	Avg.
none	.75	102	110	104	100	104a*
none	1.5	100	98	106	101	101a
none	mix	112	108	102	108	107a
.75	.75	96	104	99	103	100a
.75	1.5	104	110	98	96	102a
.75	mix	96	100	98	92	98a
1.5	.75	63	68	74	61	66d
1.5	1.5	100	102	98	99	100a
1.5	mix	86	72	77	81	79c
3.0	.75	61	66	64	67	64d
3.0	1.5	71	68	64	69	68d
3.0	mix	83	84	87	93	87b
Control		100	100	100	100	100

Analysis of variance

Source of variation	df	SS	MS	F value
replication	3	14.47	4.82	1.95
treatments	12	102.22	8.52	3.45**
reps x treatments	36	88.98	2.47	
total	51	205.67		

*Different letters denote treatments differ at 5% level.
**Denotes 1% significance level.

Table 10. Pigweed control with .5 pound rate of trifluralin.

Depth of incorporation (in.)	Depth of planting (in.)	Average fresh weight as % of control				
		I	II	III	IV	Avg.
none	.75	100	102	108	98	103a
none	1.5	101	99	100	102	100a
none	mix	97	98	100	97	98a
.75	.75	96	100	102	99	99a
.75	1.5	102	100	96	98	99a
.75	mix	94	96	100	98	97a
1.5	.75	9	11	12	9	10c
1.5	1.5	96	101	100	99	98a
1.5	mix	16	11	17	14	14c
3.0	.75	21	19	23	17	20b
3.0	1.5	22	29	24	24	25b
3.0	mix	26	23	27	24	25b
Control		100	100	100	100	100

Analysis of variance

Source of variation	df	SS	MS	F value
replications	3	.24	.08	3.08
treatments	12	799.14	66.60	2.56**
reps x treatments	36	.93	6.026	
total	51	800.31		

*Different letters denote treatments differ at 5% level.
**Denotes 1% significance level.

Table 11. Barnyardgrass control from .25 pounds of trifluralin/A.

Depth of incorporation (in.)	Depth of planting (in.)	Average fresh weight as % of control				
		I	II	III	IV	Avg.
none	.75	100	96	92	100	97a*
none	1.5	100	100	98	100	99a
none	mix	98	100	94	98	97a
.75	.75	48	52	55	41	49e
.75	1.5	86	79	82	80	82b
.75	mix	64	61	68	63	64c
1.5	.75	55	42	59	43	50e
1.5	1.5	46	51	43	43	46e
1.5	mix	57	52	49	47	51e
3.0	.75	79	88	82	84	83b
3.0	1.5	73	78	68	71	73d
3.0	mix	52	49	51	55	53e
Control		100	100	100	100	100

Analysis of variance

Source of variation	df	SS	MS	F value
replications	3	.45	.15	683
treatments	12	223.64	18.64	100**
reps x treatments	36	6.37	.18	
total	51	230.46		

*Different letters denote treatments differ at 5% level.
**Denotes 1% significance level.

Table 12. Barnyardgrass control from .5 pounds of trifluralin/A.

Depth of incorporation (in.)	Depth of planting (in.)	Average fresh weight as % of control				
		I	II	III	IV	Avg.
none	.75	96	94	97	96	95a*
none	1.5	98	97	101	97	97a
none	mix	1C2	94	95	97	98a
.75	.75	18	14	16	16	16d
.75	1.5	21	17	15	16	17d
.75	mix	15	14	13	13	14d
1.5	.75	28	24	28	25	26c
1.5	1.5	2	0	0	2	1e
1.5	mix	14	17	17	16	16d
3.0	.75	34	31	37	33	34b
3.0	1.5	11	9	11	12	11d
3.0	mix	21	24	24	24	23c
Control		100	100	100	100	100

Analysis of variance

Source of variation	df	SS	MS	F value
replications	3	.23	.07	.003
treatments	12	761.40	63.45	29.51**
reps x treatments	36	77.41	2.15	
total	51	839.04		

*Different letters denote treatments differ at 5% level.
**Denotes 1% significance level.