Original Research Article

"Effect of seed hardening on seed germination and morphological parameters in Linseed (*Linum usitatissimum* L*)*"

ABSTRACT

Seed hardening refers to different processes that involves treating seeds to enhance their resilience, break seed dormancy and improve their chances of successful germination and plant establishment during harsh conditions. Seeds are soaked in the solutions of KCl, NAA, KNo_3 and $CaCl_2$ to break dormancy and increase the germination percentage and improves plant morphological parameters in linseed. The experiment was carried out for "Effect of seed hardening on seed germination and morphological parameters in Linseed (*Linum usitatissimum* L*)*" during *Rabi* season in the year 2022 at Field Experimentation Centre, Department of Genetics and Plant Breeding, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology And Sciences, Prayagraj, Uttar Pradesh on linseed crop. The experiment was laid out in Randomized Complete Block Design (RCBD) with 13 treatments and 3 replications. T_0-Control, T_1-NAA-25 ppm, T_2-NAA-50 ppm, T_3-NAA-150 ppm, T_4-KCl-25 ppm, T_5-KCl-50 ppm, T_6-KCl-150 ppm, T_7-KNo_3-25 ppm, T_8-KNo_3-50 ppm, T_9-KNo_3-150 ppm, T_{10}-$CaCl_2$-25 ppm, T_{11}-$CaCl_2$-50 ppm, T_{12}-$CaCl_2$-150 ppm were the treatments. Linseed seeds were treated with NAA, KCl, KNo_3 and $CaCl_2$ with different concentrations (25 ppm,50 ppm and150 ppm) for 5 hours and after sowing growth, yield and yield parameters were observed. Main objectives are to determine the effect of seed hardening on seed germination and morphological characters of Linseed and to find out suitable concentration for seed hardening in Linseed. It was noticed that T_9-KNo_3-150 ppm treatment performed better significantly different at 5% level of significance, when compared with other treatments where as minimum was observed in control. The highest germination percentage(92.20%), plant height(74.34 cm), number of primary branches(3.87), number of secondary branches(23.53), seeds per capsule(8.13), seed yield per plant(3.42) and harvest index(25.38 %) showing better results when treated with treatment (T_9)-KNo_3-150 ppm for 5 hours and followed by Treatment(T_{11}) $CaCl_2$-50 ppm. Very less days (72) required for 50 % flowering and maturity(111.67) was observed in treatment T_9 when compared with other treatments. It concluded that T_9(KNo_3-150 ppm) was superior in all the growth and yield parameters in linseed. So we recommended that treatment T_9 is best seed hardening treatment for linseed according to this experiment.

Keywords: Seed hardening, Field emergence, Biological yield, NAA, KCl, KNo_3 and $CaCl_2$

INTRODUCTION

Linseed (*Linum usitatissimum* L.) (2n = 30) is a major Rabi oilseed crop and one of the oldest crops grown. It is an annual, self-pollinating plant species of the Linaceae family known as "Alsi" that is thought to have originated in southwest Asia, specifically in India **(Vavilov, 1935 and Richharia, 1962)**. It is a member of the Linaceae family, which contains 14 genera and over 200 species. Linum derives its name from "lin" or "thread," and Usitatissimum is a Latin word that means "most useful." When used as an oilseed, it is also known as flaxseed or linseed, and when used for fibre, it is known as fibre flax or simply flax (in Europe).

In 2021 world linseed production is 3.34 million tonnes and cultivated area is 41,42,449 ha**(FAO,2021).**In 2022 India Linseed production was 1 lakh tonnes and productivity is 574 kg/ha **(ICAR 2022).** At the end of fiscal year 2023, India is estimated to produce nearly 140 thousand metric tons of linseed **(Statista,2023).** Major linseed producing states are Madhya Pradesh, Chattisgarh, UP, Maharashtra, Bihar, Odisha, Jharkhand, West-Bengal, Nagaland and Assam.

Nutrients per 100 g of edible flaxseed contains Protein 6.5 g, Fat 20.3 g, Minerals 37.1g, Crude fiber 2.4 g, Total dietary fiber 4.8 g, Carbohydrates 24.5 g, Energy 28.9 kcal, Potassium 530mg, Calcium 750mg, Phosphorous 170mg. (**Soni *et al*., 2016).** As a percentage of total fat, flax seeds contain 54% omega-3 fatty acids (mostly ALA), 18% omega-9 fatty acids (oleic acid) and 6% omega-6 fatty acids (linoleic acid); the seeds contain 9% saturated fat, including 5% as palmitic acid. Flax seed oil contains 53% 18:3 omega-3 fatty acids (mostly ALA) and 13% 18:2 omega-6 fatty acids(**Soni *et al*., 2016).**

Flax seeds are a good source of several vitamins and minerals. They are Thiamine essential for normal metabolism and nerve function, Copper essential mineral and important for growth, development, and various functions**,** Molybdenum essential trace mineral is abundant in seeds, grains, and legumes, Magnesium that has many functions in our body and Phosphorus usually found in protein-rich foods and contributes to bone health and tissue maintenance(**Soni *et al*., 2016).**

Hardening of seeds to required chemicals enables the plants to overcome the specific stresses. This process actually hardens the protoplasm (by osmoregulation), which enables the seeds to absorb more water under favourable situations to maintain its viability under unfavourable conditions. Hardening of seeds resulted in the absorption of more water due to increase in the elasticity of cell wall and development of a stronger and efficient root system **(Krishnasamy and Srimathi, 2001)**.

Naphthalene acetic acid (NAA) is a synthetic plant growth regulator and a type of auxin, which is a class of plant hormones that play a crucial role in regulating various aspects of plant growth and development. Calcium chloride can be used as a seed coating material to improve the seed's resistance to stress conditions, such as drought and salinity. Coating seeds with a calcium chloride solution helps protect the seeds during early growth stages and enables better establishment of the seedlings. Potassium nitrate can stimulate seed germination by breaking seed dormancy. Dormancy is a natural state that prevents seeds from germinating under unfavorable conditions, such as extreme temperatures or moisture levels. By treating seeds with potassium nitrate, farmers can help break this dormancy and promote faster and more uniform germination. Potassium can help plants to withstand to environmental stresses such as drought, salinity, and temperature fluctuations. Treating seeds with potassium chloride may enhance the ability of seedlings to withstand adverse conditions**(Robertson,2016).**

Materials and Methods:

Description of experimental site:

The experiment was conducted in *Rabi* season of 2022 in field experimentation of Department of Genetics and Plant Breeding, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (25 24' N, 810 51' E). The soil was of sandy clay loam in texture, p^H of water is 7.1, Organic matter (0.50%) and Electrical conductivity (0.37 dsm^{-1}). The experimental material for present investigation comprised of 13 treatments was conducted in Randomized Complete Block Design (RCBD)with 3 Replications.

Treatment details:

T_1-NAA-25 ppm (5hrs), T_2-NAA-50 ppm(5hrs), T_3-NAA-150 ppm(5hrs), T_4-KCl-25 ppm(5hrs), T_5-KCl-50 ppm(5hrs), T_6-KCl-150 ppm(5hrs), T_7-KNo_3-25 ppm(5hrs), T_8-KNo_3-50 ppm(5hrs), T_9-KNo_3-150 ppm(5hrs), T_{10}-$CaCl_2$-25 ppm(5hrs), T_{11}-$CaCl_2$-50 ppm(5hrs), T_{12}-$CaCl_2$-150 ppm(5hrs) along dry seed with distilled water as control.

Treatment preparation:

25 ppm solution: Measure out 2.5 mg of NAA, KCl, KNo_3 and $CaCl_2$ and add them to 100 ml volumetric flask separately. Then add water and dilute to 100 ml solution. Soak the seeds in these solutions for 5 hours before sowing.

50 ppm solution: Measure out 5 mg of NAA, KCl, KNo_3 and $CaCl_2$ and add them to 100 ml volumetric flask separately. Then add water and dilute to 100 ml solution. Soak the seeds in these solutions for 5 hours before sowing.

150 ppm solution: Measure out 5 mg of NAA, KCl, KNo_3 and $CaCl_2$ and add them to 100 ml volumetric flask separately. Then add water and dilute to 100 ml solution. Soak the seeds in these solutions for 5 hours before sowing.

Seed sowing and germination:

Linseed variety GS-129 seeds were provided by Department of Genetics and Plant Breeding, Naini Agricultural institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (Uttar Pradesh) India. Seeds were sown in soil at the depth of 2-3 cm with spacing of $30\times 10\ cm^2$ @ 40 kg/ha. Total 30 seeds were sown per treatment in 3 lines in each replication. Irrigation given weekly basis in such a way that the moisture content remained > 80% and 4 hoeing were given to keep plots free from weeds. Individual treatments were harvested with the help of sickles and threshed to separate the seeds. Linseed crop taken 110 days for harvesting from 19 December 2022 to 08 April 2023.

In the present investigation, data of the following pre and post- harvest data was recorded as Germination percentage(%), Plant height, Number of Primary branches, Number of Secondary branches, Days to 50% flowering, Days to Maturity (Days), Number of seeds per capsule, Seed yield per plant(g) and Harvest index (%).

Fig.1 Pre-sowing seed treatment with different concentrations of NAA, KCl, KNo_3 and $CaCl_2$

Fig 2. Linseed crop after 20 days of sowing

RESULTS AND DISCUSSION:

Germination percentage(%): Seed hardening is one of the pre-sowing seed treatment techniques which shows the significant positive effect on the field emergence in Linseed. Maximum emergence was observed in treatment T_9 with 92.20% and followed by treatment T_{10} and T_{11} with 91.10%. Potassium nitrate can stimulate seed germination by breaking seed dormancy.

Plant height(cm) (90 DAS): Seed hardening is one of the pre-sowing seed treatment techniques which shows the significant positive effect on the plant height in Linseed. maximum plant height was observed in treatment T_9 with height of 74.34 cm and followed by treatment T_{11} with 67.33 cm.

Number of primary branches: Seeds treated with NAA which is a class of plant hormones that play a crucial role in regulating various aspects of plant growth and development. Along with the NAA, remaining treatments are also increased the primary branches in linseed. Treatment T_9 showed the maximum primary branches with 3.87 followed by T_{11} with 3.40 primary branches per plant. Remaining all the treatments showed significant performances over the control.

Number of secondary branches: Treatment T_9 with KNo_3-150 ppm(5hrs) showed significant increase in the secondary branches of linseed with the value of 23.53 and followed by treatment T_{11} with value of 21.87 in this experiment. Potassium nitrate and Calcium chloride can be used as a seed coating material to improve the seed's resistance to stress conditions and improves the seedling establishment and increase the branching number.

Days to 50 % flowering: Treatment with KNo_3-150 ppm(5hrs) takes minimum days (72) for flowering after sowing followed by treatment T_{10} and T_{11} takes 74 days for flowering after sowing. Maximum days for flowering was taken by control. Seed hardening treatments mainly NAA and $CaCl_2$ play a crucial role in regulating various aspects of plant growth, development and flowering.so seed hardening reduced the days for flowering and useful for early development of crop.

Days to maturity: Seed hardening treatments like KNo_3, KCl and NAA causes early flowering which results early maturity of crop that can reduce the crop duration. Treatment T_9 required minimum days for maturity (111.67) followed by T_7 with 112.67 days for maturity but control takes 123.33 days for maturity.

Number of seeds per capsule: Seeds treated with NAA regulating various aspects of plant growth and development. Along with the NAA, remaining treatments are also increased seed per capsule in linseed. Treatment T_9 showed the maximum seeds per capsule with 8.13 followed by T_{11} with 7.67 seeds per capsule. Remaining all the treatments showed significant performances over the control.

Seed yield per plant (g): Seed hardening is one of the pre-sowing seed treatment techniques which shows the significant positive effect on the seed yield in Linseed. maximum yield was observed in treatment T_9 with 3.42 g and followed by treatment T_{11} with 3.07 grams per plant. all the seed hardening treatments increase the seed yield over the control.

Harvest Index (%): Treatment T_9 with KNo_3-150 ppm(5hrs) showed significant increase in the economic yield as well as biological yield of linseed. Treatment T_9 showed the maximum harvest index with the value of 25.38% and followed by treatment T_{12} with value of 24.38% in this experiment. Potassium nitrate and Calcium chloride can be used as a seed coating material to improve the seed's resistance to stress conditions and improves the seedling establishment.as a result seed hardening increased all the parameters significantly when compared with the non treated seeds.

Table.1 Mean performances of different seed hardening treatments on germination percentage in Linseed (*Linum usitatissimum* L)

Treatment code	Treatment concentration	Mean
T0	Control	83.3
T1	NAA-25 ppm	84.4
T2	NAA-50 ppm	89.96
T3	NAA-150 ppm	86.6
T4	KCl-25 ppm	84.4
T5	KCl-50 ppm	85.53
T6	KCl-150 ppm	84.4
T7	KNo_3-25 ppm	87.73
T8	KNo_3-50 ppm	91.06
T9	KNo_3-150 ppm	**92.2**
T10	$CaCl_2$-25 ppm	91.1
T11	$CaCl_2$-50 ppm	91.1
T12	$CaCl_2$-150 ppm	88.86

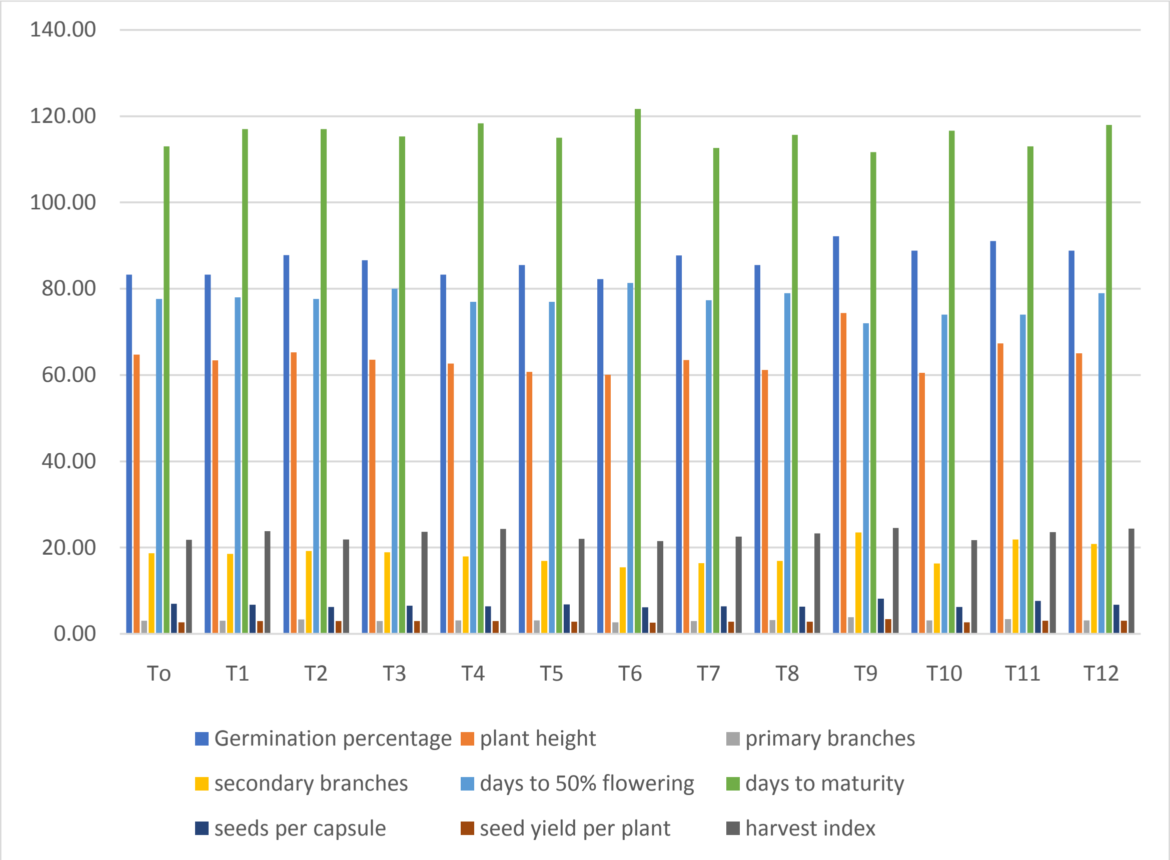
Grand mean	87.74
C.V.	5.36
C.D(0.05 *p*)	5.73
S.E(m)	1.96

Treatment	**Plant height (90DAS) (cm)**	**Number of primary branches**	**Number of secondary branches**	**Days to 50% flowering**	**Days to maturity**	**Number of seeds per capsule**	**Seed yield per plant (g)**	**Harvest Index (%)**
T0	58.47	2.53	15.27	81.67	123.33	6.00	2.61	21.57
T1	63.39	3.07	18.53	81.00	117.00	6.73	2.95	23.83
T2	65.27	3.33	19.20	77.67	117.00	6.20	2.96	22.92
T3	63.53	2.93	18.93	80.00	115.33	6.53	2.95	23.64
T4	62.67	3.13	17.93	77.00	118.33	6.40	2.99	24.33
T5	60.73	3.13	16.93	77.00	115.00	6.80	2.79	22.04
T6	60.05	2.67	15.40	81.33	121.67	6.13	2.63	21.59
T7	63.51	3.00	16.40	77.33	112.67	6.40	2.82	22.53
T8	61.19	3.20	16.93	79.00	115.67	6.33	2.82	23.26
T9	74.34	3.87	23.53	72.00	111.67	8.13	3.42	25.38

T10	60.53	3.13	16.33	74.00	116.67	6.20	2.68	21.76
T11	67.33	3.40	21.87	74.00	113.00	7.67	3.07	23.60
T12	65.06	3.13	20.80	79.00	118.00	6.73	3.06	24.38
Grand Mean	63.54	3.12	18.31	77.77	116.56	6.63	2.90	23.16
S.E(m)	1.64	0.14	1.01	1.86	1.77	0.25	0.08	0.79
C.V	4.80	7.79	9.53	4.14	2.63	6.60	4.85	5.97
C.D(0.05 *p*)	4.48	0.41	2.94	5.43	5.17	0.74	0.24	2.32

Table 2. Mean performances of different seed hardening treatments on morphological parameters in Linseed (*Linum usitatissimum* L)

Fig. 2 Bar graph showing the mean values due to seed hardening treatment on different parameters in linseed.



CONCLUSION

It is concluded that from the present investigation of seed hardening, treatments with KNo_3, NAA, KCl and $CaCl_2$ showed significant increase in the growth and yield parameters of Linseed. The treatment KNo_3-150 ppm (T_9) found superior in field emergence, plant height, number of primary branches, number of secondary branches, seeds per capsule, seed yield and harvest index followed by treatment(T_{11}) in all parameters. By reducing the seed dormancy with NAA treatments field emergence rate increased. Through $CaCl_2$ seed treatment, establishing strong seedling that can increased the seed yield under stress condition. KNo_3 treatment increased the crop growth and branches number hence increasing the seed yield. Thus seed hardening treatment in linseed increases the growth and yield parameters significantly compared with the control. So we recommended that treatment T_9 is best seed hardening treatment for linseed according to this experiment.

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