INFLUENCE OF SEASONS AND NUTRIENT INVIGORATION ON SEED QUALITY IN GREENGRAM

ABSTRACT

The influence of seed invigoration on seed yield and quality was studied in two seasons, i.e., summer and *kharif*. Among the seasons studied, seed quality parameters significantly differed for both seasons. Summer recorded the highest values in growth and yield parameters, *viz*., field emergence and plant population at harvest (91.75 and 87.75 %, respectively), number of nodules (35.71), seed yield (q/ha) (3.49), and seed quality parameters, *viz*., seed germination (%) (g) (91.7), and seedling vigour index I and II (3392 and 2252, respectively). But the lowest hard seeds were recorded in kharif (71.71%). Among treatments studied, 1 % $ZnSO_4$ recorded the highest values in growth and yield parameters, *viz*., field emergence and plant population at harvest (96.50 and 91.17 %, respectively), number of nodules (38.50), pod length (cm), and number of seeds per pod (11.00 and 12.23, respectively). also in seed quality parameters, *viz*., seed germination (%) and 100 seed weight (g) (94.7 and 3.78, respectively), shoot length and root length (25.93 and 14.51 cm, respectively), mean seedling length (cm) and mean seedling dry weight (mg) (40.44 and 278, respectively), seedling vigour index I and II (3829 and 2636, respectively), and total dehydrogenase activity (A_{480nm}) (1.825).

KEY WORDS: Green gram, Seed Invigoration, Nutrients.

1. INTRODUCTION:

Greengram is a short-duration pulse crop, as farmers are interested in growing it for three seasons in a single year. Because of the presence of a hard seed coat or dormancy in greengram, demonstrating proper crop stand establishment at the field level during the germination period is difficult. As a result, we designed the current research programme to address issues such as field germination delay, how to break the hard seededness in selected three greengram varieties, and seed yield and quality parameters. Low yields are caused by poor seed nutrition, which can be remedied by applying nutrients to the plant via the foliar mode, which has a greater impact on seed quality than soil nutrition and reduces fertiliser costs for farmers. Major problems with pulses during storage were also studied using different packing materials, seed treatment chemicals, and solarisation treatment studies to control storage pests.

2. MATERIAL AND METHODS:

Seed invigoration treatments have been developed to improve seed performance during germination and early seedling growth. So it is necessary to develop suitable techniques in order to improve greengram seed germination capacity and evaluate the effects of different priming treatments. Improved seed invigoration techniques are being used to reduce the germination time, synchronise germination, improve the germination rate, and increase seedling stand (Lee and Khim, 2000).

Hydro-priming is a traditional pre-sowing seed treatment that involves soaking seeds in tap water for an appropriate amount of time before dehydrating them for further sowing. In hydro-priming, seeds imbibe an adequate amount of water to initiate the germination process but elude the protrusion of the radicle and plumule. Seeds are hydrated for a known interval, which jerks metabolic actions inside the seed, but dehydration after priming averts completion of germination. At the time of sowing, this seed absorbs moisture from the substrate, resulting in quick and synchronised emergence. This conventional method significantly enhances the activities of hydrolytic enzymes, which bring about the breakdown of food material available in the endosperm and deliver energy to the living embryo for further growth. Alterations in seed cell membrane integrity occur due to ageing and storage, which cause a decline in the viability and vigour of the seed. Priming invigorates seeds through repair mechanisms by creating oxidative stress.

To overcome adverse environmental conditions like low rainfall and low soil moisture that prevent germination and seedling establishment, seed priming is given as a presowing seed treatment, which acts as a boon to farmers in dryland agriculture. It has a synergistic effect on early and uniform seed germination and enhances tolerance to pests and disease during the early crop stage. It controls soil- and seed-borne fungi. Seed priming has presented promising and even surprising results for many seeds, including legume seeds.

Micronutrients act as cofactors for many enzymes, performing a critical role in metabolic processes that fasten the readily available energy during germination, which helps in faster emergence, faster growth, a higher germination rate, etc.

Keeping all this in view, the present investigation was conducted to find out the impact of various chemicals on various growth, seed yield, and quality parameters of greengram grown in summer and *kharif*. Since season is the one factor affecting the growth and yield of crops, it has a great influence on flowering time, dry matter accumulation, seed set, and seed yield.

The present experiment of seed invigoration treatments on greengram var.KKM-3was carried out during Summer 2021 and *Kharif* 2021 in order to improve the seed quality. The seeds were soaked in respective solution for three hours (T_3-T_7) in a ratio of one kg seed: 3L solution before the day of sowing and then dried back to original moisture content for 34 h and all the seeds were treated with *Rhizobium* @ 50 g/kg seed.The present experiment was carried using different chemicals as seed priming agents such as $MgSO_4$,KH_2PO_4, KNO_3, $CaCl_2$, $ZnSO_4$,KCl and hydro priming to improve seed yield and quality parameters in greengram variety KKM-3.

Seasons:

S_1:Summer, 2021
S_2:*Kharif*, 2021

Treatments:

T_1:Hydro priming for 3h
T_3:Primingwith 1% $MgSO_4$
T_3:Priming with 3% KH_3PO_4
T_4:Primingwith 0.5 % KNO_3
T_5:Primingwith 3% $CaCl_3$
T_6:Primingwith 1% $ZnSO_4$
T_7: Priming with 1% KCl
T_8: Control

3. RESULTS AND DISCUSSION:

Seed priming significantly enhances activities of hydrolytic enzymes which brings breakdown of reserve food material available in endosperm and deliver energy to the living embryo for further growth. Uniform crop establishment under favourable as well as in unfavourable environmental conditions is significant pre-requisite for better seed yield. Seeds show variation in germination due to low vigour, hard seed coat and abiotic stressed conditions. Invigorate seeds by treating before sowing and it played imperative role on crop establishment. Seed priming is a physiological invigoration technique majorly stimulates repairing of cell organelles, metabolism essential for germination. One of the very traditional pre sowing seed treatment is hydro-priming which includes hydration of seeds in tap water and dehydrated them back to original moisture content until sowing. In the priming treatments seeds imbibe adequate amount of solution/water to initiate germination process but elude protrusion of radicle and plumule (Sharma *et al.*, 2021).

Micro and macro nutrients as a priming agent in a low optimized concentration it has a potential to increase germination percentage, crop emergence, stand establishment, seedling development, mineral uptake, dry matter accumulation and enhanced water use efficiency, vigor index, hundred seedling weight, mean root and shoot lengths, leaf area and yield attributes. Priming activate metabolic changes required for germination and easy mobilization of reserve food materials resulting in sugars can be used for protein synthesis during germination which improves germination rate and uniform growth of the plants (Rouhi*et al.*, 2011).

3.1 Growth parameters

3.1.1 Field emergence (%)

The seasons showed significant difference in field emergence. Among two seasons, summerrecorded highest field emergence (91.75 %) and lowest was recorded in *kharif* (89.79 %). Field emergence also differed significantly among different eight seed invigoration treatments. The treatment T_6 (Priming with 1 % $ZnSO_4$) recorded the highest field emergence (96.50 %) followed by T_4 (Priming with 0.5 % KNO_3) and T_3 (Priming with 2 % KH_2PO_4) (93.83 % and 93.00 %, respectively), while lowest was recorded in control (85.50 %).

The micronutrients plays an important role in plant growth in pulse crops where Zn is main constituent of an enzyme essential for the synthesis of plant hormone indole acetic acid, which is presumed to be capable of stimulating emergence and highest field emergence due to stimulated hypocotyl growth, also increased cell elongation with KH_2PO_4 (Kavitha and Srimathi, 2020). In present work Zn nutrient priming better in showing field emergence and the similar results were also reported by Ananthi*et al.* (2015) and Devi *et al.* (2019).

3.1.2 Plant height at 30 DAS (cm)

The seasons showed significant difference for plant height at 30 DAS. Among two seasons, summerrecorded highest plant height (14.38 cm) and lowest was recorded in *kharif* (13.16cm). Plant height (cm) at 30 DAS differs significantly among eight seed invigoration treatments. The treatment T_6 (Priming with 1 % $ZnSO_4$) recorded highest plant height (18.17 cm) followed by T_4 (Priming with 0.5 % KNO_3) and T_3 (Priming with 2% KH_2PO_4) which are on par with each other (16.93 cm and 16.10 cm, respectively) and lowest was recorded in control (9.87 cm).

Plant height is an important criterion for any crop in providing more places for flower production leading to better pod / fruit production. Priming increased oxidative enzymatic activity of compounds leading to improved seedling growth and plant height. The rationale for seed priming is to mobilize the seeds their own resources in addition to the external resources for maximum improvement in stand establishment and yield. The similar findings were also reported in soybean by Limba*et al.* (2020).

The seeds treatment was done in combination with *Rhizobium*. Hence, the increase in plant growth due to increased uptake of nutrients by micro organisms associated with plants and their synergistic effect (Kavitha and Srimathi, 2020).

3.1.3 Plant height at 60 DAS (cm)

The seasons showed significant difference for plant height 60 DAS. Among two seasons, summerrecorded highest plant height (29.95 cm) and lowest was recorded in *kharif* (28.92 cm). Plant height at 60 DAS differed significantly among different seed invigoration treatments. The treatment T_6 (Priming with 1 % $ZnSO_4$) recorded highest plant height (32.37 cm) followed by T_4 (Priming with 0.5 % KNO_3) and T_3 (Priming with 2% KH_2PO_4) (31.50 and 31.93 cm, respectively). While, lowest was recorded in unprimed seeds (26.20 cm).

The increase in plant height might be due to an increased supply of nutrients during initial stages and also due to more nodulation by *Rhizobium*. The association also regulate the physiological processes in the ecosystems by involving in the decomposition of organic matter, fixation of atmospheric nitrogen, secretion of growth-promoting substances, increasing the availability of mineral nutrients. Thus, the rhizosphere effect through microbial activity modifies the plant itself by providing the plant growth and increasing the availability of elements to the root zone.

Seed priming enhanced the availability of macro and micro nutrients throughout the crop growth period which might have helped in increasing translocation into the plants without any loss that contributed for better photosynthetic activity and ultimately reflected on significant increase in plant height. Similar results also reported by Elankavi*et al.* (2019).

3.1.4 Number of nodules plant^{-1}

The seasons showed significant difference in number of nodules per plant. Among two seasons, summerrecorded highest number of nodules(35.71) and lowest was recorded in *kharif* (33.04). Number of nodules per plantdiffered significantly among seed invigoration treatments. The treatment T_6 (Priming with 1% $ZnSO_4$) recorded highest number of nodules(38.50) followed by T_4 (Priming with 0.5 % KNO_3) and T_3 (Priming with 2% KH_2PO_4) (37.67 and 37.33, respectively) while lowest was recorded in control (27.67).

Nutrient seed priming and inoculation of seeds with *Rhizobium* recorded more number of nodules at all the growth stages. A high population of rhizobia before sowing is required to ensure the survival on seed and in the soil to bring about effective nodulation, because pulse productivity mainly depends upon optimum nodulation (Kurundkar*et al.*, 1991).

The increased nodule number plant^{-1} due to the *Rhizobium* inoculation was also reported in pulses by Prakash*et al.* (2012) in blackgram.

3.1.5 Number of clusters plant^{-1}

Kharif and summer seasons showed significant difference in number of clusters per plant. Among them, summerrecorded highest number of clusters per plant(6.36) and lowest was recorded in *kharif* (5.37).Number of clustersper plant differs significantly among seed invigoration treatments. The treatment T_6 (Priming with 1% $ZnSO_4$) recorded highest number of clusters(7.17) followed by T_4 (Priming with 0.5 % KNO_3) and T_3 (Priming with 2% KH_2PO_4) (6.83 and 6.45, respectively) while, lowest number of clusterswas recorded in control (4.73).

$ZnSO_4$ helped in rapid cell multiplication and resulted in expansion of leaf area thereby accelerating the photosynthetic rate and concentration of total chlorophyll ultimately increased all growth parameters. The improvement might be due to Zn availability required for the synthesis of lipids, protein, carbohydrates and nucleic acid which are necessary for the superior growth and development of plants also helpful for increasing number of clusters. The present research on increasing number of cluster were also agreement with Valadkhan*et al.* (2015).

3.1.6 Plant population at harvest (%)

The seasons showed significant difference in plant population. Among two seasons, summerrecorded highest plant stand(87.75 %) and lowest was recorded in *kharif* (84.25%). Plant populationdiffers significantly among different eight seed invigoration treatments. The treatment T_6 (Priming with 1% $ZnSO_4$) recorded highest plant population(91.17 %) followed by T_4 (Priming with 0.5 % KNO_3) and T_3 (Priming with 2% KH_2PO_4) (89.00 % and 89.13 %, respectively) while, the lowest plant populationwas recorded in control (79.17 %).

The seeds primed with 0.5 % $ZnSO_4$ enabled quick emergence and established well in the field with a higher population. Seed priming with chemicals play a major role in increasing leaf and stem dry matter and redistribution of dry matter in reproductive parts leads to improve in the biomass helps the plant to withstand (Arun*et al.*, 2020). Seed priming with 1% KNO_3 shorten the time from seed emergence to harvest, improved crop stand and dry matter partitioning to grain in maize (Vazirimehr*et al.*, 2014).

3.2 Yield parameters

3.2.1 Number of pods plant^{-1}

Significant difference was observed insummer and *kharif* fornumber of pods per plant. Where, summerrecorded the highest number of pods per plant(13.37) and lowest was recorded in *kharif* (12.14**)**. Number of pods per plantdiffers significantly among different eight seed invigoration treatments. The treatment T_6 (Priming with 1% $ZnSO_4$) recorded highest number of pods(16.43) followed by T_4 (Priming with 0.5 % KNO_3) and T_3 (Priming with 2% KH_2PO_4) which are on par with each other (13.77 and 13.37, respectively) while lowest number of podsper plant was recorded in control (10.10).

Priming could have triggered the biosynthesis of nucleic acids, proteins, and the consequential enhancement of cell division, besides the enhanced metabolic activity of the plants resulting on the increased uptake of nutrients. Hence, availability of energy is more due to higher metabolic accumulation which helps in increasing production of more number of pods in $ZnSO_4$ seed priming. Poor translocation of metabolites to the reproductive stage may be one of the reasons for lower yield in control. Similar results on increasing number of pods were also reported by Golezani*et al.,* (2011) in soybean and Kalpana*et al.,* (2015).

3.2.2 Pod length (cm)

The *kharif* and summershowed significant difference in pod length. Among two seasons, summerrecorded highest pod length (9.44 cm) and lowest was recorded in *kharif* (8.42 cm). Pod length (cm) differs significantly among different seed invigoration treatments. The treatment T_6 (Priming with 1% $ZnSO_4$) recorded highest pod length (11.00 cm) followed by T_4 (Priming with 0.5 % KNO_3) and T_3 (Priming with 2% KH_2PO_4) (10.05 cm and 9.90 cm, respectively) while lowest pod length (cm)was recorded in control (6.27 cm) .

Due to rhizobial activities during pod formation, availability of nutrients are more, which results in availability of high energy for longer growth which triggers seed for more cell division and growth leads to increasing in pod length also could be increased mineral uptake and assimilate translocation during pod formation stage (Gana, 2010).

3.2.3 Number of seeds pod^{-1}

The seasons showed significant difference in number of seeds. Among two seasons, summerrecorded highest number of seeds per pod (11.18) and lowest was recorded in *kharif* (10.35). Number of seeds (cm) differs significantly among different eight seed invigoration treatments.The treatment T_6 (Priming with 1% $ZnSO_4$) recorded highest number of seeds (12.23) followed by T_4 (Priming with 0.5 % KNO_3) and T_3 (Priming with 2% KH_2PO_4) (11.88 and 11.93, respectively) while lowest number of seedsper podwas recorded in control (8.08).

Priming helps in improving yield contributing factors like number of pods, pod length results in increased number of seeds per pod. The similar results are in line with Golezani*et al.* (2011) in soybean.

3.2.4 Seed yield per plot (g)

The seasons showed significant difference in seed yield per plot. Among two seasons, summerrecorded highest seed yield (219.96 g) and lowest was recorded in *kharif* (173.97 g). Seed yield per plot differs significantly among different eight seed invigoration treatments. The treatment T_6 (Priming with Priming with 1% $ZnSO_4$) recorded highest seed yield (kg) (268.34 g) followed by T_2 (Priming with 1% $MgSO_4$) and T_3 (Priming with 2% KH_2PO_4) (223.17 g and 216.48 g, respectively) while, the lowest seed yield was recorded in control (132.70 g).

Yield on priming might be due to modulation of enzymes of sucrose metabolism in actively growing plant parts, the pod wall and the seeds during development (Kaur*et al.*, 2005) in chickpea.

Higher seed yield of summergreengram crop was associated with high net assimilation ratio, thus permitting higher seed growth rate and better performance throughout its growth and improved yield contributing factors. Favourable climatic conditions during the summerhave resulted in higher dry matter and seed yield compared to the *kharif* (Umair*et al.*, 2011). Lower yield in *kharif* may be due to the fact that *kharif* crop had to be harvested under low humidity, low temperature and water stress condition resulting in poor seed filling and resulting in more dead seed. Among seasons studied in present work, Summer shown highest seed yield.

3.2.5 Seed yield per hectare (q)

The seasons showed significant difference in seed yield per ha. Among two seasons, summerrecorded highest seed yield (3.49 q) and lowest was recorded in *kharif* (2.76 q). Seed yield differs significantly among different seed invigoration treatments. The treatment T_4 (Priming with 0.5 % KNO_3) recorded highest yield (4.26 q) followed by T_2 (Priming with 1 % $MgSO_4$) T_3 (Priming with 2% KH_2PO_4) (3.54 q and 3.44 q, respectively) while lowest was recorded in control (2.11 q).

The least yield was recorded under control might be due to lack of adequate supply of nutrients and activation of different metabolic pathways to enhance in growth and yield components of the crop ultimately reflecting on yield parameters. The highest seed yield was documented when mungbean seeds were primed with micro nutrients in present work and results are in line with the findings of Umair*et al.* (2011) and Haider*et al.* (2020).

3.2.6 Seed recovery (%)

The seasons showed significant difference in seed recovery. Among two seasons, summerrecorded highest seed recovery (96.7 %) and lowest was recorded in *kharif* (94.8 %). Seed recovery differs significantly among different eight seed invigoration treatments. The treatment T_6 (Priming with 1% $ZnSO_4$) recorded highest seed recovery (97.10 %) followed by T_4 (Priming with 0.5 % KNO_3) and T_3 (Priming with 2% KH_2PO_4) (96.2 % and 96.8 %, respectively) while lowest seed recovery was recorded in control (91.1 %).

Seed priming resulted in rapid seed filling, increased activities of synthase pathways. The higher requirement of assimilate at seed filling might have been resulted in more efficient conversion of sugars by activation of metabolic pathways and higher sink strength leads to higher seed production also reduce the losses of improper filling of seeds, which helps to increase recovery percentage of seeds (Kaur*et al.,* 2005).

3.3 Seed quality parameters

3.3.1 Hundred seed weight (g)

Kharif and summer seasons showed significant difference in hundred seed weight. Among two seasons, summerrecorded highest 100 seed weight (3.91 g) and lowest was recorded in *kharif* (3.02 g). Hundred seed weight differ significantly among different eight seed invigoration treatments. The treatment T_6 (Priming with 1% $ZnSO_4$) recorded highest 100 seed weight (3.78 g) followed by T_4 (Priming with 0.5 % KNO_3) and T_7 (Priming with 1 % KCl) (3.59 and 3.55 g, respectively) while lowest 100 seed weight was recorded in control (2.89 g).

Reduction in the 100 seed weight in *kharif* could be due to insufficient seed filling affected by increased respiration and lower photosynthesis, slower growth rate. Present work on pre-sowing seed treatment cause an increase in seed weight which also confirmed with red gram and greengram (Jayaseelan, 1997).

3.3.2 Speed of germination

The seasons showed significant difference in speed of germination.Among two seasons, summerrecorded highest speed of germination(22.25) and lowest was recorded in *kharif* (21.54). Speed of germinationdiffer significantly among different eight seed invigoration treatments. The treatment T_6 (Priming with 1% $ZnSO_4$) recorded highest speed of emergence(24.83) followed by T_4 (Priming with 0.5 % KNO_3) and T_3 (Priming with 2% KH_2PO_4) (23.17 and 22.67 respectively) while lowest speed of emergencewas recorded in control (17.50).

Early germination and increase in speed of germination may be due to the role of micro nutrients as enzyme cofactor in germination process by increase in protein synthesis for germination and also the greater hydration of colloids, higher viscosity of protoplasm, increase in the cell wall elasticity and cell membrane that allows the early entry of moisture, which can activates the early phase of hydrolyzing the reserve food material by triggering the enzymes to activate the GA_3 in the seed which helps for faster germination.

Present work on speed of germination was also similarity with Kamaraj and Padmavathi (2017), Sharma *et al.* (2017), Elankavi*et al.* (2019), Subapriya and Geetha (2019) and Kamraj*et al*. (2020).

3.3.3 Hard seed (%)

The seasons showed significant difference in hard seeds. Among two seasons summerrecorded least hard seeds (71.71 %) and highest was recorded in *kharif* (73.04%). Hard seeds differ significantly among different eight seed invigoration treatments. The treatment T_6 (Priming with 1% $ZnSO_4$) recorded least hard seeds (68.67 %) followed by T_4 (Priming with 0.5 % KNO_3) and T_3 (Priming with 2% KH_2PO_4) (70.83 and 71.67 %, respectively) while highest hard seeds recorded in control (77.67 %).

High temperature during mungbean seed maturity could have accelerated the seed development process resulting in impaired seed coat development. At high temperature and moisture, there may be a decrease in lignin content in the seed coat which in turn facilitated the capacity and velocity of water absorption through the seed coat. Under low or mild temperature situation it failed to break the physical dormancy resulting in higher occurrence of hard seeds (Paul *et al.*, 2019 and Devi *et al.*, 2019).

3.3.4 Seed germination (%)

The seasons showed significant difference in seed germination. Among two seasons, summerrecorded highest germination (91.70 %) and lowest was recorded in *kharif* (89.00 %).Seed germination differs significantly among different eight seed invigoration treatments. The treatment T_6 (Priming with 1% $ZnSO_4$) recorded highest seed germination (94.70 %) followed by T_4 (Priming with 0.5 % KNO_3) and T_3 (Priming with 2% KH_2PO_4) (92.20 % and 92.00 %, respectively) while lowest seed germination was recorded in control (83.80 %).

Metabolic processes occurs to prepare seeds for germination and elongation of embryonic axes, where the enzymes *viz.*, amylase, ribonuclease and phosphatase are synthesized by the influence of GA and increase the effectiveness of hydrolytic enzymes such as ATP ase, protease, lipase and peroxidase. In addition to transfer of nutrients from storage tissues to the growth sites of the seed and stimulation the chemical reactions to synthetic new substances (Al-Salhy and Rasheed, 2020).

Priming with $ZnSO_4$ considered advantageous because it brought an advancement of reactions in the cell and leads to higher germination. Repairing of cell organelles and biochemical activities boost up inside the embryo/seed. Faster biochemical actions rapidly synthesize metabolites responsible for germination and quick restoring of cell components at the time of seed priming encourages speedy germination (Sharma *et al.*, 2021). Seed germination controlled by many factors by altering seed surface structure, enhancing water uptake rate, breakdown of endosperm food through higher hydrolytic enzyme activity, oxidative stress during priming process which accelerate overall development of seedlings.

The superiority of soaking seeds with KH_2PO_4 could be due to increasing in the seed phosphorus content which leads to faster growth. Further, activation of phosphorus also increases the activity of enzymes such as amylase, protease and lipase which leads to early development of the embryo and accelerate germination (Al-Salhy and Rasheed, 2021). The ability of KH_2PO_4 to penetrate the seed coat and accumulation inside the seed during activation process.

Higher germination in $ZnSO_4$ primed seeds could be due to greater hydration of colloids, higher viscosity and elasticity of protoplasm, increase inbound water content, lower water deficit, more efficient root system and increased metabolic activity. The increased seedling growth and vigor index might due to greater early vigor and a higher percentage of germination. Similar results were reported in Kamaraj and Padmavathi (2017) and Kavitha and Srimathi (2020).

3.3.5 Shoot length (cm)

The seasons showed significant difference in shoot length. Where, summerrecorded highest shoot length (24.33 cm) and lowest was recorded in *kharif* (22.91 cm). Shoot length (cm) differ significantly among different eight seed invigoration treatments. The treatment T_6 (Priming with 1% $ZnSO_4$) recorded highest shoot length (25.93 cm)followed by T_4 (Priming with 0.5 % KNO_3) and T_3 (Priming with 2% KH_2PO_4) (24.98 and 24.69 cm, respectively) while lowest shoot length was recorded in control (19.50 cm).

The increase in shoot length also due to its stimulation effect in the formation of enzymes which are important in the early phase of germination which helps for a fast radical protrusion and shoot growth in the crops. Similar results were reported by Gomathi*et al.* (2014).

3.3.6 Root length (cm)

The seasons showed significant difference in root length. Among seasons, summerrecorded highest root length (12.62 cm) and lowest was recorded in *kharif*(12.06 cm). Root length (cm) differ significantly among different eight seed invigoration treatments. The treatment T_6 (Priming with 1% $ZnSO_4$) recorded highest root length (14.51 cm) followed by T_4 (Priming with 0.5 % KNO_3) and T_3 (Priming with 2% KH_2PO_4) (13.11 and 12.99 cm, respectively) while lowest root length was recorded in control (10.52 cm).

Increased root length and root dry weight due to $ZnSO_4$ seed priming in this study might be attributed to the fact that zinc is required for stimulation of several metabolic enzymes in the roots. Similar results were also reported by Demir and Oztokat (2003), Golezani*et al*, (2011), Gomathi*et al.* (2014), Shojaei and Makarian (2015), Kavitha and Srimathi (2020).

3.3.7 Mean seedling length (cm)

The seasons showed significant differences in mean seedling length. Among two seasons, summerrecorded highest mean seedling length (36.95 cm) and lowest was recorded in *kharif* (34.97 cm). Mean seedling length (cm) differ significantly among different eight seed invigoration treatments. The treatment T_6 (Priming with 1% $ZnSO_4$) recorded highest seedling length (40.44 cm) followed by T_4 (Priming with 0.5 % KNO_3) and T_3 (Priming with 2% KH_2PO_4) (38.08 and 37.69 cm, respectively) while lowest seedling length was recorded in control (30.02 cm).

Seedling growth might be attributed to the involvement of zinc in photosynthesis, cell division, protein synthesis, retaining membrane structure and providing the resistance against pathogen. Increase in seedling length could be ascribed to activity of hydrolytic enzymes during the early phase of germination. The effective mobilization of the available food reserves in the seeds resulted in the early emergence and growth of the seedlings. In proportion to increase in seedling growth, dry matter production was also increased. Similar results on seedling growth were also reported by Kavita and Srimathi (2020).

3.3.8 Mean seedling dry weight (mg)

The seasons showed significant difference in seedling dry weight. Among two seasons, summerrecorded highest mean seedling dry weight (245 mg) and lowest was recorded in *kharif* (236 mg**)**.Meanseedling dry weight differ significantly among different seed invigoration treatments. The treatment T_6 (Priming with 1% $ZnSO_4$) recorded highest seedling dry weight (278 mg) followed by T_4 (Priming with 0.5 % KNO_3) and T_3 (Priming with 2% KH_2PO_4) (260 and 255 mg, respectively) while lowest seedling dry weight was recorded in control (203 mg).

Increase in mean seedling dry weight with enhancement of lipid utilization and enzyme activity also due to the presence of bioactive substances, which results in early vigour and higher germination percentage thus enabling them to produce relatively more quantity of dry matter which discerning the cause for the hike in dry matter production by priming treatment (Gomathi*et al.*, 2014).

3.3.9 Seedling vigor index-I

The seasons showed significant difference in seedling vigour index-I.Among two seasons, summerrecorded highest seedling vigour index-I(3392) and lowest was recorded in *kharif* (3126). Seedling vigour index-Idiffer significantly among different eight seed invigoration treatments. The treatment T_6 (Priming with 1% $ZnSO_4$) recorded highest seedling vigour index-I(3829) followed by T_4 (Priming with 0.5 % KNO_3) and T_3 (Priming with 2% KH_2PO_4) (3529 and 3468, respectively) while lowest seedling vigour index-Iwas recorded in control (2532).

This increase in vigour index might be due to the beneficial effect of seed priming which induces the faster growth promoting substances and translocations of secondary metabolites to increase the mean seedling growth by which vigour index increased (Sibande*et al.* (2015), Kavitha and Srimathi (2020).

3.3.10 Seedling vigor index-II

The seasons showed significant difference in seedling vigour index-II.Among two seasons, summerrecorded highest seedling vigour index-II(2252) and lowest was recorded in *kharif* (2110). Seedling vigour index-IIweight differ significantly among different eight seed invigoration treatments. The treatment T_6 (Priming with 1% $ZnSO_4$) recorded highest seedling vigour index-II(2636) followed by T_4 (Priming with 0.5 % KNO_3) and T_3 (Priming with 2% KH_2PO_4) (2410 and 2347, respectively) while lowest seedling vigour index-IIwas recorded in control (1706).

Ability of physiologically active substances might have activated the embryo and other associated structures which results in absorption of more water due to cell wall elasticity and development of stronger and efficient root system which help in increasing vigour index (Khairul*et al.*, 2015, Kavitha and Srimathi, 2020).

3.3.11 Electrical conductivity (dSm^{-1})

The seasons showed significant difference in electrical conductivity.Among two seasons, summerrecorded least electrical conductivity (0.287 dSm^{-1})and highest was recorded in *kharif* (0.308 dSm^{-1}). Electrical conductivity differ significantly among different eight seed invigoration treatments. The treatment T_6 (Priming with 1% $ZnSO_4$) recorded least electrical conductivity (dSm^{-1})(0.249 dSm^{-1}) followed by T_4 (Priming with 0.5 % KNO_3) and T_3 (Priming with 2% KH_2PO_4) (0.258 dSm^{-1} and 0.260 dSm^{-1}, respectively) while highest electrical conductivity (dSm^{-1})was recorded in control (0.443 dSm^{-1}).

Conductivity of leachates will reflect the vigour of seed. Where membrane integrity more leakage of solutes are less and it indicates that high vigour seed. This might be due to there is strong correlation between conductivity of seed leachates and membrane integrity. Similar results were also reported by Ranganayaki and Rammorty (2015), Gangaraju and Balakrishna (2016) in blackgram which helps to improve seed quality.

3.3.12 Total dehydrogenase activity (A_{480nm})

The seasons showed significant difference in total dehydrogenase activity.Among two seasons, summerrecorded highest dehydrogenase activity (1.638) and lowest was recorded in *kharif* (1.527).Total dehydrogenase activity weight differ significantly among different eight seed invigoration treatments. The treatment T_6 (Priming with 1% $ZnSO_4$) recorded highest dehydrogenase activity (1.825) followed by T_4 (Priming with 0.5 % KNO_3) and T_3 (Priming with 2% KH_2PO_4) (1.785 and 1.693, respectively) while lowest dehydrogenase activitywas recorded in control (1.249).

Priming the seeds with micro nutrients increases the viability of seeds by activating various metabolic activities in seeds which triggers/improves the viability of seeds leads to high dehydrogenase activity (Ranganayaki and Rammorty (2015) in blackgram).

Table. 1 Influence of invigoration techniques on growth, seed yield and quality parameters in green gram during *kharif* and *summer* seasons

	Field emergence (%)	Plant Ht @ 30 DAS (cm)	Plant Ht @ 60 DAS (cm)	No. of nodules/pt	No. of clusters/Pt	Pant Population at harvest	No. of pods/pt	Seed yield/plot (Kg)	Graded yield(Q/ha)	Seed recovery (%)	Pod yield/pt (gm)	Pod length (cm)	No. of seeds/pod
Seasons (S)													
S_1	91.75	14.38	29.95	35.71	6.36	87.75	13.37	0.220	3.49	96.7	9.45	9.44	11.18
S_2	89.79	13.16	28.92	33.04	5.37	84.25	12.14	0.174	2.76	94.8	8.51	8.42	10.35
Mean	90.77	13.77	29.43	34.38	5.86	86.00	12.75	0.20	3.13	95.78	8.98	8.93	10.77
SEm±	0.49	0.32	0.30	0.88	0.18	0.91	0.31	0.007	0.11	0.4	0.31	0.13	0.21
CD (P=0.05)	1.42	0.93	0.88	2.55	0.52	2.63	0.88	0.020	0.32	1.2	0.88	0.39	0.60
Treatments (T)													
T_1	87.33	10.53	26.80	28.00	5.95	83.00	11.37	0.174	2.75	95.9	7.81	8.37	9.63
T_2	90.17	13.53	29.73	34.67	5.03	86.17	12.17	0.223	3.54	96.7	8.92	8.67	11.53
T_3	93.00	16.10	31.93	37.33	6.45	89.17	13.37	0.216	3.44	96.8	9.55	9.90	11.93
T_4	93.83	16.93	31.50	37.67	6.83	89.00	13.77	0.268	4.26	96.2	10.15	10.05	11.88
T_5	90.00	13.73	29.40	36.33	6.32	86.00	12.87	0.198	3.14	96.3	9.40	9.20	11.30
T_6	96.50	18.17	32.37	38.50	7.17	91.17	16.43	0.211	3.35	97.1	10.48	11.00	12.23
T_7	89.83	11.30	27.53	34.83	4.43	84.33	11.97	0.153	2.42	96.3	8.53	7.97	9.55
T_8	85.50	9.87	26.20	27.67	4.73	79.17	10.10	0.133	2.11	91.0	7.03	6.27	8.08
Mean	90.77	13.77	29.43	34.38	5.86	86.00	12.75	0.20	3.13	95.78	8.98	8.93	10.77
SEm±	0.99	0.64	0.61	1.77	0.36	1.82	0.61	0.014	0.22	0.8	0.61	0.27	0.42
CD (P=0.05)	2.85	1.86	1.76	5.10	1.04	5.25	1.77	0.041	0.64	2.4	1.76	0.78	1.21
Interaction (SXT)													
S_1T_1	89.33	10.40	26.40	30.00	5.57	84.67	12.07	0.184	2.92	96.5	8.06	9.40	10.60

S_1T_2	91.67	15.20	31.37	35.00	6.33	87.67	12.80	0.255	4.05	97.5	9.80	8.80	11.80
S_1T_3	93.33	16.47	32.60	38.00	7.23	89.33	13.40	0.235	3.72	97.5	10.29	9.40	12.07
S_1T_4	94.33	17.13	31.07	39.67	6.87	91.33	13.87	0.273	4.33	97.6	10.34	10.43	12.17
S_1T_5	91.33	16.13	31.67	37.33	6.57	87.33	13.00	0.260	4.13	97.2	9.41	9.67	11.47
S_1T_6	96.67	18.53	32.77	40.33	7.33	94.00	16.93	0.256	4.06	97.7	10.83	11.27	12.40
S_1T_7	90.33	11.33	27.40	36.33	5.20	86.33	13.40	0.163	2.58	97.0	8.96	8.73	9.50
S_1T_8	87.00	9.87	26.30	29.00	5.80	81.33	11.47	0.134	2.13	92.8	7.91	7.80	9.47
S_2T_1	85.33	10.67	27.20	26.00	6.33	81.33	10.67	0.163	2.59	95.3	7.55	7.33	8.67
S_2T_2	88.67	11.87	28.10	34.33	3.73	84.67	11.53	0.191	3.03	95.9	8.03	8.53	11.27
S_2T_3	92.67	15.73	31.27	36.67	5.67	89.00	13.33	0.198	3.15	96.0	8.81	10.40	11.80
S_2T_4	93.33	16.73	31.93	35.67	6.80	86.67	13.67	0.264	4.18	94.9	9.96	9.67	11.60
S_2T_5	88.67	11.33	27.13	35.33	6.07	84.67	12.73	0.136	2.16	95.3	9.39	8.73	11.13
S_2T_6	96.33	17.80	31.97	36.67	7.00	88.33	15.93	0.166	2.63	96.6	10.13	10.73	12.07
S_2T_7	89.33	11.27	27.67	33.33	3.67	82.33	10.53	0.142	2.26	95.5	8.09	7.20	9.60
S_2T_8	84.00	9.87	26.10	26.33	3.67	77.00	8.73	0.131	2.08	89.1	6.15	4.73	6.70
Mean	90.77	13.77	29.43	34.38	5.86	86.00	12.75	0.20	3.13	95.78	8.98	8.93	10.77
SEm±	1.39	0.91	0.86	2.50	0.51	2.57	0.87	0.020	0.32	1.2	0.86	0.38	0.59
CD (P=0.05)	4.03	2.63	2.49	7.21	1.46	7.43	2.50	0.057	0.91	3.4	2.49	1.10	1.71
CV (%)	2.66	11.44	5.08	12.58	14.98	5.18	11.76	17.490	17.49	2.1	16.64	7.38	9.50

Seasons:

S_1: Summer, 2021	S_2: *Kharif*, 2021

Treatments:

T_1: Hydro priming	T_2: Priming with 1 % $MgSO_4$
T_3: Priming with 2% KH_2PO_4	T_4: Priming with 0.5 % KNO_3
T_5: Priming with 2% $CaCl_2$	T_6: Priming with 1% $ZnSO_4$
T_7: Priming with 1% KCl	T_8: Control

Table. 2 Influence of invigoration techniques on growth, seed yield and quality parameters in green gram during *kharif* and *summer* seasons

	100 seed weight (g)	Germination (%)	Hard seeds (%)	Speed of emergence	Shoot length (cm)	Root length (cm)	MSL (cm)	SDW (mg)	SVI-I	SVI-II	EC (dSm^{-1})	TDH (A$_{480nm}$)
Seasons (S)												
S_1	3.91	91.7	71.71	22.25	24.33	12.62	36.95	245	3392	2252	287.10	1.638
S_2	3.02	89.0	73.04	21.54	22.91	12.06	34.97	236	3126	2110	308.60	1.527
Mean	3.46	90.3	72.38	21.90	23.62	12.34	35.96	241	3259	2181	297.85	1.58
SEm±	0.05	0.33	0.24	0.22	0.33	0.08	0.34	1.54	31.70	17.30	2.73	0.006
CD (P=0.05)	0.15	0.96	0.68	0.64	0.94	0.24	1.00	4.45	91.57	49.97	7.89	0.019
Treatments (T)												
T_1	3.41	88.2	73.50	22.00	22.69	11.44	34.13	215	3010	1896	350.78	1.402
T_2	3.47	91.3	71.67	22.00	23.88	11.80	35.68	247	3260	2255	263.93	1.624
T_3	3.53	92.0	71.67	22.67	24.69	12.99	37.69	255	3468	2347	260.75	1.693
T_4	3.59	92.7	70.83	23.17	24.98	13.11	38.08	260	3529	2410	258.07	1.785
T_5	3.50	90.8	72.33	22.00	24.37	12.68	37.05	243	3364	2212	267.23	1.569
T_6	3.78	94.7	68.67	24.83	25.93	14.51	40.44	278	3829	2636	249.53	1.825
T_7	3.55	89.0	72.67	21.00	22.89	11.71	34.60	223	3080	1988	288.82	1.514
T_8	2.89	83.8	77.67	17.50	19.50	10.52	30.02	203	2532	1706	443.68	1.249
Mean	3.46	90.31	72.38	21.90	23.62	12.34	35.96	241	3258.99	2180.90	297.85	1.58
SEm±	0.10	0.66	0.47	0.45	0.65	0.17	0.69	3.08	63.41	34.60	5.46	0.013
CD (P=0.05)	0.30	1.92	1.36	1.29	1.88	0.48	1.99	8.91	183.14	99.94	15.77	0.037
Interaction (SXT)												
S_1T_1	3.80	89.0	72.67	22.00	23.36	11.52	34.87	210	3104	1869	355.57	1.452
S_1T_2	3.85	92.7	72.00	21.33	24.25	11.83	36.08	257	3344	2378	251.10	1.637

S_1T_3	4.03	93.0	71.67	22.33	25.06	13.35	38.41	263	3572	2449	246.40	1.740
S_1T_4	3.96	93.7	70.33	22.67	25.24	13.39	38.63	267	3618	2497	244.40	1.852
S_1T_5	3.92	92.0	72.33	22.00	24.51	12.86	37.37	253	3435	2331	252.17	1.647
S_1T_6	4.21	95.7	66.67	24.33	26.15	15.01	41.16	280	3938	2679	234.57	1.883
S_1T_7	3.85	89.7	71.33	22.00	23.39	11.71	35.10	223	3147	2002	255.03	1.562
S_1T_8	3.71	87.7	76.67	21.33	22.64	11.33	33.97	207	2979	1812	457.53	1.328
S_2T_1	3.03	87.3	74.33	22.00	22.03	11.35	33.38	220	2915	1922	346.00	1.352
S_2T_2	3.10	90.0	71.33	22.67	23.51	11.76	35.27	237	3175	2131	276.77	1.610
S_2T_3	3.04	91.0	71.67	23.00	24.33	12.64	36.97	247	3363	2245	275.10	1.647
S_2T_4	3.22	91.7	71.33	23.67	24.72	12.82	37.54	253	3441	2322	271.73	1.718
S_2T_5	3.08	89.7	72.33	22.00	24.23	12.49	36.72	233	3294	2093	282.30	1.490
S_2T_6	3.35	93.7	70.67	25.33	25.70	14.01	39.71	277	3721	2592	264.50	1.767
S_2T_7	3.24	88.3	74.00	20.00	22.39	11.72	34.11	223	3013	1973	322.60	1.465
S_2T_8	2.07	80.0	78.67	13.67	16.36	9.71	26.07	200	2086	1600	429.83	1.169
Mean	3.46	90.31	72.38	21.90	23.62	12.34	35.96	241	3258.99	2180.90	297.85	1.58
SEm±	0.15	0.94	0.67	0.63	0.92	0.23	0.98	4.36	89.67	48.94	7.72	0.018
CD (P=0.05)	0.43	2.71	1.92	1.82	2.66	0.68	2.82	12.60	258.99	141.34	22.31	0.052
CV (%)	7.38	1.80	1.59	4.99	6.76	3.29	4.70	3.14	4.77	3.89	4.49	1.989

Seasons:

S_1: Summer, 2021

S_2: *Kharif*, 2021

Treatments:

T_1: Hydro priming

T_2: Priming with 1 % $MgSO_4$

T_3: Priming with 2% KH_2PO_4

T_4: Priming with 0.5 % KNO_3

T_5: Priming with 2% $CaCl_2$

T_6: Priming with 1% $ZnSO_4$

T_7: Priming with 1% KCl

T_8: Control

CONCLUSION & RECOMMENDATIONS:

Seed invigoration treatments are becoming a promising tool to improve seed performance during germination and early seedling growth, which helps farmers improve their seed yields. To overcome adverse environmental conditions that prevent seed germination and seedling establishment, seed priming is given as a presowing seed treatment, which acts as a boon to farmers in dryland agriculture. From the current investigation, it was identified that, among the seasons studied, summer recorded the best growth and yield parameters (plant height, seed yield per plot, seed yield, etc.), in seed quality parameters (seed germination, total dehydrogenase activity, etc. In this connection, it is recommended to go for the summer season to get better results during seed production.

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