

Original Research Article

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## Role of Ethrel and Storage in Dormancy Breaking in Groundnut (*Arachis hypogaea* L.)

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### ABSTRACT

Experiment was conducted to evaluate the effect of different ethrel concentrations and storage periods on dormancy breaking in groundnut. Control (C<sub>1</sub>) and three ethrel concentrations; C<sub>2</sub>- 25 ppm, C<sub>3</sub>-50 ppm, C<sub>4</sub>- 75 ppm were evaluated for four different storage periods; S<sub>1</sub>-7 days after harvest, S<sub>2</sub>-14 days after harvest, S<sub>3</sub>-21 days after harvest and S<sub>4</sub>-28 days after harvest in freshly harvested groundnut dormant varieties, GG-11 and GG-20 and compared their performance with that of non-dormant variety, GG-7. The observations were recorded on seed germination (%), Speed of germination, seed vigour index-I and seed vigour index-II. The results of investigation revealed that absence of dormancy in GG-7 triggering it to reap superior results immediately in all seed quality parameters studied. All ethrel treatments gave better results when compared to control (no treatment) in breaking seed dormancy and improving seed quality parameters. With increase in ethrel concentration the responses also got improved with best always from ethrel concentration @ 75 ppm. In case of dormant genotypes, dormancy was broken and performance of seed quality parameters was driven to the level of non-dormant genotype whereas non-dormant genotype had done betterment in its performance under the influence of ethrel treatments. In case of storage study it was observed that the advancement in storage period broke seed dormancy more effectively along with improvement in seed quality parameters. Thus, from the results of the study, it seems quite logical to note that the seeds kept in storage for a period of 28 days after harvest and pre-soaked in 75 ppm ethrel concentration can effectively broke the seed dormancy and can improve all the seed quality parameters as well to a performance level that can equate with that of non-dormant genotype.

#### Keywords

Groundnut seed dormancy, Genotypes, Ethrel concentrations, Storage periods

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### Introduction

Groundnut (*Arachis hypogaea* L.) is a member of the order Fabales and family Fabaceae. It is a widely grown annual crop with self-pollinated and dicotyledonous

behaviour also known in the names of peanut, earthnut, goober pea, goober, pindas, jack nut, manila nut, pygmy nut, pignut, and monkey nut. Groundnut is the 13<sup>th</sup> most important food crop and 4<sup>th</sup> most important oilseed crop of the world. Groundnut is

cultivated in tropical, sub-tropical and warm temperate regions between 40°N and 40°S latitudes. The production is largely restricted to Asian and African countries with China, India, Nigeria, Senegal, Sudan, Burma and the United States of America are the major producers. In India six states namely Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Rajasthan and Tamil Nadu account for about 90% of the total groundnut area of the country.

Seed dormancy has been defined as the failure of an intact, viable seed to complete germination under favourable conditions (Bewley, 1997). It is a state of arrested development or physiological activity of seed. Studies by several workers indicated that seeds of Spanish and Valencia bunch types of groundnut are usually non dormant, whereas those of Virginia types are dormant (Bhaskar *et al.*, 1986). Dormancy periods up to two months is observed in Virginia type cultivars. This makes the freshly harvested seeds of Virginia type of summer season unavailable for cultivation immediately in the following *kharif* season. Seed dormancy is also a problem for plant breeders going for advancing pedigree lines in off-season. Similarly the seed analyst faces difficulty in determining germination potential of seed samples having dormancy. In groundnut, seed dormancy has been reported to be controlled by two hormones: abscisic acid which inhibits sprouting and ethylene which is accumulated in embryonic axis during storage to break dormancy to allow germination (Ketring and Morgan, 1971, 1972). In another study Nautiyal *et al.*, (1993) found different parts of groundnut seed being involved in imposing dormancy, which included the seed coat, cotyledons and embryo.

Ethylene, supplied either directly as gas or by means of an ethylene generating chemical such as ethrel or ethephon, has been found to break dormancy in several species. The

effective concentrations are in the range of 10-200 ppm. During germination, ethylene appears to have two roles; it can break seed dormancy in some species and reduce the time required for radicle emergence in non-dormant seeds. These two activities are probably related to making the seeds less sensitive to abscisic acid, which keeps the seeds dormant (Ketring and Morgan, 1972). Another factor that can be used effectively for overcoming dormancy problem is storage. In most of the crop species, dormancy is dissipated within a few to several months when the seed is stored at ambient temperatures and relative humidity or under controlled atmosphere provided the temperature is held above freezing. In the view of the above, present investigation was undertaken to assess the effect of different varieties, ethrel concentrations and storage periods in breaking seed dormancy in groundnut and how they influences various seed quality parameters.

## **Materials and Methods**

The experiment was conducted in laboratory of Seed Science and Technology, JAU, Junagadh from 23<sup>rd</sup> October to 5<sup>th</sup> December-2017 in four replications. Control (C<sub>1</sub>) and three ethrel concentrations; C<sub>2</sub>- 25 ppm, C<sub>3</sub>-50 ppm, C<sub>4</sub>- 75 ppm were evaluated for four different storage periods; S<sub>1</sub>-7 days after harvest, S<sub>2</sub>-14 days after harvest, S<sub>3</sub>-21 days after harvest and S<sub>4</sub>-28 days after harvest in freshly harvested dormant varieties, GG-11 and GG-20 and compared their performance with that of non-dormant variety, GG-7. The observations were recorded on seed germination (%), Speed of germination, seed vigour index-I and seed vigour index-II.

## **Statistical analysis**

The statistical data was analyzed by the FCRD methods as per the procedure given by Cochran and Cox. Data of seed germination

(%) was transformed as per arc sine transformation and Speed of germination, seed vigour index-I and seed vigour index-II data were transformed as per square-root transformation (Gomaze and Gomaze).

## Results and Discussion

The effect of varieties, ethrel concentrations, storage periods, interaction effect of varieties x ethrel concentrations, interaction effect of varieties x storage periods, interaction effect of ethrel concentrations x storage periods and interaction effect of varieties x ethrel concentrations x storage periods were found significant for seed germination percentage, speed of germination, seed vigour index-I & II.

### Effect of varieties

The results presented in Table 1 revealed that different varieties exerted significant effect on seed germination (%). Both dormant varieties recorded poor germination percentage with lowest marked by GG-20 (V<sub>3</sub>) [55.1% (65.9%)] while the non-dormant variety GG-7 (V<sub>1</sub>) obtained significantly highest germination percentage [71.4% (88.8%)]. Germination percentage showed significant variation between the non-dormant variety GG-7 and dormant varieties (GG-11 and GG-20). But there wasn't any significant variation between these two dormant varieties. Moreover this result also revealed a very clear differentiation in germination per cent between dormant and non-dormant varieties where both the dormant varieties recorded with lowest germination per cent when compared to the non-dormant GG-7. Similar results were obtained by Nautiyal *et al.*, (1996), Mather and Manivel (2000), Manonmani (2002), Swain *et al.*, (2002) and Asibuo *et al.*, (2008) in groundnut. Actual reason behind variation in germination per cent related to dormancy is stated differently

by different researchers. Hull (1937) reported that dormancy in groundnut is an inherent character and the rest period extended even upto two years in some varieties. John *et al.*, (1948) reported that dormancy is an inherent property of Virginia groundnut. Ketring and Morgan (1971) reported that the embryonic axis of non-dormant seeds of peanut actively produced ethylene during germination, whereas ethylene production was low in dormant seeds which might have promoted dormancy. Unlike in bunch groundnut, high content of growth inhibitors was noticed in the embryonic axis and the seed coat of dormant seeds of spreading groundnut. In addition to this inhibitory phenolic acid, particularly coumarin was present at highest levels in the dormant seeds of spreading groundnut. On the contrary, higher levels of synergistic phenolic acids, low level of coumeric acid was noticed in the non-dormant seeds of bunch groundnuts (Sreeramulu, 1974). Reddy and Swamy, (1979) reported that at the time of maturity, dormant seeds contained greater amount of ABA- like inhibitors and less cytokinins than non-dormant seeds.

The results presented in Table 2 revealed that significant differences existed for speed of germination among different varieties. Non-dormant GG-7 (V<sub>1</sub>) recorded significantly highest speed of germination [8.7 (75.9)] and least was recorded by dormant variety GG-20 (V<sub>3</sub>) [6.2 (43.6)]. Variation speed of germination between dormant and non-dormant varieties were very clear with both the dormant varieties recorded with lowest values when compared to the non-dormant GG-7. Unlike germination percentage, here significant variation existed between the dormant varieties (GG-11 and GG-20) with highest result obtained by GG-11 for speed of germination. Varietal differences in this parameter may be contributed from their genetic makeup. This result was in

accordance with the results obtained by Mahesh, (2007) in groundnut and Sebastian, (2014) in proso millet and foxtail millet.

The results displayed in Table 3 and Table 4 revealed that significant differences existed among varieties for seed vigour index-I and seed vigour index-II. Non-dormant GG-7 (V<sub>1</sub>) displayed significantly highest seed vigour index-I [30.1 (910.0)] and vigour index-II [114.8 (13058.0)]. Lowest result was given by GG-20 (V<sub>3</sub>) for vigour index-I [21.7 (539.9)] which was *at par* with GG-11 (V<sub>2</sub>) [22.0 (536.7)] and vigour index-II [84.9 (8350.0)]. Varieties had shown significant variation for seed vigour index-I and seed vigour index-II. Even though significant differences were not there between dormant varieties, prominent variation existed between dormant varieties (GG-11 and GG-20) and non-dormant GG-7 revealing the role of dormancy in determining the seed vigour index. These results were in accordance with the findings of Mahesh, (2007) in groundnut, Adebisi and Ajala (2007); Sebastian, (2014) in proso millet and foxtail millet.

### **Effect of ethrel concentration**

The results presented in Table 1 revealed that different levels ethrel concentration exerted significant effect on seed germination (%). Pre-soaking of seeds in ethrel solution induced significant improvement in germination when compared to control (C<sub>1</sub>) [39.7% (45.1%)]. Among the three ethrel treatments, ethrel @ 75ppm (C<sub>4</sub>) resulted in significantly maximum germination percentage [73.1% (90.1%)] and minimum was recorded with ethrel @ 25 ppm (C<sub>2</sub>) [61.2% (74.9%)]. All the ethrel treatments improved the germination above Indian Minimum Seed Certification Standards (IMSCS-70%) while control had fallen far below of standard germination due to the presence of dormancy. Françoise *et al.*,

(2014) reported dormancy can be regulated by the hormonal balance between abscisic acid and gibberellins where ethylene plays a key role in dormancy release and based on studies using inhibitors of ethylene biosynthesis and analysis of mutant lines altered in genes involved in the ethylene signaling pathway (*etr1*, *ein2*, *ain1*, *etr1*, and *erf1*) demonstrated the involvement of ethylene in the regulation of germination and dormancy. Similar results were also obtained by Wang *et al.*, (2012) in groundnut and he reported that inhibitors present in seed coat may be inducing dormancy. John *et al.*, (1948), Toole *et al.*, (1961), Ketring and Morgan, (1971), Gowda, (2014) also stated the same opinion in breaking groundnut seed dormancy and improving germination per cent. During germination, ethylene appears to have two roles. Ethylene can break seed dormancy in some species. It can also reduce the time required for radicle emergence in non-dormant seeds. These two activities are probably related to making the seeds less sensitive to abscisic acid, which keeps the seeds dormant (Ketring and Morgan, 1972). Ethylene treatment requires less time and it is effective at low concentrations and at usual seed-germinating temperatures. Maiti *et al.*, (2006) reported that the causal mechanism for breaking dormancy induced by chemical treatments might be due to some chemical changes in the seed during the change from solution to gel stage by soaking and drying process. This might be associated with the washing away of inhibitors like ABA and further during the process, the porosity of the seed coat might have increased and resulted in increases germination per cent.

The results presented in Table 2 revealed that different levels ethrel concentration resulted in significant effect on speed of germination. Ethrel @ 75 ppm (C<sub>4</sub>) recorded significantly highest [8.3 (69.6)] speed of germination and lowest speed of germination was displayed by

control (C<sub>1</sub>) [4.9 (31.4)]. All the ethrel treatments promoted fast germination when compared to control and also increase in ethrel concentration significantly improved speed of germination. Dormancy is a condition that prevents seeds from germination even though they are viable and provided with optimum conditions for germination. Ethylene gas at low concentrations directly related with initiation of reactions required for converting the quiescent cells to an active state of growth. Ethylene production by seeds begins immediately after the onset of imbibition and increases with time of germination and this endogenous production accompanies the natural decline of dormancy. Exogenously applied ethylene can intervene gradual breaking of dormancy and can accelerate that process (Ketringand Morgan, 1971). Gowda, (2014) in groundnut and Sebastian, (2014) in prosomillet and foxtail millet obtained similar results.

The results presented in Table 3 and 4 revealed that different levels ethrel concentration exerted significant effect on seed vigour index-I and II respectively. Ethrel @ 75 ppm (C<sub>4</sub>) recorded highest seed vigour index-I [28.9 (839.8)] and vigour index-II [113.6 (12965.0)]. Lowest was observed in control (C<sub>1</sub>) for both vigour index-I [17.0 (388.9)] and vigour index-II [65.2 (5794.0)]. Seed vigour index-I and seed vigour index-II were significantly improved by ethrel treatments and among them ethrel @ 75 ppm gave most promising results followed by rest of the two treatments leaving control far behind. Here also as described earlier the hormonal interactions between ethylene and gibberellins influenced by the external application of ethylene producing compounds might have induced GA<sub>3</sub> which activate  $\alpha$ -amylase that can digest the available carbohydrates into simple sugar so that energy and nutrition were easily available to

faster growing seedlings (Françoise *et al.*, 2014). This might have promoted seedling dry weight and thus the seed vigour index. More over the enhancement in germination percentage by ethrel treatments also paved way for obtaining higher results in seed vigour index. Gowda, (2014) in groundnut, Meharunnisa *et al.*, (2012) in sunflower, Sebastain, (2014) in prosomillet and foxtail millet got similar results.

### **Effect of storage periods**

The results presented in Table 1 revealed that different storage periods significantly effected on seed germination (%). Germination percentage increased with advancement of storage periods. Significantly highest germination percentage was recorded at 28 days after harvest (S<sub>4</sub>) [68.7% (84.8%)] whereas the lowest seed germination percentage was recorded at initial storage period, 7 days after harvest (S<sub>1</sub>) [49.6% (59.1%)]. Existence of fresh seed dormancy in groundnut seeds which require resting period for breaking it might have resulted in low germination percentage during initial storage periods and with the advancement in storage period, parameter improved and fetched maximum result at final stage of storage due to natural breakdown of dormancy. Similar results are also obtained by Sreeramulu, (1974) reported that decrease in inhibitory phenolic acid and increase in synergistic one in both cotyledons and embryonic axis, as storage period advanced resulted in breaking dormancy. Nautiyal *et al.*, (1993) reported that the degree of maturity, position of kernel in the pod and the storage period all had a confounding influence on the seed dormancy.

The results presented in Table 2 revealed that different storage periods exerted significant effect on speed of germination. Significantly highest speed of germination was recorded at

the final stage of storage period ( $S_4$ ) 28 days after harvest [8.1 (66.3)] whereas the lowest was recorded at initial stage ( $S_1$ ) 7 days after harvest [5.9 (42.8)]. This variation may be due to the existence of fresh seed dormancy in groundnut seeds which require resting period for breaking it and to advance to better germination. The slow release of this dormancy may be the reason behind betterment of speed of germination over storage period.

The results presented in Table 3 and Table 4 revealed that different storage periods exerted significant effect on seed germination (%). With the advancement in storage period an increasing tendency was observed for seed vigour index-I & II. Significantly highest seed vigour index-I [26.9 (736.0)] and seed vigour index-II [106.1 (11458.0)] was recorded at 28 days after harvest ( $S_4$ ). Minimum vigour index value was recorded at 7 days after harvest ( $S_1$ ) for vigour index-I [21.2 (562.5)] and vigour index-II [80.1 (8075.0)]. Improvement in parameters along storage period may be contributed by the release of dormancy during storage

### **Interaction effect of varieties x ethrel concentration**

In case of interaction effect of the varieties and ethrel concentration, maximum germination percentage was obtained by the non-dormant GG-7 pre-soaked in 75 ppm of ethrel solution ( $V_1C_4$ ) [76.3% (94.2%)] and minimum by dormant GG-20 in control ( $V_3C_1$ ) [23.2% (20.5%)]. Endogenous production of ethylene accompanies the natural decline of dormancy, so that exogenously applied ethylene can intervene in the gradual breaking of dormancy and can accelerate that process. When this property of different ethrel concentrations combined with three different varieties with that might have different genetic makeup for the control of

dormancy, significant variations produced in their interactions. Similar results were obtained by Wang *et al.*, (2012) for germination percentage, in which they explained significant differences in interaction may be due differential sensitivity of groundnut varieties for ethrel treatments. Maity *et al.*, (2006) also obtained significant interaction effect between sunflower varieties and ethrel treatments for germination percentage.

Maximum speed of germination was scored by GG-7 treated with 75 ppm of ethrel solution ( $V_1C_4$ ) [9.1 (82.3)] and it was *at par* with ethrel @ 50 ppm treated GG-7 itself ( $V_1C_3$ ) [8.9 (78.3)]. Minimum speed of germination was recorded by GG-20 under control ( $V_2C_1$ ) [2.6 (8.5)]. Irrespective of varieties in all interactions ethrel treatments resulted in significant improvement in speed of germination when compared to control and among them ethrel @ 75 ppm gave most superior result followed by 50 ppm and then 25 ppm in all varieties. In case of non-dormant variety GG-7, all the ethrel treatments promoted in more betterment of all the parameter. While in case of dormant varieties these treatments effectively broke the existing seed dormancy and increased their performance to the level of non-dormant variety.

Maximum significant increase in seed vigour index-I as well as vigour index-II was marked by GG-7 treated ethrel @ 75 ppm ( $V_1C_4$ ) [31.8 (1014.9) and 119.5 (14292.0)] respectively. Minimum result was obtained by GG-20 under control ( $V_3C_1$ ) for vigour index-I [10.0 (148.1)] and [37.9 (2168.0)]. All ethrel treatments resulted in mostly significant improvement from control and preceding concentration irrespective of varieties. At a particular ethrel concentration it was the non-dormant GG-7 recorded maximum results. Ethrel treatments effectively broke the

existing seed dormancy and increased the performance of dormant varieties in all these parameters to the level of non-dormant variety. The already better performing non-dormant variety enhanced their performance to more heights under the influence of ethrel treatments. Sebastian, (2014) in proso millet and foxtail millet got similar results for seed vigour index parameters.

### **Interaction effect of varieties x storage periods**

In case of interaction effect of varieties x storage period, non-dormant GG-7 recorded maximum germination percentage at 7 days after harvest ( $V_1S_1$ ) [75.3% (90.8%)]. While minimum germination was recorded in dormant variety GG-11 at 7 days after harvest ( $V_2S_1$ ) [37.5% (42.7%)] and it was *at par* with GG-20 at 7 days after harvest ( $V_3S_1$ ) [38.1% (43.5%)].

GG-7, the non-dormant variety gained maximum speed of germination at 7 days after harvest ( $V_1S_1$ ) [8.9 (78.5)] and it was *at par* with storage period, 14 days after harvest of same variety ( $V_1S_2$ ) [8.7 (76.0)]. While minimum speed of germination recorded in dormant variety GG-11 at 7 days after harvest ( $V_3S_1$ ) [4.4 (23.4)].

As the storage period advanced a decreasing tendency was followed in case of non-dormant variety, GG-7 with highest value marked at 7 days after harvest and lowest result at 28 days after harvest. While in case of dormant varieties, a tendency completely opposite to that of non-dormant variety were observed, with lowest results at 7 days after harvest and maximum recorded at final stage of harvesting (28 days after harvest). Any how the best interaction effect was produced by GG-7 at 7 days after harvest. Gowda and Reddy, (2008); Yadav *et al.*, (2014); Janila *et al.*, (2013); Meena *et al.*, (2017) in groundnut,

Vujakovik *et al.*, (2012) in sunflower got similar results for germination percentage.

GG-7, the non-dormant variety at 7 days after harvest ( $V_1S_1$ ) scored significantly highest seed vigour index-I [31.6 (998.4)] as well as vigour index-II [117.3 (13777.0)]. Minimum seed vigour index-I was scored by GG-11 at 7 days after harvest ( $V_2S_1$ ) [18.5 (340.8)] and it was *at par* with GG-20 at 7 days after harvest ( $V_3S_1$ ) [18.8 (348.3)] while it was GG-20 at 7 days after harvest ( $V_3S_1$ ) [58.8 (4855.0)] scored least for vigour index-II. Interaction effect of GG-7 and storage periods for seed vigour index-I and seed vigour index-II showed significant variation between initial storage period and rest of the storage periods with maximum result from 7 days after harvest and with no significant variation as advancement in storage periods. Interaction effect of GG-20 significantly improved over storage periods. In case of GG-11 both seed vigour index parameters improved with significant variation during initial storage periods (7, 14 and 21 days) which became non-significant later (28 days after harvest). Yadav *et al.*, (2014); Janila *et al.*, (2013); Meena *et al.*, (2017) in groundnut got similar results.

In case of non-dormant varieties, seed quality (viability and vigour) decreases with increase in storage duration. Seed deterioration during storage was due to the damage in cell membrane and other chemical changes in the seed system such as the protein and nucleic acid accumulation. During storage, loss of membrane integrity of all cell organelles accelerates aging. Aging results in reduction in germination percentage and those seeds that do germinate produce weak seedling as well as weakens seedling growth parameters like seedling length and seedling weight.

In case of dormant groundnut varieties, fresh seed dormancy exists, for that they require an

after ripening period or a resting period for breaking it and to advance into germination phase. This stage of arrested growth, if it falls within storage duration, then seeds can easily escape from seed deterioration and aging. This may be the reason behind promising results from dormant varieties (GG-11 and GG-20) and declining outcomes from non-dormant variety (GG-7) with advancement in storage period.

### **Interaction effect of ethrel concentration x storage periods**

For the interaction effect of ethrel concentrations x storage periods, seeds treated with ethrel @ 75 ppm significantly gained maximum germination percentage at 28 days after harvest ( $C_4S_4$ ) [78.2% (95.6%)] and it was *at par* with the same ethrel concentration at 21 days after harvest ( $C_4S_3$ ) [77.2% (94.9%)]. While minimum germination percentage was recorded in control at 7 days after harvest ( $C_1S_1$ ) [24.1% (28.0%)].

Seeds treated with ethrel @ 75 ppm gained maximum speed of germination at 28 days after harvest ( $C_4S_4$ ) [9.0 (81.2)] and it was *at par* with ( $C_4S_3$ ) [8.8 (77.6)]. Significantly lowest speed of germination was marked in control at 7 days after harvest ( $C_1S_1$ ) [3.4 (23.1)].

Lowest result was recorded in control (water soaking) at 7 days after harvest and as the storage period advanced, outputs also increased but couldn't achieve standard germination percentage even at final stage of storage. This increasing tendency in control with each storage period may be due to the slow release of dormancy during storage. Individually each ethrel concentration promoted enhancement in these parameters with advancement in storage period, where interaction with 7 days after harvest gave lower results, while interaction with final storage period (28 days after harvest) gave

higher results. Here the slow release of dormancy by the storage period was accelerated by the ethrel treatments, and increase in ethrel concentration more strongly and fastly broke the dormancy. Germination was maintained and many times obtained much above the standard germination prescribed to IMSCS in all storage periods by ethrel @ 50 ppm, 75 ppm and ethrel @ 25 ppm (except 7 days after harvest). Even though maximum result was given by ethrel @ 75 ppm at 28 days after harvest, non-significant variation existed for last two storage periods (21 and 28 days after harvest) for ethrel @ 50 and 75 ppm treatments.

Seeds treated with ethrel @ 75 ppm at 28 days after harvest ( $C_4S_4$ ) gained significantly maximum seed vigour index-I [29.6 (875.1)] which was *at par* with ( $C_4S_3$ ), ( $C_4S_2$ ) and seed vigour index-II [117.8 (13870.0)] which was also *at par* with ( $C_4S_3$ ). While minimum seed vigour index-I [10.3 (289.6)] and seed vigour index-II [37.4 (40.96)] was marked in control at 7 days after harvest ( $C_1S_1$ ). In all storage periods control recorded minimum interaction effect in seed vigour index-I and ethrel @ 75 ppm marked highest followed by 50 ppm and then 25 ppm. In case of seed vigour index-I and seed vigour index-II with increase in ethrel concentration and advancement in storage period significant improvement were produced by interactions. This may be because germination percentage, a parameter that determines vigour index found to follow same pattern of improvement in the same interaction.

If we observe the pattern of variation in case of interaction effect of ethrel concentrations and storage periods, we can see the improvement in parameters with the increase in ethrel concentration (from 25 ppm to 75 ppm) and with the advancement in storage duration (from 7 days to 28 days after harvest).

**Table.1** Three way table of main effect and interaction effect for germination %

Character: Germination %																				
	V <sub>1</sub>				V <sub>2</sub>				V <sub>3</sub>				VC			CS				
	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	V <sub>1</sub>	V <sub>2</sub>	V <sub>3</sub>	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	C↓
C <sub>1</sub>	66.4 (84.0)	65.9 (83.3)	62.5 (78.7)	60.7 (76.0)	2.9 (0.0)	21.9 (14.0)	48.5 (56.0)	55.1 (67.3)	2.9 (0.0)	16.7 (9.3)	28.1 (22.7)	45.0 (50.0)	63.9 (80.5)	32.1 (34.3)	23.2 (20.5)	24.1 (28.0)	34.8 (35.6)	46.3 (52.4)	53.6 (64.4)	39.7 (45.1)
C <sub>2</sub>	72.0 (89.3)	69.2 (87.3)	68.6 (86.7)	67.5 (85.3)	40.0 (41.3)	48.1 (55.3)	68.6 (86.7)	70.8 (88.7)	32.8 (29.3)	60.2 (75.3)	67.5 (85.3)	69.8 (88.0)	69.1 (87.2)	56.9 (68.0)	57.6 (69.5)	47.9 (53.3)	59.2 (72.7)	68.2 (86.2)	69.4 (87.3)	61.2 (74.9)
C <sub>3</sub>	75.2 (93.3)	71.0 (89.3)	72.2 (90.7)	71.6 (90)	50.0 (58.7)	56.0 (68.7)	74.3 (92.7)	75.1 (93.3)	55.2 (67.3)	67.1 (84.7)	72.2 (90.7)	73.7 (92.0)	72.5 (90.8)	63.8 (78.3)	67.0 (83.7)	60.1 (73.1)	64.7 (80.9)	72.9 (91.3)	73.4 (91.8)	67.8 (84.3)
C <sub>4</sub>	79.6 (96.7)	76.0 (94.0)	75.2 (93.3)	74.3 (92.7)	57.2 (70.7)	63.9 (80.7)	79.6 (96.7)	80.7 (97.3)	61.6 (77.3)	72.3 (90.7)	76.7 (94.7)	79.6 (96.7)	76.3 (94.2)	70.4 (86.3)	72.6 (89.8)	66.2 (81.6)	70.7 (88.4)	77.2 (94.9)	78.2 (95.6)	73.1 (90.1)
VS →	75.3 (90.8)	72.0 (88.5)	69.6 (87.3)	68.5 (86.0)	37.6 (42.7)	47.5 (54.7)	67.8 (83.0)	70.4 (86.7)	38.1 (43.5)	54.1 (65.0)	61.1 (73.3)	67.0 (81.7)	71.4 (88.8)	55.8 (66.8)	55.1 (65.9)	49.6 (59.1)	57.3 (69.4)	66.2 (81.2)	68.7 (84.8)	S ←
S.Em ±	V	0.3591		C	0.4146		S	0.4146				VS	0.7182		VC	0.718 2	CS	0.829 3	VCS	1.436 4
CD	V	1.0080		C	1.1640		S	1.1640				VS	2.0161		VC	2.016 1	CS	2.328 0	VCS	4.032 2
CV%	4.1167																			

- Values in parenthesis are original value
- Data has been transformed as per arcsine transformation.
- V: Variety; V<sub>1</sub>: GG- 7; V<sub>2</sub>: GG-11; V<sub>3</sub>: GG-20
- C: Ethrel Concentration; C<sub>1</sub>: Control; C<sub>2</sub>: Ethrel @ 25 ppm; C<sub>3</sub>: Ethrel @ 50 ppm; C<sub>4</sub>: Ethrel @ 75 ppm
- S<sub>1</sub>: Storage Period; S<sub>1</sub>: 7 days after harvest; S<sub>2</sub>: 14 days after harvest; S<sub>3</sub>: 21 days after harvest; S<sub>4</sub>: 28 days after harvest
- VC: Interaction effect of variety x ethrel concentration; VS: Interaction effect of variety x storage period; CS: Interaction effect of ethrel concentration x storage period; VCS: Interaction effect of variety x ethrel concentration x storage period

**Table.2** Three way table of main effect and interaction effect for speed of germination

Character: Speed of germination																				
	V <sub>1</sub>				V <sub>2</sub>				V <sub>3</sub>				VC			CS				
	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	V <sub>1</sub>	V <sub>2</sub>	V <sub>3</sub>	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	C↓
C <sub>1</sub>	8.4 (69.2)	8.4 (70.6)	8.1 (65.0)	7.8 (60.5)	0.7 (0.0)	2.3 (4.9)	5.6 (31.5)	6.5 (41.8)	0.7 (0.0)	1.9 (3.3)	2.7 (6.9)	4.9 (23.7)	8.2 (66.4)	3.8 (19.5)	2.6 (8.5)	3.4 (23.1)	4.2 (26.3)	5.5 (34.5)	6.4 (42.0)	4.9 (31.4)
C <sub>2</sub>	8.9 (77.9)	8.6 (72.9)	8.5 (72.3)	8.5 (71.8)	4.7 (21.7)	5.7 (31.9)	7.7 (59.2)	8.0 (63.0)	4.2 (17.6)	6.1 (37.1)	7.6 (57.9)	8.1 (64.4)	8.6 (73.7)	6.5 (44.0)	6.5 (44.3)	5.9 (39.1)	6.8 (47.3)	8.0 (63.2)	8.2 (66.4)	7.2 (54.0)
C <sub>3</sub>	9.1 (82.2)	8.8 (77.5)	8.8 (77.4)	8.7 (76.0)	5.7 (31.6)	6.3 (39.6)	8.3 (67.9)	8.8 (76.2)	6.3 (39.6)	6.9 (47.4)	8.2 (67)	8.6 (74.1)	8.9 (78.3)	7.3 (53.8)	7.5 (57.0)	7.0 (51.1)	7.4 (54.8)	8.4 (70.8)	8.7 (75.4)	7.9 (63.0)
C <sub>4</sub>	9.2 (84.8)	9.1 (82.9)	9.0 (81.1)	9.0 (80.6)	6.4 (40.1)	7.0 (48.9)	8.8 (76.5)	9.0 (81.4)	7.0 (49.0)	7.3 (52.7)	8.7 (75.2)	9.1 (81.7)	9.1 (82.3)	7.9 (61.7)	8.0 (64.6)	7.6 (58.0)	7.8 (61.5)	8.8 (77.6)	9.0 (81.2)	8.3 (69.6)
VS →	8.9 (78.5)	8.7 (76.0)	8.6 (74.0)	8.5 (72.2)	4.4 (23.4)	5.3 (31.3)	7.6 (58.8)	8.1 (65.6)	4.6 (26.5)	5.6 (35.1)	6.8 (51.7)	7.7 (61.0)	8.7 (75.9)	6.4 (44.8)	6.2 (43.6)	5.9 (42.8)	6.6 (47.5)	7.7 (61.5)	8.1 (66.3)	S ←
S.Em±	V	0.0241		C	0.0278		S	0.0278				VS	0.0482		VC	0.048 2	CS	0.055 7	VCS	0.096 4
CD	V	0.0677		C	0.0782		S	0.0782				VS	0.1354		VC	0.135 4	CS	0.156 3	VCS	0.270 7
CV%	2.3650																			

- Values in parenthesis are original value
- Data has been transformed as per arcsine transformation.
- V: Variety; V<sub>1</sub>: GG- 7; V<sub>2</sub>: GG-11; V<sub>3</sub>: GG-20,
- C: Ethrel Concentration; C<sub>1</sub>: Control; C<sub>2</sub>: Ethrel @25ppm; C<sub>3</sub>: Ethrel @50ppm; C<sub>4</sub>: Ethrel @75ppm
- S: Storage Period; S<sub>1</sub>: 7 days after harvest; S<sub>2</sub>: 14 days after harvest; S<sub>3</sub>: 21 days after harvest; S<sub>4</sub>: 28 days after harvest
- VC: Interaction effect of variety x ethrel concentration; VS: Interaction effect of variety x storage period; CS: Interaction effect of ethrel concentration x storage period; VCS: Interaction effect of variety x ethrel concentration x storage period

**Table.3** Three way table of main effect and interaction effect for seed vigour index-I

Character: Seed vigour index-I																				
	V <sub>1</sub>				V <sub>2</sub>				V <sub>3</sub>				VC			CS				
	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	V <sub>1</sub>	V <sub>2</sub>	V <sub>3</sub>	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	C↓
C <sub>1</sub>	29.5 (868.9)	28.8 (831)	26.9 (724.7)	26.1 (680.2)	0.7 (0.0)	9.7 (95.4)	19.9 (395.4)	21.9 (479)	0.7 (0.0)	7.6 (66.2)	12.5 (162.2)	19.1 (364.1)	27.8 (776.2)	13.1 (242.4)	10.0 (148.1)	10.3 (289.6)	15.4 (330.9)	19.8 (427.4)	22.4 (507.8)	17.0 (388.9)
C <sub>2</sub>	31.2 (973.6)	30.5 (932.6)	29.0 (843.3)	28.7 (820.9)	17.4 (301.2)	20.3 (411.1)	26.0 (676.4)	26.4 (699.3)	14.8 (219.3)	24.4 (592.7)	26.3 (688.9)	26.8 (718.5)	29.9 (892.6)	22.5 (522.0)	23.1 (554.9)	21.1 (498.0)	25.1 (645.4)	27.1 (736.2)	27.3 (746.2)	25.2 (656.5)
C <sub>3</sub>	32.4 (1049.1)	31.2 (974.3)	30.2 (912.1)	29.8 (890.1)	21.7 (468.6)	23.6 (557.5)	27.8 (771.2)	28.0 (783.1)	23.1 (534)	26.4 (698.9)	27.4 (752.2)	27.8 (772.1)	30.9 (956.4)	25.3 (645.1)	26.2 (689.3)	25.7 (683.9)	27.1 (743.6)	28.5 (811.9)	28.5 (815.1)	27.5 (763.6)
C <sub>4</sub>	33.2 (1102.0)	32.4 (1046.3)	31.1 (965.7)	30.8 (945.5)	24.4 (593.4)	26.2 (685.7)	28.8 (831.1)	29.0 (838.4)	25.3 (639.8)	27.7 (768.2)	28.6 (820.1)	29.0 (841.3)	31.8 (1014.9)	27.1 (737.1)	27.7 (767.4)	27.6 (778.4)	28.8 (833.4)	29.5 (872.3)	29.6 (875.1)	28.9 (839.8)
VS →	31.6 (998.4)	30.7 (946.0)	29.3 (861.4)	28.8 (834.2)	18.5 (340.8)	20.0 (437.4)	25.6 (668.5)	26.3 (699.9)	18.8 (348.3)	21.5 (531.5)	23.7 (605.9)	25.7 (674.0)	30.1 (910.0)	22.0 (536.7)	21.7 (539.9)	21.2 (562.5)	24.1 (638.3)	26.2 (711.9)	26.9 (736.0)	S ←
S.Em ±	V	0.1211		C	0.1398		S	0.1398				VS	0.2422		VC	0.2422	CS	0.2797	VCS	0.4844
CD	V	0.3399		C	0.3925		S	0.3925				VS	0.6799		VC	0.6799	CS	0.7851	VCS	1.3598
CV%	3.4092																			

- Values in parenthesis are original value
- Data has been transformed as per square-root transformation.
- V: Variety; V<sub>1</sub>: GG- 7; V<sub>2</sub>: GG-11; V<sub>3</sub>: GG-20,
- C: Ethrel Concentration; C<sub>1</sub>: Control; C<sub>2</sub>: Ethrel @25ppm; C<sub>3</sub>: Ethrel @50ppm; C<sub>4</sub>: Ethrel @75ppm
- S: Storage Period; S<sub>1</sub>: 7 days after Harvest; S<sub>2</sub>: 14 days after Harvest; S<sub>3</sub>: 21 days after Harvest; S<sub>4</sub>: 28 days after Harvest
- VC: Interaction effect of variety x ethrel concentration; VS: Interaction effect of variety x storage period; CS: Interaction effect of ethrel concentration x storage period; VCS: Interaction effect of variety x ethrel concentration x storage period

**Table.4** Three way table of main effect and interaction effect for seed vigour index (mass)

Character: Seed vigour index-II(mass)																				
	V <sub>1</sub>				V <sub>2</sub>				V <sub>3</sub>				VC			CS				
	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	V <sub>1</sub>	V <sub>2</sub>	V <sub>3</sub>	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	C↓
<b>C<sub>1</sub></b>	110.9 (12288)	109.2 (11921)	105.8 (11195)	103.6 (10743)	0.7 (0.0)	38.5 (1497)	77.3 (5984)	85(722 6.7)	0.7 (0.0)	29.6 (1007)	50.1 (2588)	71.2 (5077)	107.4 (11537)	50.4 (3677)	37.9 (2168)	37.4 (4096)	59.1 (4808)	77.7 (6589)	86.6 (7682)	65.2 (5794)
<b>C<sub>2</sub></b>	115.6 (13372)	112.7 (12693)	112.5 (12655)	111.4 (12400)	68.1 (4643)	79.0 (6250)	102.7 (10540)	104.4 (10907)	52.2 (2734)	95.6 (9141)	102.3 (10469)	105.0 (11033)	113.0 (12780)	88.6 (8085)	88.8 (8345)	78.7 (6916)	95.8 (9361)	105.8 (11221)	106.9 (11447)	96.8 (9736)
<b>C<sub>3</sub></b>	120.4 (14497)	115.0 (13221)	116.1 (13479)	115.3 (13290)	88.0 (7741)	95.0 (9017)	112.5 (12662)	112.9 (12755)	85.3 (7283)	104.1 (10843)	110.2 (12148)	111.6 (12450)	116.7 (13622)	102.1 (10544)	102.8 (10681)	97.9 (9841)	104.7 (11027)	112.9 (12763)	113.3 (12832)	107.2 (11616)
<b>C<sub>4</sub></b>	122.3 (14949)	118.9 (14132)	118.8 (14123)	118.2 (13963)	99.9 (9994)	107.4 (11535)	118.3 (13986)	118.7 (14082)	96.9 (9401)	112.1 (12565)	115.3 (13289)	116.4 (13563)	119.5 (14292)	111.1 (12399)	110.2 (12205)	106.4 (11448)	112.8 (12744)	117.4 (13799)	117.8 (13870)	113.6 (12965)
<b>VS →</b>	117.3 (13777)	113.9 (12992)	113.3 (12863)	112.1 (12599)	64.2 (5594)	80.0 (7075)	102.7 (10793)	105.3 (11243)	58.8 (4855)	85.4 (8389)	94.5 (9624)	101.1 (10531)	114.2 (13058)	88.0 (8676)	84.9 (8350)	80.1 (8075)	93.1 (9485)	103.5 (11093)	106.1 (11458)	<b>S ←</b>
<b>S.Em±</b>	<b>V</b>	0.4680		<b>C</b>	0.5404		<b>S</b>	0.5404				<b>VS</b>	0.9360		<b>VC</b>	0.9360	<b>CS</b>	1.0808	<b>VCS</b>	1.8719
<b>CD</b>	<b>V</b>	1.3137		<b>C</b>	1.5170		<b>S</b>	1.5170				<b>VS</b>	2.6275		<b>VC</b>	2.6275	<b>CS</b>	3.0339	<b>VCS</b>	5.2529
<b>CV%</b>	3.3880																			

- Values in parenthesis are original value
- Data has been transformed as per square-root transformation.
- **V:** Variety; **V<sub>1</sub>:** GG- 7; **V<sub>2</sub>:** GG-11; **V<sub>3</sub>:** GG-20.
- **C:** Ethrel Concentration; **C<sub>1</sub>:** Control; **C<sub>2</sub>:** Ethrel @25ppm; **C<sub>3</sub>:** Ethrel @50ppm; **C<sub>4</sub>:** Ethrel @75ppm
- **S:** Storage Period; **S<sub>1</sub>:** 7 days after harvest; **S<sub>2</sub>:** 14 days after harvest; **S<sub>3</sub>:** 21 days after harvest; **S<sub>4</sub>:** 28 days after harvest
- **VC:** Interaction effect of variety x ethrel concentration; **VS:** Interaction effect of variety x storage period; **CS:** Interaction effect of ethrelconcentration x storage period; **VCS:** Interaction effect of variety x ethrel concentration x storage period

In case of dormant groundnut varieties, fresh seed dormancy exists, for that they require an after ripening period or a resting period for breaking it and to advance into germination phase. This stage of arrested growth, if it falls within storage duration, then there will be slow release of dormancy over the storage period. When this storage period combines with ethrel concentration, dormancy release was accelerated because ethrel (an ethylene compound) can effectively break seed dormancy and can also reduce the time required for radicle emergence in non-dormant seeds.

### **Interaction effect of varieties x ethrel concentrations x storage periods**

In case of the interaction effect of varieties x ethrel concentration x storage period, seeds treated with ethrel @ 75 ppm gained maximum germination percentage at 28 days after harvest in case of dormant variety GG-11 ( $V_2C_4S_4$ ) [80.7% (97.3%)] which was *at par* with other treatments; ( $V_1C_4S_1$ ), ( $V_2C_4S_3$ ), ( $V_3C_4S_3$ ) and ( $V_3C_4S_4$ ). While minimum germination per cent was recorded in control at 7 days after harvest [2.9% (0.0%)] for both dormant varieties ( $V_2C_1S_1$  and ( $V_3C_1S_1$ ))

When comes to the speed of germination, GG-7 seeds treated with ethrel @ 75 ppm at 7 days after harvest ( $V_1C_4S_1$ ) gained maximum result [9.2 (84.8)] and it was *at par* with many other treatments; ( $V_1C_4S_2$ ), ( $V_1C_4S_3$ ), ( $V_1C_4S_4$ ), ( $V_1C_3S_1$ ), ( $V_2C_4S_4$ ) and ( $V_3C_4S_4$ ). While minimum speed of germination was recorded in control at 7 days after harvest [0.7 (0.0)] for both dormant varieties; GG-11 ( $V_2C_1S_1$ ) and GG-20 ( $V_3C_1S_1$ ).

Seeds of non-dormant varieties GG-7 treated with ethrel @ 75 ppm 7 days after harvest ( $V_1C_4S_1$ ) gained maximum seed vigour index-II [33.2 (1102.0)] which was *at par* with

( $V_1C_4S_2$ ), ( $V_1C_3S_1$ ) and seed vigour index-II [122.3 (14949.0)] which was also *at par* with other treatments; ( $V_1C_4S_2$ ), ( $V_1C_4S_3$ ), ( $V_1C_4S_4$ ), ( $V_1C_3S_1$ ) and ( $V_2C_4S_4$ ). Significantly lowest result for seed vigour index-I as well as vigour index-II was recorded in control at 7 days after harvest [0.7 (0.0)] for both dormant varieties; GG-11 ( $V_2C_1S_1$ ) and GG-20 ( $V_3C_1S_1$ ). Here in case of all interactions higher seed vigour index were promoted by ethrel @ 75 ppm and least values for seed vigour index were recorded in control for all varieties irrespective of storage periods.

In case dormant varieties, availability of resting or after ripening period during storage aids in slow release of dormancy without deterioration of seed quality and exogenous application of ethrel that counteract the seed germination inhibitors promoted improvement in all parameters over the advancement in storage period and increase in ethrel concentration. For non-dormant variety, advances in storage period resulted in declining of these parameters due to deterioration of seed quality due to aging but ethrel treatments effectively rectified these storage problems.

In conclusion, ethrel treatments and storage can be used as a tool for breaking the fresh seed dormancy present in groundnut seeds. Pre-soaking of seeds in ethrel @ 75 ppm and a storage period of 28 days after harvest can effectively broke the seed dormancy present in GG-11 and GG-20 and can also effectively promote improvement of seed quality parameters; germination (%), speed of germination, seed vigour index-I and seed vigour index-II to the level of performance of non-dormant variety. Increase in ethrel concentration and advancement in storage period improved all the seed quality parameters for dormant varieties; GG-11 and GG-20. Whereas advancement in storage

period deteriorated non-dormant variety GG-7, but ethrel treatment resulted in betterment of all seed quality parameters and especially helped in maintaining seed quality during storage by preventing deterioration.

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