**Tableau 2. Corrélations et regressions entre quelques caractères des akènes**

| Caractères Y | Caractères X | Nbre de couples | R | Regressions Y = | probabilités |
|---|---|---|---|---|---|
| Pk | Vk | 72 | 0.876 | $0.364X + 16.732$ | 0.001 |
| Ie | Pa.100/Pk | 72 | -0.814 | $0.017X^2 - 2.805X = 130.351$ | 0.001 |
| Ie | Vk | 72 | -0.053 | NS | 0.1 |
| Ir | Ie | 72 | -0.232 | $-0.373X + 42.865$ | 0.050 |
| Ir | Pa.100/Pk | 72 | 0.615 | $0.035X^2 - 4.266X + 161.306$ | 0.001 |
| Ir | Vk | 72 | 0.453 | $-0.093X + 47.613$ | 0.001 |
| Ir | L /Vk | 70 | 0.514 | $0.108X + 25.425$ | 0:001 |
| Ir | Ip | 69 | -0.146 | $-0.007X^2 + 1.107X - 4.373$ | 0.050 |
| Ir | Dr | 72 | 0.686 | $0.781X + 24.307$ | 0.001 |

**Tableau 3. Vigueur précoce et quelques caractères de l'akène et des jeunes plantes**

(Correlation toutes significatives p 0,001)

| Caractères | R | Caractères | R |
|---|---|---|---|
| VK | 0.338 | Surf. des cotyledons | 0.725 |
| Pk | 0.379 | Surf. des lères feuilles | 0.721 |
| Pa | 0.391 | long. lères feuilles | 0.781 |
| Vitesse de levée | 0.349 | long. hypocotyle | 0.363 |

T1982AGR03

# THE EFFECTS OF ETHEPHON ON DORMANT SEEDS OF CULTIVATED SUNFLOWER *(HELIANTHUS ANNUUS* L.).

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## ABSTRACT

**Seed dormancy in sunflower *(Helianthus annuus* L.) may be a problem in a breeding program when a rapid breeding cycle is desired. Growth regulators such as GA3, kinetin, thiourea, thiourea dioxide, and ethylene have been shown to be effective in breaking seed dormancy; however, little information is available on the effects of ethylene on dormant sunflower seeds. Studies were conducted to ascertain the most effective concentrations and exposure times to break or shorten the dormancy period in sunflower seeds.**

**Ethephon (as a source of ethylene) was found to be effective in breaking dormancy at a concentration of 50 ppm when seed was exposed for 12 to 16 hours. Damage to seeds was observed at higher concentrations and was probably related to low pH. No adverse effects were observed when treatments were adjusted to pH 6 nor were there particular advantages in breaking dormancy when higher concentrations and longer exposure times were used.**

## INTRODUCTION

Seed of wild *Helianthus* species, especially those that inhabit the northern areas of the United States, has a dormant period and a chilling requirement under moist conditions before germination occurs. Seed of cultivated sunflower has apparently lost the chilling requirement but still retains a short dormancy period of from four to six weeks (Zimmerman and Zimmer, 1978).

Seed dormancy may result from seed coat impermeability and mechanical restriction (Chen and Thimann, 1966), embryo immaturity (Amen, 1968), and hormonal balance (Coumans, Come and Gaspar, 1966). Growth regulators such as gibberellic acid and kinetin (Frankland, 1961; Hayashi, 1940; Wittwer and Bukovac, 1957), thiourea (Frankland, 1961), and ethylene (Balls and Hale, 1940), have been shown to be effective in reducing or eliminating the dormancy period of selected seeds. The production of ethylene by imbibed seeds (Toole, Bailey and Toole, 1964) has been found to contribute to the breaking of dormancy in peanut (Ketring and Morgan, 1969; Toole, Bailey and Toole, 1964) and clover seeds (Esashi and Leopold, 1969). The effect of ethylene on reducing dormancy of seeds of other crops provides some evidence of its possible influence in the breaking of dormancy of sunflower seeds.

## MATERIALS AND METHODS

### Effects of Ethephon on Dormant, Hulled Sunflower Seed

Seed was obtained from special plantings of the open-pollinated oilseed sunflower, *Helianthus annuus* L. cultivar 'Sputnik'. Seeds from 15 randomly selected heads (capitulae) were harvested and bulked. Before the seeds were dried, two replicates of 25 seeds each per treatment concentration of ethephon (2-chloroethyl-phosphonic acid) were hulled and soaked for 12, 24, 36, and 48 hours in 500 ml beakers containing approximately 250 ml of ethephon treatment solutions at concentrations of 0, 10, 100, and 1,000 ppm. Two unhulled samples were treated in the same way. The seeds were then, placed on seed germination paper discs in a dark germination chamber at 21°C. Germination percentage was recorded 48 hours later.

During the course of the germination period, the tip of the radicle became brown in color and seemed to be damaged. The number of damaged radicles was recorded. It was believed that the pH levels of 3.7 for 10 ppm, 2.8 for 100 ppm, and 2.1 for 1,000 ppm of the ethephon treatment solutions used was the cause. The pH was adjusted to 7 in subsequent tests.

### Effects of Ethephon on Dormant, Unhulled Sunflower Seed

The remaining seeds from material described above were

dried at 39°C for 16 hours and stored at 23°C. Nine days later 3 replicates of 50 seed each per treatment concentration were soaked for 6, 12, and 24 hours in 500 ml beakers containing approximately 250 ml of ethephon solutions at concentrations of 0, 50, 100, 150, and 200 ppm. Seeds were planted approximately 15 mm deep in 35 by 60 cm flats containing sandy loam soil and were grown at approximately 24°C in the greenhouse. Germination percentage was recorded 7, 11, and 17 days after planting. A similar procedure was followed 6 weeks later using seeds which had been stored for 6 weeks.

A second test was conducted one year later to obtain further information on the effects of ethephon on dormant sunflower seeds of *H. annuus* L. cultivar 'Peredovik', an open-pollinated sunflower cultivar.

**Effects of pH on Seed Damage**

Examination of the effect of pH was made because of the observed damage caused by the ethephon treatment solution on radicles. Ethephon treatment solutions of 100 ppm at pH of 2 were adjusted with 1N NaOH to pH levels of 3, 4, 5, 6, 7, 8, 9, and 10. A 20 ml aliquot of the solution at each pH level was used.

Four replicates of 50 seeds each were hulled and placed on 2 layers of Whatman 5 filter paper discs in individual 9 cm plastic disposable petri dishes. The filter paper discs of each petri dish were soaked with approximately 5 ml of the ethephon treatment solutions. The petri dishes were placed in a dark germination chamber at 23°C for 5 days. The germinated seeds were then placed under fluorescent lights at 23°C. The number of damaged seeds was recorded after 6, 10, and 14 days.

## RESULTS

**Effect of Ethephon on Dormancy in Sunflower**

Two samples each of hulled and unhulled sunflower seeds were treated with ethephon at concentrations of 0, 10, 100, and 1,000 ppm for 12, 24, 36, and 48 hours. Germination percentage was recorded 48 hours later. The results are shown in Table 1. Percent germination of the seeds in all of the treatment concentrations was significantly higher than the control. Treatment time of 24 hours with 58% germination and a treatment concentration of 100 ppm with 62% seemed to provide the best combination for germination of dormant sunflower seeds. Significant interactions of hulled and unhulled seed by treatment time, hulled and unhulled seed by treatment concentration, and treatment time by treatment concentration were noted. The hulled seeds were significantly higher in germination as compared to the unhulled seeds with 53 and 46% respectively. There was a significant reduction in germination percent of from 58 to 50 to 40 as treatment time progressed from 24 to 36 to 48 hours, respectively.

Data from a study conducted to determine the effect of the pH of ethephon on radicle growth are shown in Table 4. Significant differences were observed among the pH levels. A pH of 4 caused damage to the radicle when observed 15 days after seed germination. A pH of 2 increased radicle damage when observed 19 days after germination. A pH of 6 and 8 produced the least radicle damage.

**Table 1. Mean germination percent of hulled and unhulled sunflower seeds treated with ethephon at various concentrations and times.**

| | Treatment | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Time (hrs)† | | | | Concentration (ppm) | | | | |
| Seed Type | 12 | 24 | 36 | 48 | 0 | 10 | 100 | 1000 | Mean |
| Hulled | 52 | 54 | 53 | 50 | 36 | 56 | 72 | 45 | 53 |
| Unhulled | 44 | 64 | 49 | 27 | 32 | 45 | 54 | 52 | 46 |
| Mean | 48 | 58 | 50 | 40 | 34 | 51 | 62 | 50 | |

† LSD Time means: $P \leq 0.05 = 3$, LSD Conc. means: $P \leq 0.05 = 3$, LSD Seed means: $P \leq 0.05 = 2$.

The results of the germination of dried unhulled seeds treated with ethephon 9 days after harvest are shown in Table 2. Germination of seed at 17 days increased from 50 to 55% as treatment time progressed from 6 to 24 hours. Seed germination was significantly enhanced at all treatment concentrations above the control. Treatment time of 12 hours and treatment concentration of 50 ppm seem to be sufficient to reduce germination of dormant sunflower seeds above the control (Table 2). The application of longer treatment time and higher treatment concentration did not seem to provide any particular advantage in seed germination. Significant interactions between days after planting and treatment time, days after planting and treatment concentration, and treatment concentration, and treatment time and treatment concentration were noted. Table 2 also shows the effect of ethephon on seeds stored for 6 weeks. These data indicate no significant differences in treatment concentrations used; however, seeds soaked for 24 hours were observed to decrease in germination from 86% for 6 and 12 hours to 78% for 24 hours. There was no treatment time by treatment concentration interaction observed.

**Table 2. Mean germination percent of dried sunflower seeds with hulls treated with ethephon at various concentrations and times.**

| Treatment Time (hrs) | Days After Sowing† | | | Germ % After 6 Weeks of Storage | Treatment Conc. (ppm) | Days After Sowing† | | | Germ % After 6 Weeks of Storage |
|---|---|---|---|---|---|---|---|---|---|
| | 7 | 11 | 17 | | | 7 | 11 | 17 | |
| 6 | 18 | 43 | 50 | 86 | 0 | 14 | 27 | 40 | 84 |
| 12 | 35 | 48 | 53 | 86 | 50 | 36 | 48 | 53 | 86 |
| 24 | 44 | 51 | 55 | 78 | 100 | 37 | 50 | 54 | 82 |
| | | | | | 150 | 37 | 53 | 56 | 82 |
| | | | | | 200 | 39 | 56 | 60 | 82 |
| | | | | | Mean | 32 | 46 | 52 | |

† LSD Days means: $P \leq 0.05 = 5$, LSD Time means: $P \leq 0.05 = 3$, LSD Conc. means: $P \leq 0.05 = 5$, LSD Weeks means: $P \leq 0.05 = 9$.

Data for the experiment conducted one year later with seed from the variety Peredovik are shown in Table 3. Significant differences were observed in germination percentage of seeds soaked for 8, 16, 24, and 32 hours. Treatment concentrations also significantly enhanced the percent of germinated seed. In this experiment, 16 hours and 150 ppm was the combination which seemed to provide the greatest desirable effect. Significant interaction of all variables was noted.

**Table 3. Mean germination percent of dried sunflower seeds treated with ethephon at various concentrations and times after storage for 1 year.**

| Treatment | Germination† (%) Days After Planting | | | |
|---|---|---|---|---|
| Time (hrs) | 6 | 16 | 26 | 36 |
| 8 | 6 | 44 | 54 | 71 |
| 16 | 22 | 58 | 69 | 78 |
| 24 | 33 | 63 | 74 | 81 |
| 32 | 36 | 73 | 81 | 88 |
| Treatment Conc. (ppm) | | | | |
| 0 | 4 | 42 | 52 | 64 |
| 50 | 24 | 59 | 68 | 76 |
| 100 | 29 | 62 | 73 | 82 |
| 150 | 30 | 65 | 75 | 87 |
| 200 | 34 | 69 | 79 | 88 |
| Mean | 24 | 59 | 69 | 79 |

† LSD Days means: $P \leq 0.05 = 4$, LSD Time means: $P \leq 0.05 = 3$, LSD Conc. means: $P \leq 0.05 = 5$.

**Table 4. Mean percent of undamaged radicles of sunflower seed treated with ethephon at various pH levels.**

| Treatment pH | Number of Days After Treatment† 15 | 19 |
|---|---|---|
| 2 | 91 | 79 |
| 4 | 85 | 80 |
| 6 | 89 | 84 |
| 8 | 93 | 82 |
| 10 | 92 | 80 |
| Mean | 90 | 81 |

† LSD Days means: $P \leq 0.05 = 4$, LSD pH means: $P \leq 0.05 = 3$.

## DISCUSSION

**Effect of Ethephon on Dormancy in Sunflower.**

The experiments on the utilization of ethephon to break dormancy of sunflower seeds provide an alternative when handling seeds of freshly harvested breeding material or wild species where dormancy is more pronounced. Normally, a period of approximately 45 to 50 days is required before dormancy of cultivated sunflower seeds is broken. Zimmerman and Zimmer (1978) have shown that germination percent increased from 2% in the first week to 60% six weeks after harvest. They reported that the dormancy of *H. annuus* L. cultivar 'Sputnik' dissipated after six weeks of storage at 25°C. Results similar to those reported by Zimmerman and Zimmer were noted for the cultivar Peredovik where germination of 84% of seed stored for six weeks was achieved six days after planting and no significant differences among treatment concentrations and times were observed (Table 2).

The greatest effect of treatment time on germination is 6 to 12 hours for freshly harvested seed and 8 to 16 hours for seed stored for one year. The effect of a treatment concentration of 50 ppm on germination of dormant sunflower seed was shown to be sufficient to break dormancy, and it is recommended that this concentration be used. Higher concentrations of up to 200 ppm were not observed to markedly improve or negatively affect germination. The data in Table 1 indicate that the hulls have a significant effect in retarding seed germination; therefore, the removal of hulls, especially those of the wild sunflower species, is recommended.

**Effect of pH on Seed Damage.**

Seed germination was affected by low as well as high pH of the ethephon used. Radicle damage combined with the effect of pH on enzyme activity (Salisbury and Ross, 1969) may have contributed to the low germination of the hulled and unhulled seed shown in Table 1, especially at the higher concentration of 1,000 ppm. A pH of 6 produced the least radicle damage and provided an optimum condition for enzyme activity (Salisbury and Ross, 1969). It is suggested that treatments with ethephon be adjusted to a pH of 6 prior to use. Ethephon, per se, seemed to have no adverse effects on germinating sunflower seeds.

## ACKNOWLEDGEMENTS

Financial and Technical assistance, equipment, and facilities provided by USDA-SEA and North Dakota State University, Fargo, ND is acknowledged.

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T1982AGR04

# PATHWAYS OF YIELD ELABORATION IN SUNFLOWER UNDER VARIOUS WATER STRESSES.

# VOIES E'LABORATION DU RENDEMENT CHEZ LE TOURNESOL SOUS DIFFERENTS STRESS HYDRIQUES.

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## ABSTRACT

**Two hybrids of sunflower (cv. Relax and cv. Mirasol), chosen among high oil content varieties were grown under a shelter, in vegetation vessels, with different under-need water supplies. Two pathways, revealed by the analysis of yield components, were found to be determinant in yield elaboration. The grain production was secured either by an invariance of the total number of full-achenes, allowing to suppose the cv. Relax resistant to water stress during the seed-set, or by an invariance of the 1000 weight of achene, in Mirasol, showing a lower sensibility to water stress during the seed-filling stage. In case of late water stress, a strong vegetative development was found to be a good character for grain production but, instead of it, oil content was reduced. The path-coefficient analysis revealed that, in dry conditions, the total dry matter explained yield with the higher correlation, but especially through indirect effects. The leaf Area Index and Leaf Area Duration were narrowly correlated with yield but they acted on it through indirect effects, especially through the 1000 weight of achenes, showing that, in case of low water availabilities, leaf areas kept alive during the seed filling stage are an important character in sunflower yield elaboration.**

## INTRODUCTION

L'amélioration du rendement chez le Tournesol (*Helianthus annuus* L.) passe par l'amélioration de ses composantes principales, à savoir notamment le nombre d'akènes totaux, le nombre d'akènes pleins, le poids de 1000 grains.

Dans de nombreuses régions, le principal facteur limitant les rendements du Tournesol s'avère être son alimentation en eau (Marty *et al.*, 1975). La période durant laquelle sa sensibilité à un déficit hydrique est la plus grande débute environ 20 jours avant la floraison et se prolonge au-delà durant une autre vingtaine de jours (Robelin, 1967; Pirjol *et al.*, 1972; Muriel et Downes, 1974; Sipos et Paltineanu, 1975). Il conviendra donc d'étudier plus particulièrement les répercussions d'une alimentation en eau limitante sur le rendement au travers de ses composantes. Néanmoins, il sera nécessaire de tenir compte d'un certain nombre de caractères de la plante et notamment de ses caractéristiques foliaires (surface, durée de vie) compte tenu de leur importance dans l'élaboration de la production tant quantitative (Rawson *et al.*, 1980) que qualitative (Vrebalov, 1972; Rodrigues Pereira, 1978).

Si l'obtention de meilleurs rendements est un des objectifs majeurs de la sélection chez le Tournesol, deuxième oléagineux mondial, il convient également de discuter de l'impact de différents stress hydriques sur la qualité de la récolte. Sur ces aspects, nous avons essayé de comparer deux cultivars de Tournesol soumis à divers stress hydriques selon la méthode des "path coefficients" et de mettre en évidence les effets directs et indirects de quelques caractères des plantes sur le rendement et son déterminisme.

## MATÉRIELS ET MÉTHODS

**Plan expérimental** — Deux cultivars de Tournesol (Relax, hybride français et Mirasol, hybride américain) ont été cultivés en vases de végétation portant 2 plants chacun, en ambiance naturelle (abri grillagé) et de manière à constituer un peuplement voisin de 8 pieds/m². Une fumure de fond était appliquée avant le semis puis un certain nombre d'apports de N et K se sont échelonnés au cours du cycle de développement ("BF 3 cm", début floraison, fin floraison ...) afin que la nutrition minérale ne soit pas limitante. L'alimentation en eau était réduite à diverses fractions de l'évapotranspiration maximale (E.T.M.) du témoin Relax et différents types de stress (cf. figure 1) ont ainsi été appliqués sur les 2 cultivars à partir du début floraison. Ils se décomposaient de la façon suivante:

— 2 modalités jusqu'au stade "début floraison", la première satisfaisant l'E.T.M. du témoin (cv. Relax) et la seconde apportant seulement 50 % de cette évapotranspiration.

— à partir de ce stade "début floraison", différenciation de 7 traitements: **d'une part**, une réduction brusque de l'eau fournie de 100 % soit à 50 % de l'E.T.M. du témoin (Traitement B), soit à 30 % (Traitement C), ou de 50 % à 30 % de l'E.T.M. (Traitement F). **D'autre part**, une réduction lente, soit de l'E.T.M. du témoin à 20 % de celle-ci (Traitement D), soit de 50 % à environ 10 % (Traitement G), ceci de manière à maintenir une sous-alimentation en eau