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Effect of Seed Hardening on Seed Germination and Morphological Parameters in Linseed (*Linum usitatissimum* L*)*

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Seed hardening refers to different processes that involve 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 increase the germination percentage and improve 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

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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 and 150 ppm) for 5 hours and after sowing growth, yield and yield parameters were observed. The main objectives are to determine the effect of seed hardening on seed germination and morphological characteristics of Linseed and to find out the suitable concentration for seed hardening in Linseed. It was noticed that T_9-KNo_3-150 ppm treatment performed better significantly different at a 5% level of significance, when compared with other treatments where a 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) were 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 the best seed hardening treatment for linseed according to this experiment.

Keywords: Seed hardening; field emergence; biological yield; NAA; KCl; KNo_3; $CaCl_2$.

1. 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 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 as 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's 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 contain Protein 6.5 g, Fat 20.3 g, Minerals 37.1g, Crude fibre 2.4 g, Total dietary fibre 4.8 g, Carbohydrates 24.5 g, Energy 28.9 kcal, Potassium 530mg, Calcium 750mg, Phosphorous 170 mg [1]. 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 [1].

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 [1].

Hardening of seeds to required chemicals enables the plants to overcome specific stresses. This process actually hardens the protoplasm (by osmoregulation), which enables the seeds to absorb more water under favourable situations to maintain their viability under unfavourable conditions. Hardening of seeds resulted in the absorption of more water due to an increase in the elasticity of the cell wall and the development of a stronger and more 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 unfavourable 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 environmental stresses such as drought, salinity, and temperature fluctuations. Treating seeds with potassium chloride may enhance the ability of seedlings to withstand adverse conditions [2-5].

2. MATERIALS AND METHODS

2.1 Description of Experimental Site

The experiment was conducted in *the Rabi* season of 2022 in field experimentation of the 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 the present investigation comprised of 13 treatments was conducted in Randomized Complete Block Design (RCBD)with 3 Replications.

2.2 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 [6-8].

2.3 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.

2.4 Seed Sowing and Germination

Linseed variety GS-129 seeds were provided by the Department of Genetics and Plant Breeding, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (Uttar Pradesh) India [9-12]. Seeds were sown in the soil at a depth of 2-3 cm with a spacing of 30× 10 cm^2 @ 40 kg/ha. A total of 30 seeds were sown per treatment in 3 lines in each replication. Irrigation was given weekly basis in such a way that the moisture content remained > 80% and 4 hoeing was given to keep plots free from weeds. Individual treatments were harvested with the help of sickles and threshed to separate the seeds. Linseed crops took 110 days to harvest from 19 December 2022 to 08 April 2023.

In the present investigation, data of the following pre and post-harvest data were 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 (%).

3. RESULTS AND DISCUSSION

Germination percentage (%): Seed hardening is one of the pre-sowing seed treatment techniques which shows a significant positive effect on the field emergence in Linseed. Maximum emergence was observed in treatment T_9 with 92.20% followed by treatment T_{10} and T_{11} with 91.10%. Potassium nitrate can stimulate seed germination by breaking seed dormancy [13-16].

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

Plant height(cm) (90 DAS): Seed hardening is one of the pre-sowing seed treatment techniques which shows a significant positive effect on the plant height in Linseed. maximum plant height was observed in treatment T_9 with a height of 74.34 cm 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 in the primary branches in linseed. Treatment T_9 showed the maximum number of 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 a significant increase in the secondary branches of linseed with a value of 23.53 followed by treatment T_{11} with a 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 improve the seedling establishment and increase the branching number [17-19].

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.

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

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

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

Maximum days for flowering were 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 reduces the days for flowering and is useful for the early development of crops.

Days to maturity: Seed hardening treatments like KNo_3, KCl and NAA cause early flowering which results in early maturity of the 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.

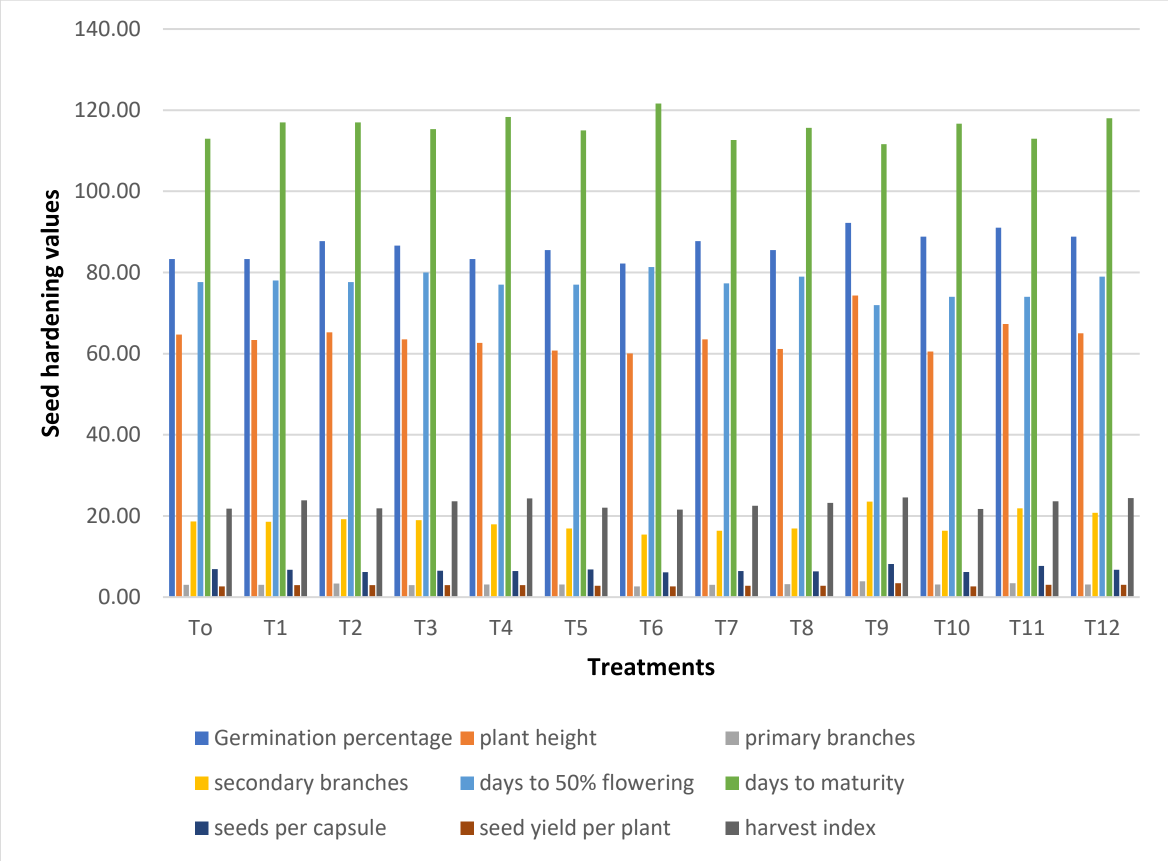

Fig. 3. Bar graph showing the mean values due to seed hardening treatment on different parameters in linseed

Number of seeds per capsule: Seeds treated with NAA regulate various aspects of plant growth and development. Along with the NAA, the 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 a significant positive effect on the seed yield in Linseed. maximum yield was observed in treatment T_9 with 3.42 g 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 a significant increase in the economic yield as well as the biological yield of linseed. Treatment T_9 showed the maximum harvest index with a value of 25.38% followed by treatment T_{12} with a 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 improve the seedling establishment. as a result seed hardening increased all the parameters significantly when compared with the non treated seeds.

4. CONCLUSION

It is concluded that from the present investigation of seed hardening, treatments with KNo_3, NAA, KCl and $CaCl_2$ showed a significant increase in the growth and yield parameters of Linseed. The treatment KNo_3-150 ppm (T_9) was 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, strong seedlings can increase the seed yield under stress conditions. 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 the best seed hardening treatment for linseed according to this experiment.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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