LONGEVITY, GERMINATION, AND EMERGENCE OF WILD HEMP, (CANNABIS SATIVA L.)

by

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INTRODUCTION

Wild hemp (*Cannabis sativa*, L.) is an annual plant which reproduces from seed. It is an introduced species that escaped from cultivation and became a common weed in the North Central United States.

In recent years there has been considerable interest in controlling this plant. Because it is an annual, control measures must prevent seed production. The key to control of wild hemp is, then, prevention of seed production, and depletion of the soil's seed supply. Another factor in annual weed control is seed dissemination. If seeds are easily transported, preventing seed production at an infestation would give no assurance of weed control. Wild hemp seeds are approximately the same size and shape as those of grain sorghum. Hemp seeds are fed upon by many birds and small animals. Studies have shown quail to pass some viable hemp seeds, but the number is probably too small for quail to be a significant disseminator. Transport by water, domestic animals, and man are probably the primary methods of seed dispersal.

The object of this study was to investigate longevity and abundance of wild hemp seeds in the soil. It was hoped the study would give an estimation of the number of years seed production of a particular infestation must be controlled to achieve eradication.

REVIEW OF LITERATURE

A proverb states "Know thy enemy." Since weeds are an enemy to a producer, it is logical for him to seek information about weeds such as; seed numbers, persistence, and the depth from which they will emerge in the soil.

Dore and Raymond (18) sampled permanent pastures and found seeds of 57 plant species with estimated numbers of over 19 million viable seeds per acre. Most of these were weed seeds which provided a continuous source from which new plants entered the pasture. Lippert and Hopkins (25) sampled mixed prairie habitats and found 18 times more weed seedlings than non-weedy seedlings. They stated that because desirable perennial grasses germinate and grow slowly, they are unable to compete with vigorous annual weeds until several years after initial establishment. In a study of plant succession in old field soils, the highest germination occurred in a field abandoned one year, but a field abandoned five years produced the greatest number of species (27).

Brenchley (6) found seed germination in forest soils diminished at increasing depths of 20.3, 40.6, and 63.5 cm. In a grass field not plowed for 300 years, the maximum number of germinable seeds occurred in the 2.5 to 5.1 cm layer of soil and declined to the 15.2 cm depth below which few seeds germinated.

Chippendale and Milton (12) obtained germinable seeds from samples taken 25.4 to 35.6 cm deep in stiff clay grassland soils. However, in peaty hillside soils few germinable seeds were found below 7.6 cm. This soil contained few earthworms and they theorized that earthworms were responsible for the occurrence of seed at greater depths. Worm casts were conditioned and some viable seeds were found in them. Worms were found to void underground in winter and summer. It is more probable that worms carry seed to greater depths than that seed moved through the soil by rain running in soil fissures.

Crocker (15) stated that loss of seed viability was due to denaturing of embryo proteins. Medium-lived grains like wheat, stored at low temperature and moisture content, may retain their viability several centuries. As seeds age, plant mutations increase significantly (16). The life span of any seed is determined by two sets of factors, genetic and environmental.

Goss (20) reported the results of J.W.T. Duval's seed burial study in which Duval buried numerous seed species at depths of 20.3, 55.9, and 106.7 cm in the soil. He found that seeds of cultivated crops such as wheat (Triticum aestivum L.), sunflower (Helianthus annuus L.) and hemp (Cannabis sativa L.) were dead after two years in the soil. Weed seeds survived better than those of cultivated plants. Burial depth had little effect upon the preservation of seed viability. The presence of seeds in the soil provides a source of continuous vegetative cover for the land.

Bruno (10) found that cultivated soil contained more viable seeds of more species than uncultivated soil. But in the former, plants growing on the surface had germinable seed in the soil, while in the latter viable seeds of some species absent on the surface were present in deep layers. The maximum depth at which viable seeds were found was 40 cm.

Roberts (31) buried seeds of 11 English annual weeds in pots and stirred the soil five times a year. He found seed germination of most species was complete after two years. In all species, there was a progressive decline in seedling number for successive years.

Studies at Rothamsted (1) found that legume seeds lying 15.2 to 22.8 cm under turf after 30 years or more were more viable than those nearer the surface. This demonstrates that seeds retain viability longer when not subjected to sudden changes of temperature and humidity. Exell (19) stated that embryos kept in a state of desiccation have prolonged seed viability. Sacred lotus (Nelumbium speciosum) seeds found in a Manchurian peat bog and estimated to be 400 years old, germinated when placed in a proper environment.

Cresuni (14) found hemp seeds stored in paper bags for 8-9 months, at 7-15° C and 65-70% humidity, had 10-15% greater viability than those after-ripened 2-3 months. He concluded that percent viability and germination were independent genetic characteristics and that longevity of hemp seeds was not due to heredity and was not correlated with either their post harvest viability or germination.

Seeds of native grasses in New South Wales stored in packets exposed to seasonal temperature and humidity were germinated for 12 years. However, only a Panicum species germinated at the end of the experiment (27).

Brown and Porter (9) buried seeds of several weed species at depths of 10.2 to 15.2 cm and 40.6 to 45.7 cm in open vials. Bindweed seeds buried near the surface became permeable more rapidly than those buried deeply. Impermeable bindweed seeds retained viability for four years after burial in the soil at 15.2 to 45.7 cm.

Timmons (36) reported an infested field of bindweed (Convolvulus arvensis L.) was tilled for 28 successive years, starting in 1920, to determine how long seeds would continue to germinate. Twenty years after the original stand was eradicated, 800 bindweed seedlings per acre were observed. In 1948, 48 seedlings were observed per acre. The results indicate that completely ridding infested land of bindweed may require 30 years or more of persistent field management before all dormant seeds have germinated or have been destroyed. Fallowing for four years reduced the abundance of buried weed seeds more drastically than short fallowing (26).

Tschirley and Martin (38) buried hulled mesquite seed (Prosopis juliflora (Swartz) D.C.) in open fruit jars 15.2 cm deep in the soil. Initial seed germination was 96% after scarification. After 2, 5, and 10 years respectively, 37%, 53%, and 90% of the total seed had germinated or rotted before retrieval. Their longevity tests indicated some seeds remained viable after 10 years of burial even where soil moisture was adequate for germination.

Twelve species of California weeds were buried in the soil and after 10 years seed of only two species germinated. Silver leaf nightshade (Solanum elaeagnifolium Cav.) germinated better than the other species after 10 years (3).

Rampton and Ching (30) buried seeds of several cool-season grasses and legumes in the soil. They found storage in air reduced dormancy but not viability, while burial in the soil for three years greatly reduced both germination and dormancy. However, red clover (Trifolium pratense L.) retained practically the same amount of hard seed dormancy after three years storage in air as in the soil (2). A tetrazolium test showed not all of the seeds remaining unsprouted and apparently sound after the germination tests were viable (24, 32). Differential longevity was observed between buried seeds of annual ryegrass (Lolium multiflorum Lam.) and perennial ryegrass (Lolium perenne L.). Annual ryegrass seed was viable after 29 months burial while the perennial ryegrass seed was dead. The persistence of Pennscott red clover seeds in the soil exceeded that of the other species. They found greater retention of viability and dormancy with increased burial depth; this trend was particularly obvious in clover seeds.

Taylorson (35) reported nondormant seeds lost viability faster than dormant seeds. Depth of placement, also, markedly influenced loss of viability. Seeds buried shallowly lost viability faster than seeds buried deeply. His findings suggested the relative degree of initial seed dormancy might be as important as the species itself in determining loss of viability of weed seeds in soils. He concluded that phytochrome control is a principal dormancy mechanism of weed seeds in soils which might be present initially and retained after burial, or acquired after burial.

Williams and Cronin (40) found seeds of three larkspurs (Delphinium spp.) and western false hellebore (Veratrum californicum Durand) buried at 0, 2.5, 7.6, 15.2 cm all germinated or decomposed in one year. No sound or ungerminated seed was recovered the second year. Seeds of all four species had a prolonged dormancy which could be terminated by a combination of low temperature, moisture, and time.

Tingey (37) placed seeds of wild oats (Avena fatua L.), winter rye (Secale cereale L.), and wheat (Triticum aestivum L.) with initial germinations of 20%, 81%, and 90% respectively in cultivated soil. As the depth at which seeds were placed in the soil was increased, the number of seedlings that emerged decreased. Only 10% as many seedlings emerged at 15.2 cm as at 2.5 cm. Wild oat seeds persisted for three years while winter rye and wheat seeds were dead within one year.

Giant ragweed (Ambrosia trifida L.) seeds germinated best if planted 5.1 to 7.6 cm deep; however, some emerged from 12.7 cm. Seed longevity was directly related to burial depth, and this trend continued to 25.4 cm (38).

Condray (13) concluded that planting depth of velvet leaf (Abutilon theophrasti Medic.) had a significant effect on seedling emergence. The viability of seed which did not germinate from 10.2, 15.2, and 20.3 cm planting depths was reduced, and seedling emergence was slower from greater depths than shallow depths.

Brenchley and Warington (7, 8) reported many weed seeds in the soil have a period of natural dormancy. Seeds buried in soil under conditions unsuitable for germination may remain viable for many years. A seed may be said to be naturally dormant if it will not germinate under favorable conditions, whereas "induced" dormancy is that state forced on a seed capable of immediate germination but is in an unfavorable environment.

Kiewnick (23) found soil microflora at their population peaks in spring and autumn can depress germination of partially dormant wild oat seeds in the soil. Soil fungi are most aggressive at 50% of soil moisture holding capacity. Compost and sandy soils stimulated seed germination as well as development of microorganisms. Destruction of wild oat seeds in sandy soils may be 15% higher than that in loam soils.

Schafer and Chilcote (34) designed a population model that represented the persistence and depletion of buried seed of a species at a point in time. The proportional equation described the components of a buried seed population: S=Pex+Pend+Dg+Dn. Pex (exogenous dormancy) is a manifestation of seed sensitivity to extremes of temperature, absence of light, etc. Pend (endogenous dormancy) among buried seed represents a condition which may include primary or secondary dormancy. Dg is a parameter of depletion based on the assumption that germination below the maximum depth of emergence results in the elimination of the seed as a reproductive unit. Dn represents a loss of viability due to physiological aging or through destruction by predatory organisms.

One of the remarkable things about the longevity of weed seeds in the soil is that most lack impermeable coats and hence absorb water when exposed to moist soil (4). It is noteworthy that fully imbibed seeds remain viable over a long period of time (5). Seeds of red root pigweed (*Amaranthus retroflexus* L.) remained dormant longer when imbibed and stored moist; this reduced the rate of respiration which probably indicated reduced metabolic activity and prolonged life.

Quick (29) reported that seed coats are important in the longevity of seed. Seed coats of most long-lived seeds have a palisade, or a Malpighian layer made up of heavy-walled, tightly-packed, radially-placed, columnar cells. The palisade layer is mechanically protective and highly impervious to water and respiratory gases. However, this layer is not so important to buried or to soil-stored seeds. Soil apparently provides protective conditions necessary for longevity.

In 1879, Beal (1, 5, 17, 22) buried 23 species of Michigan weed seeds 58.4 cm deep. Five species failed to germinate after 5 years. After 25 years 11 species germinated. Only three species germinated after 80 years of burial; viz., *Rumex crispus* L., *Oenthera biennis* L. and *Verbascum blattaria* L.

Chepil (11) mixed a known quantity of weed seeds into cultivated soil and observed their emergence. Results indicated that most species produce some seeds that germinate immediately after they are placed under favorable conditions, but some remain dormant. Weed seeds that remain dormant for many years constitute a serious agronomic problem. The duration of seed dormancy is, therefore, one of the most important factors determining the seriousness of a weed.

METHODS AND MATERIALS

Four experiments were conducted to determine; (a) longevity and viability of wild hemp seed in soil, (b) seedling emergence from several planting depths, (c) storage condition effect on seed longevity, (d) distribution of seed in the soil of natural stands.

Wild hemp seed used in all studies was collected from mature plants in Riley County Kansas during the fall of 1970.

Seed Longevity.

In October, 1970 and April, 1971 lots of 1000 wild hemp seeds were mixed with soil and buried in open-end plexiglass cylinders 7.6 cm long and 7.6 cm in diameter. Seeds were buried at three depths: 7.6, 15.2, and 22.9 cm. Experimental design was randomized complete block with three replications. Seeds were buried at the Kansas State University Agronomy Farm in a Smoland silty clay loam soil. A truck-mounted hydraulic soil probe (7.6 cm in diameter) was used to remove a measured column of soil. Then, seed and soil were mixed, poured into a cylinder placed at the appropriate depth, and the remaining soil column replaced with a minimum of disturbance. Seed samples were exhumed at three month intervals.

After retrieval, the seeds were germinated for 10-14 days at 27-32^{o} C. Ungerminated seeds were separated from the soil by dry sieving and washing the material through a 10-mesh screen. Seed number was then established, and a random sample of 100 seeds was taken from each retrieved sample. Each of the 100 seeds was halved and soaked in a 1% solution of 2,3,5-triphenyltetrazolium chloride to determine viability. Halved embryos were soaked for 2 hours.

Seeds were considered viable but dormant when radicles and cotyledons were stained red. Partially stained embryos, lack of radicle staining and/or light red staining were considered evidence of non-viability. Criteria for positive and negative reaction to tetrazolium was similar to those published for economic crop seeds (21). The tetrazolium test was rather subjective, but it was felt that the procedure provided a reliable indication of seed viability. Total seed viability was the sum of germinated seeds and seeds found viable by the tetrazolium test.

Depth of Emergence.

Forty eight wild hemp seeds were planted in wooden flats 40 cm x 65 cm and 9 cm deep. Each flat was divided with pasteboard strips into five equal spaces. Seeds were planted at depths of: 0, 1.3, 2.5, 5.1, and 7.6 cm, in three soil types: loam, sand, and clay loam. Soil type was determined by the Bouyoucos method. Experimental design was randomized complete block with three replications. Prepared flats were placed in a greenhouse at 10-32° C for 25 days.

Storage Temperature.

Packets of 100 seeds were stored under three temperature ranges; cold, warm, and diurnal. Cold storage was obtained in a refrigerator (1° C), warm storage was in the laboratory (20-27° C), and a diurnal temperature was obtained by burying seeds 15.7 cm deep in sealed 0.47 liter bottles. Seeds were retrieved monthly and germinated on moistened blotter paper at room temperature for 7-10 days.

Seed Distribution in Natural Stands.

Soils from seven sites were sampled for their wild hemp seed content. Sites 1, 2, and 3 with the respective soils Hanie very fine sandy loam, Tully silty clay loam, and Ivan silt loam were sampled in October, 1970. Sites 4, 5, 6, and 7 were sampled in October of 1971 and had Ivan silt loam, Kahola silt loam, Carr-Sarpy complex, and Ivan silty clay loam soils, respectively. In 1970 sampled increments were: duff, 0 to 5.1 cm, 5.1 to 10.2 cm, 10.2 to 15.2 cm, 15.2 to 20.3 cm, 20.3 to 25.4 cm, and 25.4 to 30.5 cm. Each increment had a surface area of 0.1 m^2. Sampling depth was reduced in 1971 to the duff, 0 to 5.1 cm, and 5.1 to 10.2 cm soil increments. Locations were sampled with a randomized complete block design with three replications.

Samples were taken by isolating a 0.1 m^2 column of soil and using a sampling pan to remove a layer 5.1 cm thick. Seeds were isolated by dry sieving and then washing individual soil samples through a 10-mesh screen. After the samples were air dried seeds were separated from gravel and organic debris by means of a laboratory seed cleaner. Following counting, seeds were germinated on moist blotter paper for 10 days under continuous light at 27-31° C. Seeds which failed to germinate were halved and soaked in a 1% solution of 2,3,5-triphenyltetrazolium chloride for two hours.

Total viability was the sum of the number of germinated seeds and seeds viable according to the tetrazolium test.

RESULTS AND DISCUSSION

Seed Longevity.

The number of seeds retrieved decreased logrithmically with extended burial time (Figure 1). Out of the original 1000 seeds buried 440 and 550 seeds were recovered after 15 and 9 months for studies one and two, respectively. Some of this seed loss may have been due to experimental error in the retrieval process. Results indicate agents responsible for seed destruction were more active during warm summer months than cold months. Apparently, soil organisms active at high soil temperatures are more destructive to buried seeds than physical weathering during cold months. This probably accounts for the initial rapid seed decomposition in study two.

The rate of seed decomposition was affected by burial depth (Figure 2). In study one, the 22.9 cm depth had the most seeds (690) while the 15.2 cm depth had the least (560). In study two the 7.6 cm depth contained the most retrieved seeds (690), and the number decreased sharply to the 15.2 and 22.9 cm depths where 558 seeds were retrieved. Although results of studies one and two are somewhat different, they probably will become more similar with extended burial time. It is probable that retrieved seed numbers will decrease at all burial depths with extended time, but this loss may be greater for seeds buried shallowly than seeds buried deeply. Barton (4) stated that seeds at shallow depths are more subject to agents responsible for seed decomposition than seeds at great depths.

Wild hemp seed germination was affected by soil conditions (Figure 3). In study one, germination decreased from 11.5% at burial to 7.0% three months later. Germination increased significantly in April

Fig. 1. Persistence of wild hemp seed as influenced by length of soil burial.

Fig. 2. The effect of soil burial depth on wild hemp seed persistence.

Fig. 3. Germination of wild hemp seed as influenced by length of soil burial.

Fig. 4. The effect of soil burial depth on wild hemp seed germination.

Fig. 5. Viability of wild hemp seed as influenced by length of soil burial.

Fig. 6. The effect of soil burial depth on wild hemp seed viability.

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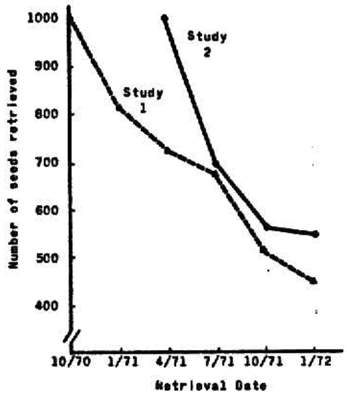
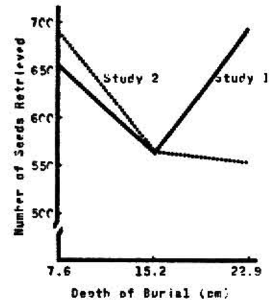


Fig. 1



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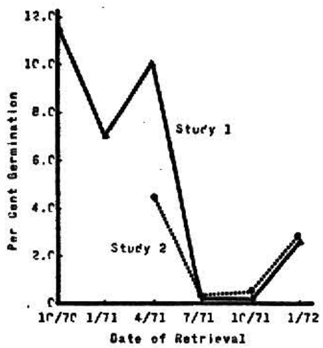

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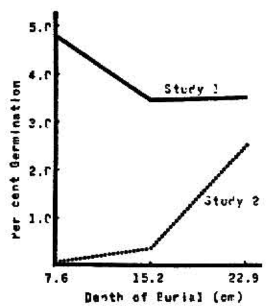

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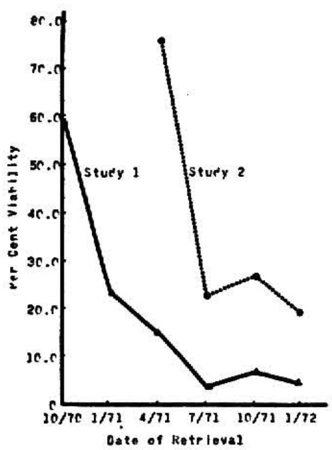

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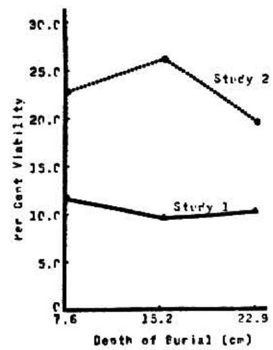

Fig. 6

(10.7%) which coincided with the natural emergence of wild hemp seedlings. Germination was 0.3% in July and October when seedlings do not emerge under natural conditions. Germination was significantly higher in both studies during January, 1972. Apparently, high soil temperatures adversely affect wild hemp seed germination. This coincided with observed natural flushes of seedling emergence in the spring and fall of each year.

Studies one and two had different rates of germination at the three burial depths (Figure 4). The 7.6 cm depth had the highest percent germination for study one while the 22.9 cm depth had the highest germination for study two. Higher germination was expected from seed recovered from the 7.6 cm depth of study two, as seeds from both the 7.6 cm and 15.2 cm depths germinated significantly less than seeds from the 22.9 cm depth.

Study two's low germination was probably due to its seeds not being through the optimum season for germination (March-April). Wild hemp seeds are sensitive to seasonal changes in climate and germinate best in cool temperatures. This could explain why shallowly buried seeds are affected more by the climate than seeds buried deeply.

Seed viability decreased from 59% to 4% after nine months burial in study one, and then remained relatively constant at 4% for six months (Figure 5). Seed viability in study two decreased similarly from 75% to 23% after three months and then remained at about 20% for the next six months.

Results indicate that a population of seeds introduced into the soil loses viability quickly for a period of time and then continues to lose viability at a decreasing rate. Agents responsible for seed destruction may be more active in warm soils than in cold soils as indicated by the differential loss of seed viability in studies one and two (Figure 5). Seeds in study two lost approximately the same amount of viability in three warm months as seeds in study one did in six cold months. Viability, calculated for the 1000 buried seeds, decreased with extended time. However, if viability was calculated over the actual number of seeds retrieved it increased after an initial decrease. This is probably due to the high decomposition rate of nonviable seed as compared to the relatively stable condition of viable seed. Taylorson (33) found this same differential decomposition rate and attributed it to dormant seeds remaining viable longer than nondormant seeds.

Depth of seed burial had no significant effect on seed viability (Figure 6). Study one had an average viability of 11% for all depths, and viability for study two was 22% for all burial depths. As burial time is extended seeds buried at shallow depths will probably lose viability faster than those buried at greater depths.

Depth of Emergence.

Wild hemp seedling emergence was inversely related to planting depth (Figure 7). Seedlings from surface-planted seeds gave 73% emergence while seedlings from seeds planted 5.1 cm deep gave 35% emergence. A second plant count was made 24 days after planting and seedling abundance continued to decrease with increasing depth of planting. However, seedlings from seeds planted deeply were more susceptible to damping-off. Seeds planted 7.6 cm deep had an 8% reduction in seedling abundance 7 days after the first count. The plant count made 17 days after planting represents seedling emergence and the plant count made 24 days after planting represents seedling establishment.

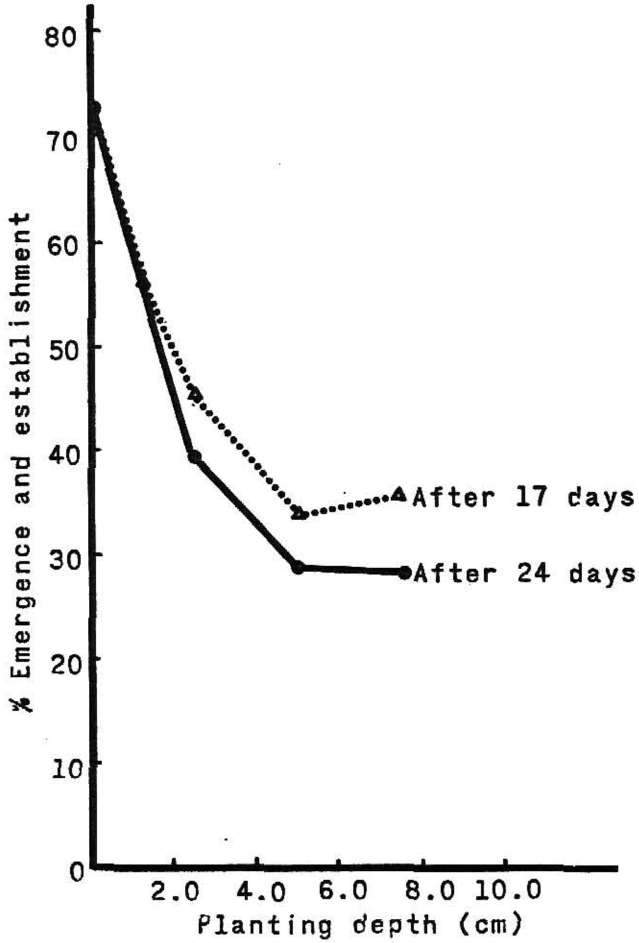

Fig. 7. Wild hemp seedling emergence and establishment from seed planted at five soil depths.

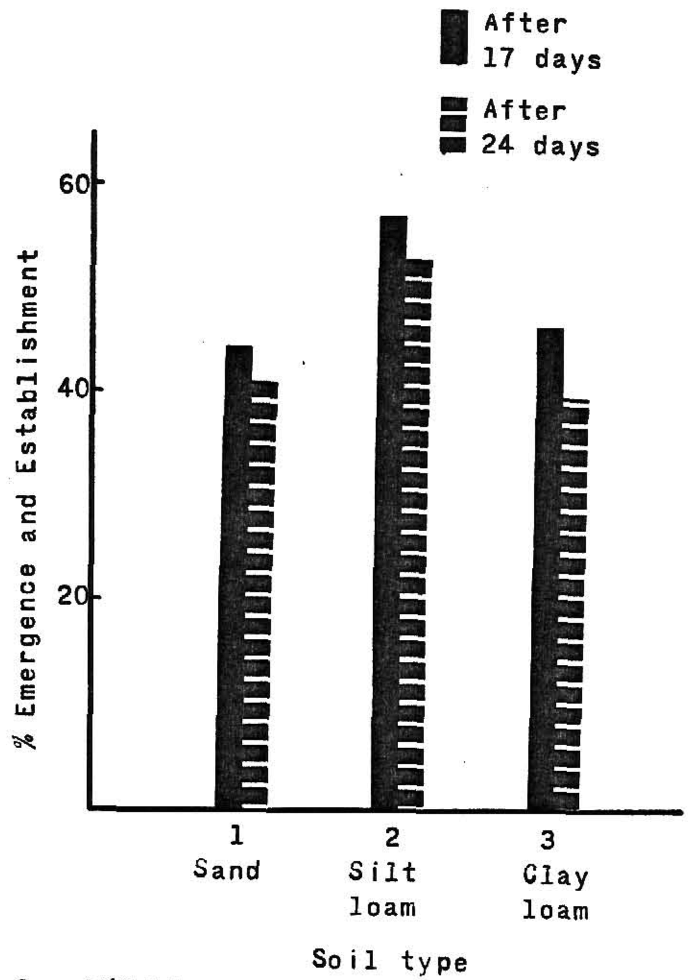

Fig. 8. Wild hemp seedling emergence and establishment in three soil types.

Seedlings may fail to emerge because they lack sufficient stored energy to reach the surface or are attacked by damping-off organisms. The more deeply seeds are planted the more energy their seedlings must expend to emerge. Emergence from great depths weakens seedling vigor and makes seedlings more susceptible to microbial attack (preemergent damping-off).

Soil type had no significant effect on seedling abundance 17 days after planting (Figure 8). Emergence was 56%, 44%, and 44% for loam, sand, and clay loam soils, respectively. Seven days after the first count seedling number was reduced in all three soils. Seedling mortality was highest in clay loam (7%) and lower in loam and sandy soils (3%). The loam soil had significantly more established seedlings than the clay loam or sand 24 days after planting.

Damping-off organisms are stimulated by surface moisture. Generally, the surface of clay soils remains moist longer than that of sandy soils and thus promotes microbial activity. Seedlings also must expend more energy to emerge from clay soils and may become weakened in the process. These are possible explanations for the greater decrease in seedling abundance in the clay loam soil..

Storage Temperature.

After 15 months, wild hemp seed viability was relatively unaffected by storage temperatures (Figure 9). However, storage temperature had a great influence on germination, and germination generally increased with time. Seeds kept in cold storage had consistently low germination, while the germination of seeds stored at room temperature and natural diurnal temperatures was highly variable. Germination of seeds stored at diurnal temperatures was 7.6% in June, 1971 and then increased to

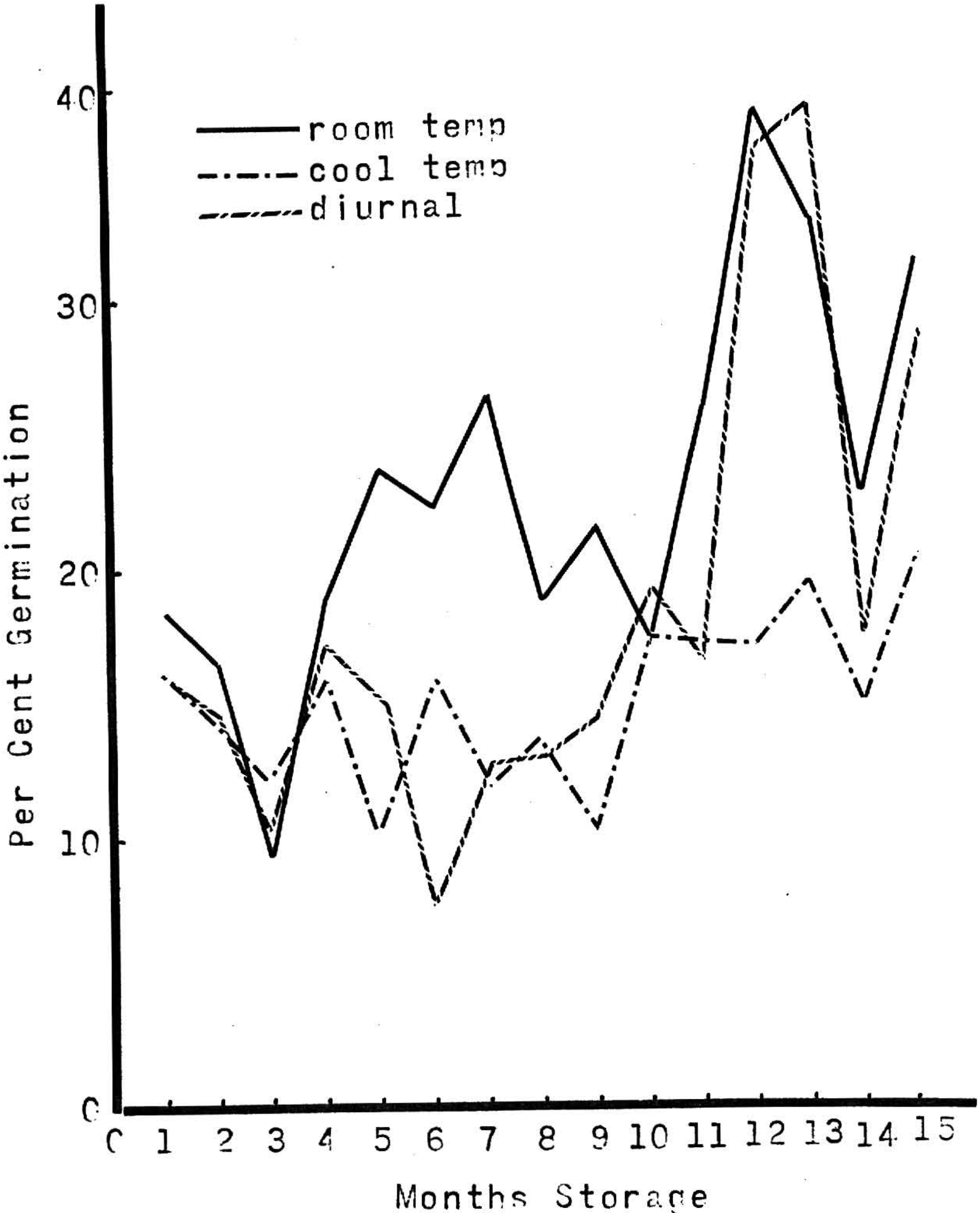

Fig. 9. Wild hemp seed germination after storage at three temperatures.

37.2% in January, 1972. Seeds stored at room temperature generally gave the highest germination.

Seeds kept in cold storage would normally be expected to have high germination as seed dormancy would have been broken. Apparently, cold-stored seeds have to be exposed to higher temperatures for a period of time before they will germinate well. This was illustrated by seeds stored under diurnal temperatures, where germination was low during the winter but increased substantially when the soil temperature increased in the spring. In wild stands, most germination occurs from late February to mid-April. At other times during the year virtually no seeds germinate even when moisture is available.

Germination of seeds stored at room temperature was variable. Apparently, wild hemp seeds have an endogenous rhythm like that known to exist for seeds of other plant species. Salisbury and Ross (33) found germination of certain seeds appeared to be best at certain times during the growing year, even though the seeds had been stored under constant temperature, light and moisture.

Seed Distribution in Natural Stands.

Wild hemp seeds were most abundant in the 0 to 5.1 cm soil increment and their abundance decreased sharply with increased depth (Table 1). Few or no seeds were found below 10.4 cm. Because of this relationship, soil samples were not taken below 10.2 cm in 1971. Wild hemp seed content of the duff, the next largest population, was somewhat variable between locations and decreased with time after natural seed drop. Most of this decline was probably due to the seeds' being fed upon by birds and small animals. An abundance of surface duff would undoubtedly be a positive factor in surface seed number, because of the protection duff offers.

Table 1. Wild hemp seed abundance, germinability and viability in soil from seven locations. Riley Co. Kansas 1970-1971.

Soil Depth(cm)	1970: Locations 1	1970: 2	1970: 3	1971: 4	1971: 5	1971: 6	1971: 7	Avg.
Total Seed								
Duff	13.7 b[1]	31.0 a	14.7 b	154.3 a	118.7 a	29.0 ab	52.7 a	59.2
0.0- 5.1	41.3 a	28.7 a	67.7 a	203.0 a	73.3 ab	67.3 a	35.0 a	75.2
5.1-10.2	1.0 b	2.3 b	8.7 b	14.3 b	13.7 b	10.7 b	8.3 a	8.4
10.2-15.2	0.3 b	3.0 b	11.3 b					4.9
15.2-20.4	1.0 b	1.0 b	6.7 b					2.9
20.4-25.5	1.7 b	2.0 b	2.3 b					1.7
25.5-30.4	0.3 b	1.7 b	0.0 b					0.7
Percent Germination								
Duff	2.1 a	15.2 a	20.6 a	7.0 a	13.3 a	12.7 a	4.0 a	10.7
0.0- 5.1	9.5 a	4.3 b	8.0 b	5.3 a	11.7 a	5.0 ab	6.3 a	7.2
5.1-10.2	0.0 a	0.0 b	3.5 b	2.3 a	8.3 a	2.0 b	1.7 a	2.5
10.2-15.2	33.3 a	0.0 b	0.0 b					11.1
15.2-20.4	0.0 a	0.0 b	0.0 b					0.0
20.4-25.5	33.3 a	0.0 b	0.0 b					11.1
25.5-30.4	0.0 a	0.0 b	0.0 b					0.0
Percent Viable Seeds								
Duff	26.2 a	55.1 a	74.3 a	71.0 a	50.0 a	29.0 a	17.7 b	46.2
0.0- 5.1	40.6 a	15.2 a	57.4 ab	68.3 a	39.3 a	33.3 a	43.0 a	42.4
5.1-10.2	0.0 a	16.7 a	45.8 abc	14.3 b	47.0 a	18.0 a	6.3 b	21.2
10.2-15.2	33.3 a	0.0 a	25.7 bcd					19.7
15.2-20.4	8.3 a	33.3 a	28.1 bcd					23.2
20.4-25.5	33.3 a	0.0 a	19.4 cd					17.6
25.5-30.5	0.0 a	33.3 a	0.0 d					11.1

1 Values followed by same letter are not significantly different (.05) according to Duncan's New Multiple Range Test.

Low seed numbers at lower depths probably resulted from impedence of seed movement in the soil. Relatively large differences in seed abundance between 1970 and 1971 could have been due to greater seed production at the 1971 locations.

Other studies have shown that wild hemp infestations were correlated with soil disturbance and most of the locations sampled had signs of relatively recent disturbance. Wild hemp seeds probably entered the soil profile through disturbance rather than through earthworm activity or other mechanisms as Chippendale and Milton (12) proposed.

Germination was generally higher in seeds from the duff. However, germination was exceedingly low in seeds from all depths and locations. Seeds in the duff of location three had the highest germination (20.6%) while the seeds in the duff of location one germinated the lowest (2.1%). Germination decreased with depth and, except for location one, no germinable seeds were found below 10.2 cm. The presence of germinable seeds at great depths (10.2 to 25.5 cm) in location one probably indicates recent (within 2 years) major disturbance.

Normally, higher germination would have been expected, especially from seeds in the duff. Apparently, hemp seeds have several dormancy mechanisms. Low germination in surface seeds can be attributed to an after-ripening dormancy since most of these seeds are newly formed. Older seeds in the soil, especially those in the 0 to 5.2 cm layer, have another type of dormancy mechanism, because some viable seeds of the lower depths failed to germinate. Other studies have shown wild hemp seeds to be light and temperature sensitive; reduced light and low temperatures enhanced seed germination. These mechanisms may have evolved to prevent all seeds from germinating at once and risk a stand failure due to natural occurrences such as a late killing frost. Wild hemp, apparently, has lost some characteristics of domestication, since prolonged seed dormancy would be an undesirable trait in a cultivated crop.

The surface duff and top 5.2 cm of soil contained the greatest percent viable seeds. The duff at location three contained seed with the highest viability (74.3%). Viability tended to decrease with increasing depth. High viability at great depths probably resulted from soil disturbances discussed earlier. The viability of a seed population tends to decrease until a relatively constant value is achieved due to nonviable seeds decomposing faster than viable seeds; when a seed dies in the soil it is soon decomposed and lost from the total buried seed population. This process would continue until the seed population is expended.

High seed viability in the top 5.2 cm of soil resulted from the presence of relatively young seed as compared to older seed at greater soil depths.

Rampton and Ching (29) found a trend to greater retention of viability and dormancy with increasing burial depth. This indicates that once a seed penetrates the soil relatively deeply it will retain its viability longer than if it remained on the soil surface.

SUMMARY AND CONCLUSIONS

Results of a buried-seed longevity study indicate that agents responsible for wild hemp seed destruction were more active during warm months than cold months. Depth at which maximum seed preservation occured was different for two studies.

In one study after 15 months, 690 seeds were recovered at the 22.9 cm depth, while in another, 690 seeds were recovered at the 7.6 cm depth after nine months. This difference was probably due to seeds of the former study being buried six months longer than those of the latter study.

Wild hemp seed had a seasonal germination pattern. Maximum germination was observed in April (10.7%) which is the period of wild hemp's natural emergence. Germination was very low in July and October (0.3%), the period when wild hemp seedlings do not emerge from natural stands. Highest germination for seeds buried 15 months was from 7.6 cm (4.8%); seeds from 22.9 cm deep gave the highest germination for seeds buried nine months (2.6%).

Seed viability decreased 35% in three months, then continued to decrease at a lower rate to 6% after 15 months burial. Depth of seed burial had no significant effect on seed viability.

Emergence of wild hemp seeds was inversely related to planting depth. Seedlings which emerged from the greater depths were more susceptible to damping-off than those from shallow depths. That could account for some mortality in natural stands.

Soil type had no significant effect on seedling establishment. Clay loam had significantly more seedling damping-off than the other soil types.

High, low, and natural diurnal temperatures had no significant effect on longevity of wild hemp seeds stored for 15 months. However, significant differences in germination for each storage temperature were found. Seeds kept in cold storage had consistantly low germination, while germination of seeds stored at room and natural diurnal temperatures was variable but significantly higher. Wild hemp seeds accumulated in the upper 5.4 cm of the soil profile in natural stands, and their abundence declined rapidly at depths greater than 10.2 cm. Seeds of the surface duff generally had the highest germination; however, germination was low for seeds from all depths. Percent viability was highest in seeds of the duff and top 5.1 cm of the soil profile. Viability then decreased sharply in depths greater than 5.1 cm. Young seeds of the upper soil profile probably caused germination and viability to be high at that depth.

Results indicate wild hemp seeds are probably short lived in the soil with a life expectancy of less than two years. However, seeds stored out of the soil will probably maintain viability longer than two years. Two different approaches to wild hemp control are indicated. One approach is destruction of seedlings from surface seeds, without disturbance of the soil profile for two successive years. Another approach is inversion of the soil profile by deep plowing. Although wild hemp seedlings can emerge from relatively great depths, their numbers would be small, since many deep seeds are dormant, and seedlings that emerge from great depths are more susceptible to attack by soil microorganisms.

The first approach is probably the more feasible for wild hemp control and would include such treatments as herbicides (sprays and granules), mowing, and flaming.

Subsequent studies should investigate natural succession in wild hemp infestations. Rate of succession may then be increased to return that area to climax vegetation more rapidly. Seed-dispersal agents should be investigated in an effort to control the spread of wild hemp infestations.

Results of this study will, hopefully, permit more precise estimation of duration and cost of control programs. Promising control measures are also indicated.

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APPENDIX

Table 2. Mean squares of analysis of variance for seed burial.

Source of Variation	df	Total Seed	No. Germ.	% Germ.	No. Viable	% Viable
			Study 1			
Depth (A)	2	68991	811	0.001	1837	0.005
Time (B)	4	204861**	17985**	0.032	65334**	0.072**
A x B	8	21161	495	0.001	1594	0.004
Error	30	25060	569	0.001	2245	0.005
			Study 2			
Depth (A)	2	29554	215.3	0.0006	23746	0.036
Time (B)	2	55643*	1599.6**	0.0045**	8981	0.055
A x B	4	60797	86.4	0.0002	50929*	0.075
Error	18	15481	245.6	0.0005	16301	0.034

Table 3. Mean squares of analysis of variance for seed distribution in soil.

Source of Variation	df	Total Seed	No. Germ.	% Germ.	No. Viable	% Viable
			1970			
Depth (A)	6	2808.0**	26.57**	199.1**	594.6**	2531**
Loc. (B)	2	294.3**	1.47	16.8	160.3**	1942**
A x B	12	157.4*	5.42	73.0	136.8**	625
Error	40	59.4	4.03	41.1	27.9	444
			1971			
Depth (A)	2	25503**	166.8**	353.8**	8725**	3754**
Loc. (B)	6	12506**	70.3*	74.1	7511**	2031
A x B	12	3524**	25.4	53.4	2084**	644
Error	40	704	14.5	35.3	636	324

*Statistically significant at 5% level.
**Statistically significant at 1% level.

Table 4. Mean squares of analysis of variance for seedling emergence.

Source of Variation	df	Plant Count	Plant Height
		First Count	
Depth (A)	4	587.0**	
Soil (B)	2	164.8	
A x B	8	63.9	
Error	28	186.0	
		Second Count	
Depth (A)	4	814.0**	382.9**
Soil (B)	2	227.2*	186.2**
A x B	8	68.9	25.5
Error	28	81.7	13.8

Table 5. Mean squares of analysis of variance for storage temperature.

Source of Variation	df	% Germ.
Time (A)	14	384.6**
Temp. (B)	2	888.1**
A x B	28	79.1**
Error	135	19.1

*Statistically significant at 5% level.
** Statistically significant at 1% level.

LONGEVITY, GERMINATION, AND EMERGENCE
OF WILD HEMP, (*CANNABIS SATIVA* L.)

by

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B. S., Kansas State University, 1970

AN ABSTRACT OF A MASTERS THESIS

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Wild hemp (Cannabis sativa L.) seeds were studied for their abundance, longevity, and emergence in soil. Wild hemp seed abundance in soil was determined for seven infestations in Riley County Kansas, Seeds were buried in soil at three depths to determine longevity, and planted at five depths in three soil to investigate seedling emergence. Germination of unimbibed seeds stored at three temperatures for extended periods of time was established.

Wild hemp seeds were most abundant in the upper 5 cm of the soil profile and seed number decreased with increased depth to 30 cm. Wild hemp seeds were short lived in the soil with a probable life expectancy of about two years. Wild hemp seeds were sensitive to climatic conditions and germinated best from March to April. Seed viability decreased from 59% to 5% after 15 months burial in soil. Warm soil conditions were more conducive to destruction of seed than cold soils. More wild hemp seedlings emerged and became established from seeds planted 0 to 2.5 cm deep than from 2.5 to 7.6 cm deep. Emergence and establishment of seedlings was higher in a loam soil than in a clay loam or a sandy soil. Storage temperature had no significant effect on hemp seed longevity after 15 months. However, seed germination was reduced by cold storage temperatures and promoted by warm storage temperatures.

Seeds buried in the soil lost viability much faster than seeds stored unimbibed. Apparently, soil contains agents capable of rapidly destroying wild hemp seeds.