Original Research Article

Effect of seed invigoration treatments on seed quality and seedling vigour in fodder maize (*Zea mays* L.)

ABSTRACT

Poor germination in fodder crops is one of the major reasons responsible for lower than potential green forage yield of cereals. Invigoration treatments aids to promote and accelerate germination, increase the vigour of seedlings, and improve stand establishment in field, vegetable, and horticultural crops. Therefore, a study was carried out to evaluate the effect of different seed invigoration treatments on seed quality parameters *viz.*, germination, field emergence, speed of germination, seedling length, dry weight and seedling vigour in fodder maize (*Zea mays* L.). The experiment was laid out in factorial completely randomized design with two factors i.e., months and treatments having 5 different seed priming treatment combinations i.e., T_1 - Priming with water for 12 hrs., T_2 - Priming with NaCl @ 4g / litre of water for 8 hours., T_3 - Priming with Poly Ethylene Glycol solution @ 10g / litre of water for 8 hours., T_4 – Priming with GA3 @ 0.2 g / litre of water for 8 hours and T_5 - Control (no priming) and the treatments were replicated four times during *Rabi*, 2022-23 at the Department of Seed Science and Technology, Seed Research and Technology Centre, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad, Telangana. The results obtained from this study indicate that hormonal priming with GA3 can be successfully employed to improve germination, field emergence, seedling length, dry weight, and seedling vigour in fodder maize (*Zea mays* L.). At the end of the study, it was observed that hormonal priming with GA3 had a significantly positive influence on mean germination per cent (90%), field emergence (87%), speed of germination (20.221%), seedling length (34.17 cm), dry weight (0.792 g), seedling vigour index-I (3082.05) and seedling vigour index-II (71.42) over the control.

Keywords: Fodder maize, Seed invigoration treatments, Seed quality parameters.

INTRODUCTION

Forage crops are typically grown for grazing purposes by livestock and consumed as animal feed or stored as silage or hay to meet production goals for attributes like growth or weight increase and to make up for seasonal feed demand and supply deficiencies. Our nation

produced 146.3 million metric tonnes of milk in 2014-15, and as of 2022, the milk output has increased to 221.06 million tonnes (Economic Survey, 2022). It went on to say that a study conducted by the National Dairy Development Board (NDDB) predicted that India's demand for milk and its products would reach 266.5 million metric tonnes in 2030. In rural areas, almost 57% of total consumption occurs. In 2030, even per-capita consumption under urban areas (592 ml) is expected to be greater than in rural sectors (404 ml).

Maize is an excellent crop in terms of biomass production; hence it has been used as animal fodder since long. Maize is considered as ideal forage because it grows quickly, produces high biomass, palatable, rich in nutrients and helps to increase body weight and milk quality in cattle. African tall is a popular fodder maize variety used for silage making in dairy industry. Maize is called as the miracle crop and the Queen of Cereals, because it has higher yield potential as compared with other cereals. It is the domestic grass of tropical Mexican origin and belongs to family Gramineae. It ranks third in terms of area occupied on hectare basis after Wheat and Rice in world. It is the crop with high yield and highly nutritious forage produced by less labour and machinery requirement as compared with other forage crops. It is grown as fodder crop alone or in the form of mixtures with legumes which helps to cope with the forage scarcity problem. It provides heavy tonnage of fodder throughout the summer season. It is a nutritious fodder and is richest feed source for livestock. It also has high export potential due to its high protein content, nutritious and palatability (Ali *et al.,* 2016). India produced 33.62 million tonnes in an area of 10.04 million hectares in 2021-22, whereas in *kharif* 2022-23, maize production was 23.10 million tonnes (1^{st} advance estimates) in an area of 9.68 million hectares (agricoop.nic).

African tall is a composite variety. Poor germination, stand establishment and fast seed deterioration is observed most of the times associated with the variety. Different seed enhancement techniques like seed priming helps to improve the planting value, crop growth, yield and quality of plant produce in fodders. Seed priming is a useful technique for accelerating uniform emergence and achieving high vigour, which improves stand establishment and yield. Different seed priming techniques have been developed, including hydropriming (soaking in water), halopriming (soaking in inorganic salt solutions), hormonal priming (with hormones), osmopriming (soaking in solutions of different organic osmotica), thermo priming (treatment of seed with low or high temperatures), solid matrix priming (treatment of seed with solid matrices), and biopriming (hydration using biological compounds) (Ashraf and Foolad, 2005). After the priming treatments, seeds were washed

with distilled water and dried back near to original weight with forced air under shade (approximately for 48 h). The laboratory temperature during the drying period was 27±2℃. A quick and inexpensive hydration method, it involves partially hydrating seeds until pre-germination metabolic activities begin without actual germination, and then re-drying them to a level that is close to their initial dry weight. In addition to increasing germination percentage, uniformity, and speed, priming also increases resilience to water and temperature stress. Growth promoting hormones are commonly used in agriculture to enhance productivity. Gibberellic Acid (GA) is one of the plant hormones involved in growth and development. It has effects on seed germination, leaf expansion, stem elongation and flowering. In addition, Gibberellins interact with other hormones to regulate various metabolic processes in plants.

The present study was therefore, planned to evaluate the effect of different seed invigoration treatments on seed quality and seedling vigour in fodder maize.

MATERIALS AND METHODS

In order to investigate the effects of different seed priming techniques on germination, field emergence and seed vigour in forage maize (*Zea mays* L.), the experiment was laid out in factorial completely randomized design with two factors i.e., months and treatments having 5 different seed priming treatment combinations i.e., T_1 - Priming with water for 12 hrs., T_2 - Priming with NaCl @ 4g / litre of water for 8 hours., T_3- Priming with Poly Ethylene Glycol solution @ 10g / litre of water for 8 hours., T_4 – Priming with GA3 @ 0.2 g / litre of water for 8 hours and T_5 - Control (no priming) and the treatments were replicated four times during *Rabi*, 2022-23 at the Department of Seed Science and Technology, Seed Research and Technology Centre, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad, Telangana.

OBSERVATIONS RECORDED UNDER LABORATORY CONDITIONS

Observations on various seed quality parameters like seed germination (%), Seedling length (cm), Seedling dry weight (g), Seedling vigour index- I, Seedling vigour index - II, Field emergence (%), Speed of germination, were recorded monthly for five months after completion of the seed treatments by following standard procedures.

Seed germination (%)

As per the ISTA rules (ISTA, 2019) the laboratory test for germination was conducted by adopting between paper method. Four replications of 100 seeds were taken for each treatment and uniformly placed on germination paper. The rolled towel was kept in the seed germinator and maintained a constant temperature of 25 ± 0.5°C and 95 per cent relative humidity. On the day of final count (7^{th} day), number of normal seedlings, abnormal seedlings, fresh ungerminated seeds and dead seeds were evaluated. Germination percentage is expressed on the number of the normal seedlings and it was collected as follows:

$$\text{Germination (\%)} = \frac{\text{Number of normal seedlings}}{\text{Total number of seeds planted}} \times 100$$

Seedling length (cm)

On seventh day of germination test, ten normal seedlings were selected randomly per replication in each treatment. The root length was measured from the tip of the primary root to base of the hypocotyl with the help of a measuring scale and the mean root length was expressed in centimetres (cm). Ten normal seedlings used for root length measurement, were also used for the measurement of shoot length. The shoot length was measured from the tip of the primary leaf to the base of the hypocotyl and mean shoot length was expressed in centimetres.

Seedling dry weight (g)

Ten normal seedlings used for root and shoot length measurements were put in the butter paper bags and kept in 100 ± 1°C for 24 hr. After the prescribed period, they were removed and allowed to cool in a desiccator for 30 minutes before weighing in an electrical balance. The mean dry weight of the seedlings was recorded and expressed in grams.

Seedling vigour indices

Seedling vigour index I and II were calculated as suggested by Abdul – Baki and Anderson (1973) and expressed in whole numbers.

Seedling Vigour Index I = Seed germination (%) x Seedling length (cm)

Seedling Vigour Index II= Seed germination (%) x Seedling dry weight (g)

Field emergence (%)

Field emergence potential of seed was measured as per the method suggested by Shenoy *et al.* (1990). Fifty seeds were selected randomly from each treatment in four replications and the seeds were sown in well prepared soil at 2.0 to 2.5 cm depth and covered with the soil. Field emergence count was taken on the 7^{th} day of sowing and the field emergence percentage was calculated by using the following formula.

$$\text{Field emergence (\%)} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds sown}} \times 100$$

Speed of germination

Speed of germination was estimated by following the method recommended by ISTA (1999). In this method four replications of 100 seeds were placed in the sand. The number of seedlings germinated at each day up to 7 days, were recorded regularly. Speed of germination is calculated as:

$$\text{Speed of germination} = \frac{N_1}{T_1} + \frac{N_2}{T_2} + \frac{N_3}{T_3} \cdots \frac{N_x}{T_x}$$

Where 'N' is number of seeds germinated at days 'T'

STATISTICAL ANALYSIS

The data recorded in laboratory experiments were analysed statistically by adopting Two Factorial Completely Randomized Design (CRD) techniques as Panse and Sukhatme (1985). The significance of mean sum of squares for each parameter was tested against the corresponding error degrees of freedom using 'F' test (Fisher and Yates, 1963). Later, the least significant difference and critical difference at 5 per cent probability level were calculated wherever F test was significant and was used to compare treatment means.

RESULTS AND DISCUSSION

The results obtained in the present investigation revealed the significant differences among the different seed invigoration treatments on improving the seed quality and seedling

vigour in fodder maize. The fast deterioration of seed germination and poor storability in fodder crops is proven to be managed by seed enhancement techniques by the present study.

The mean germination per cent was observed to be highest in the hormonal priming treatment (90%) followed by osmopriming (89%) after 5 months of treating the seed (Table 1). The field emergence in the treated seeds is observed to be highest in hormonal priming with a mean value of 87%, followed by osmopriming (85%) (Table 2), whereas in the control, it is lowest with 79%, which is nearest to minimum germination standards value of 75% (IMSCS, Trivedi, R. K and Gunasekaran, M. 2013). Significantly highest speed of germination (20.221%) was reported in the hormonal priming and it was followed by osmopriming (18.943 %). Minimum speed of germination was recorded by control with 14.784 % (Table 3).

Gibberellins are essential for improving seed germination because they play a crucial role in regulating reserve hydrolysis, which is necessary for the growth of the developing embryo. They also help to boost the embryos growth potential, which in turn increases the percentage of germination. The higher germination rate of GA-treated seed may be attributable to their fast utilisation in the formation of different amino acids and amides (Gupta, P and Mukherjee, D. 1982).

The findings are in accordance with the studies of Afrigan *et al.* (2013) in maize, Tsegay *et al.* (2018) in maize, Tiwari *et al.* (2018) in pigeon pea, Ma H.Y *et al.* (2018) in *Leymus chinensis* and Yogananda *et al.* (2004) in bell pepper seeds.

Significant differences were observed for the character total seedling length (cm). The highest mean seedling length was observed in the hormonal priming (34.17 cm), followed by osmopriming (30.86 cm) (Table 4). This indicates that the seedling vigour is improved by imposing the seed invigoration treatments. The seedling dry weight was significantly enhanced by the priming treatments (Table 5). Among treatments, the maximum seedling dry weight recorded with hormonal priming (0.792 g) followed by hydropriming (0.588 g), osmopriming (0.583 g) which are significantly higher over unprimed control (0.443 g). The interaction between storability and treatments were significant.

The increase in root length of primed seeds is because GA3 may be due to enhanced metabolic activity and activates the α-amylase. As a result, the content of protein, sugar, and RNA was also increased. This could have sped up seedling germination, improved their growth, and produced longer roots. By the use of GA3 seedling ability to absorb water has been improved. This may have triggered the enzymes needed to mobilise the food reserves existing in the embryo, which might have been used effectively to produce vigorous

seedlings. As a result, the seedlings fresh weight, which is strongly connected with their dry weight, increases (Jadhav *et al.* 2022).

The findings are in accordance with the studies of Ghodrat V and Rousta M.J (2012) in maize, Ghobadi *et al*. (2012) in wheat, Kumari *et al.* (2017) in maize, Afzal *et al.* (2008) in maize and Tsegay *et al.* (2018) in maize.

Vigour index I is the product of germination % and mean seedling length whereas vigour index II is the product of germination % and mean seedling dry weight and it was also considerably increased in response to priming treatments applied. The maximum vigour index (I and II) was obtained in hormonal priming with GA3 followed by osmopriming and hydropriming. Hormonal priming displayed highest vigour index I (3082.05) followed by osmopriming (2756.13) (Table 6) and vigour index II was also found higher in hormonal priming (71.42) followed by osmopriming (52.01) (Table 7). The hormonal priming exhibited higher germination, root/shoot length and dry weight and thus resulted in higher vigour index I and II.

The increase in the seedling vigour of primed seeds with GA3 may be due to more soluble protein contents, leading to membrane reconfiguration as well as the synthesis of specific membranes, the activation and resynthesis of some enzymes, DNA and RNA, and a higher seedling vigour index (Jeng and Sung, 1994). The increase in germination, seedling length, seedling dry weight, and ultimately vigour index caused by seed priming with GA3 is attributable to the induced large free space between the embryo and endosperm in primed seed, which is thought to play a role in speeding up germination by facilitating more water uptake

The findings are in accordance with the studies of Kumari *et al.* (2017) in maize, Tsegay *et al.* (2018) in maize, Brar *et al.* (2020) in onion, Sarika *et al.* (2013) in French bean and Tiwari *et al.* (2018) in pigeon pea.

Table 1. Effect of seed invigoration treatments on seed germination (%) in Fodder maize

Treatments	**Germination (%) at months after treatment**					
	1MAT	**2MAT**	**3MAT**	**4MAT**	**5MAT**	**Mean**
T1-Hydropriming (Soaking in water for 12 hrs)	93	87	86	88	84	88
T2- Halopriming (Soaking	89	88	84	85	82	86

in NaCl @ 4g/lit of water for 8 hrs)						
T3-Osmopriming (Soaking in PEG6000 solution for 8 hrs)	92	92	89	86	85	89
T4- Hormonal priming (Soaking in GA_3@ 0.2g/lit of water for 8 hrs)	94	92	90	88	88	90
T5- Control	88	83	83	82	81	83
Mean	91	88	86	86	84	87
	SE(m)±	**SEd**	**CD (P=0.05)**	**CV%**		
Period of storage(S)	0.847	1.198	2.392*	4.35		
Treatments(T)	0.847	1.198	2.392*			
Interaction of (TXS)	1.895	2.679	NS			

*MAT: Months After Treatment

* C.D significant at $P \leq 0.05$ level, NS- Non-Significant

Table 2. Effect of seed invigoration treatments on field emergence (%) in Fodder maize

Treatments	**Field emergence (%) at months after treatment**					
	1MAT	**2MAT**	**3MAT**	**4MAT**	**5MAT**	**Mean**
T1- Hydropriming (Soaking in water for 12 hrs)	90	85	84	81	79	83
T2- Halopriming (Soaking in NaCl @ 4g/lit of water for 8 hrs)	89	85	81	78	78	82
T3-Osmopriming (Soaking in PEG6000 solution for 8 hours)	90	89	86	81	83	85
T4- Hormonal priming (Soaking in GA_3@ 0.2g/lit of water for 8 hrs)	93	90	88	82	83	87
T5- Control	85	82	79	76	76	79

Mean	89	86	84	80	79	83
	SE(m)	**SEd**	**CD (P=0.05)**	**CV%**		
Period of storage(S)	0.720	1.019	2.031*	3.852		
Treatments(T)	0.720	1.019	2.031*			
Interaction of (TXS)	1.612	2.279	NS			

*MAT: Months After Treatment

* C.D significant at P ≤ 0.05 level, NS- Non-Significant

Table 3. Effect of seed invigoration treatments on speed of germination in Fodder maize

Treatments	**Speed of germination at months after treatment**					
	1MAT	**2MAT**	**3MAT**	**4MAT**	**5MAT**	**Mean**
T1- Hydropriming (Soaking in water for 12 hrs)	19.227	19.322	16.095	18.365	18.297	18.261
T2- Halopriming (Soaking in NaCl @ 4g/lit of water for 8 hrs)	20.133	17.852	17.700	18.067	17.363	18.223
T3-Osmopriming (Soaking in PEG6000 solution for 8 hrs)	21.518	20.569	20.095	16.070	16.462	18.943
T4- Hormonal priming (Soaking in GA_3@ 0.2g/lit of water for 8 hrs)	21.977	20.726	20.022	19.350	19.027	20.221
T5- Control	16.693	18.030	16.063	11.610	11.523	14.784
Mean	19.91	19.30	18.00	16.69	16.53	18.086
	SE(m)	**SEd**	**CD (P=0.05)**	**CV%**		
Period of storage(S)	0.242	0.343	0.683*	5.995		
Treatments(T)	0.242	0.343	0.683*			
Interaction of (TXS)	0.542	0.767	NS			

*MAT: Months After Treatment

* C.D significant at P ≤ 0.05 level, NS- Non-Significant

Table 4. Effect of seed invigoration treatments on seedling length (cm) in Fodder maize

Treatments	**Seedling length (cm) at months after treatment**					
	1MAT	**2MAT**	**3MAT**	**4MAT**	**5MAT**	**Mean**
T1-Hydropriming (Soaking in water for 12 hrs)	36.45	33.91	31.74	25.72	24.48	30.46
T2- Halopriming (Soaking in NaCl @ 4g/lit of water for 8 hrs)	32.64	30.03	28.73	24.72	23.06	27.84
T3-Osmopriming (Soaking in PEG6000 solution for 8 hrs)	35.25	32.09	31.49	28.32	27.14	30.86
T4- Hormonal priming (Soaking in GA_3@ 0.2g/lit of water for 8 hrs)	38.87	36.56	34.83	30.91	29.64	34.17
T5- Control	31.91	27.01	29.07	20.39	21.46	25.97
Mean	35.02	31.92	31.17	26.02	25.156	29.85
	SE(m)±	**SEd**	**CD (P=0.05)**	**CV%**		
Period of storage(S)	0.569	0.804	1.602*	8.52		
Treatments(T)	0.569	0.804	1.602*			
Interaction of (TXS)	1.272	1.799	NS			

*MAT: Months After Treatment

* C.D significant at P ≤ 0.05 level, NS- Non-Significant

Table 5. Effect of seed invigoration treatments on dry weight (g) in Fodder maize

Treatments	**Dry weight (g) at months after treatment**					
	1MAT	**2MAT**	**3MAT**	**4MAT**	**5MAT**	**Mean**
T1- Hydropriming (Soaking in water for 12 hrs)	0.781	0.655	0.612	0.434	0.456	0.588
T2- Halopriming (Soaking in	0.612	0.605	0.390	0.370	0.362	0.468

NaCl @ 4g/lit of water for 8 hrs)						
T3-Osmopriming (Soaking in PEG6000 solution for 8 hrs)	0.641	0.626	0.625	0.519	0.501	0.583
T4- Hormonal priming (Soaking in GA_3@ 0.2g/lit of water for 8 hrs)	0.909	0.805	0.774	0.756	0.716	0.792
T5- Control	0.613	0.481	0.443	0.332	0.348	0.443
Mean	0.711	0.634	0.568	0.482	0.476	0.575
	SE(m)±	**SEd**	**CD (P=0.05)**	**CV%**		
Period of storage(S)	0.009	0.014	0.028*	7.630		
Treatments(T)	0.009	0.014	0.028*			
Interaction of (TXS)	0.022	0.031	0.062*			

*MAT: Months After Treatment

* C.D significant at $P \leq 0.05$ level

Table 6. Effect of seed invigoration treatments on seed vigour index-I in Fodder maize

Treatments	**Seed vigour index- I at months after treatment**					
	1MAT	**2MAT**	**3MAT**	**4MAT**	**5MAT**	**Mean**
T1- Hydropriming (Soaking in water for 12 hrs)	3404.54	2950.45	2716.69	2261.58	2057.39	2678.13
T2- Halopriming (Soaking in NaCl @ 4g/lit of water for 8 hrs)	2898.83	2637.18	2417.48	2096.91	1895.09	2389.10
T3-Osmopriming (Soaking in PEG6000 solution for 8 hrs)	3244.42	2957.44	2825.55	2445.75	2307.48	2756.13
T4- Hormonal priming (Soaking in GA_3@ 0.2g/lit of water for 8 hrs)	3604.65	3373.69	3117.69	2721.59	2592.64	3082.05
T5- Control	2807.77	2533.94	2403.52	1953.00	1759.58	2291.56

Mean	3192	2891	2696	2296	2122	2640
	SE(m)±	**SEd**	**CD (P=0.05)**	**CV%**		
Period of storage(S)	34.73	49.12	97.86*	5.886		
Treatments(T)	34.73	49.12	97.86*			
Interaction of (TXS)	77.67	109.85	NS			

*MAT: Months After Treatment

* C.D significant at P ≤ 0.05 level, NS- Non-Significant

Table 7. Effect of seed invigoration treatments on seed vigour index- II in Fodder maize

Treatments	**Seed vigour index- II at months after treatment**					
	1MAT	**2MAT**	**3MAT**	**4MAT**	**5MAT**	**Mean**
T1- Hydropriming (Soaking in water for 12 hrs)	73.02	57.08	50.84	38	38.32	51.45
T2- Halopriming (Soaking in NaCl @ 4g/lit of water for 8 hrs)	54.41	53.13	32.88	31.48	29.77	40.33
T3-Osmopriming (Soaking in PEG6000 solution for 8 hrs)	58.97	57.61	56.07	44.68	42.73	52.01
T4- Hormonal priming (Soaking in GA_3@ 0.2g/lit of water for 8 hrs)	84.38	74.30	69.33	66.49	62.58	71.42
T5- Control	53.97	39.80	36.56	26.98	28.41	37.14
Mean	65	56.4	49.1	41.5	40.4	50.47
	SE(m)±	**SEd**	**CD (P=0.05)**	**CV%**		
Period of storage(S)	0.997	1.409	2.808*	8.834		
Treatments(T)	0.997	1.409	2.808*			
Interaction of (TXS)	2.229	3.153	6.281*			

*MAT: Months After Treatment

* C.D significant at $P \leq 0.05$ level

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