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Influence of Seed Invigoration Methods on Seed Quality and Establishment of Turfgrass

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A B S T R A C T

Bermuda grass is wear-tear resistant and drought tolerant among other warm season grasses with an excellent restorative capacity makes it popular grass for railway batters erosion control, pasture establishment and outdoor sports.A Laboratory and polyhouse study was undertaken to know the effect of seed invigoration methods on turfgrass seed quality and establishment at AICRP on Seed (Crops), UAS, GKVK, Bengaluru during the year 2021-22.The experiment consists of 19 different invigoration treatments laid out in CRD design with three replications. The results revealed that among the treatments, highest seed germination (26.0 %) and lowest mean germination time (5.64 days) was recorded in KNO_3 0.2% for 2 days (T_5) whereas, matrix priming with vermiculite (1:10) recorded maximum seedling emergence (99%) and speed of emergence (16.97). The higher mean seedling length (18.29 cm), mean seedling dry weight (28.00 mg), SVI-I (1683) and SVI-II (2576) was recorded significantly in GA_3 @ 50µM, followed by KNO_3 @ 0.2% for 2 days and lowest values were recorded in NaOH @ 4% and cocopeat (1:10). However, priming with NaOCl @ 4% recorded highest plant height (27.27 cm), fresh weight (0.642 g) and dry weight (0.315 g) at 60 DAS. Therefore, priming with these treatments helps in uniform growth and establishment which can be used commercially for better quality turf spread.

Keywords

Bermuda grass, priming, quality, establishment

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Introduction

Turf is one of the blessings of nature and includes both service and beauty, which provide functional, recreational and aesthetic benefits. The turfgrass industry has undergone rapid growth in its attempts to meet the public's increasing demands for products and services (Turgeon, 2002). Indian turfgrass industry is growing around 10 per cent annually. Landscape business contributes 2-3 per cent of total construction and turf has 50 per cent of landscape business. Golf courses are the heartbeat of turfgrass industry worldwide and comprises of 40% of total turfgrass, chemicals and services use. For the development of lawn/turf in Indian conditions, the choice of grasses that are available is limited and therefore very often Bermuda grass and its variants are used in making lawn/turf. Bermuda grass (*Cynodon dactylon*) also known as Bahama grass, devil's grass, couch grass, Indian doab. It is mostly found worldwide in tropical and subtropical climates. This is species comparatively drought resistant and hardy on account of its suitability for dry climate conditions and due to its deep root system (Brosnan and Deputy, 2007). Bermuda grass is wear-tear resistant and drought tolerant among other warm season grasses with an excellent restorative capacity (Turgeon, 2005; Keeley and Fagerness, 2001). The ability to become semi-dormant during severe drought and to recover from rhizomes and stolons, with average of water makes bermuda grass a preferred choice (Duble, 1996).

The use of grass for railway batter erosion control becomes a major concern where the development of good grass cover within a short time is required to minimize the risk of damage from storms. For good quality pasture establishment, besides adequate management, it is important to use seeds with high germination and vigour (Cardoso *et al.,* 2015). The sowing of turfgrass seeds that have been primed or preplant germinated (pregerminated) shortens the establishment period which may be advantageous under heavy traffic conditions such as athletic fields or where cosmetic repairs are needed urgently, where competition from weeds is expected, where a slow germinating component of a seed mixture is expensive or in low proportion, or under adverse germination conditions. Seed priming is a controlled-hydration treatment in which seeds are exposed to an external water potential sufficiently low to prevent radical protrusion, and yet stimulate physiological and biochemical activities. Hardegree (1994) noted that increased germination rate at low temperature was the main effect of priming seven native perennial bunch grasses. Osmotic priming of perennial ryegrass (*Lolium perenne L.*) seeds in PEG 8000 (- 1.1 MPa for 48 hours at 22°C) gave a short-lived advancement of germination at 25/15°C and longer gemination advancement at 5 to 15°C (Danneberger *et al.,* 1992). Matrix priming of five grass species (including *Poa pratensis*) increased seedling emergence rate but not germination percentage at 25/15°C.

Since the effect of seed priming on germination and seedling performance of bermuda grass is poorly documented, this research was aimed to investigate the effects of seed invigouration methods on seedling establishment and growth of this crop in the controlled conditions.

Material and Methods

The present investigation was carried out under both laboratory and polyhouse conditions at Seed Technology Research Unit, AICRP on Seed (Crops), UAS, GKVK, Bengaluru. Seeds of Bermuda hybrid grass were collected from The Ministers Seeds Corporation, Hospete, Karnataka.

Details of experiment

Crop: Bermuda hybrid grass
Design: CRD
Replication: 3
Treatments: 19

Table.1 Details of seed priming treatments imposed in the experiment

Treatment Details	
T_1	Control
T_2	Hydropriming (distilled water) 2 days
T_3	Osmopriming with PEG 8000 (-1.5 MPa) for 2 days
T_4	Osmopriming with PEG 8000 (-1.5 MPa) for 4 days
T_5	Priming with KNO_3 (0.2%) for 2 days
T_6	Priming with KNO_3 (0.2%) for 4 days
T_7	Priming with GA_3 (50µM)for 24 hours
T_8	Priming with H_2SO_4 (8M) for 10 minutes
T_9	Priming with NaCl (50mM)for 24 hours
T_{10}	Priming with KH_2PO_4 (0.1%) for 24 hours
T_{11}	Priming with NaOCl (4%) for 60 minutes
T_{12}	Priming with NaOH (4%) for 60 minutes
T_{13}	Osmopriming with $CaCl_2$ (1%) for 24 hours
T_{14}	Priming with cow urine (30%) for 6 hours
T_{15}	Priming with vermiwash (30%) for 6 hours
T_{16}	Priming with humic acid (2%, 20°C, 2hr)
T_{17}	Matrix priming with cocopeat (1:10) for 2days
T_{18}	Matrix priming with vermiculite (1:10) for 2 days
T_{19}	Priming with *Azospirullum* (10g/kg of seed).

For solid matrix priming, 100 seeds were mixed with 0.5

g of cocopeat and 0.5 g of vermiculite separately to which 10 ml of distilled water was added to each. The solid carriers and seeds were mixed thoroughly, sealed in a falcon tube and kept for 2 days at 30°C. After this period, seeds were sieved out and allowed for air dried at room temperature to reach to the original seed moisture content.

Observations recorded

Observations on seed germination (%) were recorded on the 21st day after incubation using the top of paper method (ISTA, 2013). Seedling emergence (%) was recorded daily up to 21 DAS under polyhouse conditions and used for calculating speed of emergence (Maguire, 1962) and mean emergence time (Ellis and Roberts, 1981). Seedling length and seedling dry weight were measured from ten normal seedlings after completion of the germination test (Anon., 2010; Anon., 1996).

Seedling vigour index-I and II were calculated using germination percentage, seedling length and dry weight (Abdul-Baki and Anderson, 1973). Plant height, number of leaves and stem thickness were recorded at 30 and 60 DAS, while fresh weight and dry weight were recorded at 60 DAS.

The experimental data collected on different parameters were subjected to the analysis of variance (ANOVA) by adopting the appropriate methods outlined by Sundararaj *et al.,* (1972). The critical differences were calculated at five per cent level of probability wherever 'F' test was found significant for various parameters under the study.

Results and Discussion

The data obtained from the experiment indicated that significant variations among the invigoration treatments for seed quality and seedling performance parameters (Table 2, 3 and 4). Variation in seedling emergence percentage among the invigoration treatments is shown in the Fig. 1.

Seed germination (%)

The highest seed germination (26.0%) was recorded in seeds treated with KNO_3 0.2% for 2 days (T_5), followed by 16.0 per cent in GA_3 50µM (T_7) whereas, the lowest germination (2.0 %) was recorded in treatments control (T_1), NaOH 4% (T_{12}) and cocopeat (T_{17}) (Table 2). The retardation in germination of both treated and by the untreated seed in the petri dishes kept in growth chamber may be due to some inherent condition of the seed coat which at room temperature hinders the exchange of gases involved in the process of respiration. Bermuda grass does not germinate well in constant temperatures, but it responds well to alternation of temperatures, especially when there is a relatively wide range between the two temperatures used in the daily alternations. The use of alternating temperatures to increase the germination of grass seeds was studied by Harrington (1923) and reported that, for germination of bermuda grass seed, daily alternation of 20°C and 35°C (16 to 18 hours in the low and 6 to 8 hours in the high temperature) was best.

Seedling emergence (%)

Among the treatments, matrix priming with vermiculite 1:10 (T_{18}) recorded highest seedling emergence (99.0 %), followed by 94.0per cent in humic acid 2% (T_{16})and 93.0 per cent in NaOCl 4% (T_{11}).The lowest seedling emergence (64.33 %) in tray was noticed in priming with NaOH 4% (T_{12}) which was on par with 64.67 in cocopeat 1:10 (T_{17}) (Table 2). The increase in emergence of treated and by the untreated seed in soil as compared to growth chamber may be due to differences in the temperature of the germinating medium, natural stratification and scarification and reduced oxygen pressure that might have taken place in the field.

Matrix priming with vermiculite resulted in highest germination due to better soil water uptake and reduces aeration problem. These findings are in line with Pill and Korengel (1997) in Kentucky bluegrass seeds.

Speed of emergence

The highest speed of emergence (16.97) was recorded in seeds treated with vermiculite 1:10 (T_{18}), which was on par with 16.75 in seeds treated with NaCl 50mM (T_9) and 16.67 in seeds treated with KNO_3 0.2% for 2 days (T_5). Whereas, the NaOH 4% (T_{12}) has recorded the lowest speed of germination (8.56) which was significantly lower than other treatments (Table 2). The speed of emergence by vermiculite might be due to absorption of considerable water by seeds resulting in enhanced physiological activities and earlier activation of various metabolic enzymes.

These findings are on par with Pill and Korengel (1997) in Kentucky bluegrass seeds, Frett and Pill (1995) in fescue species.

Mean emergence time (days)

The lowest mean germination time (5.64 days) was recorded in seeds treated with KNO_3 0.2% for 2 days (T_5) which was on par with 5.72 in PEG 8000 (-1.5 MPa) for 2 days (T_3). Whereas, the control (T_1) has recorded the highest mean germination time (8.53 days)which was on par with 8.48 days in seeds treated with hydropriming (T_2) (Table 2). The probable reason for reduced mean germination time of the primed seed may be due to the completion of pregermination metabolic activities making the seed ready for radicle protrusion and the primed seed germinated soon after planting compared with control. Priming with KNO_3 significantly advanced the rate of germination of perennial ryegrass (*Lolium perenne* L.), browntop [*Agrostis capillaris* L. (Pers.)] and Kentucky bluegrass (*Poa pratensis* L.) (Lush and Birkenhead, 1987).

Mean seedling length (cm)

The highest mean seedling length (18.29 cm) was recorded in seeds treated with $GA_3$50µM (T_7), followed by 16.92 cm in seeds treated with KNO_3 0.2% for 2 days (T_5) whereas, the lowestmean seedling length (10.3 cm) was recorded in NaOH 4% (T_{12}) (Table 2).

The increase in seedling height with GA_3 treatment was because this hormone increased osmotic uptake of nutrients, causing increased cell division and multiplication. Similar results were reported by Nagar and Meena (2015) in Anjan grass.

Mean seedling dry weight (mg)

The highest mean seedling dry weight (28.00 mg) was recorded in seeds treated with GA_3 50µM (T_7), followed by 17.20 mg in seeds treated with vermiwash 30% (T_{15}) and lowest mean seedling dry weight (11.27 mg) was recorded in cocopeat 1:10 (T_{17}) (Table 3).

This might be due to the fact that GA_3 is known to pick up the water uptake of the growing seedlings which might have activated the enzymes with mobilization of reserve materials in the embryo and thus strong seedlings were achieved as a result of good embryo growth.

Seedling vigour index-I

The highest seedling vigour index-I (1683)was recorded in seeds treated with GA_3 50µM (T_7), followed by 1550in seeds treated with KNO_3 0.2% for 2 days (T_5) and 1406 in seeds treated with NaOCl 4% (T_{11}). Whereas, the NaOH 4% (T_{12}) has recorded the lowest seedling vigour index-I (662) (Table 3) which was significantly lower than other treatments.

The increase in seed vigour by GA_3 treatment possibly due to an increase in enzymatic activity on aleurone layer causing increasedstarch hydrolysis, which would have created extra supplies of reducing 151 sugars (Paleg, 1960), increase in amylase activity (Basra *et al.,* 1990), isocitrate, lyase and peroxidase activity and increase in protein synthesis and cell elongation in embryonic axis (Soliya *et al.,* 1991).

Seedling vigour index-II

The highest seedling vigour index-II (2576) was recorded in seeds treated with GA_3 50µM (T_7), followed by 1332in NaOCl 4% (T_{11}) which was on par with 1302 in KNO_3 0.2% for 2 days (T_5). Whereas, the cocopeat 1:10 (T_{17}) has recorded the lowest seedling vigour index-II (729) (Table 3) which was significantly lower than other treatments.The highest seedling vigour in GA_3 was attributed to enlarged embryos, higher rate of metabolic activity and respiration, better utilization and mobilization of metabolites to growing points and higher activity of enzymes. Enzymatic and hormonal mechanism stimulate metabolic process such as sugar mobilization, protein hydrolysis, oxidation *etc*. (Earlplus and Lambeth, 1974), which leads to increase in seedling dry weight which in turn increase in seedling vigour.

Plant height at 30 and 60 DAS

The highest plant height (9.92 cm)at 30 DAS was recorded in seeds treated with NaOCl4% (T_{11}), followed by 9.43 cm in KNO_3 0.2% for 2 days (T_5) whereas, the lowest plant height (7.48 cm) at 30 DAS was recorded in vermiwash 30% (T_{15}). After 60 days of sowing, the significantly maximum plant height (27.27 cm) was recorded in seeds treated with NaOCl 4% (T_{11}) which was on par with 26.27 cm in $CaCl_2$ 1% (T_{13}) (Table 3).

Whereas, the *Azospirullum* (T_{19}) has recorded the lowest plant height (16.43 cm) at 60 DAS. Increased plant height by primed seed is may be due to increased rate of cell division and cell elongation in the cambium tissue of the internodal region.

Table.2 Effect of seed invigoration methods on germination, seedling emergence, speed of emergence and mean emergence time in Bermuda hybrid grass

Treatments	Germination (%)	Seedling emergence (%)	Speed of emergence	Mean emergence time (days)	Mean seedling length (cm)
T_1	2 (8.13)	88 (69.74)	10.45	8.53	13.62
T_2	3 (9.36)	87 (69.16)	10.22	8.48	14.11
T_3	6 (14.18)	88 (69.86)	14.93	5.72	15.10
T_4	4 (11.54)	82 (65.31)	12.29	7.49	12.46
T_5	26 (30.66)	92 (73.23)	16.67	5.64	16.92
T_6	12 (20.27)	90 (71.89)	12.70	7.78	15.05
T_7	16 (23.58)	92 (73.59)	15.42	7.24	18.29
T_8	6 (14.18)	88 (69.46)	10.36	8.30	11.68
T_9	4 (11.54)	92 (74.49)	16.75	8.06	13.24
T_{10}	10 (18.43)	81 (64.45)	13.20	7.74	11.84
T_{11}	8 (16.43)	93 (75.81)	13.03	7.64	15.06
T_{12}	2 (8.13)	64 (53.34)	8.56	7.81	10.30
T_{13}	6 (14.18)	92 (73.31)	15.93	7.63	12.61
T_{14}	3 (9.97)	76 (60.77)	12.15	6.39	14.14
T_{15}	4 (11.54)	71 (57.24)	9.41	7.42	12.48
T_{16}	5 (12.46)	94 (76.84)	14.85	7.22	12.52
T_{17}	2 (8.13)	65 (53.53)	10.86	6.27	13.41
T_{18}	3 (10.40)	99 (85.38)	16.97	7.38	13.74
T_{19}	4 (11.02)	85 (67.22)	14.09	7.21	12.53
Mean	**6.60 (13.90)**	**85.23 (68.66)**	**13.10**	**7.34**	**13.64**
S.Em. ±	**0.20 (0.34)**	**2.13 (2.0)**	**0.28**	**0.17**	**0.23**
CD (P=0.05)	**0.58 (0.96)**	**6.09 (5.67)**	**0.81**	**0.48**	**0.66**
CV (%)	**5.31 (4.19)**	**4.33 (5.02)**	**3.75**	**3.98**	**2.95**

*Value in parenthesis are arc transformed values

Table.3 Effect of seed invigoration methods onmean seedlingdry weight, seedling vigour index-I, seedling vigour index-II and plant height in Bermuda hybrid grass

Treatments	Mean seedling dry weight (mg)	Seedling vigour index-I	Seedling vigour index-II	Plant height (cm)	
				30 DAS	60 DAS
T_1	13.57	1199	1194	8.03	22.30
T_2	14.27	1232	1246	8.88	23.57
T_3	14.43	1329	1270	7.73	22.60
T_4	12.73	1026	1048	8.35	18.23
T_5	14.20	1550	1302	9.43	25.73
T_6	12.27	1359	1108	9.16	23.50
T_7	28.00	1683	2576	9.23	24.97
T_8	11.77	1024	1032	9.28	24.77
T_9	13.87	1218	1275	9.18	23.23
T_{10}	11.97	960	973	7.77	22.50
T_{11}	14.27	1406	1332	9.92	27.27
T_{12}	12.83	662	825	8.92	23.37
T_{13}	13.03	1156	1194	9.05	26.27
T_{14}	12.33	1071	935	7.88	19.87
T_{15}	17.20	883	1213	7.48	17.80
T_{16}	12.07	1181	1138	8.91	20.83
T_{17}	11.27	867	729	8.03	17.13
T_{18}	12.83	1359	1270	9.13	22.30
T_{19}	13.50	1066	1148	7.98	16.43
Mean	**14.02**	**1170**	**1200**	**8.65**	**22.25**
S.Em. ±	**0.22**	**34.67**	**30.77**	**0.13**	**0.36**
CD (P=0.05)	**0.62**	**99.25**	**88.11**	**0.37**	**1.05**
CV (%)	**2.69**	**5.13**	**4.44**	**2.61**	**2.84**

Note: DAS: Days after sowing

Table.4 Effect of seed invigoration methods on number of leaves, stem thickness, fresh weight and dry weight of plant at 60 DAS in Bermuda hybrid grass

Treatments	Number of leaves		Stem thickness (mm)		Fresh weight at 60 DAS	Dry weight at 60 DAS	
	30 DAS	60 DAS	30 DAS	60 DAS			
T_{1}	4.79	7.57	0.46	0.73	0.324	0.116	
T_{2}	5.05	8.30	0.48	0.82	0.387	0.123	
T_{3}	4.70	6.38	0.46	0.81	0.393	0.125	
T_{4}	4.72	6.48	0.48	0.83	0.355	0.111	
T_{5}	5.15	8.13	0.50	0.84	0.429	0.159	
T_{6}	5.08	7.93	0.47	0.80	0.400	0.158	
T_{7}	5.19	8.93	0.52	0.90	0.396	0.137	
T_{8}	4.88	7.60	0.40	0.66	0.352	0.149	
T_{9}	5.15	8.11	0.48	0.77	0.434	0.145	
T_{10}	4.92	7.42	0.45	0.75	0.395	0.105	
T_{11}	5.15	8.40	0.50	0.81	0.642	0.315	
T_{12}	4.79	7.37	0.39	0.65	0.348	0.150	
T_{13}	5.00	8.07	0.46	0.75	0.341	0.155	
T_{14}	4.63	7.12	0.46	0.78	0.392	0.142	
T_{15}	4.61	6.18	0.49	0.82	0.279	0.085	
T_{16}	5.00	7.90	0.40	0.65	0.263	0.083	
T_{17}	4.63	7.13	0.42	0.69	0.266	0.084	
T_{18}	4.88	7.48	0.51	0.79	0.427	0.132	
T_{19}	4.88	7.80	0.39	0.64	0.186	0.052	
Mean	**4.90**	**7.60**	**0.46**	**0.76**	**0.369**	**0.133**	
S.Em. ±	**0.07**	**0.18**	**0.009**	**0.014**	**0.005**	**0.003**	
CD (P=0.05)	**0.20**	**0.52**	**0.025**	**0.041**	**0.015**	**0.007**	
CV (%)	**2.43**	**4.16**	**3.34**	**3.23**	**2.43**	**3.27**	

Note: DAS: Days after sowing

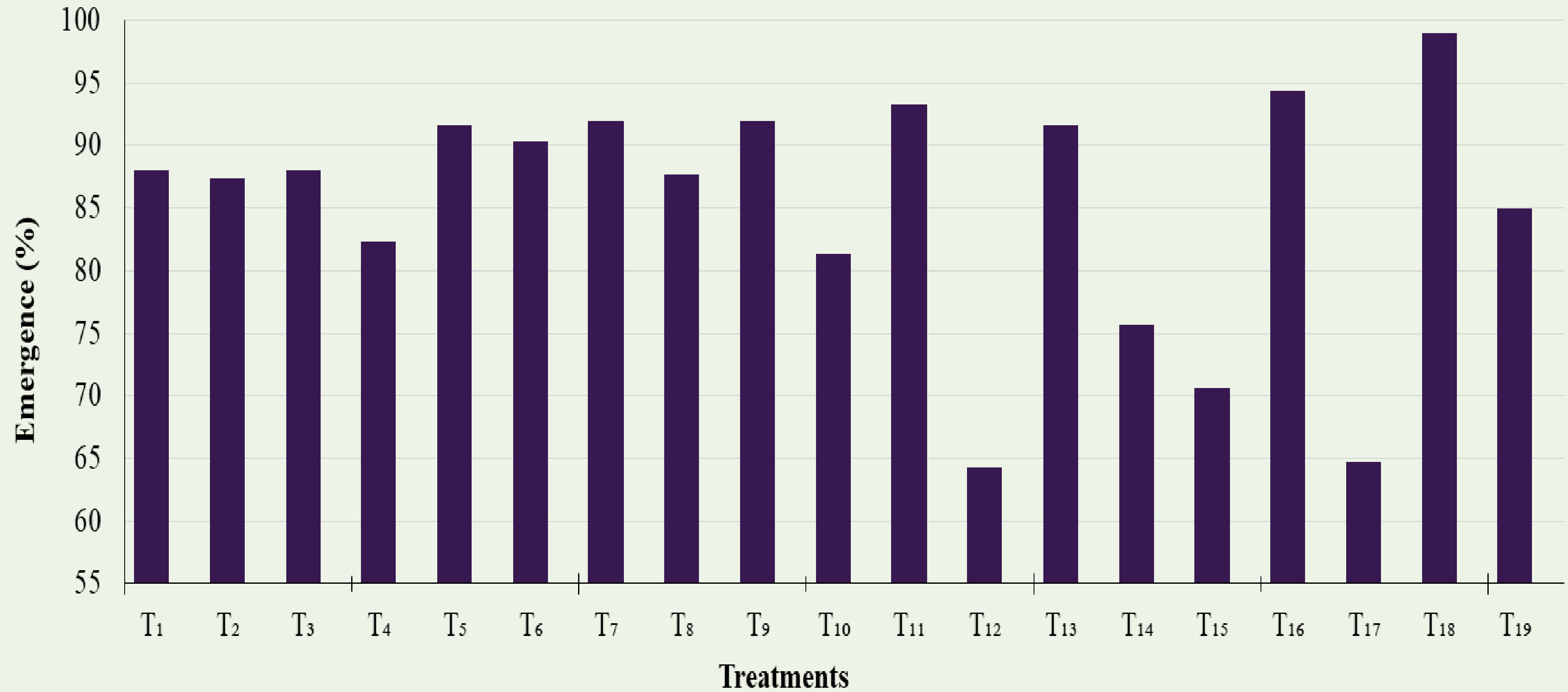

Fig. 1. Effect of seed invigoration methods on seedling emergence (%) over control of Bermuda hybrid grass

T_1 - Control
T_2 -Hydropriming (distilled water) 2 days
T_3 - Osmopriming with PEG 8000 (-1.5 MPa) for 2 days
T_4 - Osmopriming with PEG 8000 (-1.5 MPa) for 4 days
T_5 - Priming with KNO_3 (0.2%) for 2 days
T_6 - Priming with KNO_3 (0.2%) for 4 days
T_7 - Priming with GA_3 (50µM) for 24 hours
T_8 - Priming with H_2SO_4 (8M) for 10 minutes
T_9 - Priming with NaCl (50mM) for 24 hours
T_{10} - Priming with KH_2PO_4 (0.1%) for 24 hours
T_{11} - Priming with NaOCl (4%) for 60 minutes
T_{12} - Priming with NaOH (4%) for 60 minutes
T_{13} - Osmopriming with $CaCl_2$ (1%) for 24 hours
T_{14} - Priming with cow urine (30%) for 6 hours
T_{15} - Priming with vermiwash (30%) for 6 hours
T_{16} - Priming with humic acid (2%, 20°C, 2hr)
T_{17} - Matrix priming with cocopeat (1:10) for 2days
T_{18} - Matrix priming with vermiculite (1:10) for 2 days
T_{19} - Priming with *Azospirullum* (10g/kg of seed)

Number of leaves at 30 and 60 DAS

The highest number of leaves (5.19) at 30 DAS was recorded in seeds treated with GA_3 50µM (T_7) which was on par with 5.15 in seeds treated with KNO_3 0.2% for 2 days (T_5), NaCl 50mM (T_9) and NaOCl 4% (T_{11}). Similar trend in number of leaves was observed upto 60 DAS, where the highest number of leaves (8.93) was recorded in seeds treated with GA_3 50µM (T_7), followed by 8.40 in seeds treated with NaOCl 4% (T_{11}).

Whereas, the vermiwash 30% (T_{15}) was recorded the lowest number of leaves (4.61 and 6.18) at 30 and 60 DASwhich was significantly lower than other treatments (Table 4). The increase in number of leaves as results of GA_3 application might be due to fact that activity of GA_3 at apical meristem resulting in more nucleoprotein responsible for increasing leaf initiation and expansion. The results are in confirmation with that of Nimbalkar *et al.,* (2012) in karonda.

Stem thickness at 30 and 60 DAS

The highest stem thickness (0.52 mm) at 30 DAS was recorded in seeds treated with GA_3 50µM (T_7) which was on par with 0.51 mm in vermiculite 1:10 (T_{18}) and 0.50 mm in seeds treated with KNO_3 0.2% for 2 days (T_5) and NaOCl 4% (T_{11}). Similarly, the highest stem thickness (0.90 mm) at 60 DAS was recorded in seeds treated with GA_3 50µM (T_7), followed by 0.84 mm in seeds treated with KNO_3 0.2% for 2 days (T_5) (Table 4). Whereas, the lowest stem thickness (0.39 mm and 0.64 mm) at 30 and 60 DAS was recorded in *Azospirullum* (T_{19}).

Increase in stem diameter of primed seeds may be due to the increased water uptake and balanced mineral accumulation by seedlings which affected cell division and elongation. Similar findings were reported by Shanmugavelu (1970) in tree plant species.

Fresh weight at 60 DAS

The maximum fresh weight (0.642 g) at 60 DAS was recorded in seeds treated with NaOCl 4% (T_{11}), followed by 0.434 g in seeds treated with NaCl 50mM (T_9)and 0.429 g in seeds treated with KNO_3 0.2% for 2 days (T_5).

Whereas, the *Azospirullum* (T_{19}) has recorded the minimum fresh weight (0.186 g) at 60 DAS (Table 4).

Improved fresh weight may be results of increased cell elongation and division, nucleic acid synthesis and repair in primed seeds.

Increased fresh weight by NaOCl 3.5% was recorded by Yildiz *et al.,* (2017) in*Lathyrus chrysanthus* Boiss. Priming with NaCl increases fresh and dry weight of plants by improving seedling vigour, metabolism of reserves, enhanced K^+, Ca^{2+} accumulation and reduced Na^+ accumulation in wheat plants (Afzal *et al.,* 2008).

Dry weight at 60 DAS

The maximum dry weight (0.315 g) at 60 DAS was recorded in seeds treated with NaOCl 4% (T_{11}), followed by 0.159 g in seeds treated with KNO_3 0.2% for 2 days (T_5) and minimumdry weight (0.052 g)was recorded in *Azospirullum* (T_{19}) (Table 4). The increase in dry weight by NaOCl primed seed was due to high tissue water content, increased cell division and synthesis of metabolites. Similar findings were reported by Yildiz *et al.,* (2017) in *Lathyrus chrysanthus* Boiss.

In conclusion, the present investigation revealed that among seed invigoration treatments, seed priming with vermiculite 1:10 (T_{18}), NaOCl 4% (T_{11}), KNO_3 0.2% for 2 days (T_5) and GA_3 50µM (T_7) recorded significantly higher seedling emergence (99.0 93.0, 92.0 and 92.0 per cent, respectively) and also recorded higher speed of emergence, mean seedling length, mean seedling dry weight and seedling vigour indices, which ultimately has improved the uniform growth and establishment and help the turf industry to establish grass very quickly by avoiding competition from weeds.

Hence, priming with these treatments could be used commercially for better quality turf spread.

Author Contributions

Moulasab Jabbarasab Bagawan: Investigation, formal analysis, writing—original draft. K. Vishwanath: Validation, methodology, writing—reviewing. B. N. Radha:—Formal analysis, writing—review and editing. K. J. Sowmya: Investigation, writing—reviewing. H. V. Ramegowda: Resources, investigation writing—reviewing. N. Lokeshwari: Validation, formal analysis, writing—reviewing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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